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# EMERGING HARVESTING ISSUES AND TECHNOLOGY TRANSITION AT THE END OF THE CENTURY

## PROCEEDINGS

1860
SVEUČILIŠTE U ZAGREBU
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1669

IUFRO - OPATIJA '99
September 27 – October 1, 1999
Opatija, CROATIA

HRVATSKE ŠUME

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**Opatija, CROATIA**

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3.06.00 Forest Operations under Mountainous Conditions
3.07.00 Ergonomics

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# Contents

# Expression of regret and actual faith in future

**Stanislav Sever, Tibor Pentek**

You have in your hands the result of work that started more than 11 years ago at the IUFRO XX World Congress (International Union of Forestry Research Organizations) held in August 1995 in Tampere, Finland. At the final meeting of all participants, the Congress adopted a five-year programme of research and workgroup meetings. Thus for the five-year period between two Congresses, in the list of meetings for the year 1999 preceding the Congress, as one of two proposals of Division 3 of IUFRO *Forest Operations and Techniques*, the proposal was also introduced of its Research Groups, 3.06.00 *Forest Operations under Mountainous Condition* and 3.07.00 *Ergonomics*, to nominate Croatia for the organisation of the Conference entitled *Emerging Harvesting Issues in Countries in Transition*. In order to avoid the misinterpretation of »transition« as a social or political term, in July 1998 at the meeting of officers of Division 3 in Zurich, the name of the Conference was changed to a more adequate one: *Emerging Harvesting Issues in Technology Transition at the End of Century*, and participation in the work of the Conference was accepted as well as the Research Group 3.04.00 *Operational Planning and Control*; *Work Study*. The Faculty of Forestry of the University of Zagreb was directly in charge of the organisation, and Mr. S. Sever, who is one of the signatories hereof, was appointed project leader by IUFRO, and in the period between 1995 and 2000 he was the Deputy Coordinator of IUFRO Research Project 3.06.00. It should be noted that the proposal was given and decision made in August 1995, at the time when Croatia was liberating the last parts of a third of its country, which had been occupied for years, in the military action called »Storm«. The time and place of the Conference were accepted: September-October 1999 in Opatija. On-site programme was to be held at the working sites of Gorski Kotar. Implementation programme, as well as the final name of the Conference, was confirmed at the above mentioned Zurich meeting (IUFRO Mid Term Meeting) of IUFRO officers (co-ordinators and vice co-ordinators) of IUFRO Division 3 Research Projects, and it was harmonised and adapted to IUFRO organisational changes. The confidence shown by the oldest international forestry organisation IUFRO in young, just liberated, independent Republic of Croatia, looks as a significant acknowledgement and support even from this time distance. At that time quite different opinions could also be heard but not by IUFRO officers.

And there was also a serious generation gap between the two signatories – during the IUFRO XX World Congress 1995 one signatory was starting his last five-year period of work before retirement, while the other just graduated from the Faculty of Forestry in Zagreb. It should be noted that until the meeting date and the beginning of fulfilment of the last obligation, publication of proceedings, the work was carried out as scheduled. However, near the end of the century, new circumstances and events arose that prevented publishing of the expected proceedings for years. The elder signatory of this Introduction expresses his *sincere regret* for not having fulfilled his obligations with an apology to all authors, Conference participants, IUFRO officers, etc. A new generation of the Croatian foresters, who were gaining their education at the time of the Conference and many transitions, living under different conditions caused by events beyond our control, *restored faith* in a better future for the Croatian forestry and its connections with IUFRO, at least corresponding to the level achieved in 80s and 90s. By their participation in this project, they proved to be able to cope with the most demanding global requirements of scientific promotion of forestry. Although there are many persons who took part in the preparation for publishing the proceedings and have not been officially acknowledged, two names should absolutely be added: Ružica Beljo-Lučić and Stjepan Dekanić. I would like to thank them as well as those officially engaged in publishing the proceedings!

Although the papers in front of you are the result of researches carried out at the end of the 20th century, and at the time being we are in the second half of the first decade of the 21st century, it can be stated that many foresters are still far away from helicopters, harvesters and even openness of their forests achieved and described in some papers: such papers can be their guideline. On the other hand for those who have gone much further, publishing of their papers should encourage them to speed up and reach new achievements. I would like to thank them for their patience and help, as partly due to their papers and publication of these Proceedings after the volume 25 of the journal *Mehanizacija šumarstva (Forestry Mechanisation)*, the life of journals continued through the Croatian variant of *Nova mehanizacija šumarstva (New Forestry Mechanisation)*, as well as the English one: *Croatian Journal of Forest Engineering* – CROJFE. You will be welcome on the pages of these journals if you find time and motive to publish any of your papers.

In this Introduction, we would also like to thank all who helped in any way with holding the Conference, both from Croatia and abroad. Here are the names of some of them who supported and encouraged us by excellent cooperation during the organisation, which then obliged us not to give up publishing of papers even seven years after the Conference. First of all our thanks go to IUFRO General Executive Secretary, Mr. Heinrich Schmutzenhofer, dipl. ing., retired since 2003; Dr. sc. Ewald Pertlik, IUFRO representative for the organisation of the Conference; our late Professor Dr. sc. Simeun Tomanić, for many years IUFRO's associate member and officer, who was granted the Distinguished Service Award by IUFRO Executive Board as the first Croatian forester since the establishment of the independent Republic of Croatia at the meeting in Opatija, who introduced many of us in this leading and respectable world forestry organisation since mid 70s; reference should also be made of those who were not in a position to take part at the Conference personally, but gave their support in writing or in some other way wishing all the best to the meeting of foresters coming from all over the world: Mr. H. Höfle, Chairman of Joint Committee FAO/ILO/ECE; Mr. K. Dummel, Director of Kuratorium für Waldarbeit und Forsttechnik – KWF; the late Mr. U. Bort, Vice President of the University of Rottenburg); Mr. D. Guimier, Manager of Eastern Division of Forest Engineering Research Institute of Canada – FERIC; Mr. S. Baldini, University of Tuscia, Italy; Mr. H. Phillips, Ireland; Mr. Jannusz M. Sowa, Forest Faculty, University of Agriculture, Kraków, Poland; Mr. A. Meštrović, Deputy Minister of Forestry of B&H Federation, Sarajevo, B&H, and many others. We would like to express our sincere thanks to all contributors mentioned above as well as those not mentioned who remembered us at that time, regardless of the improper delay of this publication. Special thanks go to our colleagues from Slovenia! Eleven scientists from Slovenia gave their contribution to new knowledge and valuable meeting. Among registered scientists from 16 countries of all over the world, from New Zealand to USA, 27 participants out of 82, from 12 countries, arrived and took active part in the work of the Conference. Many of them sent their contributions to the Conference, as they could not personally attend the Conference for different reasons (illness, new job, difficulties with visas of the African colleagues, etc.). Although 63 papers of 87 authors were presented at the Conference in one way or another (talk, poster), these Proceedings only contain a smaller number, as some authors gave up their preparation for publishing or informed the Editorial Board of having published the paper in another journal. And finally, the Editorial Board would like to apology to the authors if any typing, printing or author error occurred despite proofreading and reviewing both in the Croatian and English version.

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# Forest Work Science at The End of The 20th Century – The Current State and Development Trends

Simeun Tomanić

***Abstract***

*The article scans the state of development of the forest work science at the end of the 20th century, examines the challenges and obstacles this science must tackle and, finally, proposes some future development trends.*

*State of development. From a global perspective the forest work science shows significant disparity in terms of development. Of the numerous causes of this disparity the author singles out the following: forest and environment diversity in terms of terrain and climate, biological features of forest stands, the role of forests and forestry in a country's economy, the impact of science in general and forest work science in particular in a given society, the extent to which forest work science contributes to practical use in forest work, creative capabilities of the scientists involved in research of forest operations and techniques.*

*Challenges. A sound and intensive use of forest resources can ensure a growing benefit to society. The demand for such use is constantly rising. The prerequisites for an increased efficiency of forest work are: the development of new forest operation methods, tools and equipment; replacing man as a source of operational energy by new technical devices; increasing forest work productivity; providing for the safety and health of forest workers; increasing workers' standard of life and, accordingly, their work motivation within forestry; protecting the forests, the soil, and the environment from damage during forest operations; ensuring progressive and sustainable forest management.*

*Resistance and obstacles must be considered in future research of forest work, particularly in practical application of scientific discoveries. The most prominent causes of resistance, regardless of the discovery value, are: Conflicting interests of the users of forest resources. Eternal distrust in validity of new scientific discoveries. Unwillingness to take the risk when investing in research and/or applying research results.*

*Development trends. No spectacular changes should be expected to mark the beginning of the new millenium. Future development of forest work science will continue in accordance with the rules and trends in this decade. To ensure future development it is necessary to: Stimulate scientific discoveries and inventions which will contribute to the advance of forest practice. Provide researchers with a fast and easy access to information by further developing international cooperation and use of modern information technology in order to avoid unnecessary duplication of research. Create specific work methods and technical devices for particular work conditions. Increase forest work science efficiency by constantly monitoring and supporting application of new scientific discoveries.*

***Key words:*** *work study, forest operations planning and control, ergonomics, forest workers*

## 1. Introduction

The end of the 20th and the beginning of the 21st century, and the transition to the third millennium, present a significant moment in the history of mankind in which to consider and evaluate numerous aspects of spiritual and material life. It is an occasion in which to review the achievements of science and practice in the past, to make an assessment of the current state of science and the quality of life, and to attempt to anticipate the development in the forseeable future. Forestry shall, undoubtedly, partake in and contribute to these activities.

The XXI IUFRO World Congress, to be held in 2000, will provide an extraordinary opportunity for the world's forest science to envisage global visions for forestry, its strategic tasks, and its role in satisfying the needs of society for forest resources. Also, the year 2000 will see between 60 and 70 international IUFRO meetings that will gather between 2000 and 3000 scientists from all over the world. These meetings will, too, provide opportunities for making valuable contributions to the assessment of the achievements of forest science and practice, and to anticipate future development trends.

The aim of this paper is to scan the state of development of the forest operations science at the end of the 20th century, to present certain challenges and obstacles that confront this science, and to point at possible ways of development of this particular field in the future.

In the past opinions were much divided on the issue of forest operations, and their place and status within the forest science and practice. Since forest operations appeared in most branches of forestry, and since they were based solely on experience and skill, they were attributed little or no scientific importance. In the course of the past two centuries scientific research of forest operations began and extended, thus inducing the appearance, development and formation of related scientific disciplines. Significant contributions were given to the foundation of forest work science (Hilf 1957), to the discovery of the law of discontinuity in evolution of forest operaions methods and techniques (Samset 1967), to development and use of winch and draw-mills in lumber transport (Samset 1985), and to directions of development in scientific research of forest operations in Europe, Canada, USA, and Japan (Sundberg 1988).

In the second half of the 20th century scientific research of forest operations has suddenly expanded in most countries and institutions – members of IUFRO. In that period Ivar Samset assumed a leading role in the development and rigorous evaluation of scientific relevance, and determination of the status of science of forest operations and technique within the forest sciences. This field was established as the Division 3 of IUFRO's eight divisions. An estimated 20% of all forest scientists have interest in or are involved in the research of forest operations and technique.

## 2. Forest operations science – State of development

The current state of development of the forest operations science can be assessed by using a number of different indicators and their combinations. In science of science it is difficult to find a scientific field or discipline which would systematically analyze all significant indicators and their cross-combinations, and which would offer an integral evaluation of the development of science on a national, regional, and global level. Such analysis and evaluation are, undoubtedly, a prerequisite for pursuing a sensible policy in scientific research and in increasing the contribution of science to the total growth of the society. This applies to each particular scientific branch, field and discipline, as well as to science as a whole.

IUFRO world congresses provide convenient opportunities for evaluation of the state of development of scientific disciplines in forestry. There are neither obligatory nor voluntary surveys of global and integral range which could show: 1. the extent to which these opportunities are taken to make such evaluations, 2. the validity of such evaluations, 3. whether investors, scientific institutions, and scientists apply such evaluations and recommendations in order to determine priorities in planning scientific research on national and regional levels. When endeavouring to envisage new aims and useful substance of IUFRO world congresses, creating a methodology for making such evaluation as well as for monitoring its application and recommendations for planning scientific research would increase the efficiency of IUFRO congresses and the entire forest science.

Figure 1 shows trends of development of IUFRO from the initiative for its foundation in 1890 until 2000. Forest operations science has followed the development of IUFRO and of science in general.

In the process of evaluation of the state of development of the forest operations science the following data and indicators can be used:

- *Number of scientists* engaged in research of forest operations. This number can be shown as: 1. an absolute figure for each particular scientific discipline; 2. relative figures for each particular discipline and the total number of scientists in all disciplines; 3. relative figures among particular disciplines, and in relation to the total number of workers employed in forestry. It is particularly interesting to compare the percentage of scientists in the total number of workers employed in forestry to the percentage of scientists in other trades (industry, agriculture, medicine, etc., as well as in all trade branches together).

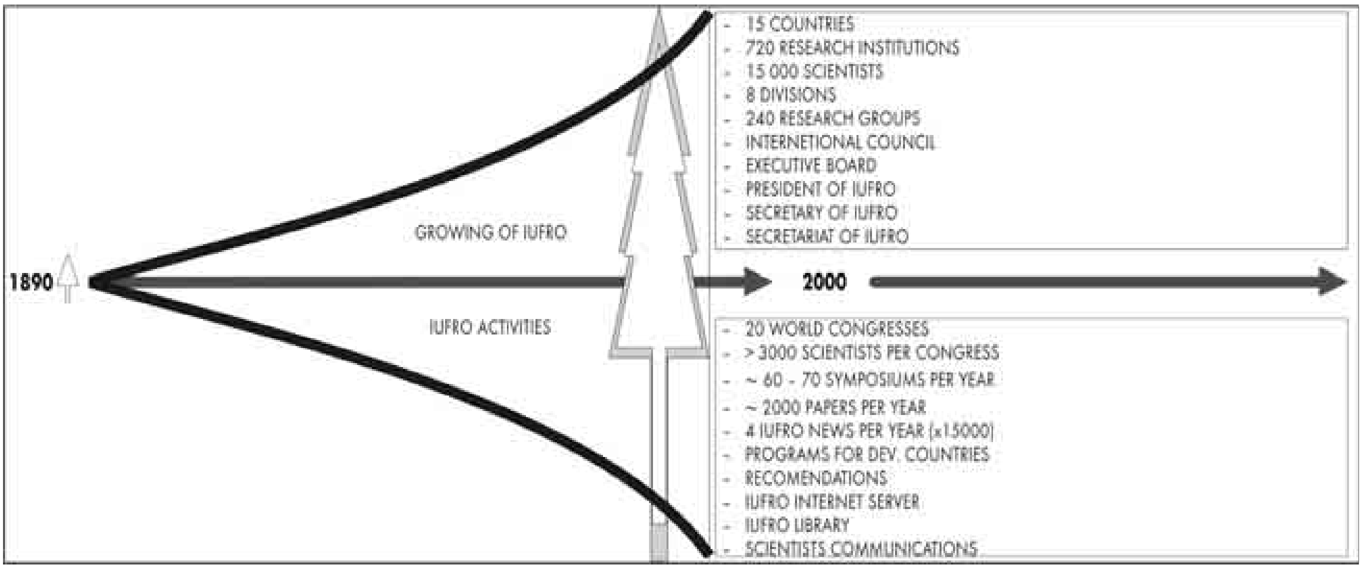


**Figure 1** Development of IUFRO from its foundation in 1890 until 2000

- *Financial resources* allocated annually for scientific research. These amounts can be shown as: 1. an absolute figure for an individual researcher, for each particular scientific discipline, and for all disciplines; 2. a percentage of the total income from forestry for all research and for each particular discipline. Data and indicators for each country can be shown in respective national currency. For calculations and comparisons on a regional or international level, data from all countries should be converted to a single currency (e.g. US$ or Euro).
- *Value of equipment and facilities* provided for scientific reasearch. This value can be shown as: 1. an absolute figure; 2. percentage with which each particular scientific discipline or field participates in the total value allotted for all disciplines covered by a given scientific institution. Correlations between the values for forestry and for other trades can be interesting in terms of analysis and evaluation of the current state.
- *Range of the field* covered by scientific research. This range is determined by the number of disciplines involved in field research and their definitions, as well as time and space in which research is carried out. Scientific discipline involves efforts to make a venture into the unknown (into »no man's land«) with the intention to discover concepts and laws as yet unknown, and to systematically interpret methods that have been applied and knowledge that has been acquired. Samset (1992) considers the term *operation* to refer to any work or activity in motion. Consequently, *forest operations science* refers to all activities performed by forest workers using their tools or machinery. This includes establishment, cultivation, and protection of forest stands, maintenance of growing stock, and forest harvesting. Also included are environmental protection, working conditions, ergonomics, engineering, forest roads, and economics of forest operations.
- *Number of scientific discoveries* in a field covered by forest operations provides a reliable foundation for evaluation of a scientists, a scientific discipline, or a scientific field. Value of a scientific discovery is determined on the basis of: 1. the area it covers and the duration of its application; 2. its contribution to a better use of resources in forestry; 3. its impact on increase in work quality and productivity; 4. its contribution to humanization of forest work; 5. its impact on increase of economic efficiency of forest operations in practice; 6. possibilities to predict situations of crisis in the foreseeable future and ways to avert them.
- *Number of published scientific papers* in a given period of time is used in evaluation of a scientists, a scientific discipline, or a scientific field. The correlation of numbers of scientific papers published by scientists, in various scientific disciplines, fields, and regions, as well as their trends in given periods of time, can be used in evaluation of scientific achievement. This kind of indicatior is easier to calculate, and their use is more frequent, but their validity is inferior to that of the evaluation of scientific discoveries.

Current state of the forest operations science is marked by an enormous span in the levels of development. In some places ancient methods are used, together with tools that date back several thousand years. Scientific research in these places are only symbolic or totally non-existant. At the same time, in other places, work- and production processes employ the most recent achievements of the human mind. Work processes are carried out in most difficult conditions in terms of terrain and climate with the aid of highly sophisticated machines and the newest information technology devices. Highly skilled workers sit in comfortable cabins and operate machines performing forest operations. Workers in the field are able to constantly communicate among themselves and with their superiors by using computer or telephone network. This enables fast exchange of information, speeds up problem solving and decision making, and ensures high work productivity and high economic efficiency of forest operations.

The old fashioned manual work with the aid of hand tools and animal power is still performed in poor and underdeveloped countries where human labour is cheap. The most recent achievements of the forest operations science are applied in developed countries which lead the way in forest science and practice. This broad span includes various levels of development of forest operations and techniques, combinations of old fashioned solutions and more recent findings, as well as their intertwining in certain areas. The difference in the levels of development stems from diversity of terrain, climate, and vegetation, as well as technical, historic, economic and other features that influence forestry in its setting.

## 3. Challenges to the forest operations science

The demand for the uses of forests and forestry is constantly increasing. This includes all uses, regardless of their type or value. The demand is increasing because Earth's population increases progressively. The standard of living is constantly raised, and that causes greater and more versatile human need for the uses of forests and forestry. This coincides with the expansion of farmland at the expense of forests, and this in turn results in significant pressure on forest eco-systems and their environment. Researching the balance between the growing demand for the uses of forests and ensuring a progressive and sustainable forest management presents an important challenge to entire forest science, and especially to the forest operations science.

A sound and intensive utilization of forest resources can ensure significantly more benefits than society currently has. Finding answers to the question how to achieve this goal presents a challenge to both those who endeavour in the devolopment of forestry and those who expect to benefit from the forest resources. One of the important prerequisites for successful development of forest production is an increased efficiency of forest operations. This can be achieved in several ways. Here are some examples:

- *Development of new forest operations methods* which will enable faster production of the same or completely new products and goods. This also includes improvement of current methods which increase economic efficiency in forestry.
- *Development of new tools and equipment* for forest operations enables covering of larger areas, reduces the duration of work operations and global production processes. By using multipurpose forest machinery, limitations of energy supply for forest operations begin to cease. This opens new possibilities for development of new methods and techniques.
- *Increasing work productivity* is possible with: a) practical application of the existing scientific discoveries; and b) new discoveries and their application. Intertwining of these two factors is possible in all cases, regardless of the level of development of the given country or region, and regardless of the differences in natural, technical, economic, and social features.
- *Ergonomic research* in forestry.Its aim is reduction in number and degree of injuries, and of professional diseases of forest workers. Most forest operations involve high-risk because of the number and degree of injuries, physical strain in manual and moto-manual work, terrain and climatic features of working conditions, and dangers to which workers are exposed. Application of results of ergonomic research in forest operations contributes to protection of life and health of the workers, and to an increase of their life expectancy and their active life. This is an important challenge to scientists, forest workers, and employers. Balance between investments in occupational safety, and losses due to injuries, illnesses, reduced productivity, and shortening of workers' active life makes a good criterion in deciding whether to invest in ergonomic research. This criterion covers the interests of employees, employers, and researchers alike.
- *Raising living standards* of forest workers, replacing man as a source of work power by multipurpose forest machines, application of the »less sweat – more knowledge« rule at work, salaries sufficient to motivate workers to keep their jobs

and not to search for better paid jobs outside forestry – these considerations will contribute to humanization of forest operations. This approach to forest workers and their work will increase their motivation to work in forestry, and this will ensure sufficient workforce for forest operations.

- *Protecting forests, forest soil, and environment* from damage during forest operations should ensure stability of forest eco-systems. Most forest operations disrupt this stability. Interventions in forest eco-systems are carried out in order to regulate biological and technical processes for the purposes of forest management. They result in positive stimulation and not in the disruption of the stability of forest eco-system which would lead to its destruction. The ability to act in such a way, especially in unpredicted emergency situations, present a challenge for scientists and professionals gifted with creative inspiration.
- *Progressive and sustainable forest management* is a basic condition for performing valid and acceptable forest operations, regardless of the ephemeral interests of forest owners, entrepreneurs, or any other subject. Uses of forests and forestry are a permanent and growing need of all generations. Forest operations misjudged due to ignorance, selfish interests or greed may cause damage beyond repair. Multidisciplinary team work of scientists and field professionals in search for new concepts and in practical application of new discoveries provides an essential foundation of progressive and sustainable forest management.

## 4. Resistance and obstacles in research of forest operations

Resistance and obstacles are a constant companion to scientific research, discoveries, inventions, and their application in practice. Their most significant causes are:1. unpredictability of ventures into the unknown; 2. conflicts of interest; 3. distrust in the validity of new scientific discoveries; 4. unwillingness to risk investing in research and practical application of research results.

- *Unpredictability of ventures into the unknown*. Each venture into the unknown, into »no-man's land«, is accompanied by numerous questions, surprises, groping in the dark, and failed attempts. Prerequisites for a scientific discovery, or invention, or an improvement are creative inspiration, imagination, curiosity, necessary equipment, and numerous attempts. Even with these prerequisites scientific research is often followed by failed experiments, mistakes, and disappointments. Strong motivation, willingness to work, persistence in effort, and even good luck, contribute to the probability of a scientific discovery or invention.
- *Conflicts of interest*. There is a great number of researchers and potential beneficiaries of the same or different uses of forests and forestry. Their interests may be identical, different, or conflicting. Their rights and responsibility in terms of forest resources may also be different. Therefore, their relations to forest eco-systems, forest operations and techniques differ significantly. A contractor carrying out forest operations in someone else's forest will endeavour to achieve maximum work productivity and make maximum profit in the least possible time, regardless of the damage to forest stand, roads, and environment, or ergonomic working conditions. If an owner carries out forest operations in his own forest, in most cases he will act as a good manager: he will protect the forest and the facilities from damage, he will ensure progressive and sustainable forest management, and he will satisfy his need for the uses of forest. It is possible to say that the number of interests equals the number of beneficiaries. In addition, the number of beneficiaries and their interests are subject to change in time and space. Elements of forest eco-systems also changes, and so do work methods and equipment, and their relations. All these factors, as well as many others not mentioned here, cause resistance to scientific discoveries and obstacles in their practical application. If there is a conflict of interest among the beneficiaries, the advancement of one will cause resistance in others because of their relative stagnation or falling behind. If their interests are identical, the advancement of one will cause resistance in others because of envy, unsuccessful competition, or loss of reputation.
- *Distrust in the validity of scientific discoveries* is a constant companion to all research. Distrust in the new breeds resistance. Resistance to scientific discoveries and inventions, and their application, results in idleness of mind, dull-wittedness, acceptance of the current conditions regardless of their level and efficiency, inclination towards the inherited work methods and techniques, and poor motivation for work. Discoveries and inventions, and their application in practice, require additional efforts to accept, to understand, to master, and finally to apply the new knowledge. This disturbs the peace of old ways, it requires change of habits, and causes insecurity in one's competence. All these things cause distrutst and resistance to new ideas.

- *Unwillingness to take risk.* Since investing in research cannot guarantee certainty of success, investors often hesitate to take a risk by making such investments. Practical application of scientific discoveries and inventions involves numerous difficulties, particularly in the period of training and establishing a new routine. Some discoveries and inventions require modification and improvement during application in practice. This, too, requires the risk to be shared between the researcher and the investor.

## 5. Forest operations in the future – development trends

It is a thankless task to make any kind of prediction. At the time of prediction we do not have adequate information about conditions in which the predicted events, forest operations, or any kind of change will take place in the future.The quality and quantity of information on future events decreases with the length of time to which the prediction refers. This reduces the probability and reliability of the prediction. Some predicted events will never take place. Some will, but in unpredicted circumstances. Also, some events will take place that have not been predicted at all. However, not to make any predictions would mean to await for the future wearing a blindfold. Therefore, predicting the development trends in forest operations and technique is a vital necessity, and this applies to all other fields in forestry as well as to other fields in general.

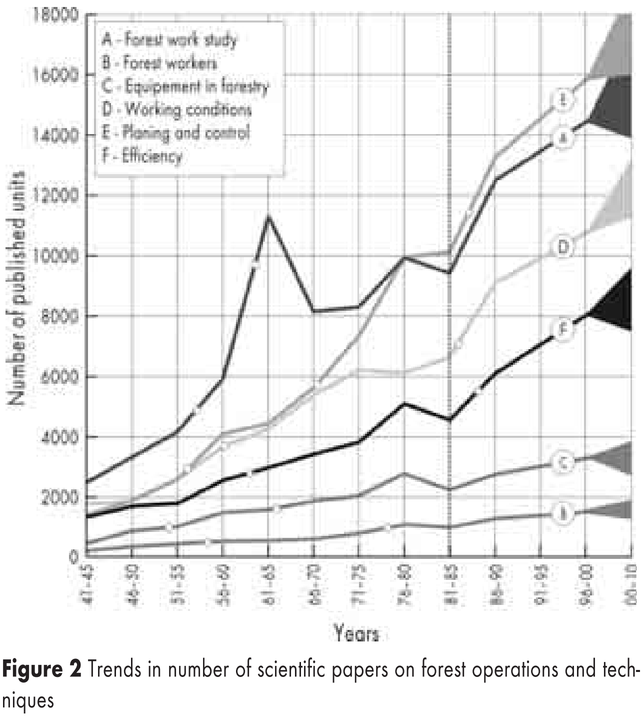


**Figure 2** Trends in number of scientific papers on forest operations and techniques

Study of development trends in forest operations and technique in the past can help make sufficiently reliable predictions for such trends in the near future. Most scientists researching the prediction of science development think that the rules and trends of development in the next decade will resemble those of the current moment (Dobrov 1966). Possible exceptions in a certain discipline or region do not alter the general trends. Still, opinions of scientists on the subject of long term predictions of science development differ significantly (Bronowski 1973). Taking these opinions into consideration, no spectacular changes in the development of forest operations and technique should be expected in the near future. Figure 2 shows a realistic expectation for the beginning of the next century in terms of levels and rules of development trends.

The trends for the number of published units for the second part of the 20th century (Figure 2) have been determined on the basis of data of the CAB – International. Published units have been divided into six groups: A – Forest work study; B – Forest workers; C – Forest equipment; D – Working conditions; E – Forest operations planning and control; F – Operational efficiency. The criteria for classification were: the title, the key words, the main subject of research, and the year of publication. Trends for the number of published units are drawn in different lines. There are small circles on each of the lines. The section of the line between two circles shows the time in which the number of published units has doubled (redoubling time). Redoubling time shows the intensity of development. The shorter the redoubling time, the higher the intensity of development of a certain discipline or branch, and vice versa. Redoubling time in forestry disciplines is sighificantly longer than in chemistry, physics, mathematics, medicine, etc. This comparison and the causes of difference are not the subject of this paper. However, significant differences have been observed. It would be useful to research these differences, their causes and consequences, especially from the point of view of forestry.

All trends on Figure 2 show a growth tendency. Forest work study and forest operations planning and control show the highest growth rate, followed by research in working conditions and operational efficiency. The lowest growth rate can be seen in the research of equipment in forestry and forest workers. In the next decade a similar order and correlation of the researched trends can be expected. It is possible than some of the trends changes direction, but it is difficult to believe that their order could be altered or that their correlation could be significantly disrupted.

## 6. Conclusions

The end of the 20th century and the beginning of the 21st, and the transition to the third millennium, present a significant opportunity to consider and evaluate numerous aspects of material and spiritual life. It is an occasion for us to review the achievements of science and practice in the past, to make an assessment of the current state, and to attempt to anticipate the development in the forseeable future. Forestry shall partake in and contribute to these activities.

The XXI IUFRO World Congress and many scientific symposiums to be held in 2000, will provide an extraordinary opportunity for the world's forest science to envisage global visions for forestry, to define strategic tasks of scientific research, and its role in satisfying the needs for forest resources.

Scientific research of forest operations and technique follow the development of IUFRO. In the second half of the 20th century the range of scientific research of forest operations has suddenly expanded in most countries and institutions – members of IUFRO. Evaluations of scientific relevance of forest operations and control appeared in the same period and were recognized. The status of *forest operations science and technique* within forest sciences was determined. IUFRO, which is divided into eight divisions, assigned Division 3 to this field (IUFRO Division 3).

Creating methodology for making an evaluation of the state of development of forest operations as well as monitoring its application and international recommendations for planning scientific research would increase the efficiency of forest operations science and of the entire forest science.

- The current state of development of the forest operations science can be assessed by using the following data and indicators: 1. the number of scientists involved in research, in absolute and relative figures; 2. financial resources allocated annually for scientific research; 3. value of equipment and facilities provided for scientific reasearch; 4. range of field and types of activity covered by forest operations; 5. number of scientific discoveries and their value in terms of improving the efficiency of forest operations; 6. number of published scientific papers in a given period of time and their cat egories.

Current state of the forest operations science and practice is marked by an enormous span in the levels of development. Ancient methods are still used, as well as tools that date back several thousand years. At the same time, in other places, work- and production processes employ the most recent achievements of the human mind. This broad span includes various levels of development of forest operations methods and techniques with combinations of old fashioned solutions and more recent findings. The difference in the levels of development of forest operations and technique is a consequence of diversity of terrain, climate, and vegetation, as well as technical, historic, economic, and other features that influence forestry in its setting.

The most important challenges to the forest operations science are the following: 1. development of new methods; 2. development of new tools and equipment; 3. replacing man as a source of work power by multipurpose forest machines; 4. faster output of old and brand new forest products, and other benefits of forest; 5. increasing work productivity; 6. minimizing hazards in forest operations; 7. health care and prolongation of life expectancy and of active life of forest workers; 8. raising living standard and humanization of work of forest workers; 9. protecting forests, forest soil, and environment from damage during forest operations; 10. increasing economic efficiency of forest operations and technique; 11. ensuring progressive and sustainable forest management.

The causes of resistance to the research of forest operations are: 1. unpredictability of new scientific findings; 2. conflicts of interest among the beneficiaries of the same or different uses of forest, and between the owner of the forest and the contractor performing forest operations; 3. resistance to change and acceptance of the current state; 4. eternal distrust in the validity of scientific discoveries; 5. unwillingness to take risk on account of possible failures which accompany all scientific research.

It is necessary to predict the development of forest operations methods and technique, regardless of the degree of reliability of such predictions. No spectacular changes should be expected in the development of forest operations methods and technique in the near future. Realistic expectations are that in the beginning of the next century development trends will continue in accordance with the rules and trends of this decade. Possible exceptions in a certain discipline or region will not alter general trends significantly.

## 7. References

Anon, 1999: Tree CD-ROM. CAB – International, Wallingford, UK.

Bronowski, J., 1984: Uspon čovjeka (The Ascent of Man). Otokar Keršovani, Opatija, 1984.

Dobrov, G. M., 1966: Nauka o nauci (Science of science). Naukova dumka, Kiev.

Friedman, G., 1959: Kuda ide ljudski rad? (Ou va le travall humain?), Beograd.

Hilf, H. H., 1957: Nauka o radu (Arbeitwissenschaft). Otokar Keršovani, Rijeka.

Samset, I., 1967: The Law of Discontinuous Evolution (Zakon diskontinuirane evolucije). Journal o Japanese Forestry Society 49.

Samset, I., 1985: Winch and Cable Systems (Sustavi vitlova i žičara). Martinius Nijhoff/Dr. W. Junk Publishers, 539 pp.

Samset, I., 1992: Forest Operations as a Scientific Discipline (Šumski radovi kao znanstvena disciplina). NLH, As, Norway.

Silversides, C. R., Sundberg, U., 1988: Operational Efficiency in Forestry (Djelotvornost rada u šumarstvu), Vol. 2: Practice. Kluwer Academic Publishers, Dordrecht/Boston/London.

Šoštarić, K., 1999: Otkrića i poticaji (Discaveris and Impulses). Gazophylacium 1999(1–2): 46–65.

Sundberg, U., Silversides, C. R., 1988: Operational Efficiency in Forestry (Djelotvornost rada u šumarstvu), Vol. 1: Analysis. Kluwer Academic Publishers, Dordrecht/Boston/London, 1988.

Sundberg, U., 1988: The emergence and establishment of forest operations as a discipline of forest science (Pojava i osnivanje šumskih operacija kao discipline šumarske znanosti). Swedish University of Agricultural Sciences, Garpenberg, Sweden.

Thompson, M. A., 1995: Observation and Analysis of Performance in Forest Work (Praćenje i analiza učinaka šumskoga rada). XX IUFRO World Congress Proceedings, Tampere, Finland, 1–3.

Tomanić, S., 1989: Može li šumarstvo proizvoditi više? (Can Forestry Production Be Increased?). Meh. šumar. 14(1–2): 2–10.

Tomanić, S., 1995: Choice of Subject of Research in Forest Operations (Izbor predmeta istraživanja šumskih radova). Invited paper. XX IUFRO World Congress, Div. 3 Proceedings, Tampere, Finland.

Tomanić, S., 1995: Čovjek i šumski rad – Vremenske perspektive (Man and Forest Work – A Time Perspective). Arh hig rada toksikol 46(1): 55–63.

Tomanić, S., 1998: Djelotvornost radnih metoda pri proredi šumskih sastojina (Work methods efficiency in thinning of forest stands). Meh. šumar. 23(3–4): 117–127.

# Cost and Production Modeling Tool for Wood Procurement Logistics

**Esko Mikkonen, Zhangren Lan**

***Abstract***

*In a European Union financed study project "PromotE" a production cost calculation and production estimation procedure was developed for wood harvesting. The model utilises basic cost calculation principles and allows as many as 36 cost factors to be included. Used variables can be selected as the necessary basis. Investment, interest rate, service life, scheduled hours a year, and utilisation factors must be given, however. Production estimates can be calculated for the most common forest machines such as feller-bunchers, harvesters, forwarders etc. Those are based on the production functions published in recent literature. By combining these two items the unit cost of production can be estimated. The computer program "ProCost" has been programmed with Borland Delphi utilising its database features.*

***Key words:*** *modelling, costs, production, wood procurement, logistics*

## 1. Orientation

The identification and optimization of a sound harvesting system is based upon the specification of timber harvesting machine chain options by means of the costs calculation and analysis of harvesting machine. In principle, the machine chain options in harvesting system are primarily concerned with comparing alternative machines on the basis of an economic measure of effectiveness, which could go further to finalize the harvesting-transportation-wood handling options. The modeling of harvesting machine cost calculation is based on the window-based programming procedure. Friendly user interface development environment could facilitate the data input from users and communications among the routines, especially with a harvesting machine database system.

## 2. Objectives

It is of importance that harvesting operations be conducted as efficiently as possible in a target area of harvesting timber in any case. The objective of modeling harvesting machine chain options is to develop a graphical interface model of harvesting machine costs. Such costs of a specific machine are useful in selecting the best cost effective equipment for the conditions encountered on a given operation area. This model is used to generate the actual data by simulation for the general purpose harvesting system optimizer (GPHMO).

## 3. Methodology

To provide useful efficiency data about harvesting operations, specific time and cost study and analysis must be made. In general, harvesting machine costs consist of four main kinds:

1) Labor cost;
2) Depreciation and purchases of harvesting machine;
3) Materials and supplies; and
4) Overhead.

Machine purchases involve the investment of considerable sums before the actual operations. This part of costs is based on the depreciation schedule within an operating life of 1 to 5 years or longer, depending upon the particular items. Labor costs include all wages and salaries, and such indirect items such as payroll taxes for social security benefits as well as machine operator's compensation premiums and other fringe benefits. Materials and supplies include items used up or consumed in the operation. Overhead costs are related to those that are not directly incurred by the harvesting machine operation.

Cost and efficiency analyses could reveal true relationships between alternative methods of harvesting machine performing the same function. The value of timber products from harvesting area and the costs of harvesting machines, and labor costs should reach such proportion to make inefficiency very costly and unacceptable. A measure of production output and the cost of performing the operation are directly regarded as a machine rate, which is expressed as the costs of operating a unit of production on an hour basis.

The procedure of machine cost calculation and data exchange among them will be accomplished under the control of friendly graphical user interface.

## 4. Detail description of programming

A cost calculation model has been developed to generate the actual data as the input in the General Purpose Harvesting Method Optimizer (GPHMO). The procedure of a cost calculation could be carried out in three different ways, i.e.

1) cost calculation for single machine
2) machine combination, meaning that it includes both base machine and its appliances
3) several machines included in production chain, e.g. harvester and forwarder etc.

### 4.1. Interface design

**Figure 1** Main window for a cost calculation model

Main window in the cost calculation model is shown in Figure 1. Pulling-down menu items include 'Input Data', 'Basic Machine', 'Combination', 'System Chain', and 'Help'. Menu 'Basic Machine' includes different types of machine to be selected in a cost calculation procedure, which are:

- Harvester
- Forwarder
- Feller-buncher
- Processor
- Skidder
- Slasher
- Multi-Logger
- Loader
- Chipper
- Chain saw
- Other

A table has been stored in harvesting machine database system (HMDBS) for each type of machine. Individual machine can be selected by browsing navigator-button in the window, by which simple attributes of the machine are displayed beneath the navigator-button; i.e.,

1) Model type of machine
2) Engine power
3) Machine size with dimension, and
4) Machine costs.

Graphical display shows the picture of each machine corresponding to the selection in navigator-button click. In addition, interface also includes two items of information display to show the basic assumption of cost calculation, which can be changed in data-input and specification window. Before going to the following step, there are four items within separate 'box' that should be checked. Those are shown as below,

1) Interest formula
- Short term
- Long term, or
- Annually

2) Residual value scheme
- Salvage
- Decreasing-in-value

3) Depreciation scheme
- Even sum yearly
- Degressive
- Progressive

4) Monetary unit
- Euro
- USD
- FIM

- DM
- Skr, or
- Other

### 4.2. Data structure and input

Click menu 'Data input' in main window. Interface for machine data input is shown as Figure 2. In this window, pulling-down menus are itemized with the following.

1) Data file: open existing file, save new data file etc.
2) Edit: general file editing function
3) Machine types: selection of machine which is connected with main window
4) Analysis: machine cost analyses function included
5) Report: final reports of machine costs.

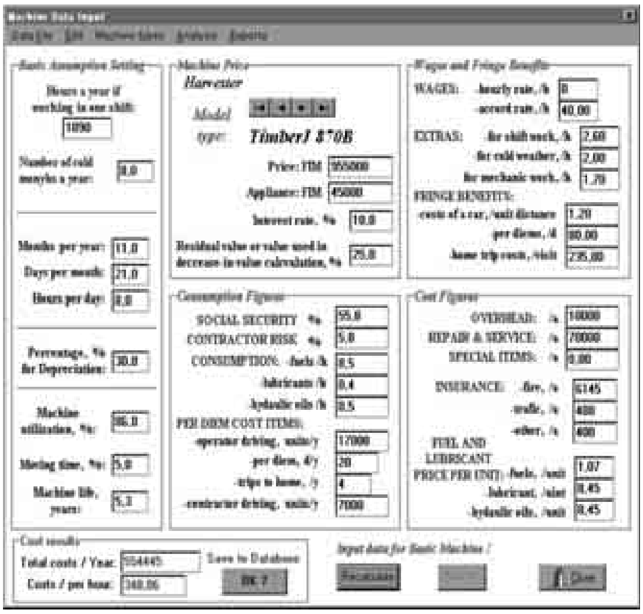

**Figure 2** Window for data input and machine cost calculation

Interface has been designed as a series of data to be input in cost calculation model. It consists of five groups of machine cost calculation and analyses factors. Each group is presented with more detail below.

1) Basic assumption setting
   - Hours a year if working in one shift
   - Number of cold months a year
   - Working months per year
   - Days per month
   - Hours per day
   - Percentage for depreciation (%)
   - Machine utilization (%)
   - Moving time (%)
   - Machine life (years)
2) Machine price
   - Model type of machine: connected with main window
   - Machine price
   - Its appliance
   - Interest rate (%)
   - Residual value or value used in decrease-in--value calculation
3) Consumption figures
   - Social security cost (%)
   - Contractor risk cost (%)
   - Fuel consumption per hour: including fuels, lubricants, and hydraulic oils
   - Per diem cost items: including follows,
     – Operator driving, units per year
     – Diem per year
     – Times of trip to home per year
     – Contractor driving, units per year
4) Wages and fringe benefits
   - Wages: hourly rate, or accord rate
   - Extras per hour: for shift work, for cold weather, or for mechanic work
   - Fringe benefits: costs of a car (per unit distance), per diems, or home trip cost
5) Cost figures
   - Overhead costs yearly
   - Repair and service yearly
   - Special items yearly
   - Insurance per year: including fire, traffic, and other etc.
   - Fuel and lubricant price per unit: including fuel, lubricant, and hydraulic

Once individual machine is selected and data input, click button 'Calculate' and results of machine total costs per year and hour costs can be displayed in the box 'Costs results'. Machine hour costs can


**Figure 3** Standard dialogue window for import of data

also be saved to database system by clicking the button 'Save to database'. In the pulling-down menu item 'Data file', data input and costs results for individual machine can be saved as a specified 'file'.

And by opening a standard dialogue box as follow (Figure 3) the import of data file can be done for cost calculation of a specified machine that was saved in previous calculation.

### 4.3. Connection to harvesting machine database system (HMDBS)

HMDBS, as a module, has been built in the GPHMO (PromotE Task 4.2 report) software package. Cost calculation model has always been connected with the machine database system. In the windows (as Figure 1 & Figure 2), machine type or individual machine selected is always from a single table stored in database. Field (attribute) 'Machine Cost' in the table would store a data saved from the result of cost calculation procedure, or edited directly from user through the editing or updating function situated in the database system. Being aware of GPHMO in the Task 4.2, cost calculation module has been integrated together with other procedures. However, in any case of harvesting machine operation, cost calculation module could be employed alone to carry out the options of harvesting machine chain. In this case, as a single software package of cost module to be installed, HMDBS is a non-visual component that can not be activated as a single window within the cost calculation module itself.

### 4.4. Analyses of cost items and parameters

In the window 'Machine Data input', click menu 'Analysis' item system will open a window 'Variable Analysis' (as shown in Figure 4). There are two kinds of procedure of variable analyses, i.e. one way and two ways in different cases, which can be selected by simple click radio-box 'Analysis way'.

#### 4.4.1. One way analyzing method

One way method will only activate main cost item box. In the cost item box, one cost variable can be selected, and at the same time 'Lower bound', 'Upper bound' and points of analyses must be defined. For instance, select the price of machine and set:

- Lower bound: 75000
- Upper bound: 135000, and
- Points of analyses: 8

As shown in the table display of the window. Final results of analysis indicate the ranges of machine costs relating to different machine prices within the bounds.

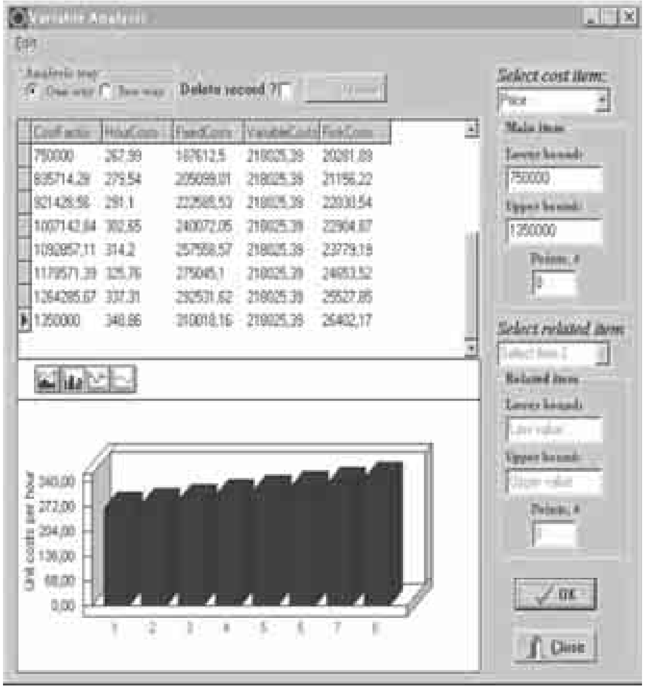


**Figure 4** Window for analyzing cost items and parameters

#### 4.4.2. Two ways analyzing method

Two ways analyses involve main cost item and its related item that is also related to item's 'Lower' and 'Upper' bound to be defined. Clicking two ways method will activate main cost item and its related item. Once two key items are selected and corresponding bounds are defined respectively, results will show the ranges of machine costs within the bounds of cost items.

#### 4.4.3. Display of analyzing results

As shown in window Figure 4, display of analyzing results can be both table type and graphical type. In table display, results can be saved to database as a table and printed out, too. In graphical display, users can easily change the type of graphical display by clicking the corresponding button as shown in the window design.

### 4.5. Machine cost report

The report of machine costs data can be printed out. Simple click of 'Report' menu will open a report window as shown in Figure 5.

In this window, users can select one item in Radio-Button box and print its results out. Final report of machine cost calculation has been formatted in one page, which includes items as follows,

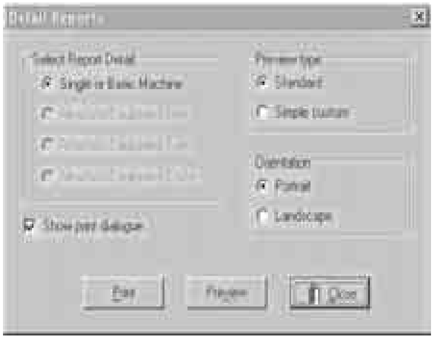

**Figure 5** Window for report of machine cost calculation results

1) Machine price
2) Salvage value and depreciation scheme
3) Working time
4) Consumption figures and unit price
5) Costs: including fixed costs and variable costs
6) Total costs annually, and
7) Per unit costs: machine hour.

## 5. Discussion and conclusion

This graphical software for calculating harvesting machine cost can be run alone for the purpose of harvesting-transportation-wood handling options or work together with software package of GPHMO for optimizing harvesting system. Modeling of harvesting machine cost calculation may be summarized as follows,

This model can be used in different countries and circumstances. Graphical user interface design of software is easy for users to input data and report final results of harvesting machine cost at a harvesting company level.

Based on the principle of cost calculation method, this model could be applied for different type of forest machines and its related equipment, for instance, to be employed in both ground-based harvesting system and cable logging system etc.

Machine hour cost is calculated in certain circumstances of machine operation. Harvesting machine chain options in cost-effective way should be based upon the degree of similarity in terms of harvesting machine productivity.

## 6. References

John A. White etc., 1977. Principles of Engineering Economic Analysis. By John Wiley & Sons, Inc.

User's Guide, Borland Delphi for Window 95 & Windows NT. Borland International, Inc., 100 Borland Way.

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# Work Study – A Forgotten Scientific Branch in Forestry?

**Boštjan Košir**

***Abstract***

*The paper deals with the situation of work-study branch in forestry today in view of the transition situation in Slovenia. The result of work-study is work simplification, shown through the reduction of standard times, improvement of working time utilization and lowering the costs per unit of production. Standard times enable comparisons among different technologies and international comparisons as well, the latter however not being very favorable for Slovenian forestry. A relatively low productivity causes high production costs, which means that forest enterprises will manage production successively only if they gain positive stumpage price for the owner by choosing and selling best quality of the timber. Thinnings and working units with low wood concentration will not be of interest and therefore these operations will be avoided. This will be much more relevant in private forests where the forest owner's will and his needs are of the uttermost importance. Today's practice of establishing the input variables for standard times computation in Slovenia does not correspond to the theory of work organization and work-study. At the time when forest enterprises and private entrepreneurs have to work in most unstable and unpredictable conditions, the following simplified equation could be derived: Savings due to management's measures>Savings due to production improvement. Different management activities regarding sales, market, involvement of politics, different institutions etc. are far more important than concerns about the production improvement. It could be assumed that Optimal strategy = Success of managerial activities + (Production improvement = near zero) or: Optimal strategy ⇨ Success of managerial activities. The last equation is also proven by the fact that since 1990 forest enterprises have not been supporting projects and other activities in the field of work-study. We can expect better co-operation between forest enterprises and research teams when the economical and political situation is stable and both sides of the above equation are in dynamical balance i.e.: Optimal strategy = Success of managerial activities + Production improvement. There are many ways of overcoming the present situation, some of them being discussed in the paper.*

***Key words:*** *work organisation, work study, transition, Slovenia*

## 1. Introduction

Work-study is a scientific branch, which has been developed for work simplification based on studying working processes. It is based on the concept that time means money and thus time became one of the basic parameters of industrialization and development of technology in different fields including forestry. The question is how to increase the working time utilization and how to simplify the present operations so as to get maximum output in relation to the input of energy, material and information. The first work-studies in the field of forestry appeared at the beginning of the century, but later on special research teams were established in many countries dealing with the problem of work-study in forestry (Sundberg and Silversides 1988). Subsequently the field has been divided to work time, work method studies and payment.

Research activities in the field of forestry techniques and operations included work-studies and especially time measurements. A part of the studies was included in postgraduate studies. There have never been professionals to deal only with work-studies in Slovenia. Despite this we were able to satisfy the needs for accurate time studies in forest engineering for a long period of time. On the other hand the standard times of different silvicultural work or forest protection operations have always been statistical or based on experience. The delay in following up and changing the existing standard times on scientific base has started with the breakdown of the normal technological development. There have always been ways to adapt the existing and sometimes not any more accurate standard times to practical use. Proper standard times can be used for many purposes and therefore it would be necessary to start using them again.

## 2. Development

The development of work-study branch has always been closely connected with the time measurements, method studies and ways of payment. In many decades of work-study development different scientific branches have been included and contributed much to the quality of results. Work measurement with standardized procedures does not represent the scientific challenge any more (Košir 1996). This does not mean that work-study is not any more at the top of professional specialization in forestry.

The biggest problem of this field is the comparability of studies conducted by national institutions with different approaches. Great efforts were made to standardize internationally the work-study terms, the division of the calendar time and measurement procedures (Bjorheden and Thompson 1995, Košir 1996). Work-study remains a professional branch, which should also have our full attention in the future – just like cost calculations, which have never been compared between different countries.

Every new technology, new machine or new form of work organization brings something new to our knowledge that has important impact on practical life. Those impacts affect the worker who is most frequently paid by piece rate, the employer because of different unit costs and the forest owner who gets higher or lower forest rent. The state should not be indifferent and not only because it is the biggest forest owner but because the state should take care of the benefit of all citizens. It is not just the same how high the hourly production is, and – the result of work-studies are always a simplification of working processes, better organization and consequently – lower costs per unit of production.

Consequently pretty accurate methods of method study, time study and job evaluation have been developed, which are the tools of professional research teams in the framework of different research projects. They use all available modern equipment as hand-held computers, video, proper software etc. Single study could also last for several months or even more if it is connected with excessive field work and depends upon the production system borders and demanded accuracy. The professional time study experts are included in this process, which is full of small and deep traps despite its tricky simplicity.

Methods of method and time study are the scientific approach to work organization. Accurately defined procedures help us to look into the working processes, measure them and make proper analytical conclusions. The approach is crowned with the synthesis to achieve minimal goals and estimation of simplification. When performing work studies we urgently need good staff – specialized work-study experts – as we frequently meet working processes that are not yet stabilized or are quite new and not well known. In conducting such studies there is always the need for changes, for transformation of less efficient processes to more efficient processes. Experienced researchers with wide knowledge of technological processes in forestry are indispensable for achieving success. Work-study today also includes some other scientific branches and the cooperation of different specialists in research team is of essential importance. The measurements are not cheap, but high costs have a quick return.

## 3. Present

A number of cases show extremely inappropriate attitude towards work-study, although this has been the subject of lectures at the Forestry Department of the Biotechnical Faculty in Ljubljana for almost thirty years. At postgraduate level special emphasis is placed on work-study for the students who wish to improve knowledge of forest engineering, work organization and economics. According to the Forestry Act standard times of forest operations should be prepared by Forestry Institute of Slovenia. Despite this – if we have in mind professional teams – organized work-studies have not been established yet. In the last several years not a single original study has been carried out with the purpose of setting standard times. There are a lot of excuses for this, and today we have pretty old standard times in official use not to mention the missing time studies for new machines and other changes in forest operations.

There is no trace of the tripartite system of accepting new standard times, which are used in state forests (Košir et al. 1992). The actual standard times were determined by the Ministry of Agriculture, Forestry and Food and are too old, and therefore not accurate, but they are still the best indicators of production times of various forestry work operations. Standard times for cutting are over twenty years old and almost the same problem is met with tractor skidding. There are no standard times for downhill cable skidding and the rest of standard times needs check studies as many processes and equipment have been already slightly changed.

Whose interest is then to improve standard times and make their use proper? It seems nobody's! Most important entries to standard times are determined by the professionals, who are in no way dependent upon the accuracy of their use and success in forest production. Many of them are even not experienced enough in this respect as they belong to the Public Forestry Service, which has many other tasks to perform. For many of these professionals the accuracy of standard times is not an issue at all and they consider the difficulty of finding entries far more important. However strange it may sound, the state office, which manages the state forests, obviously does not wish to know the normal production rates and normal costs. On the other hand it is also strange that trade unions and employers are satisfied with this practice, although the existing standard times are the measure of normal work specified by bilateral contract between them. In the multitude of not enough defined relations, poor standard times are obviously not the major problem as nobody does have serious objections.

Standard times also enable international comparisons between forest operations in different conditions and the productivity of different technologies. Open market in the European Union and neighboring countries considers such analysis very important, but at this moment nobody cares about the fact that the results of comparisons are not very favorable for Slovenian forest enterprises (Košir 1997). A relatively low productivity causes high production costs, which means that forest enterprises will successively manage production only if they gain positive stumpage price for the owner by choosing and selling the best quality of timber. Thinnings and working units with low wood concentration will not be of interest and therefore such operations will be avoided. This may not be quite true in state forests where the influence of the Public Forest Service is higher, but much more in private forests where the will of forest owner is of the uttermost importance.

Daily productivity of chain saw cutting is about 2 $m^3$/h (conifers, small wood) or 0.5 h/$m^3$. The difference between their productivity and the productivity of Slovenia – annual cut in Slovenian state forests – accounts for around 500 mill. SIT. If we consider other more advanced technologies of tree felling and processing the difference would become much higher. There is another example: if the allowable cut were defined higher by only 5 % in average the difference in cutting costs would amount to some 80 mill. SIT, which is very a high amount in comparison with the annual funds intended for research program in forestry (which does not include any work-study). Who does not still care about checking and following up the standard times?

The practice of defining the entries to the standard times interferes with reason and with the procedures we know from the past, as well with any practice applied abroad. This practice also does not correspond to the theory of work organization and work-study. In the eighties the practice was quite different. The entries to the standard times were defined as a part of operational planning by forest technicians and forestry engineers who dealt with the production process. Through operational control the feedback information and interactions between the real operations and men who made operational plans were always available. Technological maps based on terrain classification were drawn for some state forests. Some of them were accurate enough to help finding some of the entries for the cutting units even without field work. When some errors were made – that was found pretty quickly – as forest rangers had permanent contact with the top forest enterprise administration and with the workers in forest production. Today the problem is that forest rangers, employed by the Public Forest Service, do not have so important feedback information of the actual use of standard times. How could they develop, especially young foresters, the necessary knowledge if they can not follow the effects of their efforts?

In the industrial world the standard times are neither a habit nor a custom or rules of good behavior, which could be slightly broken here and there. They origin from clearly recognized effects of their use not only to the employers but also to the employees and to the state. When starting with new standard times the interest of the employer and employees are a priority. The state should interfere only when the conflict between parties is not so easy to overcome. The basic rule is that the one who needs the standard times should also care for their proper use and control of the effects. The state should take care of justice in the practical use. The discrepancy between the state and the internal company's standard times should not increase too much. Each party looks at standard times with different eyes, and their objections are clearly understandable. Maturity of all parties will start when they understand that it is impossible to cheat the other party forever. That is why the just use of independently established standard times is of such importance for everybody.

The companies can survive in the recent economical and political situation in different ways with various perspectives in the nearest future. When forestry enterprises are threatened not only with competition among them, but even more with unpredictable moves of forestry politics, the following simplified equation could be accepted:

**Savings due to management's measures ⇨ Savings due to production improvement.**

The position of the company, which struggles for survival is almost entirely dependent upon the activities of its top management as lobbying, active work in political parties, charges in the court and similar. These moves of the company's leadership are far more important then real development in the technological core of the organizations. Higher productivity would require important investments in knowledge and equipment, which carries some risk by definition. Forestry companies are much more ready to invest in machines than in human resources or even in some disputable studies of working processes. The stress is placed on present productivity without much concern about the future. The share of technical development in the company's success is very modest compared with the meaning of top management activities. the following equation can be derived:

**Optimal strategy = Success of managerial activities + (Production improvement = near zero)**

or:

**Optimal strategy ⇨ Success of managerial activities.**

Among other consequences of this equation there is also the fact that since 1990 the forest enterprises have not financed the work-study projects and other related activities. Only several of them have performed such studies by themselves for their own needs. They searched for internal reserves and they found them in the reduction of the number of workers in production and administration, in geographical restructuring and repositioning of their functional units, while the technologies have remained the same. Fair play in negotiating for stumpage prices with forest owners, lobbying and marketing of their services bring more economical stability then investment in research work, waiting for uncertain results, which are often limited in practical use considering the possibilities of the research teams. The results often develop solutions without finding the way to achieve the goal.

Better cooperation between research teams and forest enterprises could be expected when economical and political situation is stabilized to the degree to provide dynamical balance between the sides in the above equation. For forestry it will be when the approximate market shares of each forest enterprise are known. The efforts for spreading the single market share will be transferred to special domains, work in private forests, as well as to the actual technological development.

**Optimal strategy = Success of managerial activities + Production improvement.**

Some signs of the needs for cooperation between research institutions and forest companies become more and more evident, although they are still too rare and vague to speak about renovation optimistically. We are still deeply in the transition, which gives new opportunities and chances for better life to many people, but compelling them to the struggle for the positions without any compromise. Today it is true for the individuals and enterprises, but tomorrow it will also be true for the state in the society of much stronger allies.

## 4. Tomorrow

The Forest Act separated the inseparable – planning and executing – and the consequences will remain for a long time since the connection between Public Forest Service, forest owners, administration of the state forest and private companies are being established very slowly. There should be a concerted action to overcome, more or less, normal problems of this transitional period. Our forestry should not be left without some important knowledge. The ways for improving the present situation are various, but some of them might be the following:

- It should be the concern of the Ministry to introduce work-studies in Forestry Institute of Slovenia providing funds for financing at least one specialist. The studies envolving ergonomics, safety at work, economy and environmental friendliness of processes should be encouraged.
- The working group for standard times with Forestry Institute of Slovenia should be reshaped, and particular tasks should be assigned specifying responsibility and status. The first task should be the establishing of DAA system (development, accepting, accompanying, Košir et al. 1992).
- A part of DAA system accepts new standard times, which is to be done by the Ministry and should be accomplished quickly after completing the proposal.

- WGST should give the priorities of standard time renewing, check studies, regarding available time and funds.
- WGST should be informed of the results following up the use of standard times, eventual difficulties, errors or similar.
- State Forest Offices should be responsible for supervising and checking the proper use of standard times for operational planning purposes, among other activities. Financing of the necessary check studies is expected.
- Trade unions should also pay more attention to work-study results and normal use of standard times for labor assessment and payment. Safety at work and ergonomics should be among their priority interests.
- The Public Forestry Service should also be involved in work-studies. This organization covers the whole country with good information system and good personnel. It would be a pity not to use this potential.

Forestry companies hide a great potential – like a compressed spring. The economy is always rational in view of the present priorities and emergencies. Nobody can be forced to manage rationally or invest unselfishly in knowledge without instantaneous benefits. Managerial teams in forest companies have not yet passed their test in front of the boards of their shareholders. They will take the future courses of every single forest company with changing interest in collaboration between the company and research teams, according to the current company's needs. It would be right if companies appeared at this moment as partners in establishing the new approach to work-study. Many of them follow closely their productivity and the use of their internal standard times, but this is – form the point of view of work--study– not enough. True simplifications of working processes are gained by minute studies of work place time and its comparison with the existing – assumed – standard times used in state forests. The difference would motivate the entrepreneurs to achieve better productivity and the State Forest Office would be motivated to check and change the existing standard times. And where is the end of this circle? Obviously nowhere and never as this is contrary to the basic elements of searching for better technologies. Yet this looks like development, which is not enough for defeating the adversary, but enough to give priority to the actual productivity improvement.

## 5. Conclusion

The use of standard times remains an important part of the profession with great economical impact on the State Forest Office, forest owners, forest workers and on forest enterprises. Correct standard times should work as a compass among different categories of subjects involved in forest production, as they are the measure of normal work at present. Today's situation in forestry does not support the need for accurate standard times and their use since it is much easier to achieve the economical effects by lobbying, speculation and similar. There is no motivation for new work-studies or even for check studies of working processes in forestry at present. This is the only possible explanation for using pretty old standard times for most frequent forestry work, not to mention that for some operations there are no standard times at all. Forestry companies cannot be expected to finance the extensive work-study projects. The responsibility lies with the Ministry and the State Forest Office, which are expected to provide balanced financing of research teams. New wave of studies is expected in the years to come involving ergonomics, economics of working processes, safety at work and environmental impact of the operations.

## 6. References

Bjorheden, R., 1991: Basic Time Concepts for International Comparisons of Time Study Reports. Journal of Forest Engineering 2(2): 33–39.

Bjorheden, R., Thompson, M. A., 1995: An International Nomenclature for Forest Work Study. – Report of working group, IUFRO S3.04.02, Garpenberg, Fredericton, 16 p.

Košir, B., Medved, M., Dobre, A., Žgajnar, L., Bitenc, B., 1992: Uporaba casovnih normativov v gozdarstvu republike Slovenije od l. 1985 do l. 1990.– Strokovna in znanstvena dela, IGLG, No. 110, 60 p.

Košir, B., 1996: Organizacija gozdarskih del. University of Ljubljana, Biotechnical Faculty, Dep. of Forestry and Forest Resources, 2nd edition, Ljubljana, 223 p.

Košir, B., 1997: Pridobivanje lesa. – University of Ljubljana, Biotechnical Faculty, Dep. of Forestry and Forest Resources, Ljubljana, 330 p.

Sundberg, U., Silversides, C.R., 1988: Operational Efficiency in Forestry – Volume 1: Analysis. Kluwer Academic Publishers – Forest Sciences, Dodrechts/Boston/Lancaster, 1–219.

... 1993. Zakon o gozdovih.– Ur. L. R. Slovenije, 30/1993, Ljubljana, p. 1677–1691.

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# Low Cost Harvesting for Small Scale Forestry in Japan

**Hideo Sakai**

***Abstract***

*Forestry in Japan has fatally serious problems. 1) About half of slopes exceed more than 25 degrees. 2) Planted young conifers, less than 50 years old, cover about a quarter of the land. 3) The individual forest makes about 60 % of the forest area and there are few owners of large forests.*

*These features make high-standard road construction difficult. Various kinds of small forestry vehicles and narrow strip roads of less than 3 m in width play an important roll in small-scale forestry in Japan. The method of hanging a block to pass a cable from the winch through under the arm of the grapple crane to haul thinned logs was invented by some forwarder operators about ten years ago. This method promoted the development of a domestic, small, mobile tower-yarder, which was suitable for Japanese operational conditions. A tower yarder of 200 m mainline capacity is installed on a four- or six- wheel-drive mini-forwarder with a 60 horsepower engine. It is equipped with an interlocked hydraulic winch, which transfers torque between the haulback drum and the main drum, enabling the yarder to be smaller and powerful. It is only 1,500 mm wide, so that it can move on strip roads of 2 m in width. Its yarding cost, f(L) (yen/m$^3$), can be calculated by f(L) = 7.21 L + 2130/L + 377, where L (m) is the maximum yarding distance. Even though the road construction cost is 15,000 yen/m, the total cost, including the road cost, can be minimized at 1,576 yen/m$^3$ by a road density of 105 m/ha or L = 83 m. Dense low-standard road networks realize frequent access to forest and adequate thinning, which brings the growth of stands and undergrowth. This has a beneficial effect on environmental protection.*

***Key words:*** *small scale forestry, harvesting cost, forwarder, tower yarder, forest road network*

## 1. Introduction

In Japan, 67 % of the land is forested and for a number of reasons, the forestry industry suffers gravely and has serious problems. 1) Slopes are steep, about half of them exceeding 25 degrees. 2) Coniferous trees have been planted since the 1950s and conifers less than 50 years old occupy about a quarter of the land. These planted forests have required thinning since the 1970s. 3) Individual forests make about 60 % of total forest area and there are few large forest owners. These features make high-standard road construction and forestry mechanization difficult. Only twenty years ago, manual operations such as sled or animal skidding could often be seen. Various kinds of small forestry vehicles and narrow strip roads of less than 3 m in width play an important role in small scale forestry in Japan.

This paper intends to show the status of small forestry machines in Japan and analyze the harvesting costs of using a domestic, small, mobile tower-yarder.

## 2. Small forestry vehicles

Since the 1970s, various kinds of small forestry machines including monorails and zig-zag mono-cable systems have been developed and used throughout small scale forestry. Figure 1 shows the relationship between engine power and payload capability of Japanese forwarders. The smallest forwarder of 5 kW (7 PS) and 1.2 m in wide is installed on rubber tracks. Forwarders of less than 7 kW (10 PS) are bought by small forest owners. Forwarders of 22–59 kW (30–80 PS) with a payload capability of 2000–2500 kg are popular among forest owner's associations. Now, grapple

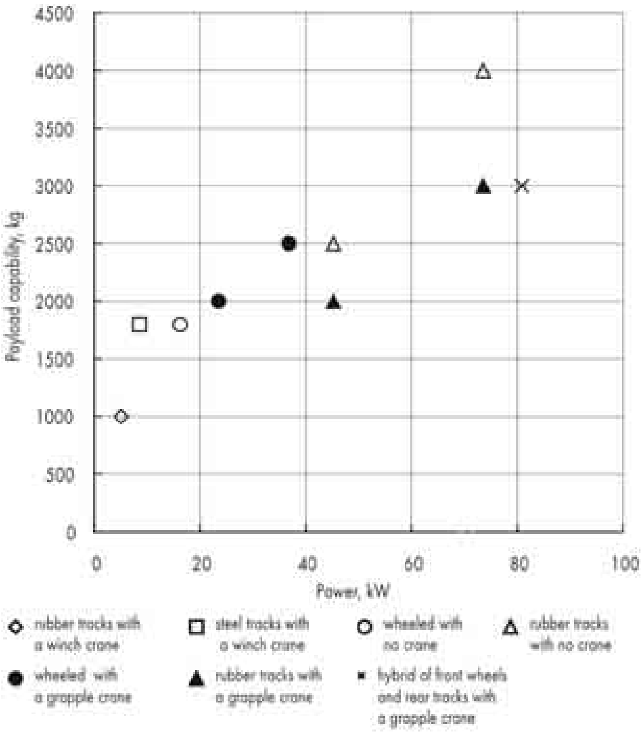


**Figure 1** Relationships between engine power and payload capability of Japanese forwarders

cranes play an important role on such vehicles as they facilitate loading. Recently, rubber tracked forwarders of more than 74 kW (100 PS) have become popular. Some of them are not equipped with loader cranes because they are used in combination with processors or log-loaders. A hybrid type forwarder of 1.85 m in width with front wheels and rear rubber tracks has been introduced. Rear rubber tracks reduce the ground pressure caused by heavy loads and recover the road surface disturbed by the front wheels. The machines are so narrow that a road width of 3 m is sufficient to accommodate them. Relationships between road width and the machines used in Japan are shown in Table 1.

Now, a processor of 55 kW (75 PS) and 1.88 m in width has been developed for thinning (Figure 3). As the power of traditionally used excavators of the same size is about 41 kW (56 PS), this small processor may be said to be equipped with a high power engine to supply hydraulic power to delimb thinned logs.

## 3. Cost analysis of a mobile tower yarder

Cable logging skills are traditionally highly developed in Japan. A method of hanging a block to pass a cable from the winch through under the arm of the grapple crane to haul thinned logs was invented by forwarder operators about ten years ago.

**Table 1** Relationships between road width and machines used in Japan

| Road width | Vehicles width | Example of vehicle type | Notes |
|---|---|---|---|
| m | | | |
| 1.5 | 1.2 | Rubber tracks | |
| 2 | 1.26 | Three-wheeled | |
| 2.3 | 1.4 | Four- or six-wheeled | |
| 2.5 | 1.85 | Hybrid of front wheels and rear rubber tracks | |
| | 1.65 | 2 ton truck | Road bed must be stable |
| 2.7 | 2.3 | 0.28 $m^3$ back hoe | |
| 3.0 | 2.3 | Wheel skidder | Tree length logging |
| | 2.4 | Rubber tracks | |
| | 2.14 | 4 ton truck | Radius of curve must be great |
| | 2.5 | 0.50 $m^3$ back hoe | |

This method promoted the development of a domestic, small, mobile tower-yarder suitable for Japanese operational conditions. A tower-yarder of 200 m mainline capacity is installed on a four- or six-wheel--drive forwarder with a 24 kW or 44 kW (33 or 60 PS) engine. It is equipped with an interlocked hydraulic winch, which transfers torque between the haulback drum and the main drum, enabling the yarder to be smaller and more powerful (Shishiuchi *et al.* 1993). The maximum pulling force is 1,500 kg. Being only 1,500 mm wide, it can move on 2 m in wide strip roads.

Based on an experiment carried out at the thinning site of a 27 year-old Sugi (*Cryptomeria japonica*) stand, this machine's yarding cost, f(*L*) (yen/m$^3$), can be calculated by use of the equation

$$f(L) = 7.21\ L + 2130/L + 377$$

as shown in Figure 2, where *L* (m) is the maximum yarding distance (Sakai *et al.* 1989). A survey of the main data is given in Table 2.

Annual road maintenance costs are estimated to 0.4 % of the road construction cost of current prices

**Table 2** Main data for cost calculation

| | |
|---|---|
| Machine price (=*M*), yen | 10 million |
| Depreciation and maintenance cost, yen/day | 0.000 733 *M* |
| Labor cost, yen/man·hr | 2000 |
| Average payload, $m^3$ | 0.3 |
| Cycle time of yarding, sec | 1.333 *L* + 57 |
| Rigging time per line, sec | 7.5 *L* + 230 |
| Fuel and oil cost, yen/$m^3$ | 0.63 *L* + 27 |

*L* – maximum yarding distance, m
1 USD = 100–110 yen

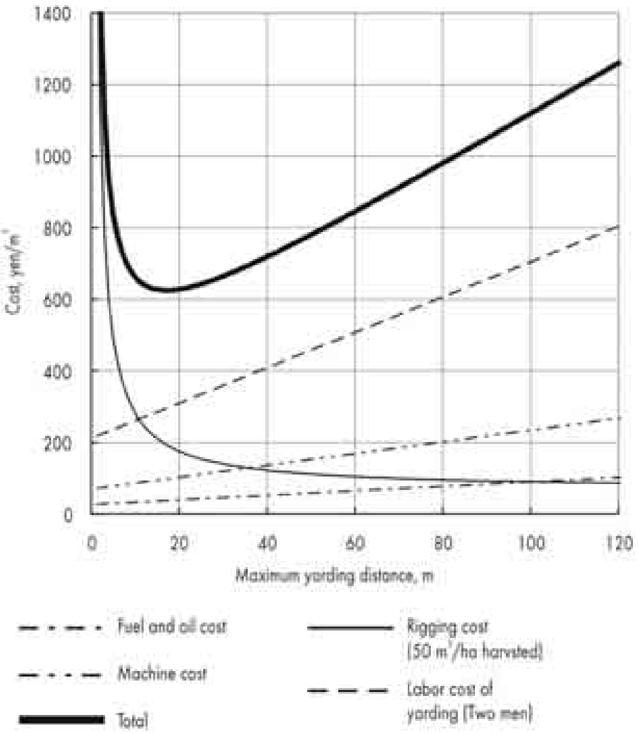


**Figure 2** Yarding cost of a mobile tower yarder on a thinning site

in Japan (Sawaguchi and Ohkawabata 1993). Road density (m/ha) can be derived from the maximum yarding distance, $L$ (m), by $5000 \times k / L$, where $k$ is a correction factor of road space (Dietz *et al.* 1984). Assuming that the annual growth in stand volume is $v$ ($m^3$/ha), road cost (yen/$m^3$) can be calculated by $0.004 \times r \times 5000 \times k / (v \times L)$, where $r$ is the road construction cost (yen/m). By adding this road cost to the above f($L$), the total cost (yen/$m^3$) can be obtained.

Even though the road construction cost, $r$, is 15,000 yen/m, the total cost including road cost can be minimized to 1,576 yen/$m^3$ by maintaining a road density of 105 m/ha or restricting $L$ to 83 m, where $k$ is 1.75 and $v$ is 11 $m^3$/ha (Figure 3). As a result, when road construction cost is low, very cheap logging costs with high road density can be achieved.

## 4. Environmental protection by use of tower yarder

Dense low-standard road networks realize frequent access to forest sites and enable adequate thinning, which promotes growth of both stands and undergrowth. Well thinned forests not only increase the stand volume but also eradicate surplus evaporation by thinned trees, which retains water in the forest soil. Established undergrowth prevents soil

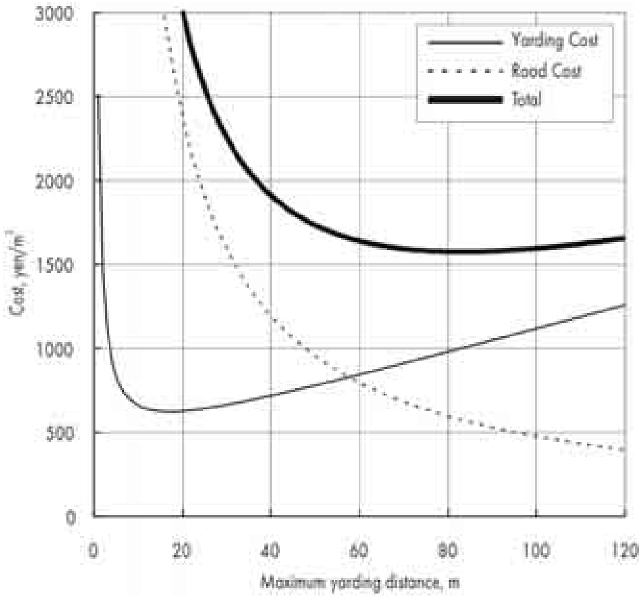


**Figure 3** Total cost of yarding cost and road cost

erosion. These effects are beneficial to environmental protection.

Even though roads of 3 m in width are constructed with a density of 100 m/ha, the loss of growing site is about 7 % on slopes of 25 degrees (Sakai and Kobayashi 1997).

## 5. Conclusions

The introduction of large-scale machines is intended with the aim of achieving cost-effective logging. But there is the possibility of utilizing small--sized, high performance forestry machines. The simplest, easiest and safest systems are required for future operations.

## 6. References

Dietz, P., W. Knigge, Loeffler, H., 1984: Walderschliessung. 426 pp, Paul Parey, Hamburg.

Sakai, H., M. Shishiuchi, J. Gotou, S. Tatsukawa, and R. Oikawa, 1989: Developing new forestry vehicles with a prehauling function using a running skyline system (IV) Operational performance. Jpn Mtg. 100, 783–786. (In Japanese)

Sakai, H. and H. Kobayashi, 1997: Forest road construction and operation systems: Considering the environmental effect on steep terrain. Proc. IUFRO/ FAO Seminar on Forest Operations in Himalayan Forests with Special Consideration of Ergonomic and Socio-Economic Problems. 38–42.

Sawaguchi, I. and O. Ohkawabata, 1993: The efficient planning of the specifications of forest road systems (I) The decision of main roads specifications by means of a formula similar to Hack's law. J. Jpn. For. Soc. 75(1), 16–23. (In Japanese with English summary)

Shishiuchi, M., J. Gotou, H. Sakai, and R. Oikawa, 1993: Development of a small mobile tower yarder with an interlocked hydraulic winch which transfers torque between the haulback drum and the main drum. J. Jpn. For. Eng. Assoc. 8(1), 17–28. (In Japanese with English summary)

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# Logging Operations in Small Private Forests in Slovenia

**Jurij Marenče**

***Abstract***

*In a highly fragmented private forest property, timber is not logged on a large scale and hence the amount of timber there is much smaller than in state-owned forests. The great majority of forest owners have a small holding and consequently the level of utilization of their machinery is low as well. The scope of work depends primarily on the size of the forest they manage. Utilization level of machines has a considerable impact on the cost of their use. Tractors are used primarily for agricultural production, as well as for forest work. The extent of forest work depends on the size of forest property. In the study the index of operating efficiency (Kg) represents the proportion as to which the costs of felling and skidding wood are covered by timber price on a truck road. Regardless of which machine was used, in a small forest holding (less than 5 ha) Kg is less than 1. The low level of utilization of machines requires the use of simple, least expensive skidding machinery. It is true that in such a case the use of small wheeled tractors is the least expensive, but they are limited in terms of application. The problem of uneconomical forest work, carried out by owners of a small holding in particular, could be solved by contracting out such tasks to forest work contractors, who would do the work at a lower price. Their machinery is better utilized, therefore the costs of felling and skidding are lower in a small private holding as well.*

***Key words:*** *small-scale forestry, forest work, logging, efficiency*

## 1. Introduction

The majority of forests in Slovenia are private. We estimate that after denationalization is completed, 80% of forests will be privately owned and there will be 300,000 owners.

Besides being predominately privately owned, forests are also characterized by their small size. Most forest small-holdings are less than 5 hectares in size. 85.4% of small-holdings fall into this category and they cover 38.6% of privately owned forest area. (Table 1).

Besides their small size, another characteristic of forest properties is their scattered plots. The average size of a forest plot is only 0.82 ha with each owner having on average 3.8 plots (Winkler 1995).

The highly scattered nature of the forest small--holdings, differences in how well equipped and trained the forest owners are and, primarily, the different extent of work undertaken due to the size of the property are the principal factors characterizing work carried out in privately owned forests.

**Table 1** Private forests by size

| Category of forest property, ha | % | |
|---|---|---|
| | owners | forest area |
| < 4.9 | 85.4 | 38.6 |
| 5-14.9 | 11.7 | 34.9 |
| 15-29.9 | 2.3 | 16.3 |
| > 30 | 0.6 | 10.2 |
| Total | 100.0 | 100.0 |

## 2. Problem definition

Certain studies on private forests carried out so far (Južnič 1990, Medved 1995) have shown that chain saws and tractors are poorly utilized in small forests due to the minimum capacity for work. Owners use them in their forests for only a few days a year. Due to this, the profitability of work in small private forests is questionable. This is particularly the case on small, scattered forest plots.

The principal aim of this paper is to show the level of equipment utilization used in small forest properties (category 1–4.9 ha) and the profitability of work in such conditions.

## 3. Work methods

Data on the amount of equipment used in forests and farms and property size is derived from a survey carried out in Slovenia in 1995 (Winkler and Medved 1996). Table 2 shows the average size of forest and farm property for various categories of forest estate. With respect to this area, meaning a certain extent of work for the owner, we obtained figures for the utilization of machinery and for comparing the price of wood on forest roads and the costs of felling and skidding. For the purpose of this study, we were only interested in forest property in the category 1–4.9 hectares.

**Table 2** Average sizes of forests and farms

| Category of forest property, ha | Farm area, ha | Forest area, ha |
|---|---|---|
| < 4.9 | 4.24 | 2.46 |
| 5-14.9 | 7.34 | 8.78 |
| 15-29.9 | 10.56 | 20.28 |
| > 30 | 13.09 | 51.34 |

We took into account that certain machinery is used only in the forest (chain saws) and other, besides being used in forestry work, is mainly used on the farm (tractors). For our calculations we assumed an average volume of marked trees in a stand to be 0.5 $m^3$ and relatively easy terrain with slopes to 35% and open to skidding trails or forest roads.

## 4. Owners' mechanization and machine utilization in small forest properties

Chain saws are used for felling. Small tractors, with an average engine power of 31.9 kW are used for skidding. These are farm tractors, manufactured for farm work with one differential and rear-wheel drive. For work in the forest, they are equipped with simple accessories. Only 26% of owners use a tractor winch (in average 31 kN). Two-drum winches are used in only 10% of cases (Marenče 1977).

The size category of forest dealt with in this study has an average 2.46 hectares of forest (Winkler and Medved 1996). We concluded from the survey that the average age of chain saws in the private sector was about 10 years. We used this age in our calcula-

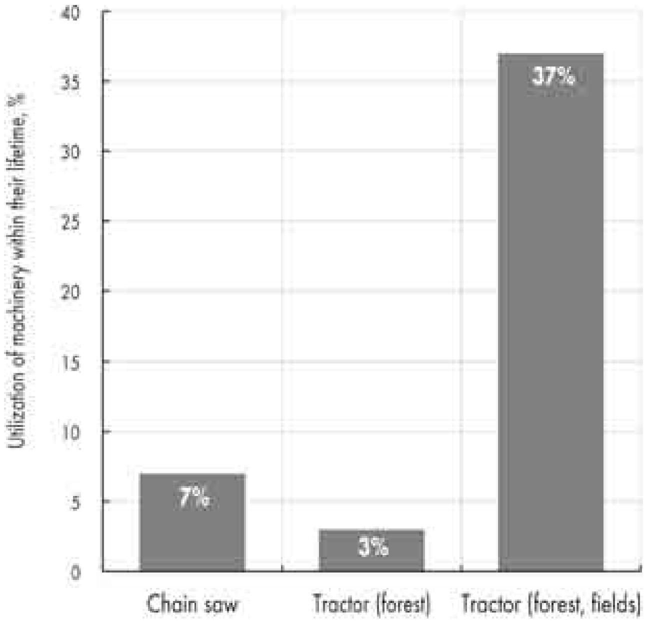


**Figure 1** Utilization of machinery within their lifetime

tions for chain saw working hours and life span irrespective of whether their lifetime capacity was utilized or not (Marenče 1997). We calculated that, due to the small amount of work, a chain saw was used to only 7% of its capacity within its lifetime (Figure 1).

In analyzing the efficiency of tractors, it was necessary to take into account that the tractor, besides working in the forest, was principally used for farm-work. The extent of work performed in the forest was dependant on the size of forest property. In our calculations we used a lifetime of 12 years for tractors.

Tractors were only used to 37% (forest, field) of their capacity within their lifetime (and only 3% working in the forest).

## 5. Calculation of operating efficiency

The utilization of machinery decisively affects the operating efficiency of work where it is used. In calculating the depreciation of chain saws, we took into account the number of their operating hours.

In tractor skidding all operating hours were considered both in the forest and on the farm. The total forestry work undertaken used only the hours performed in the forest.

The price for wood on the forest road is one of the factors decisively affecting the operating efficiency of work in the forest. This price of wood was compared to the cost of felling and skidding to find the

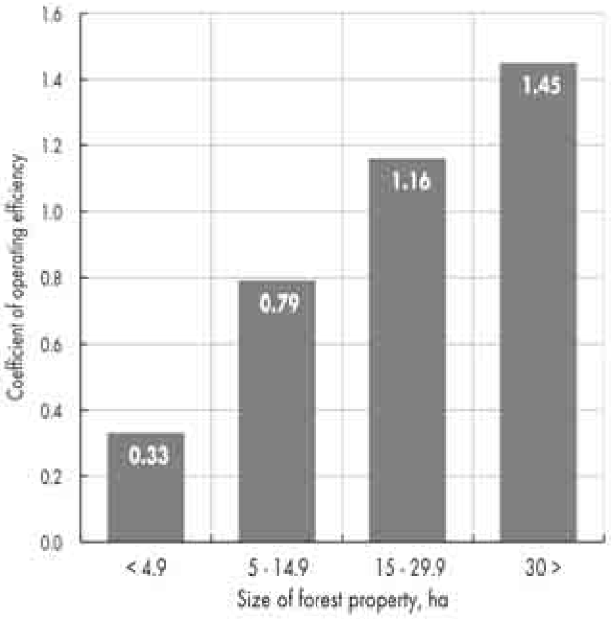


**Figure 2** Operating efficiency of work with respect to size of forest property

operating efficiency of forestry work. This was expressed as a coefficient of operating efficiency (*Oe*):

$$Oe = \text{price of wood on forest road} \,/\, \text{cost of felling and skidding}$$

Calculations show that prices cover only 33% of costs (Figure 2).

On the basis of these calculations, the following can be concluded:

- On small forest properties, the use of such machinery is not economic.
- Medium-sized tractors, the most common type used by forest owners, are suitable for light work and relieve significantly hard physical work but for achieving economic effects higher amounts of work are required.
- In larger forests, work is becoming gradually more economical. In average stand conditions (medium volume of trees marked for felling is 0.5 $m^3$) the break-even point for operating efficiency using such mechanization only occurs in forest estates of 15 to 29.9 ha meaning 10.56 ha farm and 20.28 ha of forest area – see Graph 2 (Marenče 1997).

## 6. Conclusions

Unprofitable work in small forest properties could be solved by allowing forestry work to be contracted out to less expensive operators. Machinery would be more economically used due to greater capacities and provide cheaper felling and skidding.

The work of forest owners could be more economical if they used machinery (chain saws, tractor winches for gathering wood) jointly as their use would cover larger amounts of work and they would be better utilized and cheaper.

At present the structure of properties and the habits of forest owners prevent such working conditions and most owners continue to use their own machinery only in their own forests, which is uneconomic.

## 7. References

Južnič, B., 1990: Equipment with Machines, Time Consumption and Work Performance in Private Forests, Ljubljana, Gozdarski V 48, p.124–140.

Marenče, J., 1997: Selection and Operating Efficiency of Technologies Adapted for Logging Assortments in Private Forests, Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources. Master Thesis, 141 p.

Medved, M., 1995: Harvesting Costs on the Farm, Ljubljana, Gozdarski V 53, pages 2–11.

Winkler I., Košir B., Krč J., Medved M., 1994: Calculation of Forest Operational Costs – Ljubljana, Professional and Scientific Work Part 113, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, Slovenian Forestry Institute, 69 p.

Winkler, I., 1995: Forestry Economics – study material. Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources.

Winkler, I., Medved, M., 1996: Basic Data From Surveyed Forest Owners in 1995, Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Forest Resources, Slovenian Forestry Institute.

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# Environmental aspects in forest machine business

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***Abstract***

*The role of wood as a renewable natural resource has been emphasised in recent years. Currently, people have a strong feeling for the environment and the use of natural resources. However, logging operations are frequently confronted with considerable resistance. There is an increasing pressure on manufacturers to develop logging technology that is not only capable of cost-efficiently producing high-quality wood, but that is also more environmental friendly than before. It is essential that the environmental impact of logging needs to be significantly reduced in the future, which necessitates a new technological approach.*

***Key words:*** *wood as a renewable resource, environment, new technological approach*

## 1. Introduction

The role of wood as a renewable natural resource has been emphasized in recent years. Currently, people have a strong feeling for the environment and the use of natural resources. However, logging operations are frequently confronted with considerable resistance; 2 years ago German TV broadcast a report on boreal forests, in which harvesters were pronounced as »Taiga Terminators«. Logging is rather a negative term in the public opinion and even among a lot of foresters. This fact is known as the slaughterhouse paradoxon.

Of course, we – the manufacturers, are also affected by this; there is a rather increasing pressure to develop logging technology not only aimed at cost-efficient producing of high-quality wood but also aimed at being more environmentally friendly than before. In a number of regions the industry still makes use of technology that is rapidly becoming obsolete and, therefore, it can be described as inefficient, frequently hazardous to the health of people involved and insensitive to environmental issues. In Europe, where forests are extensively used for recreational purposes, the well-being of forests cannot be over-emphasized. It is essential that the environmental impact of logging needs to be significantly reduced in the future, which necessitates a new technological approach.

## 2. Mechanical logging methods currently in use

There are two dominant logging methods employed today; the Full Tree method (FT) or the tree-length-method, and the Cut-To-Length method (CTL). In the FT method, trees are felled and then skidded to the roadside. As for the CTL method, on the other hand, trees are cut, delimbed, and bucked at the stump and after that they are carried to the roadside by specially designed machines. In the Nordic countries mechanized logging systems account for more than 90 percent of all cuttings. Globally, the share of the FT method is still three-quarters of the world's industrial cuttings, but CTL is gaining ground rapidly. To a certain extent, this is because it is more environmentally friendly, e.g. a number of studies clearly indicate that the CTL method causes less damages to the stands. The FT line machines on the other hand tend to be large and heavy, prone to inflicting damage on the working site.

## 3. Development of forest machine technology

The forest machine industry is relatively young if compared to several other industrial sectors. For example, the car industry is more than 100 years old, whereas the first forest machines were built in the

1950s. The first machines were based on farm tractors, but it very soon dawned upon those involved that such machines could not last in tough forest conditions. A tremendous input of technological development has been needed in order to upgrade the machines to the technology level of today.

Since the performance of the FT machines was not satisfactory, the forwarder evolved in the Nordic countries. An all-out effort was made to enhance the productivity and reliability of the prime mover and cranes in the 1970s. As soon as performance reached the level targeted, more emphasis was placed on ergonomic aspects such as machine vibration, the seat, visibility, noise, control levers, and pedals. This phase of development resulted in a sophisticated, high standard tractor cab. Finally, starting in the late 1980s, the focus of development has been on designing environmentally sound forwarders by employing computer controlled power transmission systems, balanced weight distribution, a multi-wheel drive, wide tires, cranes with a long reach, a good load-to-machine ratio, and the utilisation of bio-fluids.

## 4. Timberjack's environmental focus

This modern CTL method is an efficient and environmentally friendly way of operation when employed in a proper way. However, especially when the circumstances are difficult, it is the poor or insufficient or inexperienced management of forest operations that is to blame for the majority of the damage inflicted on soil and trees. Even though the development of technology is important, it has to be pointed out that most important factors having an impact on the environmental issues related to logging are planning and the selection of harvesting methods.

### 4.1. Harvester simulator

The operator of the machine plays a very important role when trying to minimize the damage inflicted on the environment. In order to teach basic operator's skills without the risks of damaging the stand, malfunctions and without putting an expensive machine out of productive work, Timberjack was first on the market with a forest machine simulator.

In the military and aviation industries the use of simulators has been known for a long time—nobody would let a fresh trainee take a plane to the skies and start learning the art of flying with an expensive aircraft and passengers. Something very similar can also be said about mechanized harvesting; the machines are a major investment and require scrupulous handling. In timber harvesting the realm of responsibility does not involve passengers, but it is the stand of trees, valuable end product and the environment instead.

The harvester simulator is a training tool that applies virtual reality to train harvester operators. Apart from a realistic and accurate simulation of machine functions, the simulator provides the possibility of defining individual stands and terrain conditions, uses the same on-board-computer system like the real harvester, and provides accurate analysis of the trainee's results during the session.

### 4.2. Environmental focus on present products

Some day the trainee will operate a real machine and because of the simulator training he has already basic skills about felling techniques and knows how to avoid damage to trees and soil. And the machine he uses has a lot of features designed with the focus on environmental issues:

**Ground pressures**: Because of a vast variety of various tire options, Timberjack forest machines can operate on different working sites causing minimum damage to the ground. For the sake of comparison: the ground pressure on the rear tire of a bicycle with a 90-kg person is about 40 kPa.

**Balanced bogie axles:** A bogie is not a bogie, they have to be optimally balanced in order to minimize the damage to the ground dividing the ground pressure equally between the front and rear tire of the bogie. Our bogies still have a slight tendency to lift the front wheel, which improves mobility and reduces injurious effects on the soil.

**Boogie design**: The ground clearance is as big as possible. This design enables less damage in the stands due to better possibility of maneuvering especially in dense stands.

**Different frame lengths**: Timberjack offers different frame length depending on the assortments or the terrain conditions. Different frames means different machine behavior and it is possible to choose the best adapted alternative regarding the terrain.

**Bio fluids:** Timberjack machines are capable of using Bio-fluids, i.e. engine oils, hydraulic oils, oils in the axle case and also coolants. Furthermore, Extraction and refill pumps provide optimum safety in case of hydraulic system harzards.

**Low emission engines:** Timberjack uses most modern engines, which provide minimum fuel consumption and emissions.

This list can be continued. It is just a summary of the most important environmental issues in Present Product Engineering.

### 4.3. Environmental aspects in manufacturing

Another very important issue is the environmental aspect in manufacturing: Timberjack manufacturing plants are using increasingly the Environment Management Systems (EMS) for process control with regard to environmental issues. For example every Timberjack plant is today preparing for an ISO 14001 certification. Joensuu factory in Finland will get the certificate this autumn. Joensuu will then be the first forest-machine factory, which has implemented an EMS. In Filipstad/Sweden they will be ready for the certification next year and Woodstock/Canada has also started the process.

Furthermore, there are two different kinds of research projects going on, dealing with Life Cycle Analysis and recycling of forest machines. The latter one is almost ready and we hope to be able to use that information rather soon in development and design of our products.

### 4.4. The walking machine

However, the most advanced approach of the design focused on environmentally friendly machines is the first walking harvester in the world introduced by Plustech in June 1995. This work was also recognized and awarded when the company received the European Better Environment Award for Industry (EBEAFI) in Ireland on July 15, 1996. The media success of the walking machine with more than 400 articles and numerous TV programs has been remarkable and is also a good example of the importance of environmental consciousness today in the world.

When it comes to the technique of interacting with the ground, walking vehicles are radically different from traditional machinery because the fundamental approach is so unique. A walking machine adapts itself to the features of the terrain. It does not matter if the ground underneath the machine is irregular for every leg is perfectly capable of finding support at the very height level they make contact with the soil.

The use of a walking prime mover opens up new possibilities when considering the dilemma involved in mechanized forest operations. The benefits of walking technology are most obvious when the machine operates in environmentally sensitive terrain where ground disturbance must be minimized. Similarly, the advantages enjoyed by the walking configuration are evident on terrain with irregular or steep features.

## 5. Conclusion

After approximately 40 years, the history of mechanized harvesting is a relatively short one. The last ten years have seen progress made at a very fast pace and this increasing trend will continue. Nowadays, the development of forest machinery requires a high level of expertise in mechatronics, power transmissions, control technologies, computer sciences, material sciences, machine dynamics, multimedia, etc. Different technologies have to be incorporated in order to be able to design products that meet customer demands. The level of technology involved in these products is relatively high when compared to other mobile work machines.

However, a forest machine is a small link in timber harvesting systems, which involve a large number of factors, not all of them being technical. As for forest machinery, the future developments will greatly depend on how the needs of the forest industry are altered with regard to logistics and to the quality of processing (this includes cross-cutting, for instance). Similarly, the trends of machine design will be strongly influenced by the need to protect the environment and by the accompanying changes in forest operations. Laws and statutes or the developmental objectives of separate areas may be clearly dissimilar from each other, resulting in different methods being used in separate areas. This is why one of the goals should be to design machines that are capable of fulfilling special requirements of different areas without any need for excessive modifications. It is the financial pressure of ever-increasing costs that would be relieved as a result. Even here we nevertheless assume that the productivity and quality of the work will not be compromised.

New technology provides considerable potential in the face of future challenges. Focusing the changes in the right direction entails not only higher efficiency but also more profound co-operation between all the groups involved. This is essential if we are to succeed – within a sufficiently long period of time – in defining and concentrating on what is vital in the development process. Furthermore, we must also get rid of old prejudices if we are to discover new, unconventional approaches. The walking technology and training simulators serve as examples of a new approach. The years to come will show how these new products find their place in everyday harvesting.

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# Analysis of forest harvesting technologies with minimum impact on soil by means of multicriterion evaluation technique

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***Abstract***

*At the moment, forest-harvesting planning is focused on the issues of environmental protection, especially soil compaction. The present study deals with the development and application of a methodology for the selection of adequate machinery and harvesting systems complying with the economic, productive and environmental requirements. It is aimed at choosing machines and systems that produce least damage to the environment, specifically to the soil, this being an important resource for the development of the productive forest of Pinus radiata D.Don. in the VIII region, Chile.*

*By means of a database selected from different studies and terrain evaluations of various harvesting systems, the main soil variables were obtained as well as the machinery directly related to productivity of the forest harvesting systems and the changes they cause in the environment. The integration of this database was made by means of the Multicriterion Evaluation Techniques.*

*In accordance with the above-mentioned, a comparative quality analysis of the harvesting systems and the models of the different machines was carried out. It was assumed that each of them was superior to the rest in all approaches used for their evaluation. In this way every alternative was superior to the rest in at least one criterion. Therefore, the selection of an appropriate alternative depends on the objectives of the expert. The results reached by this study point out that the system involving chainsaw, yarding by aerial cable systems, bucking with chainsaw and use of front loader cause minor damage to the soil. It was also determined that among the evaluated models of forest harvesting machines, those with the best productive characteristics and minor damage to the environment were: grapple skidder Caterpillar 528, feller buncher Timberjack 2628, forwarder Timberjack 1210B, harvester Ponsee ERGO HS16, and the logger Bell 220C.*

***Key words:*** *Chile, techniques, harvesting, machinery*

## 1. Introduction

Planning of harvesting operations traditionally takes into consideration effectiveness and efficiency, as well as engineering and economic features of forest production. Actually the enterprises in our country focus their interest increasingly on the effects of harvesting on the environment and on the way to reduce them. This analysis must take into account the costs and benefits of this labor in the entire system.

In the last ten years many forest enterprises in our country have elaborated a high mechanization program in the forest work to confront the increase of the production requirements. This has required a collateral aspect analysis of the use of mechanization in this type of labor and its effects on the soil, the soil being an important resource for the productivity of the forest site and the growing stock of a productive forest (Gayoso 1997).

A wrong selection of forest harvesting machinery and systems will provoke negative impacts on physical and chemical features. Alterations in soil physical and chemical features cause a productivity decrease of the forest sites. For this reason it is necessary to identify and to select the machines and harvesting systems that produce minimal impact on the environment (Gayoso 1996).

It is not simple to make the right selection of a machine type or forest harvesting system. It involves different criteria of different nature meaning that the description and evaluation of the same characteristic is not carried out from a single point of view, but from multiple perspectives or aspects. Moreover all considerations in an evaluation do not have the same significance. For this reason a methodology should be applied, which permits assigning of a definite value or consideration to each criterion from the point view of a decisive entity. It is done with the objective of joining the criteria so that the solution for the selected alternative can be fulfilled on the basis of the aims being planned by the decision-making person or persons.

The solution to this problem is the use of the multicriterion evaluation techniques, a tool orientated to assist in the decision making procedure. With these techniques it is possible to make a more adequate selection of machines and crop systems, based on the involved criteria in the evaluation.

The present study pretends to identify the methodology, which provides the selection of systems or machines for forest crop (skidder, feller buncher, forwarder, harvester and three-tires) in accordance with productive, economic and environmental criteria. They are going to present different levels of importance in view of priorities in the process of decision making and selection. It also, give a survey of the analyses of a series of forest soils, aimed at determining which of them are more susceptible to a possible mechanical intervention of forest harvesting as a result of their inherent physical-chemical characteristics.

The general objective is to elaborate, by means of Multicriterion Evaluation, a general rule that quantifies the impact on soil of different machines and forest harvesting systems, obtaining those alternatives that produce the minimum damage to this resource.

## 2. Methodology

### 2.1. Information summary

By mean of a bibliographic compilation the principal variables of soil affected by mechanized harvesting were determined. To achieve this, a comprehensive bibliographic compilation was performed of the systems and harvesting technologies used in Chile, as well as in other countries with a high forest development regarding productivity and environmental protection. In addition, information about machines actually being used in our country was obtained from the main crop machinery representatives and suppliers.

When these pieces of information were compiled, the values and restrictive measures were obtained, which were integrated by mean of multicriterion evaluation (M.C.E.)

The themes that were integrated by use of M.C.E. techniques were the following:

a) Selection of crop systems more adequate in view of productive, economic and environmental criteria.
b) Selection of the most adequate model of Skidder, Feller Buncher, Forwarder, Harvester and Three-Tires on the basis of productive, economic and environmental criteria.
c) Selection of forest soil series better adapted to harvesting operations with regard to physical and chemical criteria.

### 2.2. Multicriterion Evaluation

Initially a numeration of $m$ points was established that represented the possible alternatives or elections reachable for the decisive entity ($A_1, A_2,..., A_j,..., A_m$). Three types of alternatives were considered, the reference ones to the used harvesting systems, the machines actually used in harvesting works in our country, such as skidder, harvester and three-tires, and those which refer to the description of soil susceptibility.

A conjoint of $n$ points ($C_1, C_2,..., C_j,..., C_n$) was also required that represents the attributes or relevant criteria for the correspondent decision problem. Three series of criteria were analyzed, a series for the harvesting system, one for the machinery and another for the soil analysis. For the systems and harvesting machines the following criteria with respective subcriteria were established: productive, economic and environmental. For the soil analysis the criteria were physical and chemical.

When the concepts and alternative dimensions and criteria were described, the pieces of information determining and defining them were adequately structured. In the first place, a conjoint of m per n points ($R_{11},..., R_{ij},..., R_{mn}$), which represented the result reached for each alternative or election of each attribute or criterion, was considered. In case of harvesting systems, the matrix was 5x3, for different machines the matrixes varied in their size in accordance with the number of their alternatives and criteria, for the skidder – 18x9, for the feller – 12x9, for the forwarder – 13x11, for the harvester – 6x11 and for the three-tires – 4x10. In the case of soil series of the VIII region, the matrix dimension will corres-

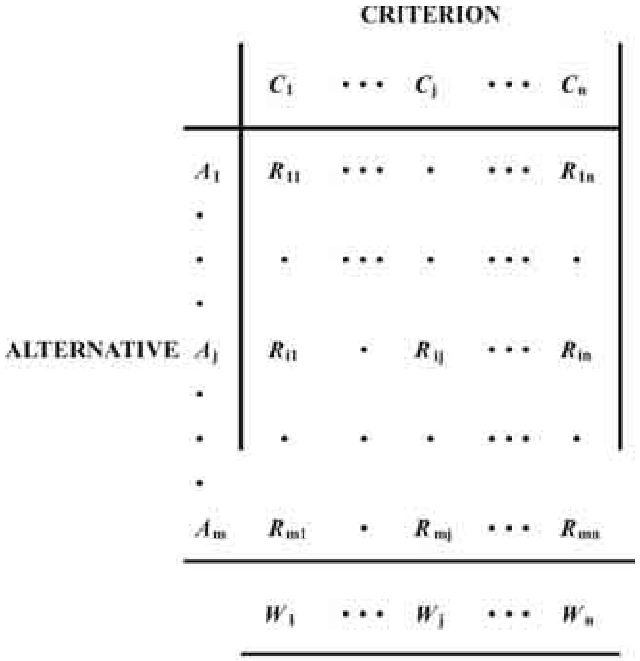


**Figure 1** Work model of EMC; Where: $R_{ij}$ = rating of i alternative with respect to criterion j, $W_j$ = weight of j criterion.

pond to the one of 16x13. On the other side, $W_j$ weights were considered grouped in the so-called weight vector, which intended to represent the structure of the decision maker's preferences (Barba-Romero 1996).

For this purpose, a multicriterion decisional problem can be represented by means of a matrix with the structure as shown in Figure 1.

This matrix is designated as the matrix of decision, which describes each alternative considered in the function of the criteria and represents the starting point of any multicriterion decisional analysis of discrete type (Barba-Romero 1996).

## 3. Results and discusion

Once completed the data matrix, which gathers the alternatives – the criteria and the evaluations (in its natural measuring scale), the weights were assigned to distinct criteria and sub-criteria involved in the evaluation of the harvesting systems. For this purpose, experts, who had come to some results in their research of this subject before, were consulted. In accordance with their experience and knowledge in this matter, the values expressed in comparative matrixes were determined by pairs for the distinctly evaluated criteria levels as shown in the following tables.

In Table 1, it can be seen that the environmental criterion is of the utmost importance for the decisive entity (56.95), since the alteration degree upon the soil that the evaluated harvesting systems represent depends on it. These alterations affect the productivity of future cycles, and besides, it is a factor of capital importance within the machinery selection. Regarding its importance it follows closely the productive criterion (33.31), because due to it the enterprises must fulfill the pre-established production demands.

And finally there are the economic criteria (9.74). In this case it is supposed that the environmental and productive acquisition of these systems is more interesting. As the consistence coefficient value ranges between 0.02 and 0.10, the obtained value judgements are consistent.

Within the productive sub-criteria, the yield (*Scp1*) is the most important for the decisive entity. It reaches a major weigh (41.82), due to its direct relation to the performance of the planned goals before harvesting. It is followed by sub-criterion fare (*Scp2*) with an inferior weight to the previous one (27.07) since the value of the production volume in $m^3$ depends on it.

**Table 1** Matrix for establishing the weight of the criterion in the selection of a more adequate harvesting system. Criterion fathers (*CP*)

| | *CP*1 | *CP*2 | *CP*3 | *Xij* Weights |
|---|---|---|---|---|
| *CP*1 | 1 | | | 0.3331 |
| *CP*2 | 1/4 | 1 | | 0.0974 |
| *CP*3 | 2 | 5 | 1 | 0.695 |

**Table 2** Matrix to establish the weight of selection criterion for a more adequate harvesting system. Productive sub-criterion (*Scp*)

| | *Scp1* | *Scp2* | *Scp3* | *Scp4* | Weights $X_{ij}$ |
|---|---|---|---|---|---|
| *Scp1* | 1 | | | | 0.4182 |
| *Scp2* | ½ | 1 | | | 0.2707 |
| *Scp3* | ½ | 1/2 | 1 | | 0.1906 |
| *Scp4* | 1/3 | 1/2 | ½ | 1 | 0.1205 |

**Table 3** Matrix to establish the weight of criteria in the selection of a more adequate harvesting system. Environmental sub-criterion (*Sca*)

| | *Sca1* | *Sca2* | *Sca3* | *Sca4* | *Sca5* | Weights $X_{ij}$ |
|---|---|---|---|---|---|---|
| *Sca1* | 1 | | | | | 0.1688 |
| *Sca2* | 1/2 | 1 | | | | 0.0789 |
| *Sca3* | 1/2 | 2 | 1 | | | 0.1557 |
| *Sca4* | 3 | 4 | 2 | 1 | | 0.3767 |
| *Sca5* | 2 | 3 | 1 | 1/2 | 1 | 0.2199 |

Then there is the hour hand cost (*Spc3* (19.06)) and finally the slope rank (*Scp4* (12.05)), a less important sub-criterion, inasmuch as all evaluated alternatives have a similar rank. The value for the consistence coefficient ranges between 0.03 and 0.10 and hence the assigned judgements are consistent.

In the environmental sub-criteria, the pressure over soil *(Sca4*) is the criterion with major weight (37.67), followed by the sediment production criterion (*Sca5* (21.99)) and increase of the apparent density (*Sca1* (16.88)). End finally there are the criteria of cone index increase (*Sca3* (15.57)) and of porosity reduction (*Sca2* (07.89)).

The criterion related to the pressure over soil was given serious consideration because it is the factor directly related to one of the alternatives of major importance with regard to the soil – the compaction of the upper layer, which affects the soil productivity in future cycles.

The sediment production is another outstanding factor, because it is related to the loss of soil layer and nutrient exportation, which brings to infertile soils of low productivity. The apparent density is related to the loss of porosity, causing insufficient aeration of the soils. The sub-criteria of cone index and reduction of porosity are related to sub-criteria of the pressure over soil and apparent density, respectively. The consistence coefficient value ranges between 0.04 and 0.10 and therefore the assigned value judgements are consistent.

Table 4 analyzes the importance of environmental criteria, the increase of the apparent density and the deep level at which this alteration is produced. It takes into consideration the fact that the first layer (0–15 cm.) is more important than that the layer ranging between 15 and 60 cm, as the first layer is where the tree developing begins.

**Table 4** Matrix to establish the weight of criteria in the selection of a more adequate harvesting system. Environmental sub-criteria 1(*Ssca*). Apparent density.

| | *Ssca1.1* | *Ssca1.2* |
|---|---|---|
| *Ssca1.1* | 1 | |
| *Ssca1.2* | 1/4 | 1 |

**Table 5** Matrix to establish the weight of criteria in the selection of a more adequate harvesting system. Environmental sub-criteria 2 (*Ssca*). Porosity.

| | *Ssca2.1* | *Ssca2.2* |
|---|---|---|
| *Ssca2.1* | 1 | |
| *Ssca2.2* | 1/3 | 1 |

**Table 6** Matrix to establish the weights for criteria in the selection of more adequate harvesting system. Environmental sub-criteria 3 (*Ssca*). Cone index.

| | *Ssca3.1* | *Ssca3.2* |
|---|---|---|
| *Ssca3.1* | 1 | |
| *Ssca3.2* | 1/5 | 1 |

In relation to Table 5, the reduction of porosity is outstanding in soil aeration and infiltration, and therefore it was considered that the upper levels (10–15 cm.) have major importance for the development of a new forest than deeper layers where a minor alteration is produced.

Table 6 shows the importance of environmental sub-criteria – the increase of cone index at deeper level where this alteration is produced. It must be taken into consideration that the first layer (0–15 cm) is more important because high cone index values indicate a porosity reduction, increase of apparent density, decrease the infiltration level and reduction of the root expansion area, which affects adversely the yield level of the new plantation.

What occurs in the first soil layer is of utmost significance for the environmental sub-criteria – apparent density, porosity and cone index. It is right there that major nutrients are concentrated and the needed conditions of aeration, drainage and soil structure for a new plantation begin.

In this way the decision matrix is obtained for the systems of forest harvesting, in which data appear presented in their natural measuring scale. Furthermore it is determined for each criterion whether it is increasing or to be maximized, or decreasing or to be minimized, the type of measuring scale for the data normalization procedure and parameter values of the measurement scales.

The productive criteria, yields and slope rank, are the criteria to maximize, because the higher they are the better the work characteristics of the system. In fact for the yield criterion, the measuring scale of the a-b type for increasing criterions was chosen. Their evaluations go from those with major value, assigning it the maximum evaluation (10) to those having minimum evaluation (0), distributing proportionally the rest of the alternatives. For the increasing criterion, rank of slope, a min-max scale was chosen, since the systems can work between a minimum slope (0%) and a maximum slope (100%) with the major evaluation (10), distributing proportionally the rest of ranks that have any evaluated crop system.

The rest of the criteria (fare, hour cost, investment, apparent density, porosity, cone index, pressure over

**Table 7** Decision matrix for the system of forest harvest

| Criterion | *CP*1 | | | | *CP*2 | *CP*3 | | | | | | | | Final Punctua-tion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weight =1 | 0.3331 | | | | 0.974 | 0.695 | | | | | | | | |
| Subcriterion | *Scp1* | *Scp2* | *Scp3* | *Scp4* | *Sce1* | *Sca1* | | *Sca2* | | *Sca3* | | *Sca4* | *Sca5* | |
| Weight =1 | 0.1393 | 0.0902 | 0.0635 | 0.0401 | 0.0974 | 0.0961 | | 0.0449 | | 0.0887 | | 0.2145 | 0.1253 | |
| Subcriterion | | | | | | *Ssca1.1* | *Ssca1.2* | *Ssca2.1* | *Ssca2.2* | *Ssca3.1* | *Ssca3.2* | | | |
| Weight =1 | 0.1393 | 0.0902 | 0.0635 | 0.0401 | 0.0974 | | | | | | | | | |
| *A*1 | 0.00 | 0.00 | 0.00 | 9.00 | 3.02 | 9.77 | 9.89 | 9.88 | 9.94 | 10.00 | 10.00 | 10.0 | 10.00 | 6.15 |
| *A*2 | 5.78 | 10.00 | 9.53 | 2.50 | 10.00 | 8.32 | 9.00 | 8.21 | 9.02 | 0.58 | 6.16 | 3.00 | 5.22 | 5.91 |
| *A*3 | 2.32 | 6.56 | 6.11 | 3.50 | 9.38 | 8.51 | 9.15 | 8.77 | 9.26 | 0.95 | 7.44 | 3.50 | 6.35 | 5.20 |
| *A*4 | 10.00 | 9.71 | 11.37 | 3.50 | 2.46 | 8.42 | 9.47 | 8.42 | 9.49 | 0.91 | 6.57 | 1.00 | 1.73 | 5.09 |
| *A*5 | 6.94 | 8.44 | 9.11 | 2.50 | 0.00 | 7.99 | 8.77 | 8.01 | 8.87 | 0.15 | 5.75 | 1.50 | 0.00 | 3.89 |

soil and sediment production) are to be decreased or minimized, since lower their value, the better their evaluation. In the criteria: fare, hour cost, investment and sediment production, an a-b scale type was used. As already mentioned, their evaluations go from those with a major value, assigning the maximum evaluation (10) to minimum values, with the minimum evaluation (0), distributing proportionally the rest of the alternatives.

For the criteria such as the increase of apparent density, porosity reduction, increase of cone index and mean pressure over the soil, the min-max measuring scale was used. As it corresponds to values in percentage, the maximum evaluation was assigned to the value of 0% and the minimum evaluation to the value of 100% (for them being decreasing criteria), distributing proportionally the rest of the evaluations.

These data cannot be compared because of their different nature and therefore their normalization was effectuated. This is why the measurement scale method was used, which can maintain the proportion between values within the same criterion. Besides, the weights are brought to summative 1. The data are now in condition of being applied to the lineal ponderate summative, in which the summative is realized by multiplication between each individual pointing of the alternative with the respective weight involved, obtaining the global ordination that grants the final ordination of the alternatives (Table 7).

The final ordination of the Table 7 shows that the first system is the more adequate and in accordance with the criteria taken into account for their evaluation. That does not mean that this alternative is to be better related to all the criteria, but only that the global summative of all the criteria by their respective weight is better than the rest of the alternatives.This ordination does not show what the optimal system to utilize is, but only the one having better characteristics according to the importance assigned to the criteria.

If system 1 (felling with chainsaw, logging with yarder and loading with front loader) is not the best one related to all the criteria involved in the evaluation, it is still good for the majority of them. However, it is not highly assessed because of the criteria, which have to be minimized such as the fare, hour cost, percentage of apparent density increase, percentage of porosity reduction, increase of cone index, pressure upon soil and sediment production. Furthermore, the importance of the slope rank must be taken into account. It is only exceeded by other alternatives in the yield criteria and investment costs. The first is inferior to all other alternatives, but the second, although inferior to some alternatives, is definitely not inferior to all of them.

None of the alternatives here evaluated depends upon one another, that is, at least one of the criteria involved in the evaluation, is superior to the rest of the alternatives, which permits it to continue being involved in further evaluations.

## 4. Conclusion

The principal soil variables affected by the mechanized harvesting are the porosity, the drainage, the apparent density, the depth, the field capacity, the permanent wilting percentage, the organic matter percentage and the macro and micro nutrients content.

The system of forest harvesting causing only minor damage to the soil, is that conformed by chainsaw felling, yarding by suspended log, crosscutting with chainsaw at the landing and the use of front loader in loading, in accordance with the Multicriterion evaluation techniques.

In the case of prevalently lowland terrain on which harvesting operations are being performed and where the issues of sediment production are minimum, the most adequate alternative would be the Nº2, that is, the system composed of felling with feller buncher, logging with grapple skidder and loading with frontloader.

If it were to choose a system in which the environmental criteria have major relevancy than the productive or economic system would be found as the most adequate. It is the system, which causes the least damage to the soil of all evaluated harvesting systems in adequate land conditions.

Now, if the soil damage were not a first priority, since soil characteristics present a minor degree of alteration and productivity is the criterion of major importance for the decisive entity, the systems with better evaluations of these criteria would be chosen. They are namely the Nº4 system (harvester-forwarder) and the Nº5 system, (felling with feller, logging with grapple skidder and forest loader).

The model of skidder, feller buncher, forwarder and loggers with the best characteristics in view of economic, productive and environmental criteria used for their evaluation was the grapple skidder Caterpillar 528, feller buncher Timberjack 2628, forwarder Timberjack 1210B, harvester Ponsee ERGO HS16, and the logger Bell 220C.

This type of analysis should be implemented at a determined site, where all characteristics are known. After comparing different harvesting systems, quantifying the alteration level generated in a determined area of study, the system causing minor damage to the environment should be selected.

## 5. References

Barba-Romero, S., 1996: Manual para la toma de decisiones multicriterio. Instituto Latinoamericano y del caribe de planificación económica y social. Dirección de Proyectos y Programación de Inversiones.

Gayoso, J., 1996: Costos ambientales en cosecha de plantaciones de Pinus radiata D.Don. Universidad Austral. Revista Bosque. 25 p.

Gayoso, J., 1997: Producción Forestal y Conservación de suelos. VII Solvotecna. Instituto de manejo forestal, Universidad Austral, Valdivia, Chile.

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# Preparation of stands in mechanized wood harvesting – effects on performance, costs and silviculture

Ulrich Bort

***Abstract***

*Altogether we can say that reduced expenditures in stand preparation induces reduced harvesting produce, more stand damage and distinct changes in silvicultural results. On the other hand, we may not underestimate the expenses for stand preparation, particularly if we are dealing with first thinnings with small yields per hectare.*

***Key words:*** *silviculture, harvesting, costs*

## 1. Introduction

The use of forest resources according to sustainable and ecological forestry is one of the principal demands of forestry objectives. In this respect, cautious regulations in wood harvesting are of crucial importance. Modern harvesters offer the possibility to fulfil these requirements on a cost efficient and ergonomically favorable basis, also providing work safety and causing a low degree of damage to the tree stands.

A reduced supply of staff in forestry enterprises makes rationalization necessary at all possible levels and hence also in the preparation of stands for harvesting. Short term changes on the wood market and the always increasing demand for »just in time« supply call for flexible structures in technical production.

## 2. Objectives

The topic of a diploma thesis was to examine how a different intensity of stand preparation in developed stands influenced the work result. The initial idea was that a first thinning and pre-structuring of stands turns them into a kind of goods store accessible for vehicles.

The question is whether, with the short-term demand for wood, the preparation of stands with positive marking of the crop trees and negative marking of the trees to be cut is necessary. An alternative theory pose the question whether a lasting crop tree marking would be sufficient for controlling forest production or whether the harvester-driver with the help of a written silvicultural work order should alone be responsible for realizing the silvicultural goals in a satisfactory quality.

## 3. Testing environment

The sampling area was a 35-year-old spruce stand with 10% of pine and an average diameter at breast height (DBH) of 16 cm. The stand had been intensively developed and was thinned 6 years ago by means of a fully mechanized first thinning. 2,011 trees per hectare showed slight damages caused by snow break and forked stem deformation. We were dealing with a typical silvicultural stand, which utilization was possible, but not urgent.

On an area of 17.9 hectares, 3 test options were installed:

- crop tree-selection and negative marking,
- only crop tree selection or
- no stand preparation whatsoever.

Silvicultural data were collected and damages to stands noted in 30 test areas. The markings were invisible to the harvester operator.

After the silvicultural situation had been recorded, the management in charge worked out detailed silvicultural objectives and prepared a work order. All over the sampling area, crop trees and removable trees were marked at the bottom of the trunk for control purposes, the marking being invisible to the harvester operator. In the option »positive-negative marking« an additional marking was done in accordance with common standards. In the option »only crop tree-marking« only the crop trees were additionally and visibly marked.

The written work order was discussed with the harvester operator in great detail while looking at the stands. The test-driver was a trained forestry engineer holding a diploma and having sufficient experience in wood processing of all three options.

A harvester Timberjack 870 with a Timberjack 743 processing head processed standard lengths of 4.5 m, 3.0 m and 2.0 m of pulpwood respectively. The forwarding was carried out with the Timberjack 1110 Forwarder.

## 4. Results

A time study following the moment method, in which 3,000 cycles were observed, lead to the following results.

As shown in Table 1, the effective working time (PWT) per tree without marking was 20% higher than in the option with positive and negative marking. Special increase of time required for driving in the stand for orientation, before the next tree could be grasped, was noted. It was also noted that the personal distribution time (usually short breaks) increased in the options providing preparation of lower intensity.

The mental stress was – according to the subjective view of the driver – much higher with the non-marked test option than with the other two.

By looking at the measured results obtained so far, this seems very plausible. Backhaus (1994) reported up to 6000 control and steering maneuvers per harvester shift and stated that »the psychological strain that the traditional lumberjack has to endure reaches a so far unknown peak.« The results of a multi-dimensional measuring concept confirm the significantly increased psychological stress. (Bölz 1988, Schmidt-Vielgut 1988). Backhaus (1994) therefore pleaded in favor of a shift rotation every three hours at the latest in order to avoid overstraining.

Besides the already existing mental stress caused by machine controlling, the driver is faced with an additional psychological task in the second option – the selection of those trees that are to be extracted. Ebert (1995) looks upon the negative marking of stands as an exhausting activity and demands that it should not be carried out for longer than two or three hours at a time.

One of the chief objectives of the ergonomic design of the working site – i.e. the reduction of one-sided strain – cannot be attained if we abandon the marking of the trees that are to be extracted. In practice, the rotation of the workers that has been assumed is not a rule. Machine controlling and the selection of trees usually have to be done during a complete shift.

There is a negative correlation between intensity of stand preparation and stand damage. On the whole, stand damages caused by the harvester are at a low level, in all options only increased by 1 % through forwarding. If crop trees are distinctly marked, they will be less damaged. Without crop tree marking, 10 % of the crop trees are damaged.

The silvicultural results (Table 2) of »positive and negative marking« option differs significantly from the third one. For example, in the crop tree marked option the average DBH is at about 17.5 cm, while in the unmarked option, it increases to 19.2 cm. In this case the harvester operator selects the »thickest« tree and extracts one of its oppressors. The distance between crop tree A and crop tree B is difficult to be estimated when sitting in the cabin. Even more so because before the next operation the machine has to be moved. This leads to a significant increase of crop tree numbers. In the non-marked option, the increase was about 68% above 200 crop trees per hect-

**Table 1** Performance/damages

| | | Crop tree selection and negative marking | Only crop tree selection | No stand preparation |
|---|---|---|---|---|
| PWT/tree (effective working time) | Min. per tree | 1.02 | 1.10 | 1.18 |
| Driving | % PWT | 20.5 | 32.7 | 36.4 |
| pers. distribution time | % GAZ | 3.9 | 9.0 | 9.3 |
| trees/GAZ* | piece/h | 56 | 48 | 44 |
| damage whole stand (damage > 10 $cm^2$) | % | 1.9 | 2.3 | 3.6 |
| damaged crop trees | % | 0 | 1.8 | 10.7 |

*GAZ – total vorking time

**Table 2** Silvicultural Results

| | | Crop tree selection and negative marking | Only crop tree selection | No stand preparation |
|---|---|---|---|---|
| crop tree DBH | cm | 17.6 | 17.3 | 19.2 |
| crop trees/hectare | piece/hectare | 206 | 223 | 335 |
| thereof »real crop trees« | % | 96 | 90 | 65 |
| cutt trees | piece/hectare | 309 | 446 | 335 |
| cutt trees DBH | cm | 15.5 | 14.4 | 15.5 |
| coverage with invisible marking | % | 91 | 63 | 47 |

**Table 3** Harvesting costs

| | | Crop tree selection and negative marking | Only crop tree selection | No stand preparation |
|---|---|---|---|---|
| harvester performance | $m^3/h$ | 8.9 | 6.4 | 7.0 |
| processing costs | €/$m^3$ | 14.34 | 17.91 | 17.49 |
| skidding costs | €/$m^3$ | 6.12 | 6.12 | 6.12 |
| coverage 1 | €/$m^3$ | 20.46 | 24.03 | 23.61 |
| stand preparation costs | €/$m^3$ | 5.07 | 2.38 | - |
| coverage 2 | €/$m^3$ | 25.53 | 26.41 | 23.61 |

are that were actually aimed at. Moreover, almost 60% of removed trees are to be found within a range of 0 to 5 meters from the middle of the skidding line and hence within the area that is susceptible to damage caused by the crane (Bort et al. 1993, Bort and Pfeil 1993). In the option with positive and negative marking, only 40 % of the crop trees are to be found within that zone.

Where only crop trees had been marked, the harvester-driver normally extracted more oppressors per crop tree, but with a smaller diameter. This affects the number of stems and harvesting costs (Table 3).

A comparison with the covered silvicultural marking carried out by the forest station showed significant deviations in »Only crop tree selection« option and »No stand preparation« option. This, however, does not necessarily give reliable information about the silvicultural quality of the operation.

The direct harvesting costs (coverage 1) are the lowest in »positive and negative marking« option at 20.46 €/$m^3$. On the »Only crop tree selection«-marked areas, they are the highest (24.03 €/$m^3$). In the non--prepared option, the higher piece volume resulting from the increased DBH could not completely compensate for higher driving and distributing times. If we compare them to the option with thorough preparation, the direct harvesting costs increase by 15% or about 3.0 €/$m^3$.

In an economical evaluation, the costs for stand preparation must be taken into account. For positive and negative marking, about 4-man hours/hectare were needed and for the mere crop tree selection about 1.7 hours/hectare sufficed. This conforms to the results of other authors. Ebert, for example, found out that, for subsequent thinnings without crop tree selection, 2.0 to 2.5 hours/hectare were needed.

With an extracted volume of 35 $m^3$/ha and 43.37 €/hour of wages for an engineer of forestry (Ministry of Finance Baden-Württemberg 1998) 2.38 €/$m^3$ for crop-tree selection and 2.69 €/$m^3$ for the negative marking were to be expended in option 1.

Contrary to the calculation supplied by the harvesting contractor (coverage 1), the non-prepared option 1 is the most advantageous for the forest enterprise (coverage 2). The cost-saving of about 8% on one hand must however be considered along with clear cutbacks on the fulfillment of silvicultural objectives. To mark only crop trees (option 2) proved to be the most costly option. Compared with a complete stand preparation (option 1), the expenses of the contractor are higher by 17% and those of the forest owner by 3%.

More severe cuttings reduce the expenditure for stand preparation/cubic meter through volume digression. According to estimates of the forestry administration Baden-Württemberg, it usually takes

2.4 minutes/m$^3$ for marking (Ebert 1995). If we multiply these figures with the above hourly wages, we get the cost of approximately 1.79 €/m$^3$ for the negative marking of the average stand in the country, the latter being clearly stronger if compared with the results of the investigation.

## 5. Consequences for practical use

The renunciation of marking of extractable trees in option 3 increases the ergonomic stress for the machine operator.

From his harvester cabin, it is not possible for the operator to accomplish the silvicultural task in favor of a crop tree oriented incrementation in the same quality as the case is with crop tree marking in the stand. Quality and distribution of potential crop trees cannot be judged well enough from the machine. Still, an almost regular reduction of stem numbers all over the area is possible.

There are significant losses in the performance of the harvesting system, which cannot even be wholly compensated for by the potential liberty to extract bigger trees. For the contractor, the economical value of the intervention is reduced.

For the forest owner, the lack of positive/negative marking leads to clearly different silvicultural results. The number and distribution of crop trees change. The risk of stand damage is enhanced and without crop tree marking the control of stand damage is hardly possible.

## 6. References

Backhaus, G., 1994: Aspekte der Arbeitssicherheit, Ergonomie und beruflichen Bildung beim Einsatz von Mehrfunktionsmaschinen in der Holzernte. Forsttechnische Informationen 4/94, 34 ff.

Bölz, K., 1988: Entwicklung der psycho-physischen Belastung und Beanspruchung als Folge der Mechanisierung der Holzernte: ein Vergleich auf der Basis eines mehrdimensionalen Meßkonzepts. Diss., Freiburg.

Bort, U., Emhardt, M., Mahler,G., 1993: Vollerntereinsatz in der Zweitdurchforstung bei vorgegebener Feinerschliessung. In: Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Abteilung Arbeitswirtschaft und Forstbenutzung: Versuchsberichte, 41 ff.

Bort, U., Pfeil, C., 1993: Mechanisierte Holzernte, Wechselwirkungen von Erschliessungs-dichte, Pfleglichkeit und Betriebserfolg. In: Forstliche Versuchs- und Forschungsanstalt Baden-Württemberg, Abteilung Arbeitswirtschaft und Forstbenutzung: Versuchsberichte, 3.1 ff.

Ebert, H.P., 1995: Eine naturnahe Waldwirtschaft braucht holzanweisende Förster. In: Der Wald, 45, 148–151.

Finanzministerium Baden-Württemberg, 1998: Verwaltungsvorschrift über Kostenfestsetzung und Benutzungs-gebühren für Inanspruchnahme der Verwaltung. In: Wissenschaft, Forschung und Kunst, 17, 26–29.

Pfeuffer, A., 1999: Unterschiedliche Bestandesvorbereitung in der mechanisierten Holz-ernte – Auswirkungen auf Leistung, Kosten und Waldbau. Diplom-arbeit, Rottenburg.

Schmid-Vielgut, B., 1988: Psycho-physische Beanspruchung der Arbeitskräfte in Holzernte-systemen unterschiedlicher Mechanisierungsgrade. Diss., Freiburg.

# Thinning trials with a dedicated steep-terrain harvester

**Raffaele Spinelli, Bruce Hartsough**

***Abstract***

*The study reports on two thinning trials carried out with the Valmet 500T dedicated steep-terrain harvester. The trials were conducted in California, on two different conifer stands: a second-growth natural forest dominated by white fir, and a young ponderosa pine plantation.The terrain was considerably steep, with an average slope gradient of 30% and peaks around 60%. The characteristics of both the stand and the terrain resembled those found on the European mountains, and especially on the Alps. The harvester proved capable of negotiating rough terrain, while remaining flexible enough to harvest different stand types. The plantation was much more difficult to harvest, due to the thick undergrowth and to the low branching of the trees. Productivity reached 25.1 $m^3$/PMH in the natural stand and 11.3 $m^3$/PMH in the young plantation. CTL technology is very interesting, because it offers the benefits of limited environmental impact, simpler logistics and increased operator comfort. Modern self-leveling carriers and efficient harvesting heads can take CTL technology to rough terrain and selection cuts, once considered beyond its range of applications.*

**Key words:** *steep-terrain harvester, Valmet 500T, thinning, plantation, natural forest*

## 1. Introduction

Cut-to-Length (CTL) harvesters are sophisticated and expensive machines. Ideally, a sophisticated machine should operate within its own range of optimum working conditions, and if it is expensive it should also maintain a high annual output.

Aiming to increased diversity, modern silviculture can hardly offer such ideal working conditions. This results in an eclectic use of forestry equipment, which is often pushed far beyond its optimum working range.

In order to accumulate a sufficient annual output, forest machines are increasingly taken to inaccessible sites and into a number of different stands. Originally designed for clearcutting uniform stands in even terrain, harvesters are now used for the selective thinning of many forest types under varied terrain conditions – including steep slopes.

Carried out in America, this study aims to provide more hard data on the performance of a self-leveling harvester when used for the selective thinning of two different stand types under variable terrain conditions.

The machine selected for the study is a Valmet 500T – a best seller in America and an interesting mix of American and European technology.

## 2. The Valmet 500T

The Valmet 500T is a purpose-built harvester, especially designed for steep-terrain operations. It consists of a heavy-duty Caterpillar 325 undercarriage, connected to the main rotating platform through a self-leveling joint. The platform can tilt 27° to the front, 7° to the rear and 20° on both sides. The platform carries a 126 kW Cummins engine, a sturdy safety cab and a Cranab 1400 two stage telescopic boom.

A Valmet 965 harvester head is mounted at the end of the boom. This is a European-style dangle head with 5 limbing knives and a hydraulic chainsaw.

A description of the machine is provided in table 1.

## 3. Materials and methods

The authors carried out a time-motion study, designed to evaluate machine productivity and to iden-

**Table 1** Machine description

| **Carrier** | type | Valmet 500T |
|---|---|---|
| Configuration | | Tracked self-leveling |
| Undercarriage | | Caterpillar 325 (D6) |
| Approx. Weight | kg | 21,500 |
| Engine | | Cummins 6BTA 5.9 lt. Turbo |
| Power | kW | 126Ž2100 rpm |
| Width | cm | 290 (610 mm tracks) |
| Length | cm | 437 |
| Height | cm | 376 |
| Ground clearance | cm | 66 |
| **Head** | type | Valmet 965 |
| Approx. Weight | kg | 1,150 |
| Max cutting capacity | cm | 63 |
| Sawbar | cm | 75« |
| Feed-rollers | n. | 2 |
| Feed-rollers | type | Solid rubber w/ basket chains |
| Knives | n. | 5 |
| Hydraulic requirements | l/min | 260 |
| Hydraulic requirements | MPa | 24 |

**Table 2** Branching class: definition and distribution in our sample

| Class | Branch density | Max. branch Ø (at the trunk) | Frequency % (sample 1065 trees) | Frequency % (sample 415 trees) |
|---|---|---|---|---|
| | | | Natural forest | Plantation |
| 1 | light | < 5 cm | 14.5 | 1.2 |
| 2 | dense | < 5 cm | 37.6 | 66.7 |
| 3 | light | > 5 cm | 29.3 | 23.1 |
| 4 | dense | > 5 cm | 14.8 | 4.6 |
| 5 | malformed | | 3.8 | 4.4 |

tify those variables that are most likely to affect it. Cycle times were split into a number of time elements considered as typical of the working process.

Time elements were recorded with a Husky Hunter hand-held field computer. The computer ran a Siwork3 timestudy software.

Daily output was estimated by measuring a sample of logs from the amount produced each day. Total length and mid-diameter were used to calculate log volume. The sample would include batches of large sawlogs, small sawlogs and pulpwood, separated by species. The daily sample would be applied to the log count of that day only.

Individual trees were assigned a branching class, meant to reflect the density and dimension of their limbs (Table 2). Values were attributed through eye-estimates. Discrete branching coefficients have been used in a few other studies concerning CTL harvesters (Emeyriat *et al.* 1997, Raymond *et al.* 1988).

Stand data were recorded with traditional mensuration tools: caliper for tree diameters, tape measure for distances and clinometer for slope gradient.

The machine selected for the study belonged to a Californian company that had used it for about two years. During the study, the company was harvesting a stand in the Stanislaus National Forest, near Cabbage Patch, Alpine County, California. A Valmet 862 six-wheeled forwarder moved the logs to roadside. The whole operation consisted of two machines only – the harvester and the forwarder – which were able to maintain a balanced working pace.

During the trials, the company harvested two different stands, both growing on Public Land, at an altitude of about 2,070 m asl.

The first stand was a naturally-regenerated high-elevation mixed conifer forest. True firs (*Abies concolor* Engelm., *Abies amabilis* Forbes) constituted the main species, accompanied by dominated incense cedar (*Calocedrus decurrens* Florin) and sugar pine (*Pinus lambertiana* Dougl.). Tall stumps and large decaying logs would often hinder the advance of the harvester. Slope gradient averaged 30%, with peak values of 57%.

The current operation aimed at reducing fuel build-up and consisted of an intense low thinning. This followed a selective criterion, whose goal was to maintain 5 m between the drip lines. The Forest Service had marked all removal trees above 30 cm DBH, but the operator was free to choose among the smaller ones. The thinning removed two thirds of the trees and about one third of the basal area. Removal tree size was 0.391 $m^3$ for the firs and 0.229 $m^3$ for the cedars.

The second stand was a 23 years old Ponderosa pine (*Pinus ponderosa* Dougl.) plantation, divided in two strips, placed inside the larger natural stand. Both strips had the same density and age, but one was much more developed than the other. Slope gradient averaged 19%, with peaks at 40%. Removal tree size was 0.144 $m^3$ for the pines and 0.230 $m^3$ for the merchantable invading firs and cedars. The thinning removed about half of the trees and of the basal area. The harvester operator would choose removal trees, picking defective and undersized specimens.

A description of both stands is provided in Table 3.

The study lasted 5 days and was carried out in the week between August 9 and August 13, 1999. The machine was operated by its owner, an experienced driver who had used it for the last two years. A study outline is shown in Table 4.

**Table 3** Stand composition before and after the treatment

| | Naturally regenerated forest – 97 years | | | | Plantation – 23 years | | | |
|---|---|---|---|---|---|---|---|---|
| | Trees per ha | BA $m^2/ha$ | % BA | DBH cm | Trees per ha | BA $m^2/ha$ | % BA | DBH cm |
| | Before | | | | Before | | | |
| All | 455 | 54.1 | 100.0 | 34.0 | 893 | 32.0 | 100.0 | 20.1 |
| Firs | | | 47.2 | | | | 4.7 | |
| Cedar | | | 41.1 | | | | 0.9 | |
| Pine | | | 11.7 | | | | 94.4 | |
| | After | | | | After | | | |
| All | 156 | 36.5 | 100.0 | 52.8 | 471 | 14.9 | 100.0 | 18.3 |
| Firs | | | 53.4 | | | | 8.4 | |
| Cedar | | | 32.5 | | | | 2.0 | |
| Pine | | | 14.1 | | | | 89.6 | |

**Table 4** Study outline

| | | Natural forest | Plantation |
|---|---|---|---|
| Study duration | days | 3 | 2 |
| Total observation time | hours | 32.8 | 9.8 |
| Total work time (excl.meals) | hours | 29.2 | 8.6 |
| Rest breaks | hours | 2.1 | 0.5 |
| Maintenance and repairs | hours | 7.6 | 1.7 |
| Mech. Availability | % | 74.0 | 80.2 |
| Valid observations | n. | 1,065 | 415 |
| Total time of valid obs. | hours | 15.5 | 5.9 |
| Trees harvested (valid obs. only) | n. | 1,065 | 415 |
| Volume harvested (valid obs. only) | $m^3$ | 381 | 67 |

A substantial portion of the total work time was excluded from the pool of valid observations. This was due to the need for the studyman to collect other data, to the difficulty of recording all cycles in proper detail, to the elimination of anomalous cycles and to the exclusion of the productive time when the machine was used for other works than harvesting.

The operator would harvest parallel strips, about 15 m wide. He would proceed uphill, starting from the road and going all the way to the ridge. After he had reached the top boundary, he would track his way back to the road without harvesting.

Non-merchantable trees were to be cut and lopped, to accelerate mineralization. Top and lop would be dropped before the tracks, to reduce soil disturbance and limit track slippage.

Our timestudy form split the work cycle according to this routine, and a precise description of the individual time elements is reported in Appendix A.

## 4. Results

The main results of the study are shown in Table 5. A utilization rate of 65% was assumed (Brinker *et al.* 1989). In the natural stand, the harvester averaged a net productivity of 70 trees/PMH, equal to 25.1 $m^3$/PMH. In the plantation, productivity still reached 70 trees/PMH but volume output dropped to less than half, due to the much smaller tree size.

These values are consistent with those in other CTL studies conducted in western US and Canada (Drews *et al.* 1998, Hartsough *et al.* 1977, Hunt and Mithell 1995, Kellogg and Bettinger 1994, Schroder and Johnson 1997, Spinelli and Hartsough 1999).

The effect of rugged terrain and uneven stand characteristics is clearly visible: moving represents 25 to 30% of the total cycle time and brushing accounts for another 10%. Other tasks constitute a further 15% and include moving logs, placing slash under the tracks and looking for marked trees.

Basically, about half of the cycle time is spent preparing for productive work, rather than working. Felling and processing use very little time. Delimbing is very fast, unless the tree is big or the branching is bad. When the limbing resistance increases, the rollers tend to slip and tear the bark. In turn, loose bark interferes with the log length reading. The encoder wheel »jumps« over hanging bark and eventually loses its measurement. The operator then has to repeat the whole procedure. At these elevations, August is the sap season and therefore the test was carried out at the most unfavorable time for the processor.

For the rest, the Valmet head could handle even malformed trees. Narrow forks were managed by slightly opening the knives, so that they could hit the forks higher up and break them. If this maneuver wouldn't do, the operator could always drop the tree and reposition the head with the saw towards the fork, in order to cut it. The two tops would then be handled individually.

The average cycle time is almost identical for trees grown in a plantation and trees grown in a natural stand. Element breakdown is different, however.

In the plantation, thick undergrowth and low branching had the strongest effect on time consumption. Both reduced visibility, increasing the time required to locate marked trees and to move towards them. Indeed, most of the time described as »other« consisted in looking for target trees. Brushing time was twice as high in the plantation as in the natural stand, and positioning time was also longer – due to the low branching. On the other hand, felling, limbing and processing went somewhat faster, since the trees were much smaller and had lighter branching.

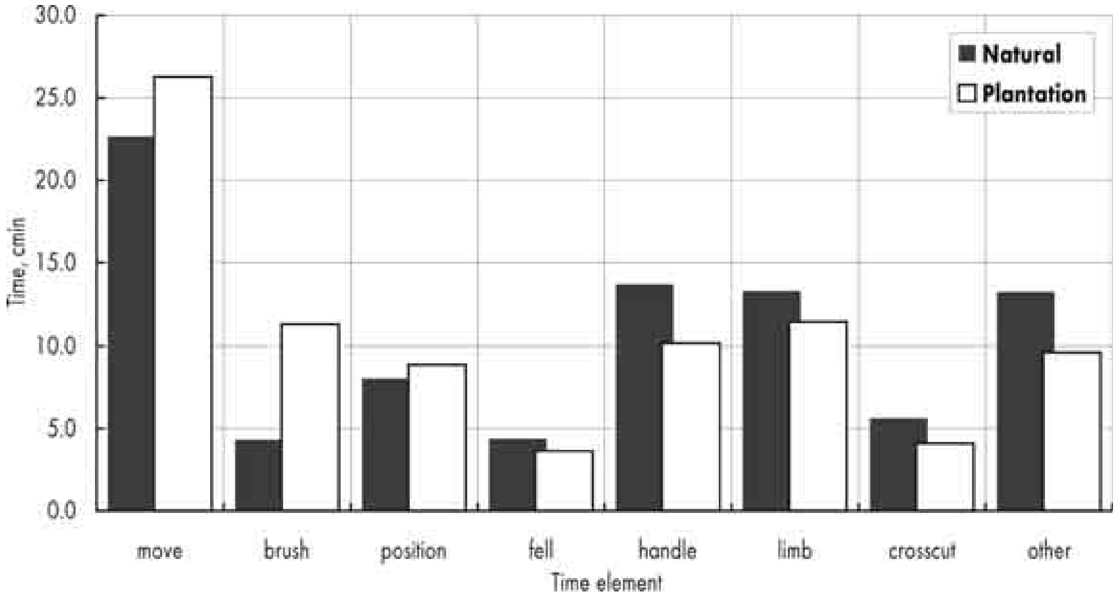


**Figure 1** Harvesting cycle: time-element breakdown

**Table 5** Productivity of the Valmet 500T harvester

| | Natural forest | | | Plantation | | |
|---|---|---|---|---|---|---|
| Observations (n.) | 1065 | | | 415 | | |
| Time Element | Mean | Std.Dev. | % of cycle | Mean | Std.Dev. | % of cycle |
| Move (cmin) | 22.7 | 35.1 | 26.6 | 26.3 | 31.5 | 30.8 |
| Brush (cmin) | 4.3 | 10.3 | 5.1 | 11.3 | 21.8 | 13.3 |
| Position (cmin) | 8.0 | 5.3 | 9.4 | 8.9 | 5.0 | 10.4 |
| Fell (cmin) | 4.4 | 3.0 | 5.1 | 3.6 | 1.8 | 4.2 |
| Handle (cmin) | 13.7 | 15.9 | 16.0 | 10.2 | 12.8 | 11.9 |
| Limb (cmin) | 13.3 | 14.4 | 15.6 | 11.5 | 12.1 | 13.4 |
| Crosscut (cmin) | 5.6 | 5.1 | 6.6 | 4.1 | 3.7 | 4.8 |
| Other (cmin) | 13.3 | 24.2 | 15.6 | 9.6 | 25.2 | 11.2 |
| Total cycle time (cmin) | 85.3 | | | 85.4 | | |
| Logs/Cycle (n) | 1.6 | | | 1.6 | | |
| Volume/tree ($m^3$) | 0.357 | 0.363 | | 0.161 | 0.122 | |
| Trees/PMH | 70.3 | | | 70.2 | | |
| Trees/SMH | 45.7 | | | 45.6 | | |
| $m^3$/PMH | 25.1 | | | 11.3 | | |
| $m^3$/SMH | 16.3 | | | 7.3 | | |

One problem with chainsaw-type harvester heads is the intrinsic vulnerability of the cutting chain. Our study checked that too, and the results are shown in table 6. A new chain can take 80 to 130 trees before it needs to be replaced. During this time, the chain may come off about 3 times, and putting it back on the bar takes about 2–3 minutes each time. Neither chain wear nor slip-off rate seem to be higher than in motor-manual processing. Much depends on visibility. In the plantation, thick undergrowth and low branching made it difficult for the operator to detect obstacles near the tree butt, which explains a higher frequency of both slip-offs and chain replacements.

Data were analyzed statistically, to reveal relationships that govern the harvesting process. On this basis, we developed a series of regression models that can help predict time consumption as a function of the most significant independent variables.

**Table 6** Saw chain duration and maintenance

| Stand | **Natural forest** | **Plantation** |
|---|---|---|
| *n* of trees | 1065 | 415 |
| *n* of chains | 8 | 5 |
| *n* of slip-offs | 19 | 15 |
| trees/chain | 133.1 | 83.0 |
| trees/slip-off | 56.1 | 27.7 |
| time to reinstall/event (cmin) | 332.9 | 211.1 |

The prediction models obtained from our study are shown in Table 7. All the terms in the equations are highly significant ($p < 0.01$), but few can account for more than half the variability. This is logically associated to a highly variable process, affected by a number of factors that could not be all included in our data collection.

The time spent handling, delimbing and crosscutting a tree is closely related to the characteristics of the tree – namely to its volume and branching.

These two characters seem to compound their effects, since we obtained the strongest correlations with functions of the »volume x branchiness« variable. That means that time consumption is high for large trees and for branchy trees, and much higher for those trees that are both large and branchy.

No significant difference was found for the handling, delimbing and crosscutting times of different tree species: the other variables in the equations already accounted for specific characters (i.e. size, branchiness) that affect the duration of these time elements.

ANOVA tests also showed that a number of time elements are longer for plantation trees than for naturally-regenerated trees.

The graphs in figure 2 are based on these relationships and allow predicting net productivity as a function of tree size and branchiness.

## 5. Conclusions

The Valmet 500T can negotiate rough terrain and it is flexible enough to harvest different stand types.

During the study, the machine handled steep slopes and thinned both a natural stand and a young plantation.

The plantation was much more difficult to harvest, due to the thick undergrowth and to the low branching of the trees. Productivity was further limited by the very small tree size.

Harvester productivity depends on a number of factors, among which tree size and shape are the most important ones. The study provided a set of equations that allow calculating productivity as a function of tree size and branchiness. The results are shown in graphic form for immediate use.

The working pace of the machine is very fast, which helps when processing small trees. Loggers think that a CTL harvester will earn its pay as long as the harvested tree yields at least one small sawlog.

As to the upper limit, the machine could harvest trees larger than 1.6 $m^3$. Natural stands may contain some trees that exceed this limit: they should be felled and processed motormanually by an operator hired for the purpose.

The hydraulic chainsaw mounted on the European-style harvester heads is somewhat more vulnerable than the disc saws found on feller-bunchers or on some American harvesters. The study checked that too, indicating that the problem is not too serious and it is often exaggerated.

**Table 7** Productivity relationships

| Time (cmin) | Regression | $r^2$ | number of observations |
|---|---|---|---|
| Move = | 22.65 + 4.92 (*plant. dummy*) | - | 1399 |
| Brush = | 4.32 + 6.27 (*plant. dummy*) | - | 1399 |
| Position = | 8.04 + 0.87 (*plant. dummy*) | - | 1399 |
| Fell = | 2.82 + 1.41 (*Br* * *Vol*) | 0.419 | 1399 |
| Handle = | 1.69 + 1.34 (*Br*) + { 8.12 + 5.65 (*plant.dummy*)} * *Br* * *Vol* | 0.472 | 1399 |
| Limb = | –0.55 + 2.36 (*Br*) + { 0.41 + 9.53 (*plant.dummy*)} * *Br* * *Vol* | 0.541 | 1399 |
| Crosscut = | 1.23 + 4.94 (*Vol*) + 0.40 (*Br*) + { 1.41 + 1.41 (*plant.dummy*)} * *Br* * *Vol* | 0.553 | 1399 |
| Other = | 13.30 – 4.37 (*plant.dummy*) | | 1399 |
| Where: | *Vol* = tree volume ($ft^3$)<br>*Br* = Branching (coeff.)<br>*plant.dummy* = Plantation dummy = 1 if trees are pines from plantation, otherwise 0 | | |

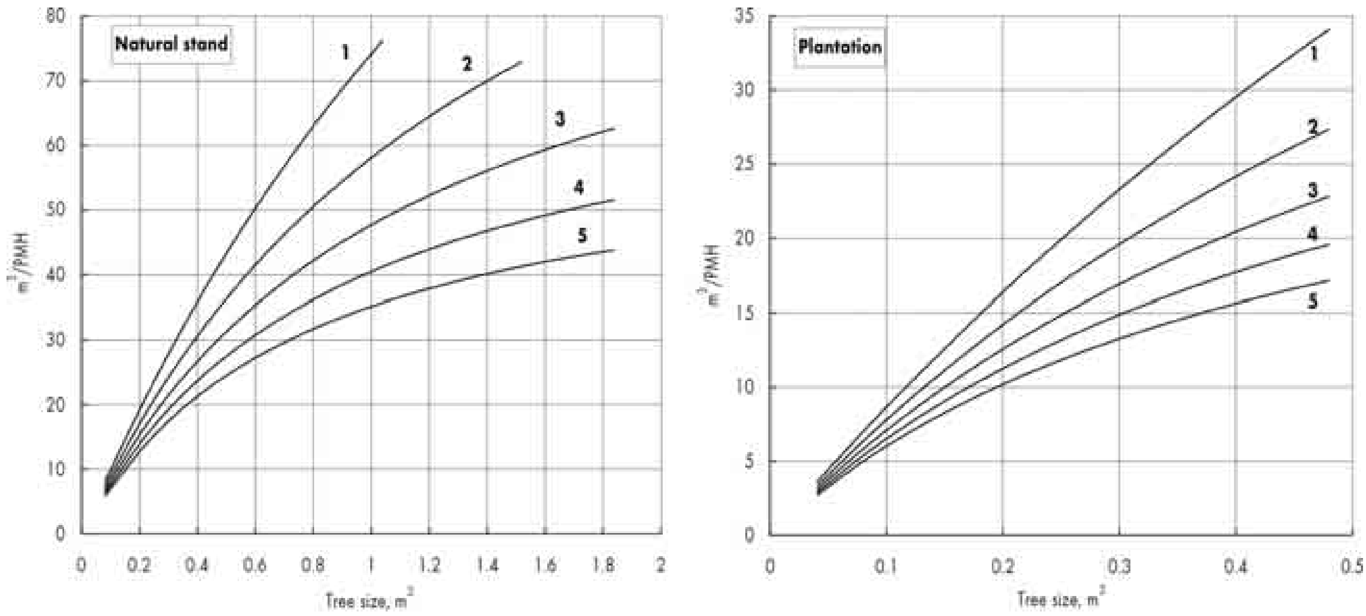


**Figure 2** Productivity as a function of tree volume for each branching class

CTL technology is very interesting, because it offers the benefits of limited environmental impact, simpler logistics and increased operator comfort. Modern self-leveling carriers and efficient harvesting heads can take CTL technology to rough terrain and selection cuts, once considered beyond its range of applications.

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## 6. References

Brinker, R.W., Miller, D., Stokes, B.J., Lanford, B.L., 1989: Machine rates for selected forest harvesting machines. Circular 296. Alabama Agric. Exp. Station, Auburn University, 24 p.

Drews, E., Hartsough, B., Doyal, J., Kellogg, L., 1998: Comparison of forwarder CTL and skyline yarder CTL systems in a natural, eastern Oregon stand. Proceedings 21st Annual COFE Meeting, Portland, OR, July 20–22, 6 p.

Emeyriat, R., Picorit, C., Reuling, D., 1997: Perspectives de la mécanisation du bûcheronnage du pin maritime – Information Forèt, AFOCEL, Fiche 561, n. 4, 6 p.

Hartsough, B., Drews, E., McNeel, J. Durston, T., Stokes, B., 1997: Comparison of mechanized systems for thinning Ponderosa pine and mixed conifer stands. Forest Products Journal 47(11–12): 59–68.

Hunt, J., Mitchell, J., 1995: Harvesting system: cut-to--length in »Compendium of commercial thinning operation and equipment in western Canada«. FERIC Special Report SR-108.

Kellogg, L., Bettinger, P., 1994: Thinning productivity and cost for a mechanized cut-to-length system in the Northwest Pacific Coast Region of the USA. Journal of Forest Engineering 5(2): 43–53.

Raymond, K., McConchie, M:, Evanson T., 1988: Tree length thinning with the Lako harvester – LIRA Report 13)(11): 6.

Schroder, P., Johnson, L., 1997: Production functions for cut-to-length harvesting in bunched and unbunched material. Proceed. 20th Annual COFE Meeting, Rapid City, SD, July 28–31, 1997, 52–61.

Spinelli, R., Hartsough, B., 1999: Steep-terrain harvesters in the US – Forest Machine Journal, 2, 20–21.

## Appendix A

| | |
|---|---|
| **Time elements:** | move = any moment tracks are rolling<br>brush = removal of undergrowth and unmerchantable trees<br>position = from when tracks stop (or brushing ends) to when the chainsaw begins cutting<br>fell = from when the chainsaw begins advancing to when the tree starts to fall<br>handle = any movement of the boom while the head holds a cut tree, provided the machine is not doing any other job (i.e. limbing etc.)<br>limb = cut tree being propelled through the knives' embrace<br>crosscut = any time one the saw is being operated to crosscut<br>other = any other productive time, mostly clearing the path from obstacles, re-handling, piling slash, ejecting tops and trying to locate the next target tree |

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# Performance of Shovel Logging in a Partially Harvested Appalachian Hardwood Stand

**Andrew F. Egan**

***Abstract***

*The steep, uneven terrain of central Appalachia (USA) offers significant challenges to conventional ground based logging systems. Rubber-tired skidding, by far the most common means of yarding wood in the region, generally involves the construction of expensive forest access systems that expose surface soils, increasing the potential for erosion and sedimentation. In addition, clearcutting is only rarely practiced in the region and most of the forestland is owned by nonindustrial private forest owners who value the amenities associated with partial harvests.*

*Shovel logging, a ground-based method that uses an excavator fixed with a grapple instead of a bucket, offers the potential to yard felled wood with less impact to forest soils than conventional rubber-tired skidding methods. Contingency table analyses suggested (a) a moderate level of dependence between the shovel and skidder treatments and the frequency of residual trees exhibiting bole damage, with the shovel logging treatment areas containing a greater number of residual trees with bole damage than the skidder logged areas; and (b) that the amount of »severe« bole damage was independent of yarding treatment. Analysis of variance revealed no significant difference between the two treatments in the size of bole damage wounds (p = 0.730). In addition, although neither conventional nor shovel logging methods can be recommended over the other based solely on short-term impacts to soil bulk density, shovel logging resulted in significantly less surface soil disturbance.*

*Based on the results of this study, shovel logging may be a viable alternative to conventional rubber-tired skidding in some situations, but the system should be used cautiously in order to reduce the frequency of residual tree damage. The use of shovel logging can minimize skid trail construction, particularly in mountainous conditions such as those found in much of Appalachia, riparian zones, and areas where sensitive surface conditions exist due to high water tables. Moreover, in the northern US, shovel logging may help to extend the logging season into the spring mud season, when conventional operations that rely on rubber-tired skidding can no longer operate without significant soil disturbance.*

***Key words:*** *shovel logging, soil bulk density, soil disturbance, residual stand damage*

## 1. Introduction and background

Like much of central Appalachia, West Virginia's steep and uneven topography contributes to some of the most difficult logging conditions in the eastern US. Although cable logging systems have been used in the region, their efficacy has met with mixed results and little enthusiasm by the logging community, and conventional ground based yarding systems using rubber-tired skidders and/or dozers continue to predominate. Unfortunately, conventional tractive yarding methods often require expensive bulldozed skid roads (Layton *et al.* 1992) that may consume over ten percent of the timber sale area (Kochenderfer 1977, Mitchell and Trimble 1959). In addition, construction of these roads often causes shallow subsurface water to be converted to surface flow over exposed soil, increasing the potential for erosion and sedimentation (Egan 1999a). Although West Virginia's Best Management Practices (BMPs) have been shown to be effective in controlling nonpoint source pollution from logging (Kochenderfer *et al.* 1997), and compliance with BMPs in the state appears to have increased over the past fifteen years (Egan *et al.* 1998), concerns within the forestry community about the adverse effects of forest road construction persist (Egan *et al.* 1996).

As in much of the central Appalachian region, nonindustrial private forest (NIPF) owners hold most of the commercial timberland in West Virginia (Birch *et al.* 1992). Although income drives most NIPF owners' decisions to harvest (Egan and Rowe 1997), clearcutting is only rarely practiced in the region, since most NIPF owners place a high value on the amenities associated with maintaining a continuous canopy, particularly recreation and aesthetics (Birch 1996). As a result, diameter-limit harvesting appears common among the region's NIPF owners (Raschka 1998), despite questions about the method's effect on forest quality and sustainablility among many in the professional forestry community (Dwyer and Kurtz 1991).

Given these circumstances, research on alternative ground-based logging methods that both limit road building and are effective in partial harvests is timely. Shovel logging, a ground-based method also known as hoe-chucking, that uses an excavator fixed with a grapple instead of a bucket, has been investigated by other researchers (Brown *et al.* 1993, Fisher 1987, Floch 1988, Kockx 1990). With few exceptions (Sloan 1992, Egan 1999b), this research has been conducted in clearcuts in the western US and Canada, and research on the efficacy of the method in partial harvests appears to be limited to a study on the effects of shovel logging on residual stands in the central Appalachian region (Egan 1999b). Yet the system's ability to reach, lift, and forward felled trees to either a landing or a bunching location for subsequent ground skidding or pre-hauling implies a potential for a wide range of logging applications.

The objectives of this research were to compare residual stand damage and surface soil disturbance effects and damage after yarding using shovel logging and conventional rubber-tired skidding. The silvicultural method applied was a deferment harvest, developed as an even-aged, aesthetic alternative to clearcutting. This method, more commonly applied in forests of Europe than those of the US, leaves a basal area of approximately 20 ft$^2$ per acre in high quality dominants and co-dominants. Leave trees are then recovered when the regenerated stand is at the end of its rotation. Therefore, deferment trees are generally selected based on seed production, phenotype, and anticipated longevity.

## 2. Methods

Three ± 5-acre replicates each of shovel logging and conventional rubber-tired skidding were randomly assigned in a partial harvest of an Appalachian hardwood stand in northern West Virginia. The study area was dominated by the Gilpin-Culleoka-Upshur soil association, described as moderately to very steep, well drained, upland soils (USDA Soil Conservation Service 1982). The slope of the treatment area ranged from 2–18 percent, with an average slope of over 8 percent. Boundaries of each of the six treatment areas were surveyed to approximate five acre treatment areas, and two-chain (132 foot) wide uncut buffers were maintained between each contiguous treatment area. Each treatment block was cruised before harvest using nine 0.1 acre sample plots per area. Results of the cruise indicated that, although treatment area number 1 had the highest and area number 4 the lowest stocking levels of any blocks, stocking on the other four blocks was comparable (Table 1).

Timber within each treatment area was marked for a deferment harvest. The post-harvest goal was a residual stand of approximately 20 ft$^2$ of basal area per acre, mimicking the range of stocking that may also be left after a seed tree harvest, latter stages of a shelterwood system, or a deferment harvest (Smith *et al.* 1989). The following timber marking guidelines were developed:

- only vigorous, long-lived trees with future timber potential should comprise the residual stand;
- residual trees should be 12 to 17 inches dbh; trees either smaller or larger than this range may be left to obtain adequate spacing; and
- average spacing between crop trees should be 50 to 60 feet.

In the summer, 1996, trees to be left were marked and all unmarked trees were to be either felled and removed, or felled and left on site if they were unmerchantable. After marking, but before timber was harvested, field crews numbered each marked tree inconspicuously with an aluminum tag at its base. At that time assessments were made of tree species, dbh, and the condition of the bole and crown. The timber on all six blocks was sold on a competitive bid basis to a logging contractor who owned an excavator fixed with a grapple attachment, a Hydro-Ax 411 feller-buncher, and several grapple skidders. Logging occurred on all six replicates during the fall, 1996. Trees were directionally felled using a feller-buncher as well as a chain saw for larger diameter trees. Felled trees were then delimbed and topped using a chain saw. The shovel logger began at the interior of each of the three shovel treatment areas,

**Table 1** Random treatment assignments, treatment areas, and pre-harvest trees per acre, basal area per acre, and volume per acre, with associated standard errors and coefficients of variation

| Treatment Area | Trees | | | | |
|---|---|---|---|---|---|
| | Treatment | Area acres | Number of trees per acre | Basal area ft$^2$/acre | Volume cords/acre |
| 1 | skidder | 4.96 | 106.67 | 140.96 | 13.32 |
| standard error | | | 8.50 | 14.81 | 1.97 |
| cv, % | | | 23.90 | 31.53 | 44.48 |
| 2 | skidder | 4.87 | 77.78 | 100.14 | 8.98 |
| standard error | | | 6.19 | 10.04 | 1.27 |
| cv, % | | | 23.86 | 30.08 | 42.37 |
| 3 | skidder | 4.84 | 73.33 | 102.69 | 9.95 |
| standard error | | | 6.67 | 8.59 | 1.32 |
| cv, % | | | 27.27 | 25.11 | 41.38 |
| 4 | shovel | 5.05 | 67.50 | 76.47 | 6.07 |
| standard error | | | 9.01 | 8.28 | 0.77 |
| cv, % | | | 37.77 | 30.62 | 35.78 |
| 5 | shovel | 4.84 | 70.00 | 91.44 | 8.76 |
| standard error | | | 12.82 | 12.56 | 1.77 |
| cv, % | | | 51.79 | 38.85 | 56.99 |
| 6 | shovel | 4.78 | 80.00 | 93.97 | 8.61 |
| standard error | | | 7.56 | 9.23 | 1.34 |
| cv, % | | | 26.73 | 27.78 | 44.05 |

picking up and swinging logs toward a skid road adjacent to all six treatment blocks. From here, logs were then conveyed by grapple skidder to a common landing for wood from both treatments. In the skidder treatment areas, a rubber-tired grapple skidder yarded tree-length logs to the same common skid road and continued to the landing.

## 2.1. Field data collection

### 2.1.1. Stand damage

Stand damage data were collected on all residual trees in the six replicates immediately after the completion of harvesting. In addition, residual stand damage in the three shovel treatment areas was assessed immediately following felling, but before trees had been yarded. Post-felling-only assessments could not be safely made in the skidder treatment areas because yarding followed too closely behind felling in those treatments. All residual trees were assessed for damage to the bole and crown. Only open wound bole damage (i.e., wounds in which the bark had been removed by logging and wood was exposed, referred to as exposed sapwood wounds by Lamson *et al.* (1984) was measured in square inches. The log position of the wound was also recorded. When wounds were inaccessible to the field crew because they were too high on the bole, estimates of their surface areas were made.

### 2.1.2. Surface soil disturbance

After logging, the type of soil disturbance was determined and measured on linear transects located perpendicular to contours. By locating the transects in this fashion, they were more likely cross skidroads and excavator tracks, since these features were typically located along contours. The azimuth used for each block was predetermined so that it would run perpendicular to the contour, but would not cross the main skid road adjacent to the sample blocks. Transects were spaced at 50′ (15.24 m) intervals, the first transect in each block located 25′ from the main haul road. The beginning of all transects was marked with a numbered stake. A 300′ (91.44 m) measuring tape was extended along the predetermined azimuth, and only disturbance types encountered along the measuring tape were recorded. Measured disturbance classes, modeled after Martin (1988), included:

1) no evidence of vehicular traffic;
2) trafficked by logging equipment: (a) primary skid trail (a major yarding artery with exposed surface soil); (b) secondary skid trail (a feeder trail with surface soil generally not fully exposed); (c) excavator trail; and (d) feller-buncher trail;
3) compaction by logs;
4) coverage by slash: (a) light (few or no limbs); (b) medium (some ground visible or large limbs); and (c) heavy (ground generally not visible—tree tops);
5) nonsoil (e.g., stumps, large rocks); and
6) percent disturbance of leaf litter: (a) 0–25% removed; (b) 26–75% removed; and (c) > 75% removed.

As each new disturbance class (with the exception of heavy slash and nonsoil) was encountered along a transect, a random selection system was used to determine whether a soil bulk density core was to be sampled at that location. The selection method allowed for a one in four chance of sampling at each change in disturbance class. This procedure resulted in a total of 271 soil cores sampled over both treatments. A metal extractor with removable sample cylinders was used to collect the soil samples. For each soil sample location, three collection sites (one for »no traffic« areas) were located along the tape. In skidder- and shovel-logged sites, cores were taken in each track made by the skidder tires/shovel undercarriage. In large areas of feller-buncher disturbance, cores were collected in the depressions left by the machine's tires. If organic matter were present on a core site, it was carefully moved (trying not to cause compaction) so that the core would contain only mineral soil. Since rock fragments have a higher density than soil, care was taken to avoid soil samples with rock fragments. If a large rock fragment were encountered, another core was taken next to the original core.

To remove a core, the extractor was held vertically and driven into the soil far enough to fill the sample cylinder. The extractor was then carefully removed from the soil. The sleeve at the bottom was removed, as were the sample cylinder and spacing cylinder. The two cylinders were separated and a knife was used to trim any soil extending past the ends of the sample cylinder. The soil in the sampler was transferred into numbered plastic reclosable sandwich bags for transport to the laboratory.

#### 2.1.3. Laboratory procedures

In the laboratory, soil samples were placed into weighed and numbered baking tins. The tins were placed in an oven at 105 °C until constant weight was reached (Blake and Hartage 1986). After having been placed in the oven for about 14 hours, each of the tins containing the soil was cooled to room temperature and weighed. The tins were returned to the oven for a minimum of three additional hours before they being removed, cooled, and weighed for a second time. The weights were recorded and bulk density was determined by the relationship:

$$\text{bulk density} = \frac{\text{oven} - \text{dry mass (g)}}{\text{volume (cm}^3)}$$

## 3. Results and discussion

As planned, the residual stands for the two treatments were very similar. There were 17.4 trees per acre left in the skidder treatment areas and 16.9 trees per acre in the shovel treatment areas after logging. The mean residual tree dbh over both treatments combined was 14.9 inches (standard error = 0.10 inches), with a range of 9.5 to 21.7 inches. The mean dbh was 14.6 inches in the shovel treatment (standard error = 0.15) and 15.2 inches (standard error = = 0.13 inches) in the skidder treatment (Table 2).

### 3.1. Stand damage

The average extent of damage to injured tree boles in both treatments combined was 28.0 in$^2$ (standard error = 3.05 in$^2$), while the average by-treatment damage per tree was 29.0 in$^2$ (standard error = 4.49 in$^2$) for the shovel logging treatment and 26.9 in$^2$ (standard error = 4.16 in$^2$) for the skidder treatment. Approximately 32.5 percent of the residual trees in the skidder treatment areas experienced bole damage. These residual stand damage results agree closely with deferment harvest trials in West Virginia that found that 31 percent of deferment trees had at least one exposed sapwood wound when conventional ground skidding was employed (Smith *et al.* 1989). Moreover, Nichols *et al.* (1994) found that 22–44 percent of residual trees was wounded when chain saws and cable skidders were used in a partial harvest of northern hardwoods. In the same study, 20–31 percent of residual stems were wounded when mechanized felling and grapple skidding were employed.

**Table 2** Summary of post-harvest stand conditions by treatment: number of trees, trees per acre, average dbh, basal area, and bole damage

| Atribute | Treatment | |
|---|---|---|
| | Skidder | Shovel |
| Number of trees | 255 | 248 |
| Trees per acre | 17.38 | 16.90 |
| Average dbh, inches | 15.23 | 14.65 |
| Basal area, ft$^2$/acre | 22.19 | 19.78 |
| Average bole damage per tree, in$^2$ | 26.91 | 29.02 |
| Percent of trees with bole damage | 32.5 | 40.6 |
| Number of trees with < 100 in$^2$ bole damage | 60 | 80 |
| Percent of trees with < 100 in$^2$ bole damage | 23.5 | 32.2 |
| Number of trees with severe (> 100 in$^2$) bole damage | 23 | 21 |
| Percent of trees with severe (> 100 in$^2$) bole damage | 9.0 | 8.5 |

Approximately 28 percent of wounded trees (9.0 percent of all residual trees in the treatment) had wounds of greater than 100 in$^2$ and were rated as »severe« and likely to result in decay (Nyland and Gabriel 1971). Approximately 41 percent of the residual trees in the shovel treatment areas experienced bole damage; 20.8 percent of these (8.5 percent of all residual trees in the treatment) had wounds greater than 100 in$^2$ (Table 2). In contrast to the frequency of severe damage found in this research, Smith *et al.* (1989) reported that 13 percent of residual deferment trees in their study had severe wounds.

### 3.2. Analysis of bole damage

No blocking effect was apparent in this study. Contingency table analysis indicated independence between blocking and whether a tree was damaged (chi-square $p$-value = 0.242; G-squared $p$-value = = 0.233) (Table 3). In addition, analysis of variance indicated no significant difference among the six replicates in the amount of damage per tree bole ($F$ = = 1.501; $p$-value = 0.188).

**Table 3** Contingency table analysis of the relationship between experimental blocks and whether a tree was damaged (a dichotomous yes/no variable); and shovel and skidder treatments and (a) whether a tree was damaged (a dichotomous yes/no variable) and (b) amount of damage in three categories: no damage, < 100 in$^2$, and > 100 in$^2$ (severe)

| Variables | Chi-square | G-squared |
|---|---|---|
| | *p*-value | |
| Block x damage (yes/no) | 0.242 | 0.233 |
| Treatment x damage (yes/no) | 0.062 | 0.062 |
| Treatment x damage category | 0.097 | 0.096 |

However, a relationship between treatment (skidder vs. shovel logging) and whether a tree was damaged (chi-square $p$-value = 0.062; G-squared $p$-value = 0.062) was suggested by contingency table analysis (Table 3). When bole damage was categorized by (a) no damage, (b) ≤ 100 in$^2$ of damage, and (c) > 100 in$^2$ of damage (»severe«), contingency table analysis indicated a moderate relationship between treatments and damage classification (chi-square $p$-value = 0.097; G-squared $p$-value = 0.096) (Table 3). Cell chi-squares for this analysis, however, revealed close agreement between observed and expected »severe« damage by treatment (Table 4). Finally, analysis of variance indicated no significant difference (alpha = 0.05) between treatments in the average amount of damage per tree ($F$ = 0.120; $p$-value = 0.730).

Of the other variables studied, residual tree dbh appeared to be related to (a) whether a tree was damaged (log likelihood ratio test: chi-square = 4.616; $p$-value = 0.032); and (b) levels of severity of damage (log likelihood ratio test: chi-square = 5.937; $p$-value = 0.051). However, when the logistic regression analysis was partitioned by treatment, dbh was not significantly related (alpha = 0.05) to the frequency of bole damage for either the skidder treatment (logistic likelihood ratio $p$-value = 0.316) or the shovel treatment (logistic likelihood ratio $p$-value = 0.096).

**Table 4** Observed and expected frequencies and cell chi-square results of contingency table analysis for treatment x bole damage category: no damage; < 100 in$^2$ of damage; > 100 in$^2$ of damage. Total chi-square for the analysis = 4.677; chi-square *p*-value = 0.096

| Treatment | Bole damage category | | |
|---|---|---|---|
| | No bole damage | ≤ 100 in$^2$ damage | > 100 in$^2$ damage |
| Skidder | | | |
| Observed frequency | 172 | 60 | 23 |
| Expected frequency | 162 | 71 | 22 |
| Cell chi square | 0.629 | 1.1657 | 0.024 |
| Shovel | | | |
| Observed frequency | 148 | 80 | 21 |
| Expected frequency | 158 | 69 | 22 |
| Cell chi square | 0.645 | 1.697 | 0.025 |

In addition, proximity to the nearest harvested tree appeared unrelated to (a) whether a tree was damaged (log likelihood ratio test: chi-square = = 0.528; $p$-value = 0.468; or (b) levels of severity of damage (log likelihood ratio test: chi-square = 0.698; $p$-value = 0.705). Although this latter result may not appear intuitive, the use of a feller-buncher to directionally fell and organize most harvested trees for subsequent yarding may explain the lack of a relationship between bole damage and the proximity of the nearest cut tree.

### 3.3. Pre-harvest – post-felling – post-yarding damage comparisons

In order to accurately and reliably describe damage attributable only to the shovel logging process and distinct from that deriving from either pre-harvest agents (e.g., ice) or felling, shovel treatment residual trees were assessed for damage before harvest, immediately after felling but prior to yarding, and after yarding. Results indicated that (a) there was no pre-harvest bole or crown conditions in any of the treatment areas that might mimic damage due to some aspect of the harvest cycle; and (b) shovel logging did not cause mechanical damage to tree crowns beyond that caused by felling. Trees numbered 26, 33, 34, and 52 in block 4; number 58 in block 5; and 10 in block 6 experienced some crown damage from felling. These trees exhibited the same crown damage upon post-yarding inspection, as expected, but no additional crown damage was found on either these or any other residual trees in the shovel treatment areas.

Post-felling-only bole damage was not found on any residual trees in block 4, but was found on trees numbered 5, 16, 17, 29, 42, 50, 58, 5, 70, and 71 in block 5, and 3, 5, 6, 11, 14, 25, 44, 46, 47, 58, 68, 81, and 88 in block 6. In all cases in which it occurred, post-felling-only bole damage was found in the first 8-foot log, and was classified as »severe« in three (13 percent) of the trees injured. After shovel yarding, bole damage was found on an additional 33 residual trees in block 4; 23 trees in block 5; and 22 trees in block 6.

### 3.4. Surface soil disturbance

Analysis of variance (AOV) and logistic regression were used to analyze litter disturbance and soil bulk density data.

#### 3.4.1. Litter disturbance

Results of Sheffe's multiple comparisons test indicated (a) significant differences in surface soil disturbance (alpha = 0.05) on untrafficked areas vs. that found on secondary skid trails, excavator trails, and feller-buncher tracks; and (b) differences of borderline significance in soil surface disturbance between excavator and both feller-buncher disturbance ($p = 0.053$) and primary skid trails and untrafficked areas ($p = 0.054$). In addition, logistic regression analysis revealed that both the type of treatment (skidder vs. shovel logging) (chi-square = 63.33; $p < 0.001$) and amount of slash cover (chi-square = 1305.51; $p < 0.001$) were significant in explaining the amount of litter disturbance (likelihood ratio <0.0001; $r^2 = 0.46$). There was a larger percent of skidder treatment area with greater than 75 percent litter removed (23.5 percent) than for the shovel treatment (7.7 percent) (Table 5). Moreover, AOV also revealed significant differences in the amount of litter disturbance by skidder vs. shovel logging treatment ($p < 0.0001$).

#### 3.4.2. Bulk density

Although analysis of variance revealed a significant difference in average bulk density ($F = 7.460$; $p < 0.001$) among all disturbance classes studied (Table 5), there was no significant difference between sample bulk densities on combined primary/secondary skid trails (average = 1.11 $g/cm^3$) and sample bulk densities on shovel trails (average = 1.23 $g/cm^3$) ($F = 0.114$; $p = 0.737$). Average bulk density over all samples in both treatments was 1.052 $g/cm^3$. However, the highest bulk densities were found on secondary skid trails (average = 1.15 $g/cm^3$), while the lowest were on areas that were not trafficked (average = 1.02 $g/cm^3$) (Table 6).

**Table 5** Percent litter disturbance by treatment[1]

| Treatment | 0–25 percent litter removed | 26–75 percent litter removed | > 75 percent litter removed |
|---|---|---|---|
| | (Percent of transect lenght disturbed) | | |
| Skidder | 37.8 | 17.1 | 23.5 |
| Shovel | 43.5 | 19.8 | 7.7 |

[1] Percents do not add to 100 because of areas in both treatments that were covered by slash or were non-soil

**Table 6** Average bulk density by disturbance class

| Disturbance | Bulk density, $g/cm^3$ |
|---|---|
| No traffic | 1.015 |
| Primary skid trail | 1.093 |
| Shovel | 1.123 |
| Secondary skid trail | 1.147 |

## 4. Conclusions

The value of shovel logging in clearcuts, especially on some sensitive sites, has been demonstrated in several studies, mostly in the western US and Canada. Using shovel logging in partial harvests that reduce residual stand stocking to 25 $ft^2$ per acre or less – as might occur in a deferment harvest, seed tree harvest, and latter stages of a shelterwood system – may be a viable alternative to more conventional ground skidding methods, especially on sites where there are concerns about soil disturbance and skid road building costs. This study, however, raises some questions about the use of the system in partial harvests where concern about damage to residual stands exists. Although it was clear that there was (a) no difference between treatments (skidder vs. shovel) in the average amount of bole damage per tree, and (b) no relationship between treatment and the frequency of severe bole damage, the nature of the relationship between treatment and the frequency of any bole damage was less conclusive. Contingency table analysis suggested a moderate relationship between shovel logging and rubber-tired skidding treatments and the frequency of trees damaged. However, the percentage of deferment trees with bole wounds considered »severe« in either yarding treatment was less than that reported in other deferment harvest trials in the region using conventional ground skidding (Smith *et al.* 1989).

In addition, our analyses indicated that neither of the logging methods studied – rubber-tired skidding and shovel logging – can be recommended over the other based solely on short-term impacts to soil bulk density. Further studies of soil structural resiliency (i.e., the ability of the soil's structure to reform after degradation (Pierce and Lal 1994)) for each treatment, however, may be warranted in order to quantify potential differences in long-term soil bulk density effects. In addition, future studies of the effects of changes in bulk density on residual tree growth and vigor will be undertaken on the treatment sites described in this study.

However, where mitigating litter disturbance is an objective, our results indicate that shovel logging has significant advantages over rubber-tired skidding. Shovel logging may be the better alternative when harvesting in streamside management zones, for example, where states' BMP guidelines often limit surface soil disturbance (e.g., Maine Department of Conservation 1994, West Virginia Division of Forestry 1996). Perhaps equally compelling from both environmental and economic standpoints, however, may be the use of shovel logging as a substitute for excessive skid trail construction, particularly in mountainous conditions such as those found in much of Appalachia, as well as areas where sensitive surface conditions exist due to high water tables. In the northern US, for example, shovel logging may help to extend the logging season into the spring mud season, when conventional operations that rely on rubber-tired skidding can no longer operate without significant soil disturbance.

We found that approximately 31 percent of the skidder yarded treatment areas was occupied by primary skid trails. In mountainous regions in Appalachia, this type of trail would normally be constructed with a dozer blade, exposing surface soil to the potential for erosion (Egan 1999a). No such trails were constructed on the shovel treatments or for secondary skid trails. In addition, from an operations and equipment investment perspective, shovel systems may have additional merit in the region, since when not used for yarding, the excavator may be used for other logging-related tasks, such as road building and loading. A complete economic analysis of the costs and benefits of such an investment appears warranted.

Finally, although a time and motion study was not performed during these comparative logging trials, conversations with the logging contractor indicated that shovel logging under the conditions described was at least as profitable as skidding using conventional methods. In addition, other shovel logging studies that have employed a time and motion component (e.g., Brown *et al.* 1993) have found that the method was economical. However, these studies were performed in clearcuts, suggesting that timing studies of shovel logging in partial harvests are also warranted.

Given these results, it is recommended that shovel logging may be an appropriate alternative to rubber-tired skidding in heavy partial harvests of Appalachian hardwoods. However, the use of shovel logging in partial harvests should be approached cautiously. Marking stands to accommodate the excavator and its boom may be one way of mitigating stand damage levels over those experienced in conventional yarding systems. This may be accomplished, for example, by leaving trees in groups rather than evenly scattered throughout the sale unit.

In addition, advances in shovel logging technology should enhance its efficacy in partial harvests. Smaller shovel logging equipment with shorter booms and no tail swing (a model with a 34-foot live-heel boom is now being marketed by a forestry equipment manufacturer) may help to reduce the frequency of residual stand damage under conditions similar to those in this study. To determine the merit of the method over a broad spectrum of conditions, further studies of shovel logging operating in a variety of residual stand densities and soil and slope conditions are warranted.

## 5. References


Birch, T.W., Gansner, D.A., Arner, S.L., Widman, R.H., 1992: Cutting activity on West Virginia Timberlands. Northern Journal of Applied Forestry. 9(1992):146–148.

Birch, T.W., 1996: Private forest-land owners of the northern United States, 1994. Resource Bulletin NE-136. Radnor, PA:USDA Forest Service, Northeastern Forest Experiment Station.

Blake, G.R., Hartage, K.H., 1986: Bulk Density. *In* A. Klute (ed.) Methods of Soil Analysis. Part 1. 2$^{nd}$ ed. Agron. Momogr. 9:425–444. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. P. 363–376.

Brown, C., Payne, G., Rouck, K., 1993: A hoe-chucking simulation model developed from Northwest Bay time-study data. MacMillan Bloedel Forest Operations Paper 459.

Dwyer, J.P., Kurtz, W.B., 1991: The realities of sustainable management vs. diameter limit harvest. Northern Journal of Applied Forestry. 8(1991):174–176.

Egan, A., Rowe, J., 1997: Compliance with West Virginia's Silvicultural Best Management Practices — 1995–1996. Report made to the West Virginia Division of Forestry, Charleston, WV. June 10, 1997.

Egan, A., Jenkins, A., Rowe, J., 1996: Forest roads in West Virginia, USA: Identifying issues and challenges. Journal of Forest Engineering. 8(1):33–40.

Egan, A., Whipkey, R., Rowe, J., 1998: Compliance with forestry Best Management Practices in West Virginia. Northern Journal of Applied Forestry. 15(4):211–215.

Egan, A., 1999a: Forest roads: Where soil and water don't mix. Journal of Forestry. 97(8):18–21.

Egan, A., 1999b: Residual stand damage after shovel logging and conventional ground skidding in an Appalachian hardwood stand. Forest Products Journal. 49(6):88–92.

Fisher, J.G., 1987: Logging with a hydraulic excavator: A case study. 1987. MS thesis. Oregon State University.

Floch, R.F., 1988: Shovel logging and soil compaction: A case study. 1988. MS thesis. Oregon State University.

Kochenderfer, J.N., 1977: Area in skidroads, truck roads, and landings in the central Appalachians. Journal of Forestry. 8(79):507–508.

Kochenderfer, J.N., Edwards, P.J., Wood, F., 1997: Hydrologic impacts of logging an Appalachian watershed using West Virginia's Best Management Practices. Northern Journal of Applied Forestry. 14(4):207–218.

Kockx, G.P., 1990: Soil disturbance by forwarding with log loaders on two Vancouver Island sites. Internal document. Forest Engineering Research Institute of Canada. Vancouver. July 1990.

Layton, D.A., LeDoux, C.B., Hassler, C.C., 1992. Cost estimators for construction of forest roads in central Appalachians. USDA For. Serv. NE For. Exp. Stn. Res. Pap. NE--665.

Maine Department of Conservation, 1994: Best Management Practices Field Handbook. Augusta, Maine.

Martin, C.W., 1988: Soil disturbance by logging in New England – review and management recommendations. Northern Journal of Applied Forestry. 5:30–34.

Mitchell, W.C., Trimble, G.R., 1959: How much land is needed for the logging transport system? Journal of Forestry. 1(61):10–12.

Nichols, M.T., Lemin, R.C., Ostrofsky, W.D., 1994: The impact of two harvesting systems on residual stems in a partially cut stand of northern hardwoods. Canadian Journal of Forest Research. 24(2):350–357.

Nyland, R.D., Gabriel, W.J., 1971: Logging damage to partially cut hardwood stands in New York state. State University College of Forestry, Syracuse University. AFRI Research Paper 5.

Pierce, F.J., Lal, R., 1994: Monitoring the impact of soil erosion on crop productivity. *In* R. Lal (ed.) Soil Erosion Research Methods, 2nd ed. Soil and Water Conservation Society. P. 235–263.

Raschka, J., 1998: Timber harvesting in West Virginia: A statewide study of some effects and landowner attitudes. MS Thesis. West Virginia University, College of Agriculture, Forestry, and Consumer Sciences.

Sloan, W.H., 1992: Shovel logging in the mountains of Virginia. *In* Proceedings, Southern Regional Council on Forest Engineering. Blacksburg, VA. April 20–22, 1992.

Smith, H.C., Lamson, N.I., Miller, G.W., 1989: An estheitc alternative to clearcutting? Journal of Forestry. 3(87):14––18.

USDA Soil Conservation Service, 1982: Soil survey of Marion and Monongalia Counties, West Virginia.

West Virginia Division of Forestry, 1996: Best Management Practice Guidelines for Controlling Soil Erosion and Water Siltation. WVDOF-TR-96-3.

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# Helipace, Helicopter Logging Production and Cost Estimation

**Anika Juras, Steve Martin, Donald K. Nearhood**

***Abstract***

*Helicopter logging can be a cost-effective and environmentally sound method of harvesting wood. When helicopter logging is being considered for a particular site, planners need tools for estimating production rates and costs. Helipace, Helicopter Logging Production and Cost Estimation, is a computer program that was developed to implement the estimation process used by helicopter logging experts. The model emulates helicopter loggers' methods of evaluating proposed operations for individual harvest units. Through prompts and detailed online help, the program guides the user in how to think about the proposed operation to develop reasonable input values and results. The online help provides the user opportunities to learn about the questions that need to be answered and how experts think about the questions using descriptions, photos, and ranges. Helipace was developed in 1990, and has been revised several times in the following years. An update to the program will begin in October 1999. This update is a cooperative effort of USDA Forest Service (USFS), Aerial Forest Management Foundation (AFMF), and Food and Agriculture Organization (FAO, Rome). Helipace has proven to be a useful analysis tool for western United States and western Canada. The methodology implemented in Helipace is transferable to other geographic areas; however, cooperators in other areas are needed to provide helicopter production statistics and costs. Because the weight of wood to be harvested and the residual canopy closure are significant analysis factors, a companion program, ForSee (Stand Visualization and Volume /weight Analysis) was developed to assist users in designing helicopter logging operations which are both economically and environmentally viable.*

***Key words:*** *helicopter, logging, harvest, cost estimating, planning*

## 1. Introduction

Foresters use various and continually developing technologies. Among these technologies for harvesting are high technology harvesting systems, such as helicopter logging, and logging systems computer analysis programs. These analysis programs may be developed from work-study research and/or from expert knowledge. For example, Heinimann and Caminada (1996) studied and analyzed helicopter logging operations in Switzerland and developed a productivity model based on these work-studies. The Helipace program is based on expert professional helicopter logging experience.

Harvest planners must design harvest scenarios that meet timber harvest goals and maintain environmental objectives within economic constraints. Helicopter logging is one alternative harvest planners may consider. Cost is a concern when helicopter logging is considered, but helicopter logging can be economically smart when road costs are high or the volume to be harvested is scattered.

Harvesting cost is only one harvesting consideration, one factor among others such as silvicultural objectives, environmental objectives, and timber value. The cost of harvest operations is one factor that may be significantly controlled by harvest planners. Good planning can reduce costs and increase benefits. For helicopter logging operations, planning based on knowledge of the factors that affect costs can significantly reduce harvest costs.

In order to do good planning, the harvest planner needs knowledge of factors that affect cost and safety to do good unit layout. »However, experience and ability to plan for the use of helicopters in logging has been concentrated in the individuals who work in the helicopter logging industry. Public and private planners have been unprepared to estimate helicopter logging feasibility and associated cost. Even planners who have had experience with previous helicopter logging jobs are lacking in knowledge and skill to correctly estimate new jobs, because of a lack of understanding of how the new variables will affect costs. Consequently, adequate consideration of helicopters for logging has not always occurred during the planning process. Because factors that critically affect costs have not been understood by area and sale planners, the use of helicopters has largely been a measure of last resort, leading to inefficient and lost application of helicopter capabilities.« (Lambert and Juras 1992).

## 2. Helipace

Helipace, **Heli**copter Logging **P**roduction **a**nd **C**ost **E**stimation, is a computer program that was developed to implement the production and cost estimation process used by helicopter logging experts. The model emulates helicopter loggers' methods of evaluating proposed operations for individual harvest units. »Although there have been several studies of helicopter logging operations by university, government, and industry researchers, much of this research has not been utilized, at least with respect to improving Forest Service cost estimating methods. Current methods usually predict a relatively narrow range of costs, often either too high or too low in the judgement of helicopter logging experts.« (Gonsior *et al.* 1992) This assessment of available methods provided an impetus to find a better tool. Helipace was developed through close cooperation between industry (the Helicopter Loggers Association through it's support of the Aerial Forest Management Foundation), a major forestland manager (USDA Forest Service Pacific Northwest Region) and the Pacific Northwest Forest and Range Research Station.

The Helipace model is based on nearly 30 years of experience by several helicopter logging companies. Commercial helicopter logging began in 1971 in the United States following experimental demonstrations beginning about 1960 (Binkley 1961, 1972). This experience is incorporated into the program algorithms, program data (design loads and costs), and the program help. »Helipace is unique in that it emulates the analysis process used by helicopter loggers in assessing proposed logging operations. It incorporates their experience and expertise to derive production and cost estimates which they would deduce themselves, given the same information« (Gonsior *et al.* 1992).

## 3. Model overview

Helipace is based on relatively simple, straightforward logic. It estimates a range of production rates and costs for falling, yarding, and loading timber with an aerial logging system. The aerial yarding subsystem, a helicopter and its crew, is the critical component of the system. Remaining system components (i.e., sawyers, riggers, loaders, etc.) are »tailored« by the Helipace user to match the yarding subsystem's performance.

The focus of analysis with Helipace is on the harvest unit and its associated landing. With an estimate of the total weight to be yarded from a unit to a landing, and an estimate of the average payload for the aerial yarding system, the required number of trips is estimated. The design load capacity of the aircraft depends on the elevation of the logging operation. However, expected average payload will often be less than the design capacity, depending on availability or abundance of logs and interference of residual standing trees. The Helipace user is provided guidance in estimating expected payloads ranges based on stand characteristics and cutting specifications.

Multiplying the estimated total number of required trips by the average time per cycle yields an estimate of the total yarding time for the unit. Part of cycle time is determined by the distance between the unit and landing, based on cruise speed. The remainder of cycle time entails accelerations and decelerations at the beginnings and ends of flight segments, vertical maneuvering to retrieve loads from the unit and to release them at the landing, and time spent by the pilot in searching for loads that are obscured by residual stand canopy. Flight distance is established by the unit and landing coordinates or directly by the Helipace user. Cruise speeds, acceleration and deceleration times, and basic hooking and unhooking times are incorporated in the model and need not concern the user. But the user must provide estimates of extra searching and maneuvering time, based on expectations about residual stand characteristics. Helipace help guides the user in making such estimates.

Dividing total required yarding time by the average available time for yarding in a workday yields the total number of workdays required to yard the unit. This enables expression of mean daily production rate in terms of conventional volume units, which guides estimation of the number of sawyers, loaders, and other support equipment and personnel needed to sustain it. Helipace provides help to the user in making these estimates.

With appropriate daily costs for each subsystem component, a total daily system cost is derived, which is then divided by the estimated daily production to get production cost for the unit. Normally a range of production costs is estimated by Helipace, reflecting ranges in expected average payloads as well as variations in daily system cost.

Finally, Helipace combines performance and cost estimates for individual units and produces a summary for the entire project. (Gonsior *et al.* 1992).

## 4. Design load

Through aeronautical engineering, we know the theoretical lift capacity of a helicopter. But what we really want to know is what is the best working load for a given situation and elevation. The best working load is the load that will put the most timber on a landing in a given day. Helipace predicts a design load for an aircraft at a given elevation.

The design load is the mean load expected at an elevation based on the experience of expert helicopter loggers. The variables of temperature, humidity, and barometric pressure are incorporated into this mean.

Helipace contains design load information for six helicopters, which have a design payload capacity range of 1600 kilograms to 10400 kilograms at sea level. The associated system cost data are updated using a specific cost collection methodology approximately every two years.

**Helipace Help Screen Example**

Design load is the load which, for the given aircraft and given elevation, results in optimum performance of the system (i.e., least production cost).

Design load is not the rated load capacity of the aircraft; it is an optimal load that is based on operators' experience.

Helipace determines the design load for each unit. For a given unit, the aircraft's design load is the average load that it can be expected to carry at the highest mean elevation that it will encounter in the yarding process. For uphill yarding, this is the landing elevation. For downhill yarding, this is the unit centroid elevation.

The Mean Target Load is the weight of logs (in pounds or kilograms) that is desirable for the aircraft to carry in each turn to achieve the best production rate. Helipace computes the mean target load from the design load for the aircraft and the remaining crown closure.

Mean target load decreases as remaining crown closure increases, because the residual crowns interfere with turn retrieval and less logs will be carried out in each turn.

When you assess wood availability, you are estimating probable turn weights with the mean target load as the absolute upper limit, but depending on conditions, not necessarily the upper limit you can expect to achieve.

## 5. Helipace Help

The help built into Helipace is a very important part of the program. To assist the user in taking the best advantage of the productivity model, the program includes help that guides the user in how to think about the proposed operation to develop reasonable input values and results. The user is encouraged to think in ranges of best to worst cases and to develop the situation recognition that experts use. The help content was written based on interviews with helicopter logging experts and logging systems experts.

The help contains 181 topics, approximately 30,000 words, 52 photographs, 20 charts/figures, indexed by 126 keywords, and a text search index.

The help function is available at all times to assist the program user in thinking through a harvesting situation. The example help screens on this page provide some insight to the process used in Helipace to the important variables of cycle time, payload, and wood weight per volume unit.

**An example of general help available**

When using Helipace to estimate logging costs, the user should keep in mind that maximizing payload will not give the best production rate or cost. Rather, it is the proper combination of payload and turn times that maximizes production. The user also needs to consider landing sizes and safety.

*Factors That Affect Turn Times*

Yarding distance • It's obvious that longer yarding distances require longer turn times.

Residual trees • This is a not so obvious, but very important factor for two reasons:

Search time: the more trees that are left on the stand, the harder it is for the pilot to find turns.

Vertical ascent: when there are residual trees, the pilot must maneuver in and out of the canopy, as opposed to an open area where he can swoop in and out.

Landings • Landing sizes, shapes, and approaches can all affect turn time. The use of multiple landings tends to increase turn times.

**An example of a help screen explaining terminology and concerns**

*Factors That Affect Payload*

Density altitude • Elevation and temperature affect helicopter lift capacity. When elevations are entered in Helipace, the program adjusts the design load to one that gives the best performance for that elevation. Since it's not possible to know what the temperatures will be when a sale is logged, the design load in Helipace has temperature considerations factored in.

Residual trees • Residual trees can interfere with hooking and lifting turns, especially multiple log turns. The interference results in lower turn payloads. For example, imagine needing 6 logs to make up a full turn, and that there are 30 logs on an acre with 200 standing trees. In order to lift the turn out of the residual, fewer logs will be carried.

Log availability • This is the hardest estimate to make. It answers the question »will there be enough weight in the logs available for a turn to make up a full turn?« The Helipace help topics contain guidelines and examples for assistance in making this estimate.

Weight / payunit • How much weight has to be moved to produce products (payunits) greatly affects the cost of an operation. If most of the weight yarded is lumber or veneer logs, the cost per payunit will be less. If the weight yarded includes a large amount of additional fiber, the cost per payunit will be higher.

*Safety*

Limbs are the biggest safety issue in helicopter logging. Snags can be unsafe, but they can be seen and avoided. Limbs that may fall when turns are lifted through the canopy cannot be seen until it is too late to avoid them. There is a very simple safety rule about limbs to use…

## 6. Program structure

The Helipace analysis is presented in a familiar spreadsheet-like interface. The focus of the analysis is an individual harvest unit. Planners may analyze alternative layouts for each harvest unit to meet harvest cost or value objectives. Each alternative analysis consists of a harvest unit, log landing, selected aircraft, and a cutting specification. Planners may consider different methods of achieving objectives and easily analyze the costs of these different alternatives. Harvest unit information may be accumulated to provide a planning area summary, including costs that are not harvest unit specific, such as landing construction costs and mobilization costs.

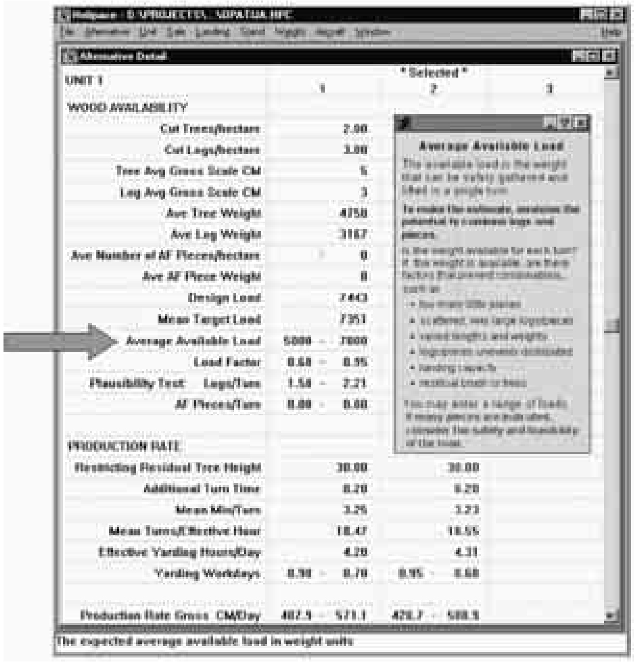


**Figure 1** This graphic is an example of the Helipace interface with the automatic help screen that may be made available to the user at each row in the spreadsheet

## 7. Program implementation

Helipace operates on the common Windows computers. Current users include forest management agencies, private consultants, and forest industry companies. USDA Forest Service uses Helipace as the official appraisal tool for helicopter harvested timber sales.

The majority of the users are in the western United States but the technique used in Helipace should be applicable in any helicopter harvesting environment. Heinimann and Caminada (1996) found, where comparisons were possible, that Helipace results compared very well with detailed work-study results in Switzerland.

The program has been freely distributed within federal forest management agencies, especially USDA Forest Service and Bureau of Land Management. Copies are available from the Aerial Forest Management Foundation for a nominal fee.

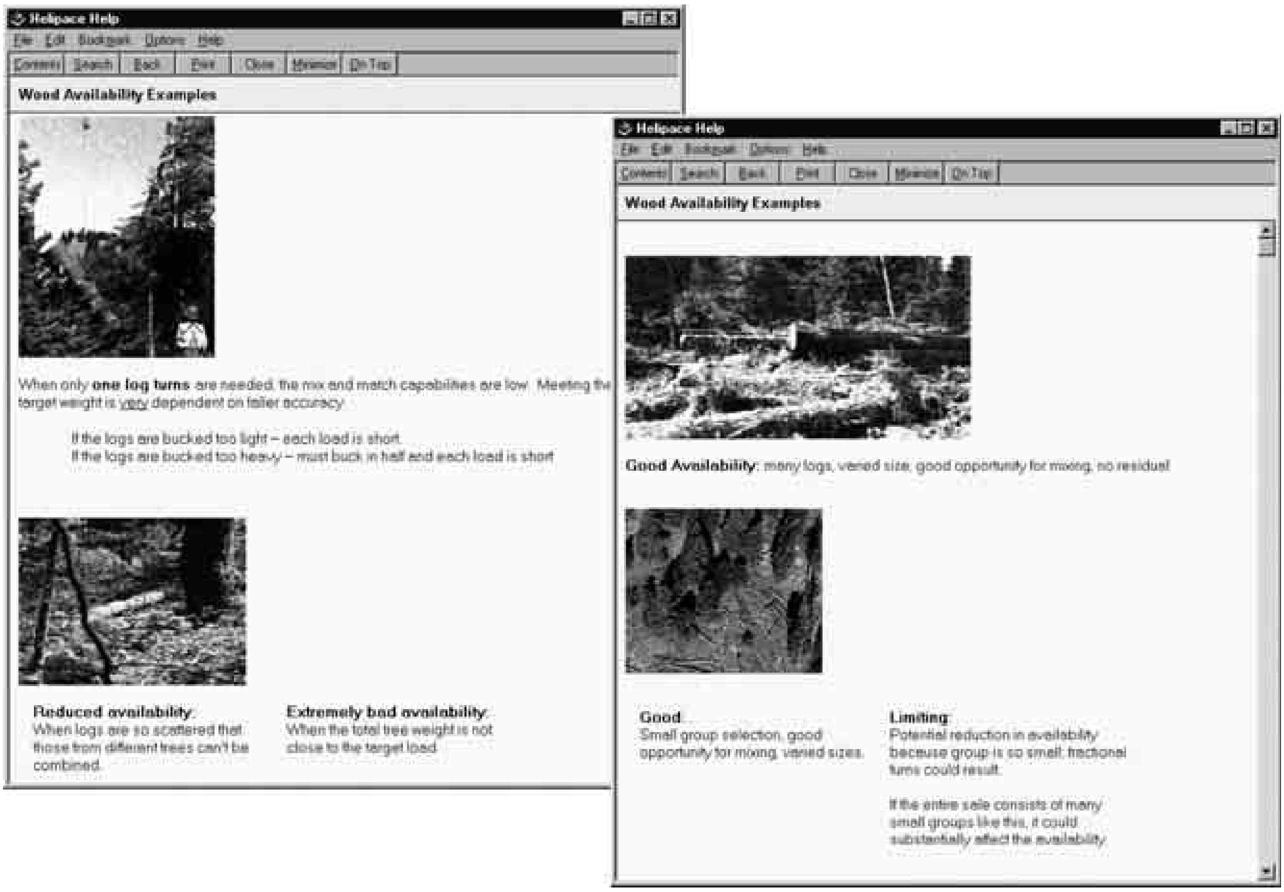


**Figure 2** Helipace structure encourages the user to take advantage of helicopter logger expertise through text, graphics, and photographs

## 8. Future development

Helipace will be revised during the next year to address several desired additions:

- More helicopters
- Additional and updated help items
- Updated cost and production data
- Use of grapple in addition to the standard hook system
- Improved use of metric measurements
- Address user questions
- Broaden applicability to more forest environments and geographic areas
- Update to Windows 95/98/NT/2000 operating systems

The development cooperators of this Helipace update, USDA Forest Service (USFS), Aerial Forest Management Foundation (AFMF), and Food and Agriculture Organization (FAO, Rome), welcome cooperation of any organization with an interest in improving helicopter harvesting operations and planning. Please contact one of the paper authors for more information.

## 9. References

Binkley, V. W., 1961: Vertical Logging with Helicopters. Master of Forestry Thesis, University of Washington, Seattle, WA, 45 pp.

Binkley, V. W., 1972: Helicopter Logging with the S64E Skycrane: report of sale. USDA-Forest Service, Pacific Northwest Region, Portland, OR, 23 pp.

Gonsior, M., Juras A., Martin S., Neal J., and Nearhood D., 1992: Helipace: A Production and Cost Estimating Tool. *In Proceedings of the 1992 Mountain Logging and Pacific Northwest Skyline Symposium* (ed. J. Sessions), 10 pp.

Heinemann H. R. and Caminada L., 1996: Helicopter Logging in Switzerland, Analysis of Selective Logging Operations. *In Proceedings of IUFRO 3.06 Forest Operations under Mountainous Conditions and the 9th Pacific Northwest Skyline Symposium*, (ed. I. B. Hedin), FERIC SR 116, 6 pp.

Lambert M. B and Juras A., 1992: Computer Supported Planning for Helicopter Logging. *In Proceedings of Computer Supported Planning of Roads and Harvesting Workshop*, Feldafing, Germany (ed. J. Sessions), 12 pp.

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# Helicopter logging

**Valéria Messingerová, Tibor Lukáč**

***Abstract***

*The paper presents the results of the analysis of helicopter logging issues, as well as the results of my own research elaborated on the basis of the practical use of a given technology in the selected localities under conditions of forest management in Slovakia. The paper includes the assessment and possibilities of rationalization of technological method, as well as the indices of helicopter efficiency in yarding felled timber (on the basis of measurements in Belianske Tatry) and timber in purposeful main felling (protected landscape region Polana). In the region of Belianske Tatry 612 m$^3$ of timber was yarded by use of MI-8 helicopter. The yarding distance was 700 m with the average time consumption of 6.46 min. per working cycle, the average load volume of 2.78 m$^3$ and the efficiency of 135.25 m$^3$ in a shift made of 50 turns. At the same time the assessment of the outside noise on the forest area network was carried out and the map of noise spreading was drawn. The maximum noise measured under the helicopter was 100 dB, while it was 85–88 dB at the distance of 50–60 m. 1,061 m$^3$ of timber from main felling was yarded by means of helicopter in PLR Polana. The average cycle time was 4.8 min at the yarding distance of 800 m. Daily volume of yarded timber was 178 m$^3$ and the average load volume was 2.4 m$^3$. The contracting price for timber yarding was SKK 1000 per 1 m$^3$ of softwood and SKK 1300 per 1 m$^3$ of hardwood. Such economically demanding technology is applied in specific conditions of mountain regions.*

***Key words:*** *helicopter, logging*

## 1. Introduction and issues

At present serious emphasis is placed on ecological characteristics of forest ecosystems such as biodiversity, forest health-state and sustainable forest functions. Various natural conditions such as terrain, soil condition, accessibility, fragmentation of stands intended for logging can arise interest in non--traditional transportation methods. In the countries with developed economy and ecology timber logging by helicopters, particularly in mountainous areas, has been increasingly used and it is becoming a current operational technology rather than an extraordinary measure (Messingerová 1994).

The results of the analysis aimed at helicopter logging abroad as well as our own experiences and research show that the interest in this transportation method has been growing. The technology of helicopter logging has been used in many European countries with developed forestry such as Switzerland, Austria, Russia, Norway, Germany and France. In Canada and the USA the share of this technology in the total volume of timber yarding is even more significant. In this paper the authors deal with technical parameters of various types of helicopters, performance characteristics, economic efficiency as well as the impact of the technology on the environment. Emphasis is placed on the selection of stands and preparation of terrain plan. High professional level of helicopter pilot and other operators is an important precondition, as this technology is demanding in view of labor safety (Sperisen 1990). The Swiss Helicopter Company – AG Heliswies, has been dealing with timber yarding for more than 10 years. To reach the performance of 20 flights per 1 hour a well-skilled team of forest workers and good organization of work is necessary (Mayer 1981). Koval, I.P., Solncev, G.K. (1992) review the application of various logging methods in the forests of Northern Caucasus where helicopter is used for yarding. They compare the damage to the environment caused by various technologies of timber yarding. In the USA and Canada helicopter technology with the helicopter load capacity of 2.5–10 tons has been used. Timber is yarded to the distance of about 1500 m with

**Figure 1** Helicopter MI-8 in operation above the yarding site

120–150 turns (cycles) per one shift. Mean performance per shift is 200–470 $m^3$ of timber.

In the forestry of Slovakia MI-8 helicopter with the load capacity of 3 t (Figure 1) has been used for timber yarding. Working procedures and technical equipment are derived from the experience with load transportation in industry. Specialized private companies are engaged for the work. Mean daily performance ranges between 200 and 250 $m^3$, mean time consumption per 1 $m^3$ of timber is about 10% of the time necessary for other timber yarding technologies.

## 2. Methods

The research of the technology was carried out in several localities in the period 1992–1999. Time measurements of particular working operations and performance per shift were carried out. Economic analysis was made with the aim to assess the performance. Measurement methodology was based on traditional methods of work assessment.

Simultaneously external noise was measured at the working site as well as in the surroundings, namely in the forest area network to the distance of 2 km. The measurements were processed into noise maps. The survey of the results from the locality in the High Tatras (Správa TANAP, LS Javorina) conducted in June 1999 is given in the paper. The model of noise transmission in a particular locality was derived from the measured values.

## 3. Results

High performance technology requires high quality technological preparation of the working site. Short time consumption per working cycle requires perfect work organization and the observance of safety at work rules applicable for aerial operations.

The requirements are as follows:

- preparation of the working site,
- preparation of sufficient amount and suitable location of log yards,
- fulfillment of technical requirements for helicopter operation.

Technological procedure should be adapted to terrain conditions, particularly to the type of logging. Whole-trees, whole-stems or assortments can be yarded by helicopter.

The operations carried out in the stand aimed at providing timber from salvage felling are namely delimbing and separating of stem from root collar. Salvage felling proceeds from the lower part of the slope and preparatory works must be performed prior to timber yarding. If the volume of stems is not high bucking of stems must be performed on the stand and suitable conditions must be provided for safe tying of stems and helicopter flight. If the timber to be logged is dispersed in the stand, the helicopter can also easily lift the stems from a particular place.

Technological procedure of helicopter yarding of trees in the stand (intentional regeneration felling) can affect considerably the efficiency and safety of this technology. By securing directional felling, optimum load weight for the helicopter can be provided in accordance with its load capacity. At the same time the risks of work safety can be minimized. In contrast to processing timber from salvage felling, other yarding and skidding equipment is mostly not necessary. Larger stems must be shortened to comply with the helicopter limiting load values. The length of logs depends on the species, volume weight of tree species, timber moisture and kind of assortment.

The performance of helicopter technology in timber yarding is considerably affected by the quality and readiness of preparatory operations in the stand. Preparation for helicopter yarding already during logging can affect time consumption necessary for tying the load and thus also the duration of the whole working cycle. Time consumption for respective operations of the working cycle is given in Figure 2, 3 and Table 1.

The helicopter crew consists of three operators (2 pilots and 1 navigator). The load is prepared, tied and untied in the log yard (unless the load is untied automatically) by other operators specially trained for the operation of load hanging below the helicopter.

Timber should be yarded outside the residential areas and industrial areas so as not to put at risk people, buildings or any equipment by load untied by accident. The working site must be protected against the presence of unwanted people. Timber yarding by helicopter must comply with applicable rules for aerial transportation and it cannot be performed in fog and strong wind. The slope and configuration of terrain as well as rain do not interfere with helicopter operation but make the work of the operators on the ground more difficult.

**Table 1** Mean time consumption per respective phases of working cycle in timber yarding by helicopter in protected landscape area Polana for mean yarding distance 800 m

| No | Working operation | Time consumption (min) |
|---|---|---|
| 1. | Flight without load into stand | 1.16 |
| 2. | Flying down into stand | 0.29 |
| 3. | Load tying | 0.62 |
| 4. | Lifting of load in stand | 0.38 |
| 5. | Flight with load | 1.61 |
| 6. | Flying down into log yard | 0.33 |
| 7. | Load untying | 0.29 |
| 8. | Load lifting | 0.18 |
| | Duration of working cycle | 4.83 |
| Number of flights per 1 day | | 72 |
| Time consumption per fuelling | | 11.23 |
| Time consumption per daily maintenance of helicopter | | 45.20 |

**Table 2** Indicators of performance in timber yarding by helicopter

| Performance indicator | Mean value |
|---|---|
| Daily volume of yarded timber ($m^3$) | 178.08 |
| Number of stems in one load (pcs) | 1.61 |
| Volume of one load ($m^3$) | 2.10 |
| Volume of one yarded stem ($m^3$) | 1.38 |
| Time consumption per 1 $m^3$ of timber (min) | 2.48 |

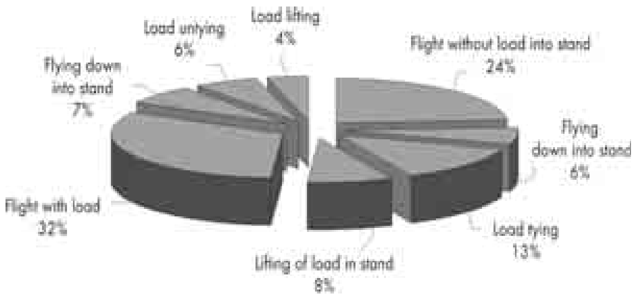


**Figure 2** Structure of helicopter time consumption in timber yarding

The performance of helicopter depends on the time of the turn, size of load per one cycle and forced idle time. The duration of working cycle depends on the performance of workers tying the load, on their ability to determine the load weight, to tie stems quickly and to prevent repeated untying in case of overload. Each helicopter is equipped with a device for measuring the weight of load by dynamometer. This equipment is used for checking the proper load weight.

Load untying can be done manually, mechanically or automatically. The size of load depends especially on the helicopter load capacity, season and daytime depending on temperature conditions. With lower temperatures lifting capacity is higher. It is better if the load consists of smaller number of stems because a shorter time is necessary for tying. Furthermore, tying is safer and the chances of accidental untying are smaller.

The load is tied to the helicopter either to the winch rope or more frequently to the fixed rope of the helicopter because lifting of load by winch is

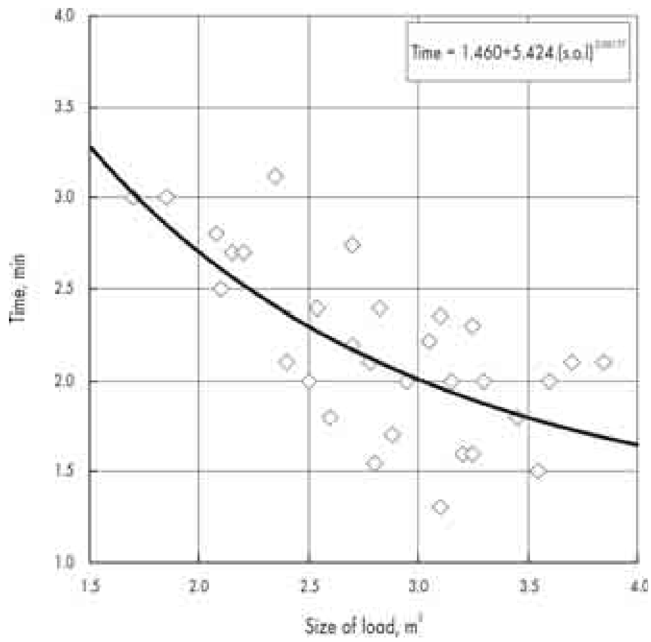


**Figure 3** Total time consumption per 1 $m^3$ depending on the size of load

slower than by fixed rope. Moreover winch decreases the useful helicopter weight. Fixed rope is long 30–50 m.

It is possible to perform timber yarding from any place. It is better if the timber is placed on a more open area, for example on the border of the stand but the load in the stand can also be lifted by helicopter moving above the stand.

From technological viewpoint the most demanding operation is tying of the load in the stand. This operation must be performed as quickly and safely as possible. Particularly during processing the timber from salvage felling the conditions for tying are demanding and difficult. It is, therefore, recommended to prepare at least two working sites on a particular plot (with 2 operators tying the load in each working site). It creates time reserve for the preparation of the following loads. The co-ordination of the whole team is implemented with the help of transmitters. Forest workers must wear ear protectors and safety helmets. Upon tying the load into the choker, forest workers must move away quickly to the safe distance as the velocity of air circulation below the helicopter is 220 km $h^{-1}$. It is also a good precaution against accidental untying of the load.

Selection of sufficient log yards and localization of log yards play an important role in the technological preparation of the working site. The location of log yard must provide the conditions for putting down the load without any time or spatial restriction. The size of log yard depends on the amount of timber and the requirements on timber sorting, for example by tree species or assortments. Though time consumption per working cycle is low with the yarding distance of 700–800 m it enables partial skidding up of stems by tractors in the yard.

From the viewpoint of technical safety it is necessary to choose a safe place for the fuel tank, which must be also suitable for fuelling.

## 4. Impact of helicopter noise on forest environment

The advantages of helicopter logging in eliminating the damage to forest environment are beyond dispute. Forest soil is not disturbed and conditions for precipitation erosion are not created. However, helicopter noise affects adversely the environment.

Noise measurements were carried out by means of Bruel and Kjaer equipment with A weight filter. Noise was measured on the ground at the working site and in the surroundings according to the procedure specified by respective hygienic standard. The helicopter noise was assessed as its effect on workers

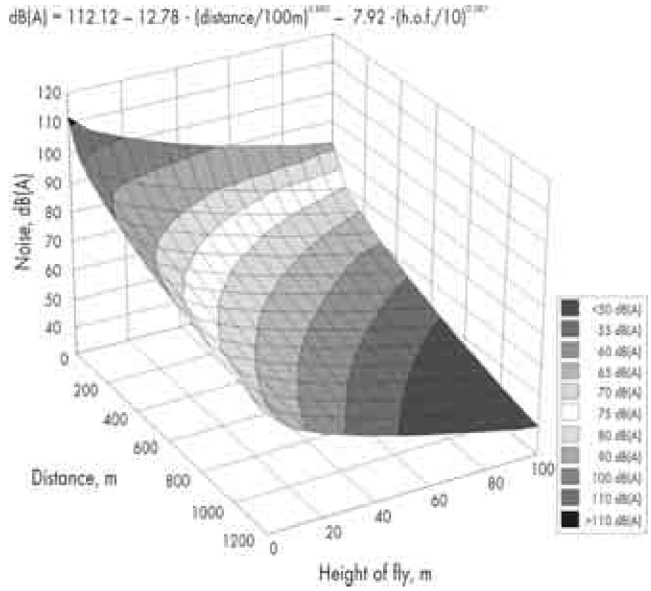


**Figure 4** Model of the intensity of helicopter noise in dB(A)

(noise at the working site) and on others (noise outside the working site). In the first case the limiting value of the noise is $L_p$ = 80 dB(A) with the correction of the basic level – 5 dB because we can consider the work of workers tying the load strenuous and demanding on the accuracy and concentration. In second case we can use the value 55 dB(A) as the highest permitted level of noise for aerial operation (Konrád and Messingerová 1993). If the helicopter is hanging over the working place (the length of rope is 50 m) the noise in that place is 93–100 dB(A). Permitted level of 80 dB(A) was found at the distance of 100–250 m depending on terrain configuration. The distribution of noise in greatly broken terrain with noise shadows (after the ridge, in dense stand) shows different distribution than in the open area. Therefore in this area the workers must wear ear protectors. The value of noise in the surroundings, in slightly broken terrain, shows that the limiting values of noise were found at the distance of 1.0–1.5 km.

Last measurements of noise were conducted in the High Tatras in June 1999. The model of noise level was derived from the results depending on the helicopter distance and height (Figure 4). Figure 5 illustrates the noise intensity in the given locality.

The helicopter technology achieves 8–10 times higher performance than tractor technology and 20 times higher performance than cableway. Consequently, the noise during helicopter operation affects forest environment for a substantially shorter period of time. This fact is important particularly in protected areas. Furthermore, the noise was measured under the most unfavorable conditions. During the

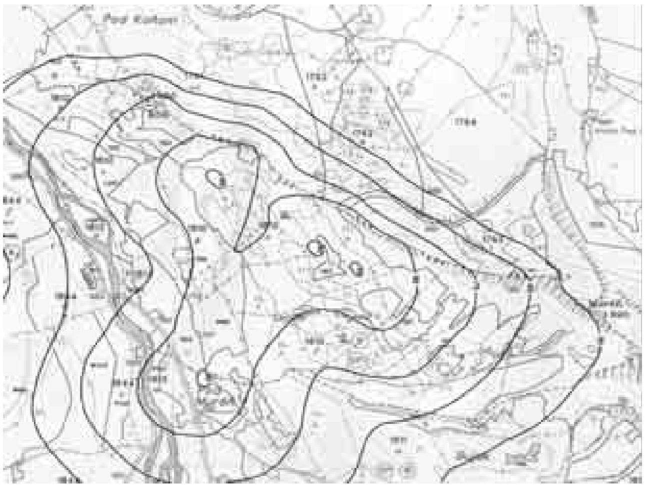

**Figure 5** Map of isolines of helicopter noise intensity in dB(A)

helicopter flight the level of noise on the ground is substantially lower.

Analysis of time consumption for respective operations was carried out. Periods of the impact of direct noise on the workers on the ground were processed. Noisy and silent intervals were calculated for the workers operating on the ground. The results presented in Table 3 show that only during a short part of the working cycle the workers tying and untying the load are subjected to excessive noise.

Forest workers tying the load are subject to injurious effects of noise for about 97 minutes per shift and forest workers untying the load for about 43 minutes.

Another issue is the effect of excessive noise from the viewpoint of disturbing the fauna, especially in protected areas. In the selection of time period it is necessary to take into consideration the periods of birds nesting and game mating and to agree the term of helicopter yarding with the governmental authorities for environmental protection.

The results show that noise exceeds the limiting values but tractors used in timber yarding also exceed these limits. Exceeding these limits is less significant for helicopters. The change of exceeded levels is not so quick and excessive noise was only measured in areas close to the tractor. At the distance of 2 m from the tractor the noise is 90–95 dB(A) and at the distance of 20 m about 75 dB(A) (Konrád 1973).

**Table 3** Noisy and silent intervals during helicopter operation

| Working operations | % | Cycle | | Shift | |
|---|---|---|---|---|---|
| | | noise (min) | silence (min) | noise (min) | silence (min) |
| Helicopter operation | 100 | 5.92 | | 300.0 | |
| Above the site of tying | 32.2 | 19.1 | 4.01 | 96.6 | 203.4 |
| Above the site of untying | 14.4 | 0.85 | 5.07 | 43.2 | 256.8 |

## 5. Conclusion

As shown by the analysis of timber yarding abroad and by our own experience, helicopter technology is a high performance and environmentally friendly technology. It is advantageous because roads need not be constructed, timber is transported without damage to forest stands and timber yarding can be performed in the stands with difficult access or with no access. In such areas traditional ways of logging cannot be used and therefore production potential of such stands has been decreasing.

Helicopter technology ensures elimination of soil erosion, quick yarding of large volumes of timber processed from salvage felling and timber utilization without any quality reduction.

Under condition that good planning and work organization are provided and taking into consideration safety and noise impact on the environment it is possible to obtain good results in spite of the fact that compared to traditional technologies helicopter logging is the most risky one.

Despite high costs of helicopter technology, this technology is supposed to be very promising in stands where requirements on the preservation of environmental stability are dominant.

## 6. References

Keegan, C. E., Fiedler, C. E., Wichman, D. P., 1995: Costs associated with harvest activities for major harvest systems in Montana. Forest products journal, Vol. 45, No.7/8, p. 78–82

Konrád, V., 1973: Vplyv hluku a vibrácií na pracujúcich pri sústreďovaní dreva traktormi. Referát ku skúške z ašpirantského minima, Zvolen, 71 pp.

Konrád, V., Messingerová, V., 1993: Rozbor technológie, spotreby casu a hluku pri približovaní dreva vrtulníkom. AFF, TU Zvolen, p. 321–333.

Koval, I. P., Solncev, G.K., 1992: Rubky v lesach severnogo Kavkaza. Lesnoe Khozjaistvo. No 1, p. 13–14

Mayer, G., 1981: Rundholzfluge mittles Helicopter. Schweiz, Hollzztg. Holz Bois 94, no. 39, p. 2–4

Messingerová, V., 1994: Sústreďovanie dreva vrtulníkom. Vedecko-pedagogická aktualita c. 6, 50 pp.

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# Delay in introducing high technologies in wood production in Slovenia – reasons and possibilities for their elimination

**Edvard Rebula, Igor Potočnik**

***Abstract***

*New technologies in wood production from boreal coniferous forests were introduced in Slovenia with a certain delay. When introducing manual mechanised work phases (power saw, manual debarking and partly mechanised hauling, manual loading) the delay was 15 to 20 years. Full mechanisation (long assortments, central mechanised yards, mechanised hauling and loading-unloading of wood assortments) was introduced with a 10-year delay. Thus the central mechanised yard in Maribor was put into operation only in 1972. Up to the early '80s 50% of conifers roundwood was processed in central mechanised yards. High technologies (phase of automation in forestry) have not been introduced yet in Slovenia. The exceptions are some attempts (wood chipper in Postojna in 1987, processor in Celje in 1989, harvester in Ljubljana in 1996) where good results have been achieved. In this field the delay is 20 years and it still continues. There are several reasons for the delay:*

- *type and characteristics of our forests: mostly broadleaved, higher diameter trees, steep and rocky terrain, lower secondary accessibility;*
- *forest management: ban on clear cutting, mostly selective and multiple-aged forests, natural regeneration, tree management, multiple-purpose role of forests, emphases on environmental and social functions of forests, selection and hierarchy of management goals and activities for their implementation;*
- *economical: the price of wood, labour and productivity;*
- *environmental: impact of high technologies on soil and stands;*
- *social: situation and organisation of forestry, living standard, transition.*

*Although the attempts of introducing high technologies gave positive results and showed that their implementation in appropriate stands and terrain conditions is competent and rational, we can not expect their fast and broad application. Besides the characteristics and functions of our forests, the reasons for their unsatisfying use also lie in low living standard (high share of unemployment, cheap and poorly organised labour force), small-scaled forest property, uncertain situation and position of forest enterprises in state forests, lack of investments and development of high technologies, etc. We estimate that 10 harvesters and processors would be enough to provide sustainable, economical and environmentally sound forest operations in Slovenia.*

***Key words:*** *high technologies, wood production, Slovenia*

## 1. What is high technology and reasons for its introducing?

High technology in wood production is work with modern machines for timber felling and wood processing (harvesters), machines for branching, bucking and transverse cutting (processors), wood chipping for boards and cellulose in forest and wood hauling with appropriate vehicles (forwarders). Some working procedures based on such technologies are automated and therefore some authors (Krivec) recognised them as phases of partly automated forest harvesting.

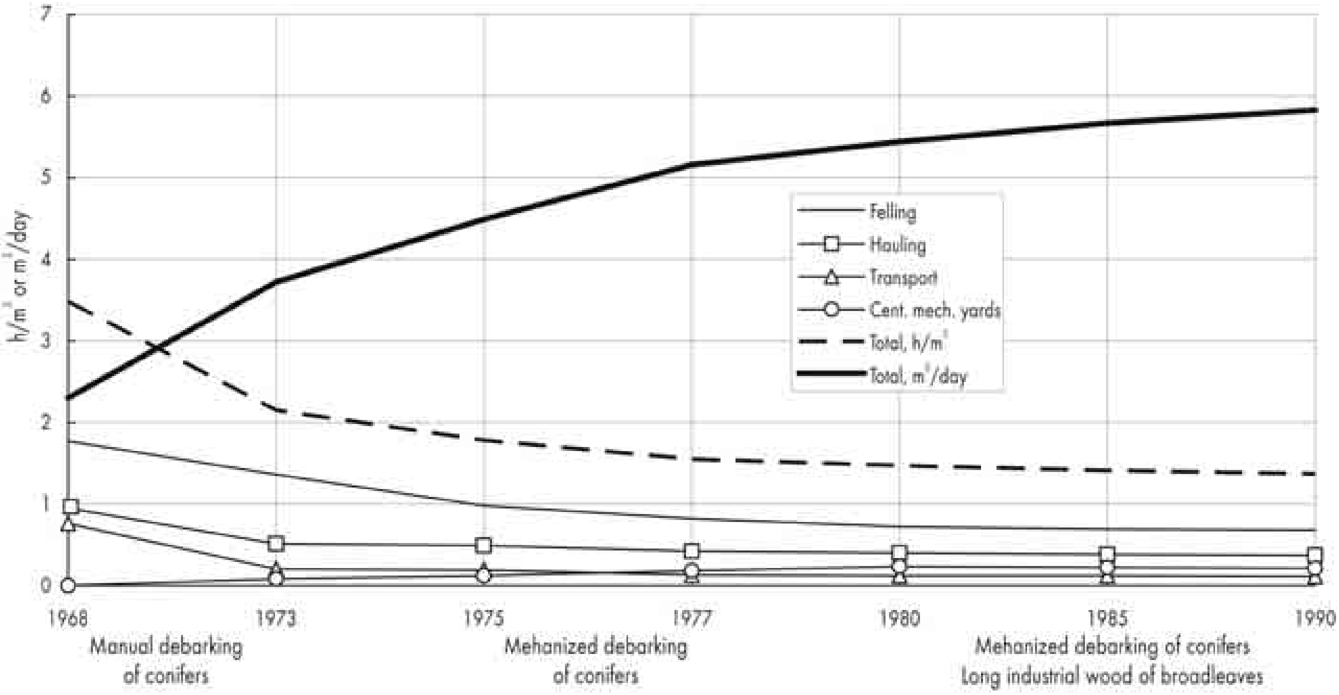


**Figure 1** Productivity of forest workers (h/m$^3$) – Forest Enterprise Postojna

New technologies are introduced for economical reasons. When work productivity increases the increase of work costs follows and then new technologies are introduced so as to provide economical work. The situation is present everywhere and Samset (1977) expressed it in the law of discontinued evolution in forestry. The situation in Slovenia regarding that law is shown in Figure 1.

The difference of forest workers productivity in a working day is shown in view of implementation of modern technologies. The productivity kept increasing up to 1980. After 1980 the technology has not changed. Due to smaller rationalisations the productivity still increases and it is close to 6 m$^3$/day. Acrording to out estimation the increasing trend of productivity will stop soon and forest work will become too expensive – we are already facing this problem with thin wood. The costs of harvesting wood of less than 30 cm in diameter is not economical any more (Rebula 1998). If we take into account investments in forests the economical level is between 35 and 40 cm. Therefore, only trees with higher diameter ensure economical harvesting. The last results show (Rednak 1999 b) that forestry in state forests is not economical any more. This should be an impulse for changes of technology.

The next reason is ergonomics. All workers engaged in harvesting are over-loaded with noise and vibrations. Lumbermen are exposed to especially high vibrations. They work on branching with power saws up to 70% of productive time. High technology is appropriate for thin wood and problems of ergonomics and economy could be solved.

Figure 1 shows that full mechanisation of forest harvesting was reached 20 years ago. At that time some high technologies were introduced in some countries. So we are 20 years late and our delay is increasing.

## 2. Reasons for delay

There are several reasons for not having introduced high technologies in Slovenia yet. Some of them are caused by natural conditions and characteristics of our forests. The problems are steep, rocky terrain and trees with higher diameter. It is certain that under the said conditions high technology will not be applied; mostly because of lower economical effects. But such difficult terrain is quite rare. It is less complicated to carry out timber processing than skidding on forest roads.

Other reasons arise from our relationship toward our forests, management goals, social relations, position of forestry, living standard, organisation of workers, etc. These reasons could be changed in time; they could become even more important or disappear completely. We believe that such reasons are the main obstacle for introducing high technologies in Slovenian forests.

The type of forest management is crucial. Environmentally sound management is an obligation provided by low. Clear cuttings are not allowed. The regeneration is mostly natural. We aim at diversity from any point of view (number of trees, age diversity, dimension diversity – selective or multiple-aged forests). We manage each tree. Silvicultural goal is the forest with higher diameter trees. Forest management is multi-purpose, not exclusively focused on productive and economic role of forest. Even in the Forest Act the productive function is always the last one. All forest activities should be oriented to nursery. The highest attention should be paid to trees left in the stand after felling. Therefore, the goals of management, forest activities and technologies depend on such approach. Also the environmental criteria for evaluating damages caused by harvesting are very high.

All the above mentioned was accepted by foresters. However the problem arises when such management has to ensure profit, expected even by the state for state-owned forests (Rednak 1999a, 1999b). Only forest owners take into consideration the economic aspect of their work.

High technologies in forestry are among the capital, intensive branches of economy. They are very expensive. They are profitable if high daily work productivity, annual productivity and amortisation are ensured. High technologies are applied in the following areas: clear cutting economy, large areas of even-aged forests, even-diameter and thin forests, high intensity of thinning.

The main reason for not having introduced high technologies yet is economical. The problem of the actual technologies is not in the efficiency but in the obstacles caused by extremely emphasised ecological and social functions of forests as shown in Figure 2.

Figure 2 comes from the harvester work-study (Timberjack FMG 1270 in 1996 in forest district Ravnik) written by Marušič (1998). There are added hypothetical costs in cases where 1.5 and 2 trees would be processed from the same standing. We estimated that the processing time (the main productive time) for 1 tree and for moving it from the first to the second standing is the same as in the study. The study covered the problem of harvesting young planted spruce stand (growing stock 100–130 $m^3$/ha) affected by snow-break. There were 804 trees cut per 1 hectare or 93.2 $m^3$ (70 % of all trees). Of course the intensity of felling was extremely high – it was up to 3.4 times higher than normally in similar stands.

Figure 2 shows that:

- under these conditions harvester operations were less expensive (we assume at least 500 hours of operational hours per year). If 1400 operational hours per year are reached, the machine work is 40 % less expensive than the manual one.
- during the working day when from one standing 3.6 trees were processed the costs were 25%

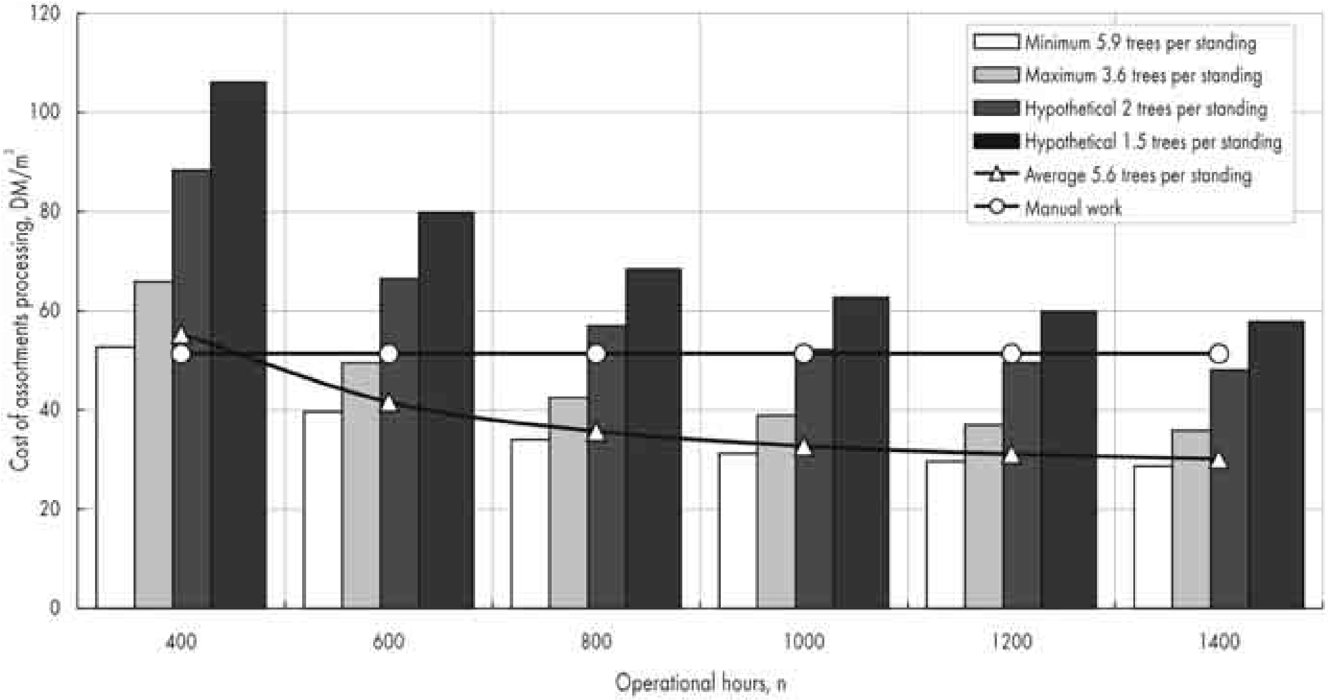


**Figure 2** Cost of assortments processing (DEM/$m^3$) with harvester Timberjack FMG 1270 in relation to number of trees processed from one standing and number of annual working hours – average tree 0.088 $m^3$

higher than in the case when from one standing 5.9 trees were processed. In the first case 1.20 min. was needed to process one tree (with 47 % of auxiliary productive time). In the second case the same share was 28 % and 0.94 min. was needed to process one tree.

- when processing less than 2 trees from the same machine standing manual work is more economical.

However, the investigated harvester is not the best suitable for thin trees and less heavy machines would be more effective. Despite it all, the relations expressed in Figure 2 show the impact of silviculture on high technology implementation. According to our estimate if harvesters used only skidding roads, with the usual intensity of felling (for Slovenia), there would be less than 2 trees processed from the same standing and more time for processing would be necessary. Therefore such technology is too expensive even in the case of 1400 of operational hours per year, which is hard to expect. Considering our organisation and working habits only 1000 operational hours per 1 year can be expected.

The next reason for the delay is the price of implementing high technologies (expensive compared to manual work), problems with repairs and spare parts. Some of the other reasons are lower living standard, cheap labour power, high share of unemployment, fear of losing jobs, etc. Wages decrease relatively slowly and nowadays they are at the level of the early '80s (see Figure 3). Wages of forest workers represent only 30–35% of wages of forest workers using high technologies.

Other reasons for the delay are also changes (political and economical) in the new country after 1991. Here are the questions of organisation of forestry, uncertainty concerning forest enterprises, denationalisation and liberalisation of forestry. The amount of state forests was reduced due to the process of denationalisation where forest enterprises perform harvesting operations. On the other hand mainly smaller owners will be given 150–180,000 ha of forests (50–60 % of former state forests). Also the amount of felling decreases. There are still some problems (political) about concession in state forests. Due to all these facts the amount of felling per forest enterprise was reduced by 50 % (45,000 $m^3$). Therefore forest enterprises are not highly motivated for introducing (expensive) high technologies, as their economy is uncertain. To achieve economical work each harvester should process at least 14–17,000 $m^3$ of assortments. Considering our working conditions and intensity of felling (thinning) there are 450–800 ha of forests appropriate for applying high technologies (in the stands or by the forest road – processors where whole trees should be transported to the forest road) – which is hard to reach. However high technologies will be introduced – sooner or later and the sooner the better. Some researches also prove (Tomanić 1998) that at the same place (state, society)

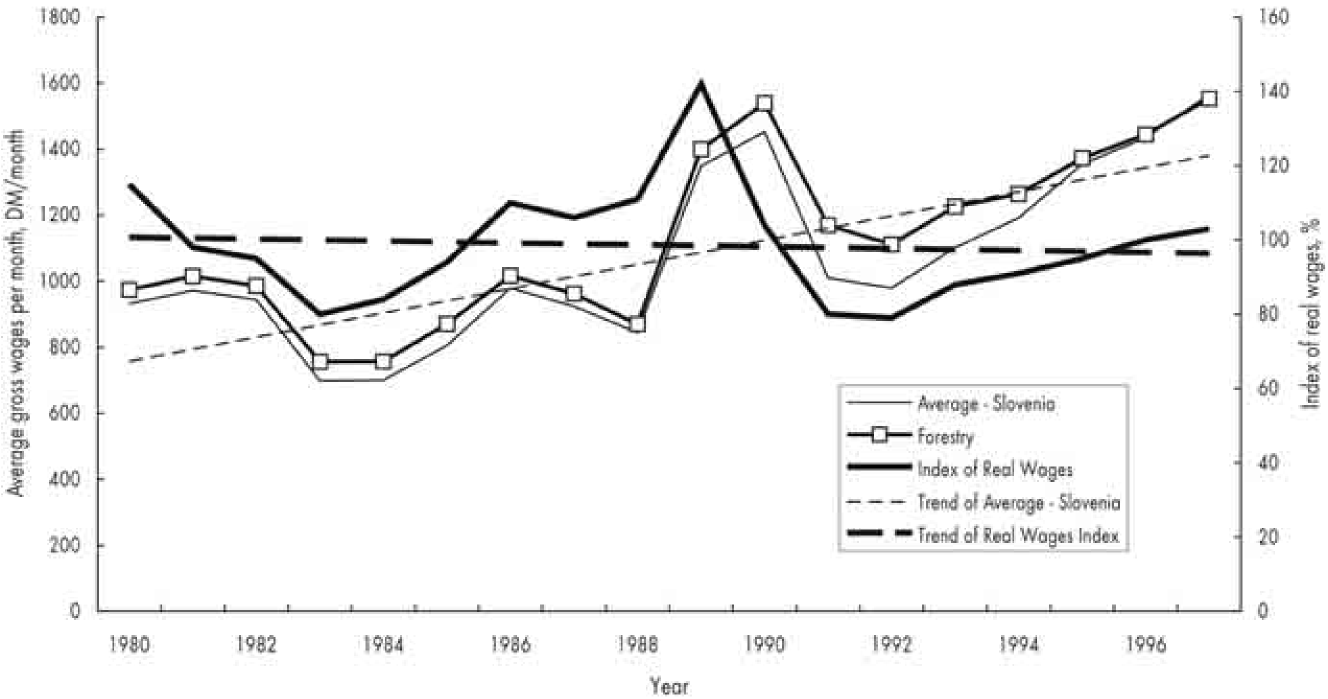


**Figure 3** Average gross wages per month (DEM/month) and indexes of real wages

and time all harvesting technologies are used, from those most simple to those highly developed.

There are also some signs showing better prospective of introducing high technologies; the most important were given by silvicultural experts. It is recognised (Diaci 1996) that silvicultural goals from the past are not in contradiction with the results of modern forestry. Even though forest nursery is not focused only on wood quantity and quality, the productive function of the forest is still the most important function in highly industrialised European countries.

As every investment should be economically effective the forest nursery should also meet the same goal. The fact is that incomes from wood selling cannot cover the expenses of nursery and prove social and ecological functions. So some extra funds (public) should be ensured and rationalisation of nursery should be implemented (Diaci 1999, Ott 1998). At this point we have to decide whether to insist on the actual nursery concepts and its expenses or to adopt the new concept and introduce high technologies due to economical reasons. Of course these goals must be achieved within the framework of ecological acceptability and economical effectiveness.

The experience on implementation of high technologies in neighbouring countries is positive. About 800 harvesters and 2000 forwarders operate in Germany. Their work is economical, especially in sanitation after calamities. Good results were established in Germany (Dummel 1999, Pausch 1999) in view of productivity, expenses and ecological acceptability of several harvesters – even of the heaviest among them. Beside the economic aspect, the ecological aspect is also acceptable. Between 1.5 and 2 million m$^3$ of wood in Austria is processed by 110 harvesters economically and environmentally acceptable – they invested DEM 55 million in high technologies. By using harvesters, stand thinning became economically positive (Becker 1995).

There are also some experiences in Slovenia. Years ago the processor was used along with the harvester (Figure 2). Processor was investigated in terms of felling and whole trees hauling (Rebula 1990a), productivity (Rebula 1990b) and economy (Rosenstein 1990). Processor was economically effective and ecologically acceptable. The economy of processor KP40 is shown in Figure 4.

We can conclude that the processor operation was economical, very much like that of the harvester (Figure 2). The economical effectiveness depends on an average tree volume and amount of work per year. The highest economical effect is achieved at the tree volume of 0.20 m$^3$/tree (diameter 20–25 cm).

Expenses of the work are increasing in Slovenia, too and some forest enterprises are not profitable any more. The same conclusion is implied by Figure 5 which shows the amount of working hours (average) covered by 1 m$^3$ of sold wood. The average

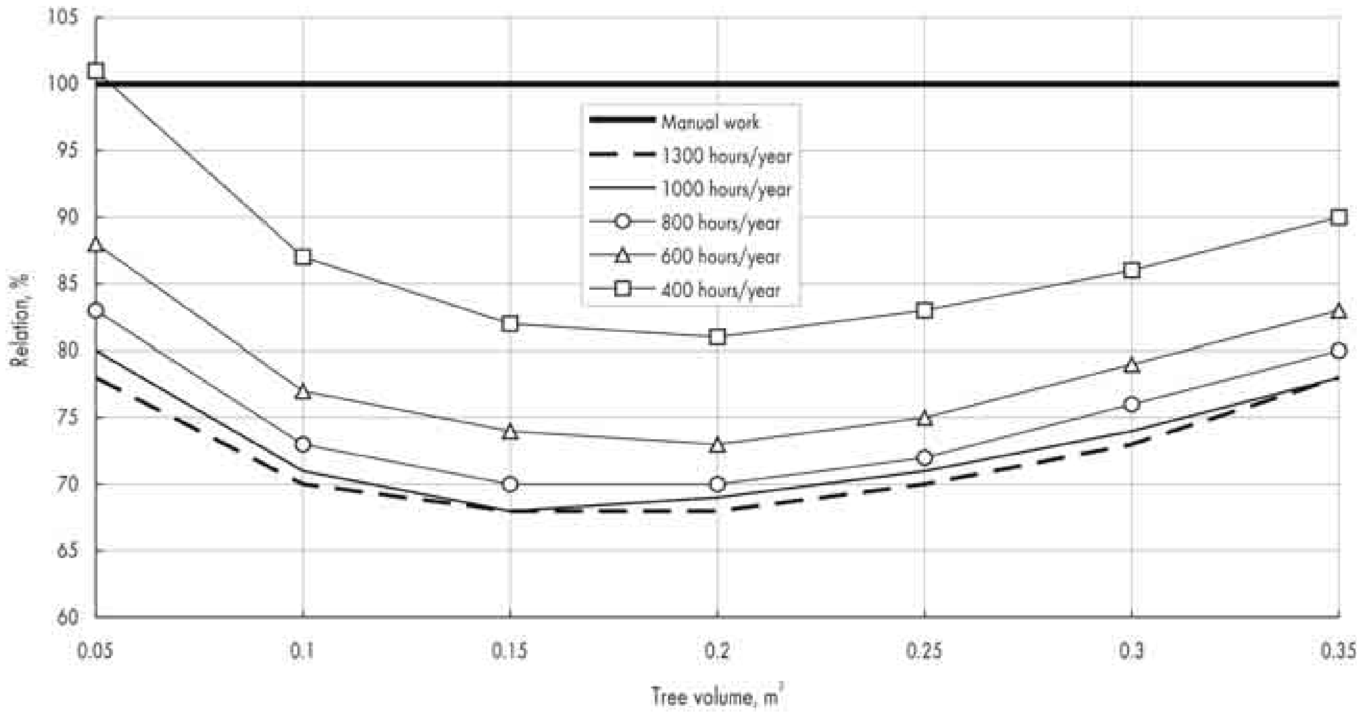


**Figure 4** Processor KP40 expenses compared with manual work (related to tree volume and operational hours/year)

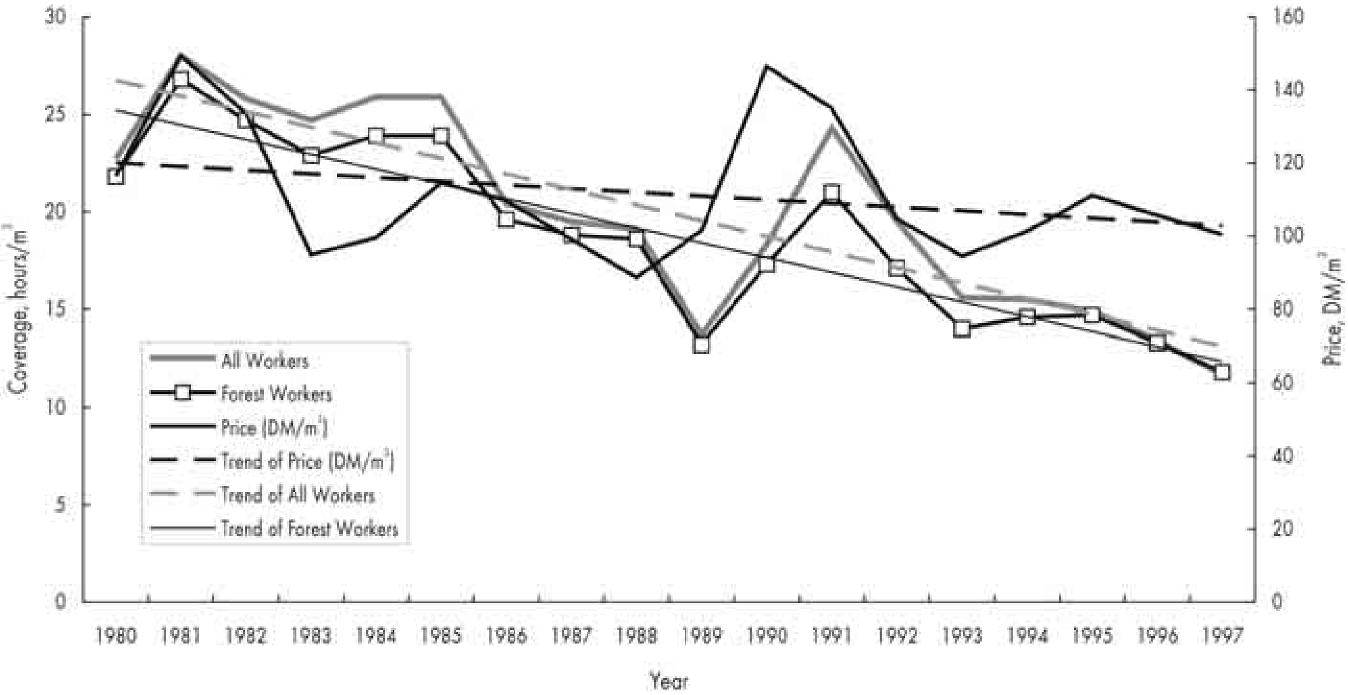


**Figure 5** Ratio of 1 m³ of solid wood (amount of working hours and the price of wooden assortments)

price of wooden assortments is also presented in Figure 5.

It can be concluded that nowadays only 70–80 % of the price is achieved compared with the early ž80s. The real value is still lower due to inflation impact. And what is more, nowadays with 1 $m^3$ of assortments we can buy only 50% of workers' hours compared with the situation we had 15 years ago. And this trend continues.

The last problem we want to point out is the issue of defining forest regions appropriate for high technologies from technical and ecological point of view. It has been estimated for Croatia that 54% of the annual cut can be harvested with the use of high technologies (Bojanin and Krpan 1997). We can establish that 80 % of forests are suitable for tractor skidding and most skidding roads are already built. The productive function is emphasised in 82 % of forests and only 6 % of forests have additional ecological or social function. Only in the period 1986–1988 5 200 ha of spruce stands were established and planted. It seems that 10 processors and harvesters could work economically – and even more so in case of ice- and snow-breaks.

## 3. Conclusion

High technology was not introduced in wood production in Slovenian state forests due to many reasons: type of forest management, inexpensive labour power and uncertain situation in forest enterprises. However, economical situation, decrease of wood process and increase of wages imply the necessity of introducing high technologies. Performed investigations come to the conclusion that high technologies are economically and ecologically acceptable. It is estimated that at least 10 high technology machines could work effectively under actual conditions in Slovenia.

## 4. References

Becker, G., 1995: Waldbau und Holzqulitet – Forst und Holz 50(18): 565–569.

Bojanin, S., Krpan, A.P.B., 1997: Mogućnost tzv. visokoga i potpunog mehaniziranja sječe i izrade te mehaniziranja privlačenja drva u šumama Hrvatske (Möglichkeit der Hoch- und Vollmechanisierung der Einschlagsarbeiten, und Mechanisierung des Holzrückens in Wäldern Kroatiens). Šumarski list 121(7–8): 135–150.

Diaci, J., 1996: Nega gozdov in kakovost v prihodnosti – Zbornik gozd. in lesarstva 51: 121–131.

Dummel, K., 1999: Mechanisierte Holzernte in Deutschland – Stand und Beurteilung. Sammelbuch 33. Internationales Symposium »Mechanisierung Der Waldarbeit« Forstliche Fakultät Zagreb, Kroatien, 1.–6. Juli 1999.

Duerrstein, H., 1999: Zukuenftige aufgaben der Forsttechnik in Oesterreih. Sammelbuch 33. Internationales Symposium »Mechanisierung Der Waldarbeit« Forstliche Fakultät Zagreb, Kroatien, 1.–6. Juli 1999.

Košir, B., Krč, J., 1994: Razmerja med funkcijami gozdov z vidika omejitev pri opravljanju gozdnih del, Zbornik gozd. in lesarstva 45: 115–189.

Martinić, I., 1993: Šumski rad na prekretnici – švedsko videnje razvoja. Mehanizacija šumarstva 18: 135–142.

Martinić, I., 1997: I u najvažnijim je europskim procesima šumarstvo na sporednom kolosjeku. Mehanizacija šumarstva 22: 125–128.

Marušič, J., 1998: Študij časa sečnje s strojem za sečnjo Timberjack FMG 1270 v gospodarski enoti Ravnik, Dipl. naloga, BF. Gozd. odd. Ljubljana.

Ott, E., 1998: O razvoju gojenja gorskih gozdov v švicarskih Alpah. Zbornik referatov »Gorski gozd« s. 65–80, BF. Gozd. oddelek, Ljubljana

Pausch, R., 1999. Versuchsergebnisse zu Produktivitaet und Pfleglichkeit hochmehanisierter Starkholzernte. Sammelbuch 33. Internationales Symposium »Mechanisierung Der Waldarbeit« Forstliche Fakultät Zagreb, Kroatien, 1.–6. Juli 1999.

Rebula, E., 1990a: Drevesna metoda sečnje in spravila in učinki pri delu. Zbornik gozd.in lesarstva, 36, s. 121–148, Ljubljana.

Rebula, E., 1990b: Istraživanje rada s procesorom KP 40. Mehanizacija šumarstva 15: 139–160.

Rebula, E., 1991a: Erozija na vlakah, Zbornik gozd. in lesarstva 37: 53–81.

Rebula, E., 1991b: Posljedice gradnje vlaka u šumi. Mehanizacija šumarstva 18: 3–10.

Rebula, E., 1998: Vpliv debeline in višine jelovega drevesa na njegovo vrednost in donosnost. Ovrednotenje zakona o kosovnem volumnu. Zbornik referatov »Gorski gozd« s. 191–205, BF. Gozd. oddelek, Ljubljana.

Rednak, A., 1999a: Gozd je lep, kako pa zanj skrbimo, Profit 22. 9. 1999. s. 6 –7 Ljubljana.

Rednak, A., 1999b. Gozdarska dejavnost lani poslovala s 160 milijononi tolarjev izgube.Vpliv ujm, stečajev kupcev in davkov, Profit 22. 9. 1999. s. 7 Ljubljana

Rosenstein, D., 1990: Gospodarnost strojnega obvejevanja drobnega drevja s procesorjem KP 40 v razmerah TOZD Vitanje (GG Celje), Dipl. d. BF. Gozd. odd. Ljubljana

Samset, I., 1977: Razvitak metoda i tehnike u šumarstvu, prevod predavanja, Zagreb

Sever, S., 1993: Stanje i mogući razvoj mehanizacije u hrvatskon šumarstvu. Mehanizacija šumarstva 18: 3–16.

Sever, S., 1993: Neke poruke s ELMIA WOOD 93. Mehanizacija šumarstva 18: 45–46.

Sever, S., 1993: Šumarsko inženjerstvo, Mehanizacija šumarstva 18: 105–106.

Tomanić, S., 1998: Razvoj metoda i sredstava u šumarstvu, Mehanizacija šumarstva 23: 25–29.

Anon., 1993: Statistični letopis R. Slovenije, Zavod za statistiko, Ljubljana

Anon, 1993: Zakon o gozdovih, UR. l. Republjike Slovenije 1993. št.30 s 1677 –1691

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# Strategies for utilization of forest biomass in the Republic of Croatia by 2030

**Julije Domac, Stjepan Risović, Stanislav Sever**

***Abstract***

*Strategy for the development of energy sector in the Republic of Croatia involves the period up to 2030, focusing its interest primarily on the increase of energy efficiency. Increase of efficiency of forest biomass utilization offers a direct, cost-effective and environmentally friendly option. The Republic of Croatia is ranked as the country with significant percentage of forests per capita with its 43.5 % of forestland and about 1/3 of the total state territory covered with forests. Total growing stock in Croatia amounts to 324,256 million m$^3$. This guarantees the possibility for a bigger share of forest biomass in total energy balance. In 1995, the share of forest biomass in total technical potential (39,059 PJ) amounted to 24,840 PJ or 63.59 %. Researches conducted so far indicate that further potential of biomass of forest origin, for the use of which certain requirements must be met, is 10,800 PJ or 98.13 %. It has been estimated that the share of forest biomass, as potential energy source in the Republic of Croatia, might reach 58 PJ by 2025, as a result of afforestation and regular activities in Croatian forests, stipulated by economic policies. In identifying the energy needs of the Republic of Croatia, forests, as potentially renewable source of biological matter, may be a continuous source of fuelwood – the primary energy. The strategy for the energy source development in the Republic of Croatia recognizes forest biomass as the most important renewable source of energy apart from large hydroelectric power stations. Recent researches conducted in the first half of 1999 confirm the above stated.*

*Increased energy production from forest biomass based on known and recognized ways of utilization and technologies, theoretical bases and experimental verifications, could in the long run contribute to: the increase of energy production from forest biomass; increase of energy efficiency and decrease of energy sources import. It could also provide regular supply; a significant decrease in the impact energy sector has on environment; new job opportunities and investments into the state welfare sector; development of legal bases and incentive measures for individual energy units and beyond.*

*Experience of the industrialized countries has shown that it is necessary to create one's own energy policy, responding to the demand for the development of a new economic system in energy sector. Still, experience of the industrialized countries in the utilization of forest biomass, even of the countries with a well designed energy policy, can only be used as assistance in our own search for the most favorable options.*

***Key words:*** *strategy, forest biomass, wood surplus, environmental protection, bioenergy power plant, energy efficiency*

## 1. Introduction

The application of high technology in the use of forests and communications opens new possibilities of acquiring and use of biomass for energy purposes. Changes in energy sector will not occur by themselves and great effort will be required to develop an organized system of energy management. In base of the experience of industrialized countries, the right balance must be established between the market and government incentives, technical-technological standpoints of energy management and social aspect of energy management. The strategy of acquiring and use of forest biomass based on sustainable development and environmental protection makes part of the draft Strategy of Energy Development in the Republic of Croatia and of the National Energy Program within PROHES Program. When analyzing this strategy, the following factors were taken into consideration: increase of energy efficiency, safe energy market supply, possibilities of joining the European pilot projects in the field of new technologies, adaptation to regional, European and global trends.

## 2. Experiences of other countries in utilization of biomass energy

In EU countries more than 1,700 PJ of energy was produced out of biomass, i.e. 59.5% of all renewable sources in 1995. It is estimated that by 2010 the production of biomass energy will have increased to 5,500 PJ, thus reaching the share of 73% (Table 1) in relation to other renewable sources.

The experiences of industrialized countries (Austria, Finland, Sweden, etc.) show that biomass from forestry and waste in wood processing plants, by implementation of high technologies, are highly ranked in the energy balance and economically well assessed. Thus, e.g. in Finland in 1994, the share of energy obtained from wood was 14% or approximately 4.3 Mt (Mt – megaton of the equivalent or equally valuable oil) with the intent to increase the share of biological origin fuel by 25% up to 2005. In Austria the share of biomass is approximately 14% in the production of primary energy while in Sweden in 1998 more than 18% of total energy consumption was provided from biomass. It is estimated that by 2002, the production of electric energy from biomass will have reached approximately 3,000 GWh per year (Tegner 1998).

**Table 1** The use of biomass in EU countries in 1995 and the assessment for 2010 (Anon 1998)

| Form of biomass energy use | 1995 | 2010 |
|---|---|---|
| Family houses heating | 301.8 TWh | 707.8 TWh |
| Regional heating and processing heat | 116.0 TWh | 464.0 TWh |
| Electric energy production | 53.4 TWh | 221.6 TWh |
| Liquified bio-fuel production | 5.8 TWh | 127.6 TWh |
| TOTAL | 477.0 TWh | 1521.0 TWh |

## 3. Forest biomass

In Croatia the area covered by forests and forestland is 2,485,611 ha or 44% of the surface of the continental territory of the country. Table 2 gives the survey of surfaces regarding the ownership (Anon. 1996A).

The division of covered forestland in view of *silvicultural forms* is significant for energy biomass, e.g. high forests, coppice forests, macchia, garrigue, bushes, cultures and plantations and in the world there are also *energy forests*, still not known in Croatia (Table 3).

There are approximately 12,300 km$^2$ of highly valuable high forests and 5,049 km$^2$ of low or coppice forests. There are 3,299 km$^2$ of different de-

**Table 2** Groups of forestland cover for three types of ownership over them

| Category of forestland cover | | Ownership | | | | | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|
| | | »Hrvatske šume« | | Other companies | | Private | | | |
| | | ha | % | ha | % | ha | % | ha | % |
| Forest | | 1,592,869 | 79.99 | 31,278 | 90.00 | 454,133 | 98.48 | 2,078,289 | 83.61 |
| Non-forested land | Productive | 323,130 | 16.22 | 1,229 | 3.73 | 6,975 | 1.51 | 331,334 | 13.33 |
| | Non-productive | 14,490 | 0.73 | 107 | 0.32 | 20 | ~ 0 | 14,618 | 0.59 |
| Barren soil | | 61,048 | 3.06 | 314 | 0.95 | 8 | ~ 0 | 61,370 | 2.47 |
| Total | | 1,991,537 | 100.0 | 32,928 | 100.0 | 461,136 | 100.0 | 2,485,611 | 100.0 |

**Table 3** The share of covered forestland in view of silvicultural form, in ha

| Ownership | High forests | Coppice forests | Bushes | Thicket | Macchia | Garrigue | Plantation | TOTAL |
|---|---|---|---|---|---|---|---|---|
| »Hrvatske šume« | 1,018,054 | 252,137 | 258,129 | 6,900 | 29,255 | 13,072 | 15,322 | 1,592,869 |
| Other companies | 25,582 | 2,404 | 1,202 | 0 | 1,569 | 132 | 398 | 31,287 |
| Private | 183,905 | 250,360 | 19,688 | 0 | 0 | 0 | 181 | 454,133 |
| TOTAL | 1,227 541 | 504 901 | 279 019 | 6,900 | 30,824 | 13,203 | 15 901 | 2,078,289 |

**Table 4** Possible annual cut of Croatian forests according to the forest yield for periods 1996–2005, 2006–2015 and 2016–2035.

| Forest yield | Possible annual cut for the given periods, $m^3$ | | |
|---|---|---|---|
| | 1996–2005 | 2006–2015 | 2016–2035 |
| Main | 22,082,122 | 24,961,210 | 69,274,365 |
| Previous | 16,860,187 | 16,001,623 | 27,777,325 |
| Selection forest | 14,597,867 | 16,156,318 | 31,984,340 |
| Total | 53,540,176 | 57,119,151 | 129 016,030 |
| Annual average | 5,354,018 | 5,711,915 | 6,450,802 |

**Table 5** Energy potential of cordwood for energy and waste and a part of wood matter in the Republic of Croatia for (half)periods 1996–2005, 2006–2015 and 2016–2035.

| Energy source | Average (half)period energy potential, TJ/year | | |
|---|---|---|---|
| | 1996–2005 | 2006–2015 | 2016–2035 |
| Fuelwood | 16,324.85 | 17,732,50 | 20,330.76 |
| Waste | 6,990.64 | 7,409.43 | 8,574.67 |
| Total | 23,315.49 | 25,141.93 | 28,905.43 |

graded formations such as macchia, garrigue, bushes and thicket and the area covered with poplar and willow plantations amounts to 0.159 $km^2$.

The growing stock of the Croatian forests is $324{,}256 \times 10^6$ $m^3$, and total forest increment in Croatia is approximately 9.6 million $m^3$ (2.96 %). By increasing the increment by different measures, it is quite reasonable to expect the possibility of the increase of the available biomass for energy purposes.

The part of growing stock planned for felling, the so-called annual cut for the period 1996–2035 is shown in Table 4, broken down according to forest yields for all owners.

A forty-year period is taken into consideration, in which for the first ten years everything is specified and for the following thirty years it is scheduled. The average felling in the first (half)period amounts annually to 5.35 million $m^3$ and by the end of the said period $6.45 \times 10^6$ $m^3$ per year. The achieved annual cut or the so-called realized annual cut, usually differs from the possible annual cut.

On the basis of the quantities and shares of assortments in total annual cut of all owners for (half)-periods from 1996 to 2035, Table 5 shows the results of the calculation of total energy potential of slightly dried ($W$ = 15 %) cordwood for energy and waste. The same Table also shows the energy potential of a part of wood matter in sawmill processing. When speaking about wood processing within wood-industrial companies, the utilization of wood can be increased for energy purposes by transforming the waste into heating energy or some other kind of energy. In sawmill processing, a 30 % residue is left after sawing 1 $m^3$ of conifers (15 % – saw dust, 15 % chips), and with broadleaved timber 40% (20 % – saw dust, 20 % chips). The waste with veneer production is 20 %.

The available surface of forestland, as shown in Table 2 – 331,334 ha of non-forested productive forestland in the Republic of Croatia, is the significant base for the assessment of forestland primarily intended for wood as energy source. Biomass obtained from *special purpose forests*, fire-burned forests, etc. should also be taken into account. Assuming that *energy forests* could be established on 30% of the said land, with a 5-year production period and biomass production of approximately 12,000 kg/ha x year of dry matter, the annual growth of 1,200 x $10^6$ kg/y can be expected with adequate investments on an area of 100,000 ha. Such annual growth could be »harvested« by use of mechanization.

Apart from the above said, by investments into *degraded forests*, the quality and quantitiy of the growing stock of bushes, thicket, macchia, etc. can be increased. In only 30% of approximatelly 330,000 ha of such forests, an increment of approximately 5 to 8% could be obtained, increasing thus the annual growth by approximately 643,000 $m^3$/a.

It is estimated that approximately 2,043,000 $m^3$ of biomass for energy purposes could be obtained annually by adequate investments into afforestation and increase of production and quality of degraded forests.

### 3.1 Processing of fuelwood

Processing of forest biomass into a form suitable for use is a complex task. Along with machine biomass chipping, handling during the process, involving transfer, trasport, storing, drying, etc. is also of considerable significance. Technological processes of fuelwood processing are partly carried out outdoor in the stand and partly in the industrial plants. Basically three operations can be distinguished in the process of forest biomass production:

- felling and bunching,
- chipping, condensing, palettizing, etc.
- transport of the produced energy source.

While the first and the third phase make part of the general forest harvesting activities, in the second phase specific machines and units are used for the production of the energy source. The use of alternative work methods depends on the used technique, tradition, economic conditions and other factors.

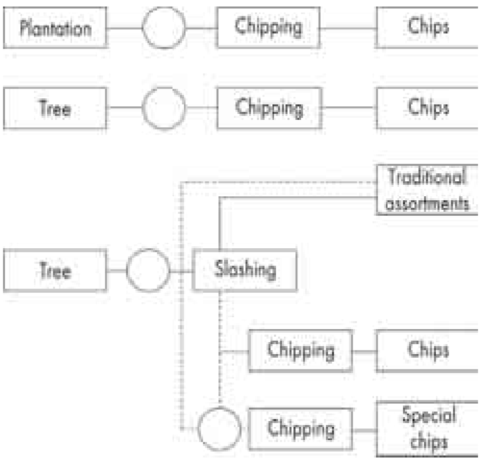


**Figure 1** Basic processing technologies applied for chipping trees biomass

Jakupović (1990) in accordance with Bojanin (Figure 1) sets forth the basic methods for biomass chipping carried out in order to achieve chips for the requirements of energy production.

As shown in Figure 1, it can be seen that timber suitable for fuelwood can be obtained from plantations, from natural forest trees and from waste left after setting apart wood assortments. In the latter case, timber and bark are chipped if involved by technological process. Otherwise timber is chipped together with the bark.

Generally timber can be left as larger assortment (split-wood, cleft-wood etc.), it can be turned into charcoal, fuelwood, gas, briquette, pallet, etc. As a result of wood processing, shavings, sawdust and grindings or chips can be obtained.

The development of forestry in the 20th century has gone through step-by-step changes in view of applied technologies and work methods. Technology is characterized by the place of processing – assortments cut at the felling site, the so-called cut-to-length method, at landing and in the mill storage. On the other hand, work methods are determined by the form and size of assortments transported out of the forest: assortments, semi and full lengths, stem, whole tree and parts of tree (Sever 1989). In order to increase energy biomass, the *chipping method* was introduced into forestry practice. The following chart shows the flow of the change of activities in forest harvesting with the change of working site (Figure 2).

In forest harvesting in countries such as Croatia, where beech is the most frequent tree species, the methods for producing fuelwood from 1 m of split-wood and from chips have been considerably developed. The share of cordwood in biomass with this species (beech) is 45 to 58 % and with the oak it is 35 to 45 %, while with conifers it is approximately 7 %.

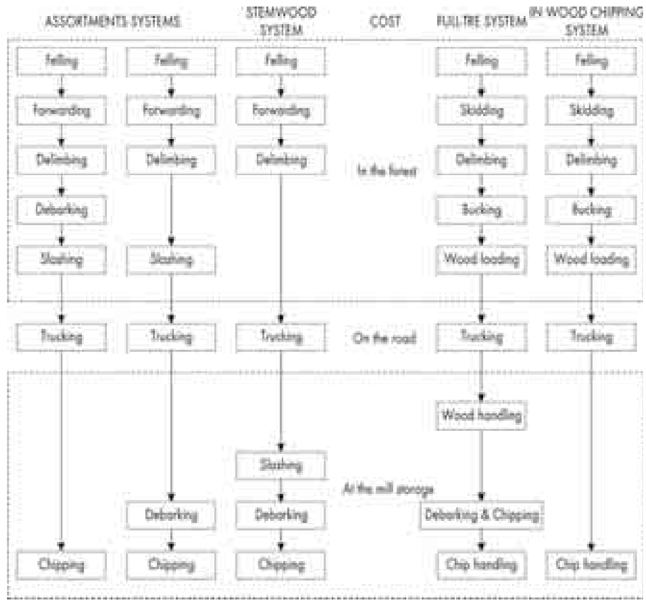


**Figure 2** Some different logging systems following the transfer of process from forest to mill storage

As in Croatia broadleaved species make up to 86 % of the total growing stock, any improvement of technology or work method results in the increase of the percentage of forest bioamass as well as in the decrease of production costs and humanization of work.

In countries where forest biomass is largely used as the primary energy source, several ways of achieving increased share of forest biomass in the energy balance are known (Anon. 1992). The process of producing chips depends on the site of its production. Chipping can be carried out at the felling site – directly on the place of felling and cutting, on skid

**Table 6** Possible ways of production of fuel chips

| Felling (1) | Felling (2) | Felling (3) | Felling (4) | Felling (5) |
|---|---|---|---|---|
| Bucking | Bucking | Chipping | Bucking | Drying |
| Skidding | Skidding | Container transport | Chipping | Bucking |
| Transport | Landing | Container transport<br>Inter-storage | Transport | Skidding |
| Unloading<br>Chipping | Transport | Reloading, transport to the user | User's storage | Chipping |
| Storage | Storage | | | Transport |
| Reloading | | | | |
| Transport | | | | |
| User's storage | | | | |

1 – Inter-storage chipping
2 – Fixed silo chippers
3 – Movable chippers
4 – Chipping on skid trail
5 – Chipping on forest road

trails or along forest roads i.e. along the roads used for transporting timber out of forest but also right next to the heating unit.

Timber chipping is carried out by chippers, which provide final fragmentation of wood waste. Chippers are divided into three groups according to their size (Hamm et al. 1994). The first group is made of small-size chippers, usually installed on a three-point linkage tractor. Their loading is always performed manually, the efficiency is low and therefore they are used for the preparation of chips for small heating units, e.g. individual households. Middle-size chippers are installed on agricultural tractors or equally suitable special forest tractors. Large-size chippers are always installed on forest third generation tractors or on their own vehicles. The machine is loaded exclusively by hydraulic crane.

For chips produced in forest, transport to the user must be provided. When designing and organizing the transport looseness of chips must be taken into consideration.

## 4. Conclusion

If we accept the fact that the European Union (EU) gives general guidelines in view of renewable energy sources, then biomass acquires an important role. Forestry and wood waste in wood processing can achieve the quickest increase of the share of forest biomass in total national energy consumption from the current 4.5% to 10% by applying their own solutions and by establishing good links between production procedures. This will become even more important following the initiative for establishing energy forests on productive non-forested forestland. In the Republic of Croatia, the following facts should be noted regarding the supply of wood as energy source:

- 80% of forests and forestland are state owned,
- a single enterprise manages state-owned forests,
- inseparability of forest silvicultural activities and activities of forest harvesting,
- available surfaces can be used for establishing energy forests,
- procedures for obtaining primary and secondary energy sources have been acquired.

Based on the above factors and some others not stated, it can be said that extended use of wood as energy source depends primarily on decisions beyond forestry influence, such as government strategy and relationship towards renewable energy sources, environmental protection, desired standard of living in village family houses, etc.

## 5. References

Anon., 1996A: Šumskogospodarsko područje Republike Hrvatske, Šumskogospodarska osnova, Tablice ŠGO-6 do ŠGO-14 (vrijedi od 1996. do 2005. Godine), Zagreb

Anon., 1996B: Razvoj i organizacija hrvatskoga energetskoga sektora. Gospodarenje šumama u Hrvatskoj. Proizvodnja i potrošnja energenata i energije, Energetski institut »Hrvoje Požar«, Zagreb, 1–76.

Anon., 1998: BIOEN Program korištenja energije biomase i otpada. Prethodni rezultati i buduće aktivnosti, Energetski institut »Hrvoje Požar«, Zagreb, 1–122.

Tegner, L., 1998: Bioenergy in Sweden. IEA Bioenergy ExCo41 Meeting, Saltsjöbaden, 13–14 May.

Risović, S., 2000: Izazov uvođenja vrhunskih tehnologija pri energijskoj pretvorbi u drvnom proizvodnom lancu. Vrhunske tehnologije u uporabi šuma, HAZU – Znanstveni skup održan 11. travnja 2000. u Zagrebu, 129–156.

Sever, S., 1989: Iveranje i iverači. Skup s prikazom lančanog rada u iskorištavanju šuma listača uz upotrebu iverača Bruks za iveranje, Modruša – Ogulin, 1–7.

Hamm, Đ., Goglia, V., Sever, S., 1994: Korištenje drvnog ostatka iz šumske proizvodnje za dobivanje iverja kao goriva u toplinskim generatorima. Mehanizacija šumarstva 19(4), 269–275.

Anon., 1992: Handbuch Fernwarme Nahwarme aus Biomasse. Landesanergieverein Ausgabe Steiermarkt, Graz, 1–107.

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# Social and Economic Aspects of Biomass Usage Projects in Croatia

**Branka Jelavić, Julije Domac**

***Abstract***

*Economic development is closely correlated with the availability and utilization of modern energy sources. It is now clear that current approaches to energy are non-sustainable and not renewable. Together with hydro, wind, solar and geothermal energy sources, biomass is considered as the essential factor of the future renewable energy strategies. Use of biomass and different biofuels offers a wide range of social and economic benefits and effects especially for the development of remote and rural areas. One of these additional benefits, which gained attraction, is the opportunity to create new, local jobs. It is obvious that high rate of unemployment in most parts of Croatia and associated high costs and loses, should lead to increased interest for creating new permanent jobs that are economically and socially useful. There are many difficulties in summarizing or comparing the effects of biomass use due to differences in biofuels supply systems, ways of calculation, definitions of limits, technology, etc. To calculate the manpower requirement in a new rapidly developing branch of business is no exact science, but rather a qualified estimate, especially in Croatian conditions. This paper deals with preliminary estimation of biomass usage contribution to creation of new jobs in Croatia. These results are a part of activities of the BIOEN Program (National energy program of biomass and waste use) and they are recognized and evaluated in recently published Energy Strategy of the Republic of Croatia.*

**Key words:** *biomass, employment, energy*

## 1. Introduction

Opening of new jobs is one of the priorities of the Croatian economic and social policy. Using biomass energy, apart from enabling effective waste management and energy recovery with minimal environmental impacts, also provides new job opportunities.

In the history of energy use, the humankind made several significant turns. Each turn was heavily conditioned by social factors. Although this is a major simplification of complex historical processes, the following illustration may serve as justification:

Energy was not the cause of industrial revolution; however, industrialization required a change in the use of energy. At the simplest level possible, the need to bring industrial facilities closer to sources of raw materials (not only sources of energy) or labor markets, required easy transportation of energy sources. This change incited the use of coal instead of timber, and, finally, of electricity.

Mobility, both commercial and individual, implying the possibility to travel, transport and commute, is one of the most valued advantages of a developed society, which at the same time called for a concentrated energy source. Locomotives drove on coal more efficiently than on timber and oil fuels were a key to the development of automobiles. However, one should bear in mind that coal and oil did not influence the desire for mobility; on the contrary – the inclination towards and the need for mobility have caused the development of energy systems to make mobility possible.

Personal comfort is nowadays also reflected in simple heating, cooling and lighting systems, and the possibility of global information exchange via the TV and electronic mail. A strong desire for personal comfort has brought about the advancement of technology, and of energy use methods to make it possible. The natural consequences are the development and reliance on electricity and natural gas.

At present, humanity is facing a new change. Lately, it is becoming obvious that future energy supply would have to be both economically and ecologically absolutely sustainable. The use of renewable energy sources and formation of a closed cycle of production, recycling and waste energy recovery is becoming the stronghold of all future developments and energy supply strategies. As far as energy output evaluation is concerned, special importance is assigned to forestry waste and timber residues, which can be seen both as industrial waste and as renewable energy source.

There are different ways of solving the problem of managing forestry and forest industry waste based on the experience of developed countries (Austria, Finland, Sweden, etc.) through economic evaluation, bringing along a range of additional positive impacts. Total energy recovery from forestry and forest industry waste or biomass shows an increasing trend in Sweden. In 1998 more than 18% of the total energy for consumption were recovered from biomass. Estimates for 2002 show an increase in biomass electricity production to 3000 GWh per year (Tegner 1998). Finland is the leading country in the world in view of energy recovery from biomass, using mostly forest biomass, peat and municipal waste. The biomass today satisfies 20% of primary energy consumption, with the Finnish Government setting the target of 25% in the year 2005. Overall, biomass in Finland satisfies over 10% of electricity requirements (Heikkinen 1998).

Due to the nature of energy recovery from biomass (smaller, decentralized consumption systems, local collection and distribution), advantages lie not only in waste management opportunities, but also in numerous positive social-economic effects. Apart from the direct impact on employment trends, i.e. new job opportunites, biomass utilization adds to the local and regional economic activity, keeping financial resources and their circulation within the local community, as well as to the development of small entrepreneurship.

## 2. Possible impacts of biomass use on new job opportunities in Croatia

Impact of energy output evaluation of biomass on employment trends is dependent on a number of factors: applied evaluation methods (co-generation plants, boiler plants, small centralized heating systems, etc.), characteristics of biomass generation (types, collection methods and areas,), and organization and implementation of energy evaluation.

The above factors are difficult to define in detail and they may differ significantly from one country

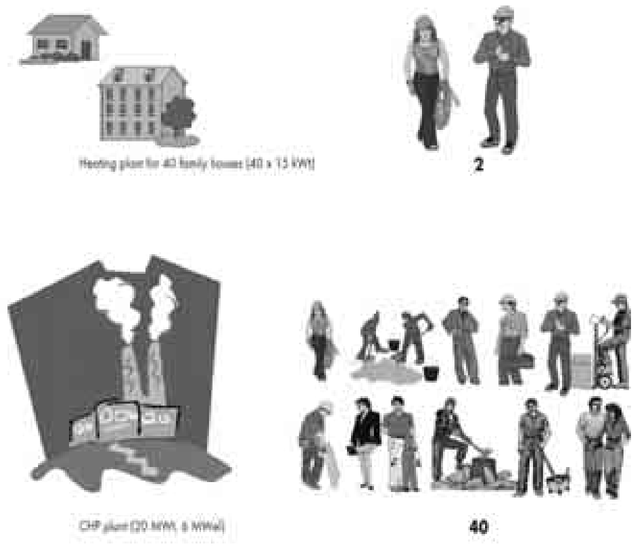


**Figure 1** Annual employment requirements for different bioenergy systems (Hakkila 1997)

to another. However, based on the research and analyses carried out to date, both in Croatia and globally, the quantity of labor force required for certain technologies can be assessed (Figure 1), having direct impact on new job opportunities. Possibilities for additional employment created by forest activities or timber industry requirements shall not be considered separately in this paper. The need for new jobs will nevertheless remain, due to biomass energy output evaluation, which could contribute not only to the creation of new jobs, but also to maintaining of the existing ones.

The first step in the assessment of likely impact of energy output evaluation of biomass on the openings of new job in Croatia was the estimate of waste quantities and of biomass energy output potential. Both a survey and an expert evaluation, involving all biomass types, have been carried out. All relevant factors have been analyzed: annual log treatment or the production of wood assortments, timber residue quantities, amount of other biomass types and current utilization of this residue (in-plant boiler-rooms, briquetting, distribution, disposal, etc.). The results point to the conclusion that we are dealing with a considerable energy output potential remaining unutilized, but also to its current inadequate and disturbing biomass management situation. Based on the total energy potential of different biomass types in Croatia, amounting to approximately 50 PJ (Domac 1998), it is possible to assess the likely impact on new job opportunities. Research conducted at the national level, in accordance with the above mentioned Energy Development Strategy and possible energy development scenarios (Granić *et al.* 1998), shows total achievements and possible contribution of biomass utilization to the creation of new jobs in Croatia (Figure 2). It is important to note that the term »biomass« in the above research includes not only forestry waste and timber residues but also waste from agriculture, foodstuffs industry, and the production of gaseous and liquid bio-fuels and chemicals. Preliminary results show that energy production from biomass could offer approximately 5000 new jobs in the year 2020 in Croatia.

Similar considerations are present in industrial countries as well. The European Union plans to recover 113 Mt of energy from biomass in 2020, which would create conditions for opening as much as 1,500,000 new jobs. Total investment requirements for opening approximately 1 million direct new jobs (funding to open indirect jobs shall be automatically earmarked from private investments) is expected to decrease by approximately 250 billion ECU in relation to the planned 345 billion ECU paid in the form of subsidies and fees for around 1.5 million unemployed during the twenty years of minimum life cycle of investment (facility) (Grassi 1997).

According to the report of the US Department of Energy (DOE), economic activities related to biomass energy recovery in the USA directly support approximately 66,000 jobs, the majority of which is in rural areas. It is expected that a capacity of over 30,000 $MW_{el}$ would be installed to run on biomass by 2020. More than 60% of fuel for the planned installations would be in the field of energy output plants, which would create over 260,000 new jobs and significantly contribute to the rehabilitation of rural economies.

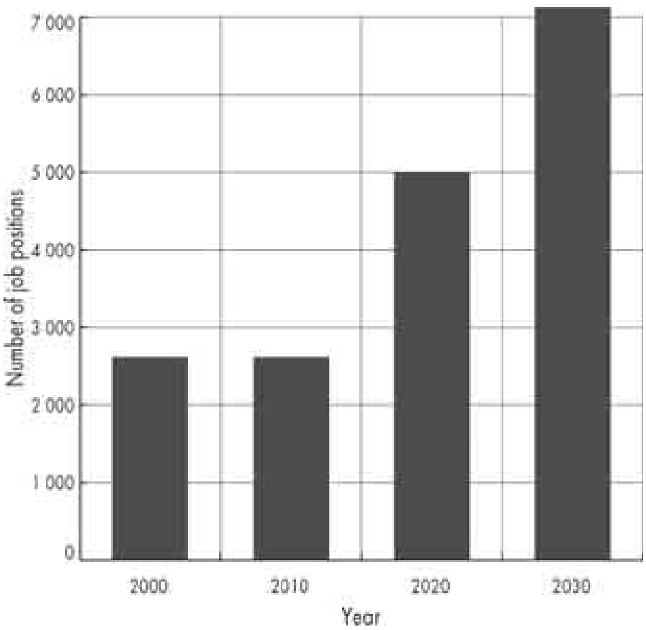


**Figure 2** Expected annual impact of biomass energy use on employment trends in Croatia

## 3. Social and economic aspects of bioenergy systems – a new international research cooperation within IEA bioenergy

Biomass utilization, bioenergy technologies, their market share, and research interests in these issues vary considerably between different countries. Nevertheless, in most of the countries social and economic benefits of bioenergy use can clearly be identified as a significant driving force in increasing the share of bioenergy in the total energy supply. In most countries regional employment opportunities and economic gains are probably the two most important issues regarding biomass use for energy production.

Social aspects of bioenergy systems mean any impact or contribution of biomass production and use for energy on employment, education, health and other social factors while economic aspects of bioenergy imply any contribution or benefit from biomass production and use for energy in terms of financial benefits, local industry creation, infrastructure development, and other economic factors.

The overall aim of the new IEA Bioenergy Task is to promote the use of biomass for energy over fossil-based competing fuels in the participating countries through achieving a better understanding of the social and economic impacts of bioenergy systems at the local, regional, national, and international level. The major objectives of this Task are:

- to determine the economic contributions (financial, local industry creation, infrastructure development, …) resulting from the deployment of bioenergy systems;
- to determine the social impacts (employment, education, health, …) resulting from the deployment of bioenergy systems;
- to encourage the exchange of information and Task results between participants and also with countries in transition.

Task collaborators will collect, collate and synthesize information to fulfill given objectives. In particular they will design and develop easy-to-use tools and guidelines needed to estimate real and complete characteristics and consequences of using biomass instead of fossil fuels for energy. Although the Task is focused mainly on the local/regional level, full account will be taken of the overall national and international framework, within which the region must necessarily work. This has particular relevance when considering issues like tariffs, taxes, government incentives, regulations, organizational structures, and similar matters. The primary means to achieve the overall Task objectives is a series of annual workshops, e-mail conferences and Internet presentations. Invited and volunteer scientific and other experts will present papers and contribute to assessments and discussions.

This 'club project' started on January 1, 2000 and will go on for three years and will reach the value of some US$ 250,000 and will initially involve: Croatia, UK, Austria, Sweden, Canada and Japan. Italy and New Zealand are also likely to join and Slovenia, South Africa and India will be observers to the work.

## 4. Conclusion

Internationally adopted need to control and reduce greenhouse gas emissions has brought new life into biomass, the world's oldest energy source used by man. Biomass utilization in energy recovery, except in cases of felling of forests not scheduled for reforestation, does not contribute to an increase in greenhouse gas emissions and could be considered as $CO_2$ neutral. Biomass is an important energy source for developing countries, and its share in energy production in industrial countries has shown recently an increasing trend, somewhere even accounting for a considerable portion of total primary energy consumption.

New job opportunities, especially in rural areas outside large towns, are one of the priorities of the Croatian economic and social policy. Utilization of biomass energy potential provides multiple benefits: it not only enables energy production with minimum environmental impact, but it also offers possibilities for more job opportunities, which has been recognized as one of major advantages of the BIOEN National Energy Program.

Utilizing biomass energy potential offers considerable opportunities for new jobs and can positively affect local and national economy. Preliminary results show that energy production from biomass could offer approximately 5000 new jobs in the year 2020 in Croatia. Industrial EU countries and other developed countries of the world are aware of these positive aspects and give significant support to projects of biomass energy utilization.

## 5. References


Anon.: Biomass Power Program. National Renewable Energy Laboratory, NREL/SP-420-5877, DOE (US Department of energy), p. 24.

Domac, J. *et al.*, 1998: BIOEN Program korištenja energije biomase i otpada – Prethodni rezultati i buduće aktivnosti. Hrvoje Požar Energy Institute, Zagreb.

Granić, G., Jelavić, B., Bašić, H., Bošnjak, R., Božić, H., Domac, J. *et al.*, 1998: Strategija energetskog razvitka Republike Hrvatske. Ministry of Economic Affairs of the Republic of Croatia, Zagreb.

Grassi, G., 1997: Operational employment in the energy sector. Presentation at the Tagung des SPD – Umweltforums, 5 July.

Hakkila, P. *et al.*, 1997: Forest Management for Bioenergy. The Finnish Forest Research Institute. Vantaa 1997. p. 237.

Heikkinen, A., 1998: Bioenergy and Power Production; Power Company's Perspective. IEA Bioenergy Task 25 International Workshop »Between COP3 and COP4: The Role of Bioenergy in Achieving the Targets Stipulated in the Kyoto Protocol«. Nokia.

Tegner, L., 1998: Bioenergy in Sweden. IEA Bioenergy ExCo41 Meeting, Saltsjöbaden.



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# Method of laying out environmentally friendly forest roads using the genetic algorithm

**Tetsuhiko Yoshimura**

***Abstract***

*It is well known that computing shortest paths over a network is an important task in many transportation-related analyses and genetic algorithm is one of the methods used for such purposes. In this study, a GIS-based expert system for laying out environmentally friendly forest roads was developed by using genetic algorithm. We defined environmental sensitiveness of each site as the site-sensitivity index which was calculated based on three factors such as types of vegetation, distance from rivers and the potential degree of slope failure occurrence. Vegetation was classified into two types of man-made and natural forests and, we believe, natural forests require protection more often than man-made forests. In addition, riparian areas should be protected as such areas often affect water quality and ecosystem of rivers. Furthermore, slope failures or landslides should be avoided as they damage forest environment and its ecosystem severely. Basically, environmentally sensitive sites, as mentioned above, should not be crossed by forest roads and environmental impacts caused by road construction should be minimized. In this study, suitable route was determined by use of computer, taking into account the site-sensitivity index and environmentally friendly forest roads were successfully laid out using genetic algorithm.*

***Key words:*** *forest roads, ecology, GIS*

## 1. Introduction

It is well known that computing shortest paths over a network is an important task in many transportation-related analyses and the genetic algorithm (GA) is one of the methods used for such purposes. In this paper, the basic concept of a GIS-based expert system to lay out environmentally friendly forest roads using the genetic algorithm was studied. The site-sensitivity index was defined as environmental sensitiveness of each site obtained based on three factors such as types of vegetation, distance from streams or lakes and slope stability. Vegetation was classified into three types: plantation, natural and virgin forest. Generally, natural forests require protection more often than plantation forests. In addition, riparian areas should be protected as such areas often affect water quality and ecosystem of streams or lakes. Furthermore, slope failures or landslides should be avoided as they damage forest environment and its ecosystem severely. Basically, environmentally sensitive sites, as mentioned above, should not be crossed by forest roads and environmental impacts caused by road construction should be minimized. This study showed the basic concept of the method of laying out environmentally friendly forest roads taking into account the site sensitivity index.

## 2. Method

### 2.1. Site-sensitivity index

We proposed that the site sensitivity index should incorporate the following factors:

- Types of vegetation
- Distance from streams or lakes
- Slope stability
- Gradient of a forest road

Vegetation was classified into three types: plantation, natural and virgin forests. We believe that natural forests require protection more often than plantation forests because more plants and animals live there and biodiversity is preserved. Virgin forests would be much more precious. Therefore, site sensitivity index related to vegetation (*V*e) was determined as shown in Table 1. In this table, the areas, which should be protected and should not be crossed by forest roads, have higher scores.

Riparian areas are important because they protect water from pollution sources on the land and they provide food, cover and travel corridors for wild life. Furthermore, riparian vegetation shades streams and provides organic debris to feed the aquatic ecosystem. In that context, environmental impacts on such areas caused by road construction should be minimized. Therefore, site sensitivity index related to riparian areas (*R*i) was determined as shown in Table 2.

In Japan, the topography is very steep and slope failures often occur. Once slope fails, large forested areas are damaged. Therefore, slope instability must be evaluated and unstable areas should not be crossed by forest roads, which often cause slope failures. We have conducted the precedent study to evaluate slope failure potentials, based on which we proposed the site sensitivity index related to slope stability as shown in Table 3. When calculating the site sensitivity index related to slope stability, the score of inclination (*In*) and that of slope cross-section (Cr) were considered.

The gradient of a forest road is an important parameter although that is actually not related to site sensitivity. If the gradient of a forest road is higher than the maximum for car traffic, the forest road is of no use. Therefore, a parameter related to the gradient of the forest road was determined as shown in Table 4.

**Table 1** Site sensitivity index related to types of vegetation (*V*e)

| Types of vegetation | Score |
|---|---|
| Plantation forest | 0 |
| Natural forest | 6 |
| Virgin forest | 10 |

**Table 2** Site sensitivity index related to distance from streams and lakes (*R*i)

| Distance from streams and lakes | Score |
|---|---|
| Within 50 m from streams or lakes | 10 |
| 51-100 m from streams or lakes | 5 |
| Over 100 m from streams or lakes | 0 |

**Table 3** Site sensitivity index related to slope stability

| Factors | Categories | Score |
|---|---|---|
| Inclination (degrees) ($I_n$) | 0-10 | 0 |
| | 11-20 | 2 |
| | 21-30 | 4 |
| | 31-35 | 7 |
| | 36 - | 10 |
| Slope cross-section ($C_r$) | Concave | 10 |
| | Parallel | 2 |
| | Convex | 0 |

**Table 4** Parameter related to the gradient of the forest road (*G*r)

| Gradient of the forest road, % | Score |
|---|---|
| 0-10 | 0 |
| 11-15 | 4 |
| 16-20 | 10 |
| >21 | 999 |

Finally, site sensitivity index is obtained as the total score of each place. The parameter related to the gradient of the forest road is also added to the total score. For example, the site sensitivity index (*SI*) of a site with the following features can be calculated using the equation (1).

- Natural forest
- 85 meters from streams
- Inclination of 32 degrees
- Convex slope
- Forest road gradient of 10 %

$$SI = \frac{V_e + R_i + I_n + C_r + G_r}{50} = \frac{6+5+7+0+0}{50} = \frac{18}{50} = 0.36 \tag{1}$$

## 2.2. Laying out a forest road using a genetic algorithm

### 2.2.1. Outline of the genetic algorithm

Genetic algorithms have recently received much attention because of their ability to solve difficult problems, just like for example neural networks. Although they are completely different, they both have their origin in biology. There are even cases where both algorithms are used to complement each other. In general, a genetic algorithm works as follows. In the first population, all chromosomes are generated randomly. Their fitness is then determined. At this point, the genetic algorithm can start generating new populations. Usually, the population size is kept constant for convenience. Reproduction consists of three distinct steps:

*Selection* represents a very important aspect of the genetic algorithm: survival of the fittest. This is usually implemented as a weighed selection, which means that individuals with a higher fitness have a better chance of being chosen. It is possible for an individual to be selected more than once, or not at all.

*Crossover* is the most important mechanism of the algorithm. It makes two new individuals by combining two old ones. There are several variations of crossover. The simplest version is one-point crossover. It works by selecting a point at which the chromosomes are cut off randomly. The parts that are cut off are then switched to make two new chromosomes (Figure 1).

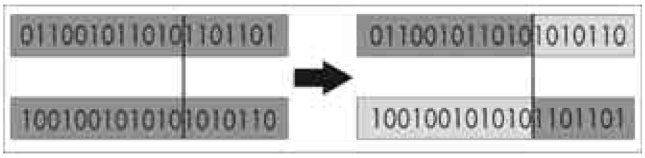


**Figure 1** Crossover

*Mutation* introduces random changes to chromosomes. It is a mechanism that has only a small chance of occurring. It simply flips a bit in a chromosome, or if the chromosome is made out of numbers, it changes a number (Figure 2). This simple process is repeated until the entire population is reproduced. The new population is decoded and the fitness of the newly created individuals is calculated. At this point, the process starts all over again.

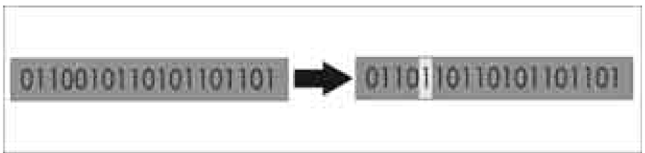


**Figure 2** Mutation

### 2.2.2. Application to laying out a forest road

In Figure 3, S is the starting point and E is the ending point. Node number is given to each point. The site sensitivity index is also given to each line between two of these nodes. The route with the least sum of these values is regarded as the best route. In this figure, there are two routes, which are shown as solid and broken lines. With node numbers, the solid one is expressed as follows:

$$31\text{-}25\text{-}26\text{-}20\text{-}14\text{-}15\text{-}16\text{-}17\text{-}18\text{-}12\text{-}6 \tag{2}$$

Similarly, the broken one is expressed as follows:

$$31\text{-}32\text{-}33\text{-}27\text{-}21\text{-}15\text{-}9\text{-}10\text{-}11\text{-}5\text{-}6 \tag{3}$$

Each line is an individual with chromosomes. In the first population, 10 individuals are generated randomly.

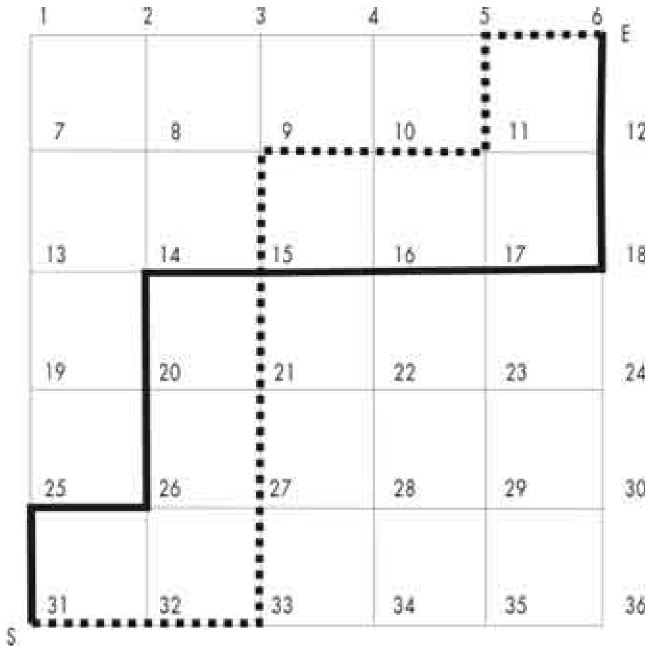


**Figure 3** Layout of forest roads

Next, crossover happens in the selection of two individuals. Selection was carried out using the tournament method. At first, the fitness value (FV) for each individual is calculated as follows:

$$FV = \frac{1}{1 + \overline{SI}} \tag{4}$$

Table 5 shows an example of the fitness values for 10 individuals. Individual 1 is the fittest one. Conversely, individual 5 has the lowest fitness value of almost 0.

**Table 5** Parameter related to the gradient of the forest road (*Gr*)

| Number of individual | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Fitness value | 0.147 | 0.119 | 0.126 | 0.142 | 0.001 | 0.134 | 0.117 | 0.111 | 0.098 | 0.074 |

Then, 10 individuals for the next generation are selected according to the tournament method. In this method, three individuals are selected randomly and the one, which has the maximum fitness value among these three, is selected for crossover process. In the same way, one more individual is selected for crossover process. If these two individuals do not have any common nodes except the starting and the ending points, crossover does not happen and these two individuals are put in the next generation as they are. If they have common nodes besides the starting and the ending points, crossover happens as follows:

- the individuals (2) and (3) will be transformed into the ones (5) and (6), respectively and the result is shown in Figure 4.

31-25-26-20-14-15-9-10-11-5-6 (5)

31-32-33-27-21-15-16-17-18-12-6 (6)

This result also means that the size of each individual is variable. Crossover is repeated until the next generation, which consists of 10 individuals, has been created.

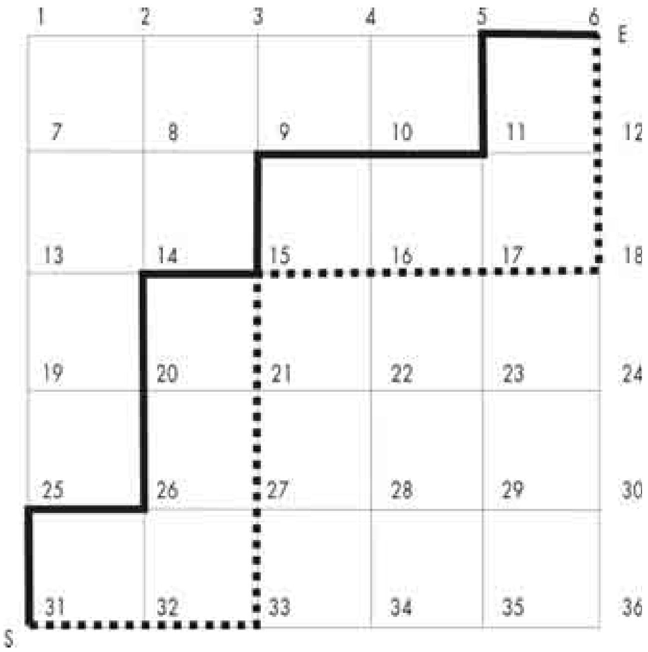


**Figure 4** Individuals after crossover

In this study, mutation also happens and mutation probability is 0.03 for each chromosome. In this study, mutation is defined as follows: when mutation happens at the point of 26 on the solid line in Figure 4, the point will be moved to the point of 19. When mutation happens at the point of 16 on the solid line, it will not move. This whole process is repeated.

## 3. Results and discussion

The first generations consisting of 10 individuals are determined as follows:

No. 1:
31-32-33-34-35-36-30-29-28-22-16-10-11-5-6 (7)

No. 2:
31-25-26-20-21-22-23-24-18-12-6 (8)

No. 3:
31-25-19-13-7-8-14-20-21-15-9-10-11-12-6 (9)

No. 4:
31-32-26-27-28-22-16-10-11-5-6 (10)

No. 5:
31-25-26-27-21-15-9-3-4-5-6 (11)

No. 6:
31-32-26-20-21-15-16-17-18-12-6 (12)

No. 7:
31-32-26-25-19-20-14-8-9-15-16-17-11-5-6 (13)

No. 8:
31-32-33-34-35-29-28-27-21-22-23-24-18-12-6 (14)

No. 9:
31-32-33-27-26-25-19-13-14-8-2-4-10-11-5-6 (15)

No. 10:
31-32-26-27-33-34-28-22-16-15-9-10-11-17-23-29-30-24-18-12-6 (16)

Then, the fitness value of each individual was calculated as shown in Table 5 and these individuals were processed with the above-mentioned method. Test field is shown in Figure 5. In this figure, node numbers and site sensitivity indices are also shown.

In the seventh generation, all individuals have come to convergence and become the one shown as follows:

31-25-26-27-21-15-9-10-11-5-6 (17)

The changes of the best, mean, worst fitness values are shown in Figure 6. According to this figure, these fitness values improved as generations were renewed. Particularly, the worst fitness value improved rapidly because the tournament method was applied. However, the individual shown as (17) is not the best one although it is a rather good one. The algorithm and parameters applied in this study still have to be improved.

Our next targets of this study are:

- To increase mutation probability
- To simulate this genetic process in larger areas

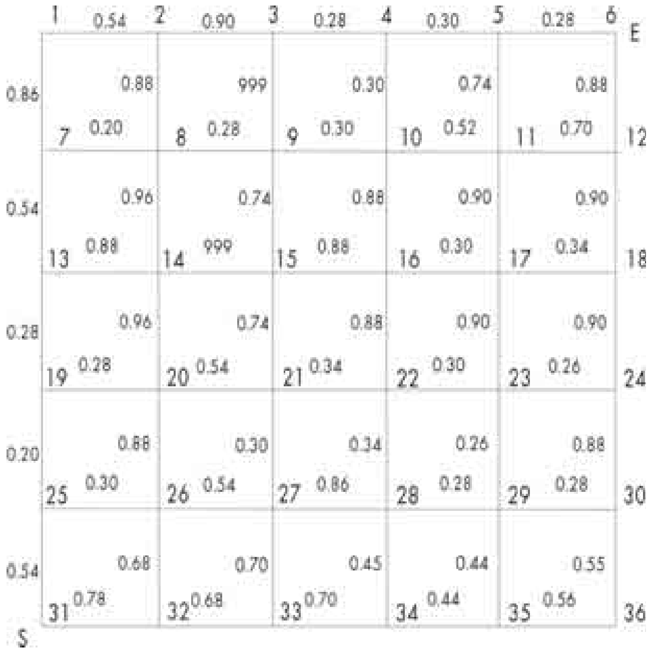


**Figure 5** Test field with node numbers and site sensitivity indices

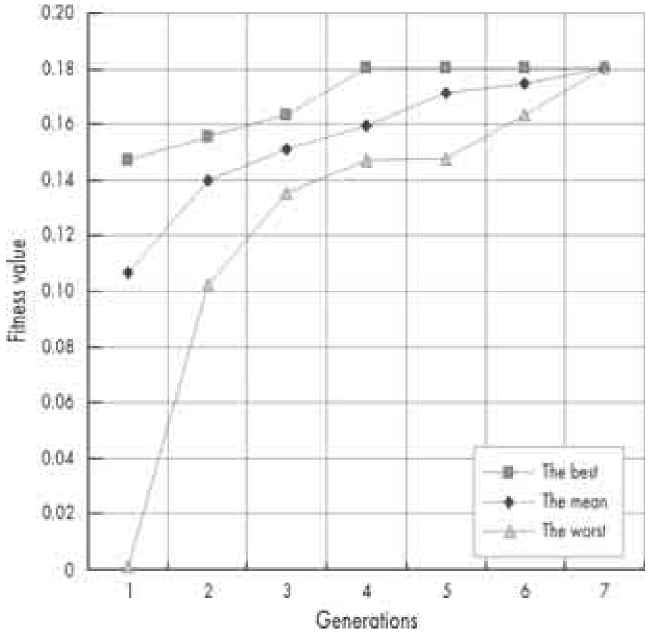


**Figure 6** Changes of the best, mean and worst fitness values

- To continue this genetic process for more generations
- To develop more sophisticated genetic process coping with multiple criteria

We will show the results of the improved method in the near future.

## 4. References

Yoshimura, T., 1997: Development of an expert system planning a forest road based on the risk assessment. Kyoto University, 82 pp, Kyoto.

Iba, H., 1994: The basic genetic algorithms – proving the truth of GA –. Omusha, 254 pp, Tokyo. (in Japanese)

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# Spatial Decision Support System for Laying Out Forest Roads on the Basis of Skidding Distances Modelling

**Ján Tuček, Erich Pacola**

***Abstract***

*Theoretical elements of cartographic tractor skidding distance model, skyline skidding distance model and their implementation on raster digital elevation model (DEM) within Arc/Info environment are presented in this paper. Modules for calculating skidding distances are programmed by Arc Macro Language (AML). Cumulative slope length has been the largest problem in using cartographic tractor skidding distance model. Map algebra tools and hydrological functions are used for calculating cumulative downhill and cumulative uphill slope length. Development diagrams of algorithms are introduced and some examples are discussed in relation to graph theory. Slope distance of line of sight checked in terms of the terrain and intervisibility has been the largest problem in using cartographic skyline skidding distance model. The calculation is based on map algebra tools and surface functions of TIN module of Arc/Info. Figures of cartographic module are introduced and some examples are discussed in relation to model development. Concept of Spatial Decision Support System (SDSS) for laying out forest roads under economic and technological criteria is also introduced. Cartographic models of skidding distances are the most important data sources for it. Powerful tools of map algebra programmed by AML implementing fuzzy logic are used in data processing in menu driven – interface designed environment.*

***Key words:*** *skidding distance, cartographic model, digital terrain model, Arc/Info, spatial decision support system, fuzzy logic*

## 1. Introduction

The primary issue related to laying out forest roads in Slovakia is not to develop a road network in previously inaccessible areas. On the contrary, transport planning in these conditions is focused on (1) laying new hauling roads on the existing forest road network in areas are not fully opened, (2) the reconstruction of selected skidding roads and some secondary hauling roads to main hauling roads and (3) the sanitation of skidding roads, which are not perspective in view of their rebuilding and using skyline technologies. Transportation planning is focused, in these cases, on judging the efficiency of the existing forest network. One of the basic criteria for making this judgement is the skidding distance.

In previous studies (Tuček 1994, Tuček 1995, Tuček and Pacola 1999) we focused our interest on the evaluation of skidding distance using DEM. The proposed skidding distance models created to be linked with IDRISI geographic information system were not automating and optimizing models for forest opening up. A program was lacking which could rapidly develop and evaluate route location based on digital elevation model.

In this study we have focused on removal models limitation described in Tuček and Pacola 1999. At the same time, we developed the theory of cartographing skidding distance model building, according to the following theory described by Tomlin (1990).

## 2. Method

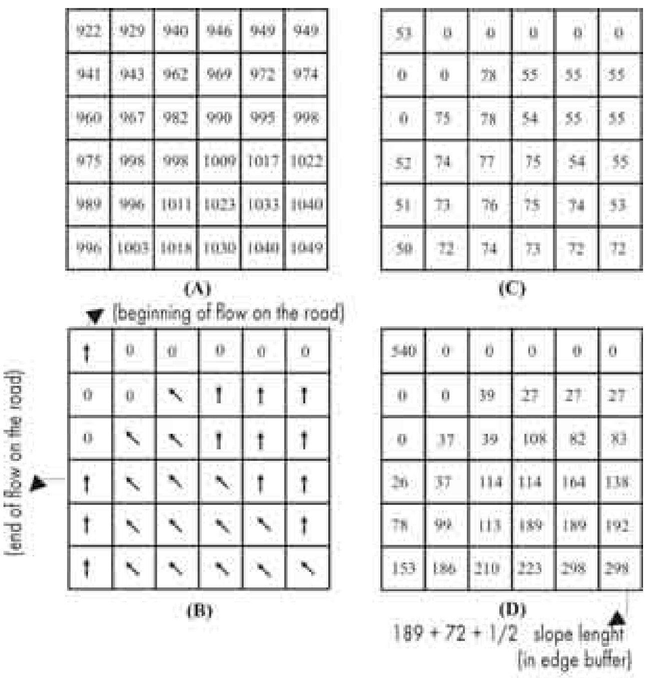
The described modules were developed for the environment ESRI'S UNIX based on ArcInfo. Powerful tools of map algebra, tools for surface modeling and Arc Macro Language (AML) were used in the process of building the specific models.

The analytical process can be simply presented as follows. The source of information for building DEM was a forest topographic map 1:10000 in scale with contour 20-m intervals. Contours and geographic objects (compartment boundaries, roads, stream network) were on-screen digitised in the environment of ArcView 3.0a. DEM used for calculating tractor skidding distances was built by applying an interpolation method for developing hydrologically correct DEM (Hutchinson 1989). This method is integrated in the ARC module called Topogrid (see Esri 1996) We used this method because of similarity of analytical processes for deriving hydrological phenomena and processes of tractor skidding distance modeling.

In the process of skyline skidding distance calculation we used LATTICE data structure together with GRID structure. Using the lattice data structure, tools for performing complicated operations of line-of-sight analysis could be applied.

## 3. Cartographic model of tractor skidding distances

The cartographic model of tractor skidding distances can be envisioned as a map of distances measured from each cell of the raster digital elevation model in the direction of maximum uphill slope to the nearest road or wood yard (Tuček and Pacola 1999). The cartographic model is the result of data processing methods (operations and procedures) developed on a series of maps (Figure 1). Each of these layers describes specific information pertaining to a common site (digital elevation model – flow downhill direction – slope length for individual cells – cumulative downhill slope length). The analogy between downhill water movement and downhill skidding under rough terrain conditions can be seen from the flowchart illustrating the method for model calculation (Figure 2).




(A) Grid representing DEM (resolution 50 m); (B) Flow direction = direction of maximum downhill slope; (C) Slope lenght calculated from maximum downhill angle; (D) Cumulative uphill slope lenght.

**Figure 1** Cartographic model of tractor skidding distances

Suddart and Herrick (1964), Greulich (1980) specified correctly the mathematical model of average yarding distance (*AYD*). The formula for setting the area »*A*« is:

$$AYD = \frac{1}{A}\int_A f(x)\mathrm{d}A$$

where »x« is the length of the direct yard from the point in the setting to the landing. *AYD* in their formula is defined as the ratio between the integral summation of distance function f($x$) and considered total area. Just as the integral of the mathematical function can be regarded as a measure of the area under function's curve between the points on its independent axis, each value generated by cartographic model (uphill spreading in DEM layer) can be regarded as a measure of the area under DEM surface along a minimum-cost path. The developed cartographic model of skidding distances results from the following assumptions:

1) Average skidding distance can be accurately computed for the areas of irregular shape. Accuracy of this calculation depends only on raster resolution,
2) Terrain features (steep slopes, streams and ridges) are taken into consideration and their influence on resulting skidding distance depends on DEM accuracy,
3) Landing can be located anywhere and fixed tractor skidding distance (distance traveled by skidder from the landing over the skidding roads to reach the compartment boundary) is calculated on indirect path following skidding road direction.

Model of tractor skidding distances is a network model. In the graph theory, network is called a graph. In our example, a graph is defined as a systematically formulated collection of nodes located in the center of cells. Links are defined as connections between neighboring nodes only. Therefore, a node can have eight links at the most with its neighboring nodes. Typical feature of these links is their orientation on the graph, which defines the direction of the maximum slope downhill gradient. Every node has been assigned its non-cumulative slope distance

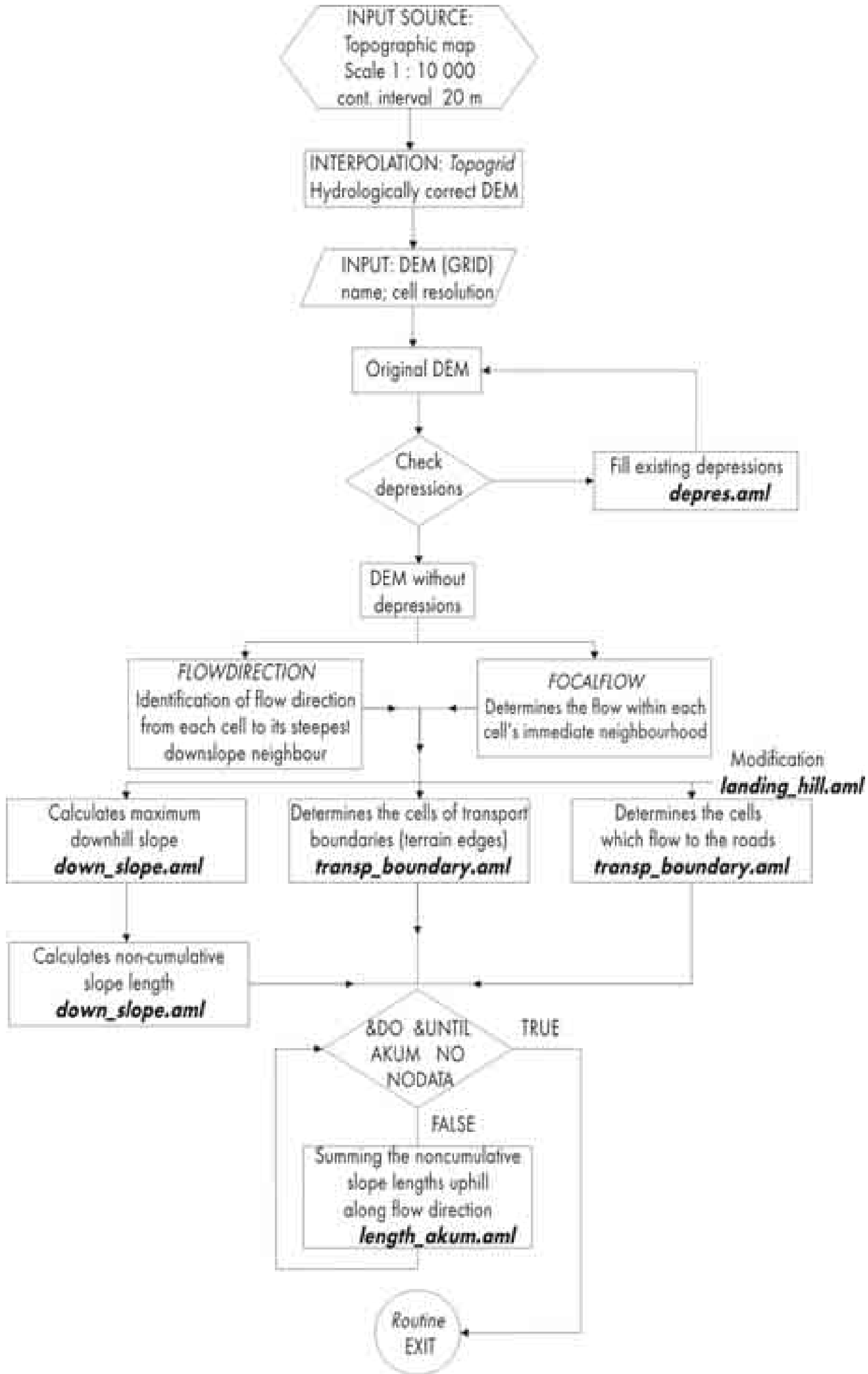



**Figure 2** Flowchart illustrating the method for calculating the value of tractor skidding distances from a DEM

from original eight links for which maximum downhill gradient was calculated. In the last step of calculation, individual slope distances are cumulated through links. Rules that control the process of cumulating can be defined as follows:

- summing non-cumulative slope lengths beginning from the cell which flows down to the road, or from the cell which represents the landing,
- summing following the uphill flow direction,
- in areas with converging flows, the shortest cumulative slope length takes precedence,
- summing non-cumulative slope length ends at the cell representing topography line (ridge).

Based on the above mentioned fundamentals, two core programs have been made for solving the subsequent problems:

UP_HILL.AML – the output of this module is the set of tractor skidding distances measured to the nearest road,

LANDING_HILL.AML – calculates the distances measured to the nearest wood landing. The program includes the combination of procedures, which are able to model the actual routes of skidder movement. In this module, a distinction is made between ground distance (the distance the skidder actualy travels from the cell representing forest compartment to the skidding road) and fixed tractor skidding distance (the distance travelled by the skidder from the landing over the skidding roads to reach the compartment boundary). The output distance is a fixed skidding distance summed over ground distances.

## 4. Cartographic model of skyline skidding distances

The cartographic model of skyline skidding distances can be envisioned as a map of distances measured from every cell as a length of the line of sight over the terrain to the nearest road cell (distance between the centre of the processed cell and the centre of the nearest road cell) (Tuček and Pacola 1999). The cartographic model is the result of data processing methods developed on a series of maps and each layer conveys the following information: digital elevation model – aspect grid – cost allocation grid (for each cell defines the zone that achieves the minimum distance in order to reach the cell) – line of sight intervisibility – slope distance of line of sight (Figure 3). Intervisibility between the processed cell and the deviation of the line of sight from gradient curve (aspect of cells are checked under the line of sight) are checked in the process of cartographing modeling which proved to be the main problem.

Skyline skidding distance model is a network model similar to the previous tractor model. However, both models are markedly different in the concept of skidding distance calculation. This new approach shows up the differences between main skidding technologies. Figure 4 shows the basis for calculating skyline skidding distance in Arc/Info environment.

The possibility of laying out skyline skidding paths is as follows:

1) The skyline tower in the cell of road and the tail spar in the cell of forest compartment are defined. If the distance between the above two mentioned cells exceeds the technological length of a cable-way system, laying out of skyline skidding path for the calculated combination of cells will not be possible. The signal value, which shows that the cell has not been reached in skyline logging operations, will be assigned to the cell (Figure 5).
2) If the two analyzed cells can »see each other« (Figure 6) and the angle deviation of the line of sight from the gradient curve (Figure 7) does not exceed the user defined limit, then laying out of skyline skidding path will be possible for the considered combination of cells.
3) Skyline skidding distance will be calculated only for the two cells, which fulfill both mentioned conditions (point 1, 2), but at the same time the calculated distance is the shortest distance from all considered combinations, which permits to lay out the skyline skidding paths from the terrain cell to road cells.
4) If the conditions of intervisibility between two cells mentioned in point two is not fulfilled, a different signal value will be noted to the cell. This value of the signal shows that tree jack must be used in the skyline skidding path.

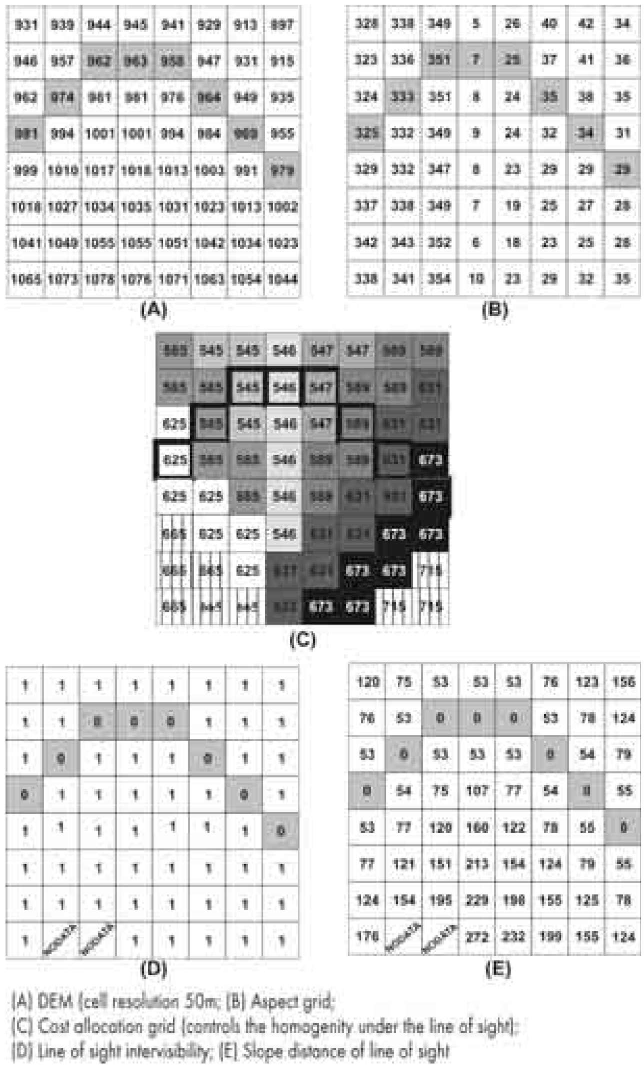



**Figure 3** Cartographic model of skyline skidding distances

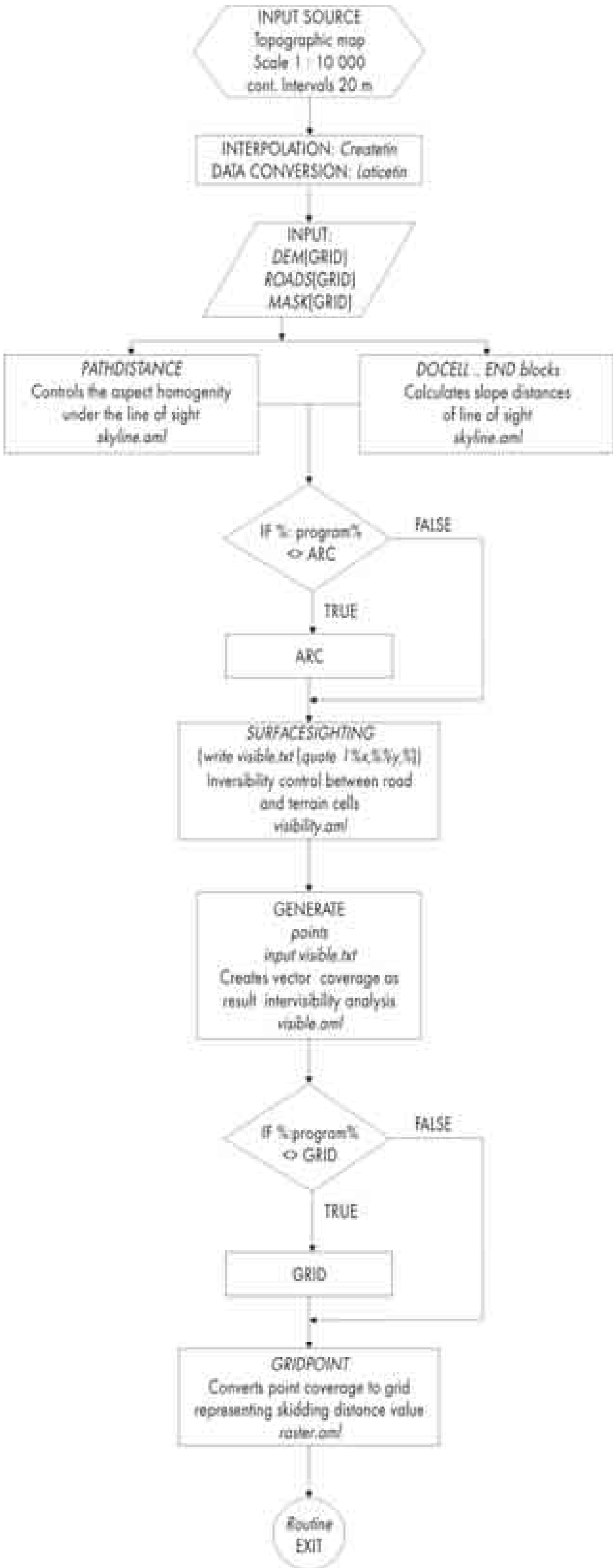



**Figure 4** Flowchart illustrating the method for calculating the value of skyline skidding distance from a DEM

The described approach in the above mentioned four assumptions concur with the reality that skyline skidding paths are laid out in the direction of gradient curve or in the permissible angle from gradient curve (parallel, not fan out routes).

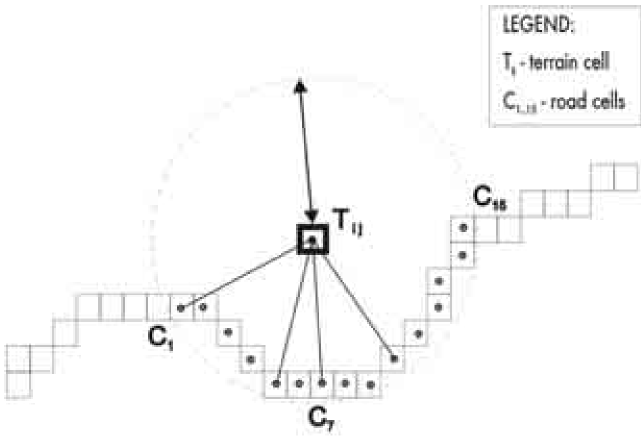



**Figure 5** Looking for road cells which can be reached in skyline skidding

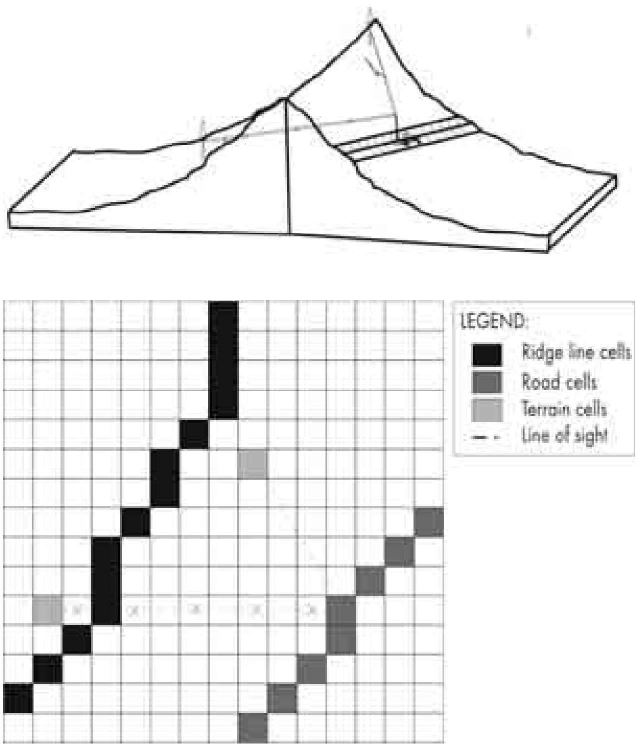



**Figure 6** Line of sight intervisibility

## 5. Conclusions

We have developed a cartographic model of skidding distances for the environment ESRI'S UNIX based on ArcInfo. All problems arisen in skidding distance modeling when using Turbo Basic environment, i. e. limited raster spatial resolution, total evaluated area and length of computer processing time

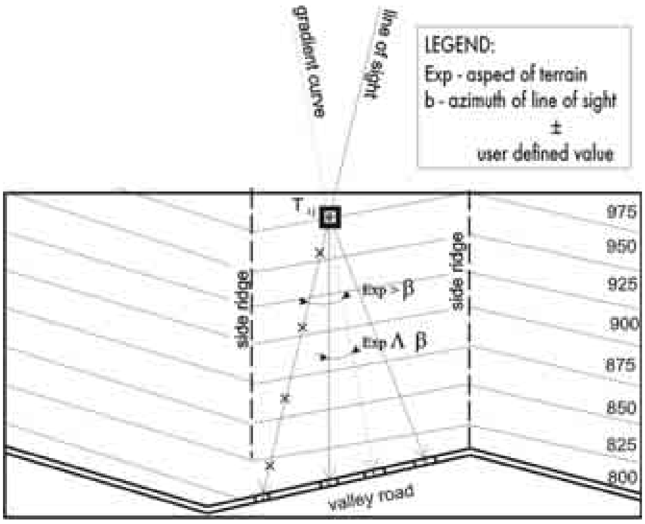



**Figure 7** Checking a skyline skidding path

were eliminated. The results can be directly used by the system, which lays out forest hauling roads automatically according to technological and terrain criteria. All presented models can be a basis for future Spatial Decision Support System designed in order to meet the needs of end users – forest engineers in planning forest road networks.

## 6. References

Anon., 1996: ArcCommands ARC/INFO Ver. 7. ESRI, Inc.

Greulich, F. E., 1980: Average yarding slope and distance on settings of simple geometric shape. Forest Science, 26 (2), 195–202.

Hutchinson, M. F., 1989: A new procedure for gridding elevation and stream line data with automatic removal of spurious pits. Journal of Hydrology 106, 211–232.

Reutebuch, S. E., 1988: ROUTES: A Computer Program for Preliminary Route Location. Pacific Northwest Research Station, General Technical Report PNW-GTR-214, 18 p.

Suddarth, S. K., Herrick, A., 1964: Average skidding distance for theoretical analysis of logging costs. Purdue Univ. Agric. Exp. Stn. Res. Bull. 789, Laffayete, Ind, 6 p.

Tomlin, D. C., 1990: Geographic Information System and Cartographic Modelling. New Jersey, Prentice Hall, Inc, 248 p.

Tuček, J., 1994: Using the GIS enviornment for opening – up of forests. In: International Seminar on Forest Operations under Mountainous Conditions, Harbin, July 24–27, p. 58–65.

Tuček, J., 1995: Computer Aided Forest Roads (localization) and Forest operations Planning. In: XX. IUFRO Congress, S 3.06 Meeting, Tampere, IUFRO XX. World Congress.

Tuček, J., Pacola, E., 1999: Algorithms for Skidding Distance Modelling on a Raster Digital Elevation Model. Journal of Forest Engineering, 10 (1), 67–79.

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# Implementation of new technologies in opening up of forest

**Dragutin Pičman, Tibor Pentek**

***Abstract***

*Forests and forestlands cover about 44 % of the Croatian area. About 78 % of the total forest and forestland area in Croatia are managed by the Public Company »Hrvatske šume« (Croatian Forests), Zagreb, through its 16 Forest Administrations all over the country.*

*It is a very heterogeneous area with regard to soil, its composition, climate, ecological, social, economical and other conditions. In general this region can be divided into Panonic area with even-aged forests, Dinaric area with uneven-aged forests and Mediterranean and Sub-Mediterranean area where we can find both even-aged, and uneven-aged forests.*

*In accordance with this diversity of conditions, forest experts and designers have to face different requirements when opening these forest regions through forest roads. Opening of mountainous forest regions such as the Dinaric area of Gorski kotar, Velebit, Velika Kapela, Mala Kapela, Plješivica, mountains of Central Lika, and single mountain ranges in other parts of Croatia are especially demanding.*

*This paper presents the actual state of openness of the whole country as well as the data on the openness that should be achieved in the future. The survey is given of up-to-date technologies and working methods used for opening forests in the world. The possibility of implementation of these or similar technologies and working methods in the Republic of Croatia as well as of methods developed by Croatian experts are also considered in this paper.*

***Key words:*** *opening up of forests, Croatia*

## 1. Introduction

Forest roads are the entrance into the forest and represent their lifelines. Their openness must be suitable for a rational management of the area regardless of their purpose – economic forests as well as protection forests. In the past, the deficiency or absolute lack of forest roads, especially in the Adriatic region, caused clear cutting and disappearance of forests.

In opening forests through forest roads i.e. in trying to find the best possible solutions, forestry experts have to maintain the balance between economic, technologic and technical, ecological, social and aesthetic requirements. It is very difficult to bring into line the above factors and choose the best option from all points of view. At the same time the optimum forest roads density of a certain area, calculated mathematically, must be taken into consideration, with the use of the model of minimum total expenses.

Nowadays, when the use of personal computers has entered into all segments of our life, it is almost unthinkable to talk about planning the road openness of a certain forest area, about spacing and designing the selected forest roads, without a general support of PC-s. The use of personal computers for forestry purposes, as a very efficient means for designing forest roads, started in 1970's. At the very beginning, PC-s represented just a replacement for the traditional way of preparing the project documentation. Today, however, the use of personal computers has a much wider range and comprehensive and complete projects of forest openness of an area are performed particularly with the implementation of new technologies and methods.

## 2. Scope of research

### 2.1. The openness of forests

The openness of forests can be divided into two levels of opening:

- primary or rough opening of forests through forest roads
- secondary or fine opening of forests through skid trails

In accordance with the above division, there are two types of openness of a forest area and hence two mathematical equations to express this openness; for the calculation of the openness through forest roads the following equation is used:

$$O_C = \frac{d_C}{P} \quad \text{m/ha}$$

and for the openness through skid trails:

$$O_V = \frac{d_V}{P} \quad \text{m/ha}$$

where:

$O_c$ = the openness of the forest area through forest roads, m/ha

$O_v$ = the openness of the forest area through skid trail, m/ha

$d_c$ = the volume of forest roads, m

$d_v$ = the volume of skid trails, m

$P$ = the surface covered by forest roads, ha

The measuring unit for expressing the openness of an area is m/ha or km/1 000 ha, and it is also possible to use m/m$^2$, i.e. km/km$^2$.

**Table 1** The least openness of forests of a certain area of the Republic of Croatia (Šikić *et all.* 1989)

| Forest area of the Republic of Croatia | The least openness, m/ha |
|---|---|
| Lowland region | 7.00 |
| Foothill-highland region | 12.00 |
| Mountain region | 15.00 |

Tables 1 and 2 show the minimum actually specified openness of forest areas and planned future openness of forest areas in the Republic of Croatia.

**Table 2** Planned openness of forests of the Republic of Croatia in certain areas in 2010 (Izvješće o problematici gradnje i održavanja šumskih prometnica i stanju otvorenosti šuma, 1997)

| Forest area of the Republic of Croatia | Planned openness in 2010, m/ha |
|---|---|
| Lowland region | 15 |
| Foothill region | 20 |
| Highland and mountain region | 25 |
| Karst region | 10 |

## 2.2. Systems of forest openness

In view of the terrain configuration in the process of forest opening, we can speak of lowland region, foothill region, foothill-highland region, mountain region and karst region. It is very important to determine properly the region in which the opening of forests is carried out since a typical form of arranging forest road network, adapted to the actual terrain conditions, is generally applied to each of the said regions.

Thus the lowland regions are usually opened through parallel forest roads, equally spaced between each other, which cross the existing openings and enclose the surfaces of very regular forms. In karst regions without distinct ridges and steep slopes, the process of opening is also carried out through closed forest roads but with very irregular forms of the enclosed surfaces.

In foothill-highland and mountain regions with wider and steeper slopes the so-called »story« forest roads are designed almost parallel and placed in accordance with layers. Diagonal roads are built between the »story« roads to connect them. In mountain regions with developed hydrography, the lines of forest roads follow the water flows and have the form of veins or feathery leaves. At the end of the valley, forest roads acquire the form of a fan.

Hence, we can distinguish two main groups of developing forest roads network in opening up the stands in different regions. (Jeličić 1988):

- closed net-like lines,
- veins with side-roads branching from the main road.

## 2.3. Factors affecting opening up of forests

Among many factors affecting the arrangement of forest roads, the effect of those most dominant ones should first be identified, then selected, defined and determined in terms of quantity. Pentek (1998) sets forth that the factors affecting most the regional arrangement of forest roads network can be divided in the following groups:

- factors connected directly to the forest region opened through forest roads network,
- factors of standardized technical characteristics for a specific category of forest,
- factors of forest stands on the opened area,
- factors of the applied method and work technology for felling and cutting,
- factors of technical means used in the II phase of harvesting,
- factors of the existing infrastructure (forest and public roads),

- factors of generally beneficial forest functions,
- ecological factors,
- climate factors,
- social factors

## 3. Results of research

### 3.1. Up-to-date technologies and working methods in opening up forests

The latest information technologies are used today for opening up forest areas in the leading European countries. They are:

- GIS – geographic information system,
- DTM – digital terrain model,
- GPS – global positioning system,
- network analyses,
- special computer programs,
- mathematical algorithms.

In Croatia, some working technologies and methods have been developed in base of the use of the above said ones and others were designed from the very beginning. Here, we talk primarily of the method of the so-called bordered areas (»buffers«) based on GIS-technology, which uses previously created computer GIS databases and prefers the method of relative openness to the traditional one.

The computer program »TROŠAK« (COSTS) has been written in the program language C++. This program can calculate the costs of the construction of forest road, i.e. the costs directly affected by the transversal slope of the ground or the terrain configuration. By entering the basic components of the usual average profile of the forest road, the transversal slope of the ground and working costs, it is possible to obtain very quickly total costs of the works for each segment of the zero line. In the designing phase the zero line represents the forest road. The comparison between total costs of several variations of forest roads can be obtained very quickly and in base of it the best option can be chosen, taking into consideration, of course, other factors.

### 3.2. Possibility of implementation of up-to-date technologies and working methods in the Republic of Croatia

Up-to-date technologies and new working methods can be widely applied in the field of opening forests. They are also applied, directly or indirectly, to the entire process of wood harvesting and even to the complete intensive and at the same time rational management of the forest eco-system. The most important possibilities of application of the modern achievements so far in the Croatian forestry, unfortunately still not accepted, are as follows:

- analysis of the efficiency of the actual forest road network,
- planning and optimization of future forest road network,
- selection of the most favorable option of the future forest road and the computer simulation,
- designing of the actual forest road,
- determining of the mean skidding distance (geometrical and actual),
- preparing several options of the zero line and the selection of the most favorable one,
- completing the land-registry of the existing forest roads,
- designing thematic computer data bases for decision making in opening up of forests,
- numerous other possibilities.

## 4. Final considerations

The possibilities of implementation of up-to-date technologies and methods in the process of forest opening are huge, but limited by technical and technological development of hardware support, software solutions of computer programmers and lack of inventiveness and ideas of forestry experts. The said technologies and working methods should be introduced in the Croatian forestry quickly and comprehensively if it wishes to maintain its role among the leading countries of the European forestry.

Modern technologies and methods offer simpler, better and quicker solutions but in our country the implementation of up-to-date technological and technical achievements in forest opening is limited to scientific research and these and such scientifically developed theoretical models and methods should by all means be introduced in practice.

It is necessary to develop new computer models for opening forests based on properly selected input parameters.

And finally, the following procedures of opening forests can be distinguished:

- traditional opening,
- opening by application of up-to-date technologies (GIS, GPS, DTM, etc.),
- combined opening.

Traditional opening has few promoters in modern forestry. This makes sense due to the general introduction of information technology in all segments of human life including forestry, of course. However, it is not sufficient just to follow the general trend of using computers and information technology and claim that forestry, too, or to be specific planning of forest roads, must take into account up-to-date tendencies.

Justification for using modern technologies in planning the optimum forest road infrastructure lies in considerable number of factors, which have to be synchronized, and to achieve this synchronization, it is necessary to process a large number of relevant information.

Combined planning is the ideal solution as it is based on the interaction of up-to-date technologies and forestry knowledge, competence and experience. It is beyond doubt that the best solutions can be determined only by testing theoretical computer models on site and in practice. Apart from checking the obtained results, it is also necessary to check the input data, as they are the key for selecting the optimum solutions.

## 5. References

Anon., 1997: Izvješće o problematici gradnje i održavanja šumskih i protupožarnih prometnica i stanju otvorenosti šuma, JP »Hrvatske šume«, p. o. Zagreb, 1–11.

Jeličić, V., 1988: Otvaranje šuma i suvremeni transport drveta. Jugoslovenski poljoprivredno-šumarski centar – služba šumske proizvodnje, Beograd, No. 88, 1–61.

Kim, J. Y., Cha, D. S., Kim, C. H., 1992: Planning methods of optimum forest road network using a digital terrain model. Research Reports of the Forestry Research Institute Seoul, 1992, No. 44, 120–132.

Kobayashi, H., 1977: A method of forest road location with an electronic computer. Bulletin, Government Forest Experiment Station, Japan. 1977, No. 294, 137–181.

Košir, B., Krč, J., 1996: Where to Place and Built Forest Roads, Experience from the Model. Seminar on Environmentally Sound Forest Roads and Wood Transport, Sinaia (Romania), 17–22 June 1996, 1–9.

Pentek, T. 1998: Šumske protupožarne ceste kao posebna kategorija šumskih cesta i čimbenici koji utječu na njihov razmještaj u prostoru. Glasnik za šumske pokuse, Šumarski fakultet Sveučilišta u Zagrebu, 93–141.

Pičman, D., Pentek, T., 1996: Čimbenici koji utječu na opravdanost izgradnje mreže šumskih prometnica, Zaštita šuma i pridobivanje drva (knjiga 2), Zagreb, 293–300.

Pičman, D., Pentek, T., 1998: Relativna otvorenost šumskog područja i njena primjena pri izgradnji šumskih protupožarnih prometnica. Šumarski list CXXII (1–2), Zagreb, 19–30.

Pičman, D., Tomaz, I, 1995: Određivanje težišta odjela primjenom osobnih računala u svrhu izračunavanja srednje udaljenosti privlačenja. Šumarski list CXIX, 3, Zagreb, 91–103.

Sakai, T., 1987: Studies on planning methods for forest road networks and decisions on the order of forest road construction. Memoirs of the College of Agriculture, Kyoto University. 1987, No. 130, 39–48.

Setyabudi, A., 1994: Design of an optimum forest road network using GIS and linear programming. ITC Journal. 1994, No. 2, 172–174.

Šikić, D., Babić, B., Topolnik, D., Knežević, I., Božičević, D., Švabe, Ž., Piria, I., Sever, S., 1989: Tehnički uvjeti za gospodarske ceste. Znanstveni savjet za promet JAZU, Zagreb, 1–40.

Tan, J., 1992: Planning a forest road network by a spatial data handling-network routing system. Acta Forestalia Fennica. 1992, No. 227, 1–85.

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# Simple reinforcement of forest roads using recycled construction material

**Adolf Schlaghamersky**

***Abstract***

*In the Federal Republic of Germany, the primary construction of state forest road infrastructure (logging roads) has reached a sufficient level for forest technicians. Several roads are yet to be constructed in the municipal forests and in private forests. Here, building forest roads will always remain a financial problem.*

*The optimal infrastructure construction and fine works remain important factors, as these must meet the new harvesting demands. Guidelines for fine infrastructure construction of forests in Germany differ in each province. In planned forest harvest of trees between 30 and 60 years in age, work using ropes has been replaced by work using cranes. The final harvesters who used logging trucks have introduced a new procedure of tree harvesting, which for the most part preserves both stands and trees. Productivity is much higher than with the older technology. However, certain shortcomings have arisen. For example, heavy equipment burdens the ground, causing compression. In clay-based soils, the soil structure is altered. Large pores are displaced and soil density is increased. As such, the intervals between driving lines plays an important role. A Swedish study (Linquist 1989) states that the driving surface should not exceed 20% of the total stand surfaced. The harvest crane reach totals 8–9 m. From this, the intervals between driving lines is 20–25 m. As such, the space can easily reach the limit of 20%, which in term reduces the important productive area in the stand. Intervals of driving lines should not in any case be less than 20 m. With certain, sensitive soils, a semi-rigid and semi-flexible system of detailed municipal and infrastructural equipping can be a solution for soils that are driven upon. Here certain sections of the driving line and driving paths are heavily burdened and, in times of poor weather, can be muddy and very deformed. These sections require simple reinforcement. Such a procedure may be questionable, as this requires a new investment that was not previously needed. Simple removal (also when referring to sections) is possible in places where the soil underlayers have a poor carrying capacity, i.e. sand, mixed with loam and clay, clay, that contains loam and wet brown soil. Reinforcing the driving lines and roads for transport using penetration brushwood matting is advantageous, under the condition that there is a sufficient quantity of brushwood. Where heavy machinery has passed several time over wet soil, deep tracks are left behind, and this can cause erosion on slopes. These paths can turn into hollow tracks which are very difficult to repair and which then remain closed to further transport. The cost of repairing such roads, which are deformed to a great extent and often filled with water, is then questionable.*

*The use of narrow rolling devices or reinforcing the tracks is recommended for their repair. Some forest offices in Germany and the Czech Republic have tried the procedure of simple reinforcement; this paper presents those results.*

***Key words:*** *infrastructure construction in forests, roads, machinery routes, driving lines, reinforcement using recycled construction material, recycled material, reinforcing tracks*

## 1. Materials

Foresters have long been seeking an answer to the question: How to properly reinforce forest roads? There are three possibilities:

- own pit with road gravel (with unsorted stone material),
- quarry waste, pre-sifted,
- broken construction waste (recycling material).

The latter material has shown to be promising, and has been tested in the Forestry Office in Münster (Schleswig-Holstein province), and in the School Forest of the Office of the Faculty of Forestry in Brno (Czech Republic). Remains of construction material had characteristics described here in detail. In the first two cases, waste from rock crushing activities was suitable (previously sifted and unsorted material from own pits) referring to materials composed of varying grain size. To reinforce tracks, a grain size of 0/56 is used for the bearing layer and 0/22–0/32 for the surface layer. Reinforcement composed of a single layer is also possible, i.e. reinforcement with 0/32 material. With unsorted rock, grain size can be used to 0/150. Previously sifted material is more commonly used now, as this is cheap and very appropriate, though as such, its price is on the rise.

A novelty for reinforcing tracks on forest paths is using recycling materials made up of construction waste materials. The production of construction materials in the procedure of recycling in the newly developed waste treatment plants has opened new possibilities for saving thanks to the use of natural rock, gravel and sand. Recycling materials, made up of construction waste, can complete replace gravel or sand material of varying particle size. Using recycling material preserves the environment, preserves natural resources and prevents the use of transport paths that increase costs. If the transport trail is extended while the quantity of natural construction material is reduced, considering that production areas are far away, the costs of constructing paths is enormously increased. With respect to the municipal and infrastructural equipping, add to this the increasingly comprehensive and expensive regulations by government bodies competent for environmental protection and those competent for landscape protection.

In the production of recycling materials (remaining construction waste), there are two main types:

- mixed of ruins, composed of full bricks, rocks, natural rock, construction concrete, roof tiles, bricks, ceramics, mortar and undesirable pieces of plastic, rubber, glass, cables and wood
- material that arose in digging up streets, composed of cement slabs, construction concrete, layers with rock gravel, layers of cement or stabilizing lime. Most commonly, the asphalt material and casement layers are separated and processes (without tar).

The mixture that is considered based on its price for road reinforcement should be composed of construction waste and can either include foreign objects or not. Construction waste is a mineral material that arises with the destruction of a structure or part of a structure, is not contaminated and is predominantly made up of concrete, rocks and bricks. According to the expert opinion of the Minister for Nature, the Environment and Urbanist Development of the Schleswig–Holstein province (1993), recycling materials may have a small degree of foreign substance pollution. Construction waste, dug-up ground and waste at the construction site must be differentiated according to the content of foreign materials (Ministry Ordinance in Schleswig–Holstein province).

The share of foreign matter depends for the most part on the sorting machine, which is part of the crushing machine. In the crushing procedure, foreign objects should be broken up into the desired particle size, otherwise these foreign objects (parts of cable and plastic) will stick out of the body found on the road and will look unusual.

This foreign matter should, as a rule, make up only 5% of the volume of the mineral construction matter. The foreign matter must not contain any toxic substances. The crushed matter is subject to testing by government authorities competent for nature protection. Crushed construction waste should not contain composite parts larger than 10–15 cm. If the sorting machine that is part of the crushing machine cannot properly separate the crushed matter, then these parts must be manually removed.

## 2. Method

In the Neumünster forest office, 3 test sections each with 3 segments 50 m in length were set up. The base soil in test section 1 (a, b, c) section 21d/22b is Gley-Podsol, which is made up of sand containing water from melting ice, with sand mixtures in the upper soil later brought in by wind and a deep water table. The ground has a high load capacity. Trial section 2 (a, b, c), area I 100: in the main segment, the same base material as in section 1 is present, but with a high water table. This is soil type Gley-Podsol, with very strong water table oscillations. A strong »swampy« base of 50–60 cm on completely compacted soil underlayers has made the old trail impassable.

Test section 3 (a, b, c), section 280/281 in the Bordersholm area. The soil forms a base of moraine with a loam underlayer. This is a deep pseudoglay on loam slopes, above the marly slopes as the base material forming the soil (Barfold 1993). Due to the high loam content, the soil can occasionally absorb large amounts of water, making it impossible to move the water to the sides. The soil surface is, in general, wet.

In this way, three basic areas with differing load capacities were selected for the construction of test sections. The first segments were reinforced for a length of 50 m. The remaining sections were reinforced as skid trails. The test sections on roads with tracks transverse profiles were set up every 5 m and measured in order to compare the differences before and after construction.

## 3. Work procedure

Two road widths (3.5 and 4 m) were built onto each test section. The upper soil layers, without load capacity, had to be pushed to the side into the stand. The depth of the excavation averaged 20–25 cm. The width of the excavation for the road was 4.5 and 5.5 m. Uneven holes were filled with recycling material 0/25 and were compacted using the vibrating roller Dynapack cH 47 (weight 10.0 t). Finally the bearing layer was laid (0/56) and the surface layer laid (0/25) and both layers were compacted. Tracks in the field were conducted without digging with the help of a truck bearing a heavy load. Material was filled into the tracks from the back of an independent truck. Material was distributed with the help of a special road sled (with a wedge plate) by the company Hassler-Krebs. These road sleds are mounted onto a front loader. Thanks to the wedge-shaped plate, the material on the road is evenly distributed into the tracks. In this way, there is no loss of material on either side of the road.

Table 1 (Barfold 1993) shows the loss of material by individual sections. It is clear that the spent material (Table 1) in sections 2 and 3 is higher. These are underground soil sections with a high water content, where once only log embankments were built over marshes) and paths reinforced with bundles of brushwood. The great need for filler material is understandable, given that the upper part of the road is vaulted above the level of the border surfaces.

In the test sections of paths with tracks, prior to construction lateral profiles were built in at an interval of 5 m and measured. Finally, after reinforcement and passage with the vehicle, the tracks were again measured using the Mini-Bruunett forwarder, which has a net weight of 15 t. Changes in the profile were measured after 1, 3, 5, 10 and 20 m$^2$ of driving over the ground.

## 4. Rezultati mjerenja

The load capacity of the underlying soil layers (CBR value) was measured from the right to left axis of the road, on the tracks using the Harrnel (WES) penetration meter. The achieved load capacity (after construction) related to compaction, was established by the company Asphalt-Labor in Wahlstedy on their own trial sections using a trial slab.

If the trial segments are classified by the guidelines for building rural roads, then the skidding paths must be put in the V class (up to 100 trucks with more than 5 t load of cargo per day). The measured CBR value was high at all places. The defor-

**Table 1** Material requirements per trial segment

| Trial segment No. | Road width | Bearing layer (0/56) | Surface layer (0/56) | Fill material (0/56) |
|---|---|---|---|---|
| | m | t | | |
| 1a | *3.5 | 26.0 | 27.8 | 0 |
| 1b | 4.5 | 37.3 | 28.2 | 42.4 |
| 1c | 5.5 | 49.6 | 25.9 | 52.6 |
| 2a | *3.5 | 72.3 | 28.5 | 0 |
| 2b | 4.5 | 47.6 | 28.7 | 45.9 |
| 2c | 5.5 | 52.9 | 39.7 | 102.1 |
| 3a | *3.5 | 34.3 | 15.1 | 0 |
| 3b | 4.5 | 44.7 | 28.4 | 49.8 |
| 3c | 5.5 | 49.0 | 14.8 | 74.0 |

* road with tracks

mation module *Ev*2 at the excavation (on the plane) was between 78 and 148 MN/m², which falls into the recommended levels (Dietz and Kol 1984). The measurement area 0+10, left track, section 3b was an exception with *Ev*2 = 54 MN/m². This area was likely not properly compacted.

Simple reinforcement of trails with tracks shows a deformation module *Ev*2 to be at low values: 27.4, 33.7, 34.4, 44.6 and 32.3 MN/m². However, these values are sufficient for the passage of heavy forestry machinery and for skidding, provided that weather conditions are favourable.

When changes to the lateral profiles on the skidding roads that are not reinforced are considered, after about 10 times of driving over this ground, substantial soil structure changes are observed, and the tracks begin to show the first signs of breaking. After the 20th time, hollows about 20 cm deep appear in the ground, with breaking in the tracks at places. Such strong ground breakage does not appear in reinforced skidding tracks.

Changes to the lateral profiles in the reinforced paths with tracks show the first deformations after the 20th time of driving over the ground. The compaction of the reinforcement increases proportion to the number of times the road is driven on. The following factors impact the skidding road condition:

- total vehicle weight,
- type of soil,
- soil moisture content,
- weather conditions,
- wheel contact surface,
- size of opening,
- manner of vehicle driving and
- tree harvest frequency.

Under the assumption that errors in construction can occur, already constructed trails with tracks were measured. The main road was tested, built in 1991 using the remains of construction materials on sand containing water from ice melting and which is strongly influenced by the water table. No deformations were found in the lateral profile, with a deformation module of 46.9 MN/m². Further measurements with the trial plate were conducted in 1975 on trails with tracks where the upper layer is made up of natural rock. The deformation module was at its lowest, at 34.9 MN/m². **According to this value, trucks cannot drive on this trail without causing great deformation to the reinforcement.**

According to the valid Agricultural Roads Guidelines (RWL – 1975), and the minimum values listed within for the deformation module, trails with

**Table 2** Measurement results with trial plate at two measurement sites on roads with tracks built in different ways

| Trial segment No. | Measurement place m | Value of CBR % | Deformation module *Ev*2 | Coagulation indicator *Ev*1/*Ev*2 |
|---|---|---|---|---|
| 1a | 0+10 m right | 59 | 27.4 | 2.06 |
| | 0+40 m left | 61 | 33.7 | 1.62 |
| 1b | 0+10 m right | 56 | 89.7 | 2.45 |
| | 0+40 m left | 58 | 59.4 | 2.08 |
| 1c | 0+10 m right | 58 | 83.0 | 1.48 |
| | 0+40 m left | 60 | 77.6 | 1.65 |
| 2a | 0+10 m right | 57 | 49.1 | 2.92 |
| | 0+40 m left | 66 | 34.4 | 2.23 |
| 2b | 0+10 m right | 57 | 113.4 | 3.03 |
| | 0+40 m left | 60 | 122.1 | 3.91 |
| 2c | 0+10 m right | 57 | 102.9 | 2.22 |
| | 0+40 m left | 58 | 127.6 | 2.57 |
| 3a | 0+10 m right | 57 | 44.6 | 2.08 |
| | 0+40 m left | 55 | 32.3 | 1.63 |
| 3b | 0+10 m right | 55 | 54.1 | 3.36 |
| | 0+40 m left | 57 | 109.7 | 6.57 |
| 3c | 0+10 m right | 56 | 107.6 | 2.48 |
| | 0+40 m left | 51 | 148.0 | 3.58 |

tracks are not required to have a load capacity to support truck transport. However, all trails with tracks that were constructed earlier with an upper layer of recycling material did not show any significant deformation. After inquiring with neighbouring forest offices which manage similar trails with tracks, it was found that there too there were no deformations from regular transport use. It is assumed that the border limits of the deformation module *Ev*2 have been set too high. The problem of ground deformation during the delivery of construction material for these tracks remains. Additional material is required to fill in the deep tire tracks.

In excavating the lateral profiles of roads with tracks, it was seen that the majority of the material remains and that on the sides a flat bulb-shape is formed, corresponding to proper transfer of wheel pressure on the ground. The elasticity of the reinforcement in the longitudinal direction also has positive significance in the transfer of weight to the upper layer. At the achieved results in the test segments, at intervals of 100 m, the costs of road reinforcement were 20 to 40% lower than the costs of standard procedures. The test sections in the School Forest of the Krtiny Forest Office at the Faculty of Forestry in Brno (Czech Republic), reinforced using leftover construction materials, did not show significant deformation even after six years.

## 5. Conclusions

According to experience, the technical properties of harmless recycling materials with a varying grain size correspond to the loads in forestry transport without deforming the bearing layer and the surface layer. The material is only further compacted with transport. The material with a varying grain size (0/16, 0/25, 0/26) allows for proper compaction due to the high degree of hygroscopity, thereby giving it an excellent load capacity.

In the case of a large amount of precipitation and with a great increase in the water table, when other roads are visibly wet and softened, roads reinforced with leftover construction materials remain dry and solid, even in zones of a high water table. As was seen with the excavation of lateral profiles in road with tracks, the hollow area in the top bearing layer is filled in with crushed construction material that are not rigid (i.e. parts of bricks) and are solidly forced in with a wedge between other solid parts. The share of clay and fine parts are in the area which is free from frost, and no frost damage was observed. The load capacity and the compaction of recycling materials from construction waste were measured with pressure plates. The deformation module *Ev*2 measured for the standard reinforcement (bearing layer and surface layer) satisfied the minimum requirements for load capacity in agricultural road construction. In roads with tracks the module *Ev*2 did not meet the minimum RWL requirements. Despite this, they could carry forestry transport over longer time periods, without any significant maintenance measures (Barfold 1993).

In the Neumünster Forestry Office (Schleswig-Holstein province), the construction of roads with tracks began in 1980, with recycling material exclusively used as a building material. The use of leftover construction materials has resulted in conservation of natural materials.

## 6. References

Anon., 1969: Betriebswerk des Forstamtes Neumünster.

Anon., 1984: Verwendung von »ubelastetum Bauschutt« bei Neubau und Erhaltung von Forstwegen. Erlaß des Ministerium für Emährung, Landwirtschaft und Forsten des Landes Schleswig – Holstein.

Anon., 1976: Richtlinien für den ländlichen Wegebau (RLW 1975). Kommissionverlag Paul Parey, Heft 103.

Barfold, H. H., 1993: Ausbau der Fahrwege mit Hilfe des Wegebauschlittens Typ Krebs/Haßler, unter Verwendung von Recyclingmaterial am beispiel des staatlichen Forsamtes Neumünster. Diplomarbeit Fachhochschule Hildesheim/Holzminden, Fachbereich Forstwirtsch., Göttingen, 1–71.

Dietz, P., Knigge, W., Löffler, H., 1984: Walderschließung. Verlag Paul Parey, Hamburg und Berlin, 1–426.

Hirt, R. 1993: Recycling: Verwendung von Sekundärrohstoffen im Straßenbau. Straße und verkehr 6/93: 1–4, Solothurm, Switzerland.

Höppner, H., 1991: Eignungsnachweis nr. 715/91 von Recycling-Material. Asphalt Labor, Wahlstedt.

Schlaghamersky, A., Barfold, H., 1994: Spurenwegebau und Recycling-Material zur wegebefestigung. Allg. Forst Zeitschrift 24:1332–1334.

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# Forest roads

**Slavko Šunjić**

***Abstract***

*This paper deals with the issues of forest opening by forest roads. The starting point of all activities is the current opening in forest administrations, forest offices and management units. In the last decade the overview of investments into the construction of roads has been changing from satisfying to disturbingly slow. Damages to roads and other infrastructure facilities caused by war, as well as about ten percent of mined forest roads, are a serious obstacle to forest management. Insufficient funds meant inadequate road maintenance or complete lack of road maintenance with adverse economic effects. Large share of external services provided by private contractors also caused problems: poor surveillance of works, non-reliability in providing services within set time limits, neglecting the sensitivity of forest environment, etc. Cutting down expenses in the implementation of the procedure, manner of work and construction, are further problems that result in being slow. Nevertheless, the objectives remain the same or just slightly lower; the intent is to build 0.3 m/ha of roads annually, which means 500 km of new roads, of which 300 km can be reasonably expected. The effects of laws and regulations related to licences for constructing and designing forest roads are still unknown, and especially so after the amendments of the Construction Act and Regulations on Engineering Chambers.*

***Key words:*** *Croatian state forests, forest opening, development of conditions*

## 1. Introduction

The forestry of the Republic of Croatia has a long tradition in designing and building forest roads. Classes such as mechanics and civil engineering were taught at the Faculty of Economy and Forestry as early as 1860 and in 1895, within the subject of forest civil engineering, marking of forest roads and railways was taught as well as designing and building of bridges.

After World War II foresters were among the first to build roads in these areas. A large number of roads, both local and main roads, were built as forest roads.

Today's Project Office Zagreb founded in 1954 employed 18 graduated forestry engineers and it has made projects for 1,500 km of forest roads and 490 km of public roads, from local ones to highways.

## 2. Openness

The openness of forests in our Enterprise at the end of 1998 is 7.27 m/ha, and the total length of forest roads we manage is 14,477 km, which represents more than 50% of public, i.e. state roads.

**Table 1** Openness of forests by forest roads

| Year | Lenght of roads | Openness |
|---|---|---|
| | km | m/ha |
| 1991 | 12 753.70 | 6.45 |
| 1992 | 12 982.80 | 6.57 |
| 1993 | 13 241.90 | 6.70 |
| 1994 | 13 581.10 | 6.87 |
| 1995 | 13 799.90 | 6.94 |
| 1996 | 14 095.80 | 7.08 |
| 1997 | 14 202.91 | 7.13 |
| 1998 | 14 476.69 | 7.27* |

* Openness of forests in 1998 was calculated in base of the total surface of 1,991,528 ha of the forest-economic base of the Croatian territory.

Generally lower openness of forests is caused by low openness of Split Forest Administration i.e. the karst region, which is lower than 3 m/ha.

In the continental part of the country, the openness varies in different regions depending on natural conditions, species and quality of forest stands, level of equipment and way of harvesting as well as on the attitude of some forestry experts toward building forest roads. Certain forest administrations have come close to optimum openness typical for the European industrial countries (Našice, Delnice, Senj). Other forest administrations have a relatively good openness considering the general conditions and state of economy, while the region of Lika, i.e. Gospić Forest Administration, lags far behind.

## 3. Investments in roads

According to the Development Program the annual volume of building forest roads was almost reached in the period 1992–1995 when 7–12% of the total income was set aside for investments, of which more than 40% was used for building forest roads.

**Table 2** Investments in lower layer (*LL*) and upper layer (*UL*) of forest road out of amortization

| Year | *LL* | *UL* | Amount | |
|---|---|---|---|---|
| | km | | $10^3$ DEM | $10^3$ kn |
| 1991 | 173.4 | 173.4 | 6 014 | 22 253 |
| 1992 | 229.1 | 229.1 | 9 835 | 36 390 |
| 1993 | 257.8 | 259.1 | 22 640 | 83 770 |
| 1994 | 149.8 | 220.8 | 11 438 | 42 321 |
| 1995 | 90.3 | 86.2 | 5 552 | 20 544 |
| 1996 | 91.5 | 90.3 | 6 266 | 22 322 |
| 1997 | 43.0 | 94.4 | 5 182 | 18 423 |
| 1998 | 164.9 | 117.3 | 5 788 | 20 953 |
| Total | 1 199.8 | 1 270.6 | 72 717 | 266 976 |

**Table 3** Investments in lower (*LL*) and upper (*UL*) layer of forest roads built as fire protection openings with elements of forest roads

| Year | *LL* | *UL* | Amount | |
|---|---|---|---|---|
| | km | | $10^3$ DEM | $10^3$ kn |
| 1991 | 12.3 | - | 242 | 896 |
| 1992 | 452.4 | 67.3 | 3 974 | 14 705 |
| 1993 | 274.0 | 68.4 | 4 573 | 16 920 |
| 1994 | 375.6 | 120.4 | 7 391 | 27 347 |
| 1995 | 320.1 | 130.7 | 6 482 | 23 986 |
| 1996 | 151.0 | 28.1 | 4 305 | 15 337 |
| 1997 | 64.1 | 63.6 | 2 969 | 10 557 |
| 1998 | 48.2 | 37.8 | 2 131 | 7 716 |
| Total | 1 697.7 | 516.3 | 32 070 | 117 464 |
| Together T.2 + T.3 | 2 897.5 | 1 669.6 | 104 787* | 384 440 |

* Mean exchange rate for DEM was 362.0029 HRK in 1998

Only after the end of war in the Republic of Croatia, the effects of terrible destruction and devastation of infrastructure, equipment, machines and entire forest complexes were felt in the whole country as well as in our Enterprise.

**Table 4** War damages

| No. | Type of good | Direct damage | | |
|---|---|---|---|---|
| | | $10^3$ HRD | $10^3$ DEM | $10^3$ kn |
| 1 | Land | | | |
| 2 | Building facilities | 287 087 | 41 012 | 147 645 |
| 3 | Equipment | 304 308 | 43 473 | 156 501 |
| 4 | Long-standing plants | | | |
| 5 | Forests and game | 933 637 | 133 377 | 480 156 |
| 6 | Cattle | | | |
| 7 | Working capital | | | |
| 8 | Cultural monuments | | | |
| 9 | Other means and goods | 219 612 | 31 373 | 112 943 |
| Total | | 1 744 644 | 249 235 | 897 245 |

Consequently all funds were used for repairing the damages and for providing all kinds of aid for the employees of the Enterprise and people in general.

From 1996–1998 only slightly more than 3% of the total income was set aside for investments in contrast to high 12% in 1993. Building of forest roads was, therefore, reduced in the same ratio. Thus in 1993 approximately 500 km of forest roads were built and in 1997 less than 100 km.

Apart from the World Bank loan for the renewal of coastal forests, also providing the construction of approximately 500 km of fire-protection roads, everything else is build at the sole expense of the Enterprise.

## 4. Maintenance

The same conditions applying to construction possibilities also go for maintenance of forest roads.

Due to inaccessibility caused by occupation and mines, some forest roads have not been maintained for more than 10 years. In some cases entire trees have grown up on the road or on its shoulder. On some roads, drainage ditches, pipelines, bridges, etc. have been completely destroyed. The problem is also that some forest administrations, mostly those not having civil engineering units, have not got machinery for the maintenance of forest roads. Expensive stone and long distance transport also affect the possibility of maintenance.

## 5. Contractors

Our own civil engineering team established in 6 civil engineering operational units carries out the construction of roads. Private contractors are engaged for a smaller part of civil engineering activities, usually those having machines we need.

At the time of intensive construction activities in past years, we carried out 48% of works by ourselves and 52% by engaging third party contractors.

A good relationship and co-operation with private contractors has never been established. They often leave us in spite of the contracted work and go to better paid jobs. This is especially frequent at the time of seasonal agricultural works (transport of turnip, cereals), and with large state civil engineering operations (highways, etc.).

The civil engineering operational units have also been affected by reduced investments so that in the last 6 years not one civil engineering machine has been purchased. The average machine age exceeds 16 years.

## 6. Technology

Different conditions cause different types of forest roads construction. In lowland region, the construction is very expensive due to long distance between stone-pit and building site (mostly more than 100 km).

After having built the basic road network with different types of soil stabilization and drainage, nowadays building is mostly carried out by use of geo-synthetic (geo-textile, geo-net).

In highland region, building is carried out by use of large-size bulldozers for breaking through the marked line, and then graders and rollers for buffers. In mountain region and in karst region, due to larger quantities of stones, building is performed by use of bulldozer and excavator equipped with hydraulic hammer for breaking through the marked line and grader and roller for the buffer.

Mining and explosive devices are almost completely out of use except in some rare cases when it is impossible to break the rock with the pneumatic hammer.

## 7. Objective

Data on the openness and transportation length in »Hrvatske šume« show that we lag behind the industrial countries in such an extent that it will take us years of intensive building to reach their current degree of openness. And these countries still invest a lot in building forest roads.

According to the Development Program of »Hrvatske šume« (1991–2025) building of 0.3 m/ha or approximately 500 km of forest roads is scheduled per year. Thus, in 25 years to come, optimum openness would be reached in some forest administrations.

The tendency is to invest more in poorly opened areas and to improve (pave with asphalt) the basic directions in better opened forests.

As the Program was developed before the war in Croatia and due to its effects, it has to be reduced to rational limits and build at least half of what was projected or 300 km a year.

## 8. Difficulties

After 100 years of designing and building roads and facilities in forestry, the Law on Building of 1 October 1999 specifying that only graduated engineers of architecture and civil engineering can deal with such activities is about to come into effect. To be specific, only they can get the license issued by the Chamber of Engineers.

Graduated engineers of forestry, agronomy, geology, mining, etc. cannot be members of the Chamber of Engineers.

The Law on Building and the Law on Chamber of Engineers were prepared without the participation of the above said experts.

An increasing area of forests is transforrmed into national parks and parks of nature where foresters are not required.

To resume, soon there will be no need for the Faculty of Forestry as an increasing number of biologists, legal experts and doctors work in forests and protect them from foresters. Many of them have hardly ever heard of biocenosis.

Water resources management use more than 64,000 ha of forest areas as retention, where water is directed when there is too much of it in the forest and out of where it is brought when forest requires it. For this »service« we pay DEM 8 million a year.

In most hunting grounds we do not know whom to charge for the damage done by game.

All of this probably happens because we, foresters, do not have our lobby. We could perhaps find it in you.

## 9. References

Anon., 1963: Šumarska nastava u Hrvatskoj 1860 – 1960. Šumarski fakultet, Zagreb.

Anon.,1974: Ceste i mostovi u Hrvatskoj. Zagreb.

Anon., 1999: Poslovno izvješće »Hrvatskih šuma« 1991 – 1998. Zagreb.

Anon., 1993: Program razvoja 1991 – 2025. »Hrvatskih šuma«, Zagreb.

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# Forest roads in Turkish forestry

**H. Hulusi Acar, Selçuk Gümüş**

***Abstract***

*Exploitation of forests requires intensive forestry practice, rational and appropriate for achieving forestry aims. Forest roads enable the transportation of wood, personnel, materials and equipment. On the other hand, they provide traffic facilities and recreation for forest visitors. Thus, forest roads create economical, social and cultural benefits. In Turkey, 17-million m³ of logs are transported on forest roads each year. Furthermore, they play an important role in other forestry activities such as forest protection, forest management, silvicultural activities, protection from erosion and plantation. Forest road construction is more expensive in mountainous areas such as Turkey is. Systematic forest road network planning studies started in 1964 and completed in 1974 by General Directories of Forestry. In these studies, a total of 144,425 km of forest roads have been planned for productive forest areas. These plans, however, had to be revised due to the development of forestry technology, requirements of the national forestry and the actual practice. According to the revision, the total length of planned forest roads amounts to 201,810 km. Up to 1994 a total of 121,503 km of forest roads were constructed, which is 60.21 % of the total road length. The planned forest road density is 20 m/ha. The growing need to control the costs of forest operations motivates forest managers to develop efficient methods for forest road networks planning, so as to minimise the total cost of logging, truck transportation, road construction and maintenance. Due to the difficulty arising from complexity and variability of the forest environment, experienced personnel using non-optimising rules of thumb usually carry out the planning of forest road networks. Geographical Information System was used successfully during forest road planning and organisation of transportation of forest products. Recently, in Turkey the investigation has been carried out in which the geographical information system (GIS) was used for planing forest road routes and determining road structure. But, it has not yet reached an adequate level. Planning of the required forest networks for the whole country should be completed in a short time by the use of the method, which is the subject of these investigations.*

**Key words:** *Turkey, forest roads, GIS, planning, construction and maintenance*

## 1. Introduction

Global forests decrease in area and number daily by human pressure and natural disasters such as forest fire. In Anatolia, forests have been damaged on a large scale, too. Moreover, easily accessed areas have been partially destroyed and only the forests on difficult terrain conditions could keep their natural form.

Forest harvesting and transport operations are essential components of sustainable forestry enterprise. Total annual harvesting of wood from world forests has reached the level of 3,470 million m$^3$. Recent FAO projections suggest that the annual global harvesting will reach 5,100 million m$^3$ by the year 2010 (FAO 1995).

Forest areas in Turkey decrease continuously the same as the world forests. The forest area in Turkey covers 20.7 million hectares and 50.7 % of the total area is productive. Grove forest rate is 66.8 % in productive areas. Turkish grove forest consists of 71.5 % of conifer, 18.7 % of hardwood and 9.8 % of mixed type forests. *Pinus sylverstris, Pinus brutia, Pinus nigra, Picea orientalis, Abies sps*, and *Cedrus libani* are the most frequent trees in conifer forests and *Quercus sp., Fagus orientalis* and *Castanea sativa* are hardwood species.

Turkish government is the owner of almost all forests in Turkey. Turkish forests are run by Government Forest Enterprises. For this reason planning, construction and maintenance of fixed type forest roads is the most important under structure establishment. Turkish Government carries it out along with other forestry operations. All forestry operations are made difficult because forests are generally located on mountainous areas.

Exploitation of forests requires intensive forestry practice, rational and appropriate for achieving forestry aims. For this reason, forest roads are one of the most important necessary tools. They enable the transportation of wood, personnel, materials and equipment. On the other hand, forest roads provide traffic facilities and recreation for forest visitors. Thus, forest roads create economical, social and cultural benefits (Erdas *et al.* 1995).

## 2. Forest roads in Turkey

In Turkey, forestry operations are carried out on a forest area of approximately 20 million ha, located in different parts of the country and under different conditions. Only the best forest road network can provide conditions for working in these wide, scattered and difficult mountainous areas. In Turkey, approximately 17 million $m^3$ logs are transported on forest roads each year. Furthermore, they have an important role in other forestry activities such as forest protection, forest management, silvicultural activities and plantation. Forest road construction is more expensive in the mountainous areas of Turkey.

In Turkey, forest road network plans have been made in accordance with the principle of the bulletin No. 202, published by General Directorate of Forestry. They take into consideration a continuous transportation aimed at meeting forestry transport requirements for all types of forest products and suitable for other forestry services providing connection between main and secondary roads such as valley roads, side roads, ridge roads, logging roads and connection roads (OGM 1984).

Systematic forest road network planning studies started in 1964 and completed in 1974 by General Directories of Forestry in Turkey. In these studies, a total of 144,425 km of forest roads have been planned for productive forest area. These plans, however, had to be revised due to the development of forestry technology, requirements of the national forestry and the actual practice. According to the revision, the total length of planned forest roads amounts to 201,810 km. Up to 1999 a total of 132,693 km of forest roads were constructed, which is 65.75 % of the total road length. The planned forest road density is 20 m/ha.

Considerable improvement has been achieved in forest road construction in our country. On the other hand, this improvement must be discussed technically and economically. As a matter of fact, approximately 250,000 ha (1.25 % of all country forests) of productive forest areas have been lost so far as 125,000 km of constructed forest roads pass trough forest areas and 20 m forest area is required for a 4 m road width. The loss of productive forest areas is an important issue nowadays when such a point is made of afforestation in our country. In this respect, the loss of forest area due to forest road construction, which is indispensable from the point of view of forest management, must be reduced or used rationally.

## 3. Forest roads evaluation from sustainable forestry point of view

### 3.1. Evaluation from the point of view of planning

Planning of forest road network in harmony with nature from ecological point of view is the most important condition because making a mistake in planning phase of forest roads that has fixed structure can not be corrected or is too difficult, too expensive and time consuming. From this point of view maximum attention is needed in the planning phase. On the contrary, planning mistakes that can be made might cause negative results on road route and around its natural environment.

Ecological criteria made of forest natural conditions such as survey structure, soil type, silviculture, protection and animals as well as technical and economical criteria must by all means be taken into consideration when planning forest roads. For example, do not cause loss of forest area by excavation material in road construction, do not construct roads above needs, do not plan construction in sensitive area from the point of view of silviculture, erosion and landslide or take some precautions in planning.

65 % of total road construction can be completed after many years in Turkey. Forest roads can be constructed and than new plans must be developed taking into consideration ecological, technical and forestry conditions instead of plans based only on the requirements of 1960's. From this point of view, old plans must be evaluated and forest road networks must be seriously corrected in the course of time.

Firstly, functional planning will be made by evaluating functional values of forests and according to this forest road networks must be planned during planning phase. Over needed road planning that will cause forest cutting must not be neglected. Possibility of transportation as well as terrain conditions and silvicultural methods that will be used must be taken into considerations. At the same time, planning must be revised so as to cause minimum damage of nature.

### 3.2. Technical development of forest road planning

Nowadays, multiple use and sustainable forestry operations are of utmost importance. Multiple use requires a planning that includes not only log production but other forest function, too.

Forest functions are evaluated under three aspects as production forest, protection forest and national parks from the point of view of forest road network planning in Turkey (Yolasigmaz 1998, Eraslan 1982). New approaches must be acquired in accordance with the evaluation of these functions and different road density for each function that has been investigated while planning the general forest road network.

Forest transportation plans must be take into consideration for the best benefit of forest roads while forest road planning. This condition is essential point of view performing duty from forest roads in production forests.

Forest transportation plans are developed after preparing forest products for transportation in accordance with road network plan, management and silviculture plans, terrain conditions, available machine park, work volume, worker capacity and work output. Plans must include care to avoid damage of transported logs, trees in stands, regeneration, forest soil and work power. It is a model that selects the best transportation form taking into consideration the order, timing and type of extraction from compartment as well as transport with trucks on forest roads.

Geographical Information Systems have become an important tool that has been used frequently in decision making process recently. Geographical Information Systems (GIS) is a system in which graphical and non-graphical data exist and can answer various spatial query.

Initial usage of geographical information systems in forest road network planning studies started at beginning of 1990's. In initial studies, it is aimed at developing product plans as quickly and accurately as possible by means of obtaining values for forest road planning from geographical information systems database. Cut and fill volume estimating, the short pat determining between two fixed points, etc. a lot of analyses could be performed easily and quickly by usage of digital terrain models. But, researches are doing their best to improve this analysis.

Recently geographical information systems have been used for selecting the best forest road routes and determining the necessity for road building in Turkey (Acar and Gümüş 1998a, 1998b). In an investigation, 107,706-m of forest roads have been planned in Trabzon Forest District. Road density, road interval and the rate of forest access were determined respectively 20.40 m/ha, 490.19 m, 93.27%. With these roads, 4,923.27 ha out of 5,278.27 ha of forest area were used for exploitation. A total of 701,151,880 $m^3$ stand volume of forests and 14381.548 $m^3$ of increment was obtained on these forest access areas. In addition, only 58 % of the total area have been determined as the best area for forest road access (Figure 1) (Gümüş 1997).


**Figure 1** The best areas for forest road planning

### 3.3. Evaluating of forest roads from construction and maintenance point of view

Forest roads are the most important infrastructure establishment based on forestry operations. According to Bayoglu, the exclusive use of bulldozers for leveling road construction operations along the road creates big damages in addition to wrong planning of forest roads. This application, causing loss of terrain or damaging forest cover under the road, is increasingly used in mountainous region (Bayoglu 1989).

Approximately 32 m wide soil material and 20 m wide rocky ground of forest area are destroyed by construction of a 4 meter forest road on an average 70 % slope terrain. Thus, 8,000 $m^3$ of soil ground and 3,300 $m^3$ of rocky ground are cut for 1 km of forest road (FAO 1985).

General Forestry Directorate will prepare new rules on application in accordance with the determination of technical improvements taking into account the environmental aspects of present conditions. Concrete and asphalt roads must be constructed only on short distances and the issues of nature destruction and cost must also be taken into consideration.

Both, harmony of nature and technical compliance, must be taken into consideration in water construction planning. If there is any deficiency of water construction in beforehand plans, these must be removed.

Forest roadsides must be suitable for technical equipment and natural structure and if it is necessary, technical supports such as afforestation and strengthening must be supplied. Superstructure and ditch that extend life of roads must be established especially on points where this is necessary.

If it is necessary, we must take benefits from mechanization in road construction. For this reason, excavation + dumper truck combined operation must be applied as practiced in developed country. It is important to use bulldozer only on soft soil. Qualified operators must be employed. If necessary, precautions for reducing damages to environment must be taken. Explosive techniques and material that do not damage environment must be used while passing rocky areas.

Maintenance of forest roads and water construction must not be ignored. Their maintenance must be done periodically at last twice a year firstly before rains at spring and after transportation at autumn.

## 4. Results and suggestions

In Turkey, high portions of forest roads have been constructed but negative phenomena such as insect disaster and landslides, etc. have not been prevented. Terrestrial evaluating is still insufficient even though great attention has been paid to environmental protection in planning stage. Forest road constructions have generally been made somewhat sloppily and hastily and taken into consideration right before production. Water constructions have been built only where momentarily required. Their maintenance has not been good enough.

As a result, available road network plans must be evaluated again from the point of view of functional planning and transport planning and constructions must continue in accordance with the new plan made for the period after 2000. Planning of roads damaging the natural environment and aimed only at achieving production, road construction with bulldozer, passing the rocky areas by dynamite, inadequate water construction and untidy maintenance works must be reorganized by using geographical information systems in planning operations.

## 5. References

Acar, H. H., Gümüş, S., 1998a: Determining of Technical Data and Maps in Forest Road Network Planning by Geographical Information Systems, KU Artvin Forestry Faculty Journal,.

Acar, H. H., Gümüş, S., 1998b: Determination of Forest Road Art Construction Requirement Usage of Geographical Information Systems, V. Esri and Erdas Meetings, 8.s, 11-12 June 1998, ODTU, Ankara.

Bayoglu, S., 1989: An Constructions Technique Do Not Damage On Environment On Mountainous Terrain, Forest Engineering Journal, Year: 26, No :12, 6-9p., Ankara.

Eraslan, I., 1982: Forest Management, Istanbul University Pub., Istanbul.

Erdas, O., Acar, H. H., Tunay, M., ve Karaman, A., 1995: Problems and Its Suggestion of Solution Interested in Forest Ergonomy and Production, Forest Roads, Transportation of Forest Products, Forestry Mechanisation and Cadastral, Turkey Forestry Report, KTU Forestry Faculty Pub. No:48, Trabzon.

FAO 1995, State of the World's Forests, Forestry Department, FAO, Rome.

FAO, 1985: Logging and Transport in Steep Terrain, Forestry Paper 14 Rev. 1, ISBN 92-5-102218-6, 333p., Rome.

Gümüş, S., 1997: Investigations on Usage of Geographical Information Systems on Selecting of Forest Road Routes, Master Thesis, 131 p., Trabzon.

Kose, S., Baskent E. Z., 1993: Importance of Geographical Information Systems in Our Forestry, Forest Ministry Vol. 3, p. 195 – 204, Pub. No: 006, 1-5 November, Ankara.

OGM, 1984: 202 Numbered Bulletin, Forest Road Planning and Execution Of Construction Works, Ankara.

Yolasigmaz, H. A., 1998: Preparing of Forest Function Maps Whit Geographical Information Systems, K.T.U. Master Thesis, Trabzon.

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# The effects of forest roads and harvesting operations on natural environment

**H. Hulusi Acar**

***Abstract***

*The damage of the environment caused by forest road constructions and forest harvesting operations has been put on the agenda together with the increase of insect damages, hazard of seed stands, annihilation of natural regeneration on down-slope roads and decrease of forest area.*

*In the developed countries, this issue has been given the necessary importance along with the environmental approach. The technical development including road construction with excavator and dumber-trucks, decreasing of dynamite damages in the process of passing the rocks, use of modern forest transportation techniques such as skylines and log-lines have been put into practice.*

*The forest roads have not been fully completed in Turkey by 1995 and 40 % of them are still to be finished so as to achieve the minimum production and harvesting in our country. However, these operations must be carried out more carefully so as to protect the natural environment.*

*Functional planning must be prepared first and then ecological, technical and forestry conditions must be taken into consideration for developing forest road network plans. Furthermore, the success of forest engineering and forest operations must be evaluated especially with respect to environmental effects. Furthermore, it is necessary to work with high-quality personnel and to use modern tools and devices to construct roads without causing the environmental damages.*

***Key words:*** *forest roads, forest harvesting, forest operations, natural environment, environmental damages*

## 1. Introduction

Natural environment has been continuously damaged for quite a long time by forest harvesting operations and forest road constructions. This issue was considered together with the increasing insect damage, hazard of seed stand, annihilation of natural regeneration on down-slope roads and decreasing of forest area after forest road constructions.

In the developed countries, these environmental protection issues have been given the necessary importance. The environmental experts have developed road construction with excavators and dumber-trucks, decreasing dynamite damages in mining the rocks. Forest harvesting has also been up-graded by use of modern forest transportation techniques such as skylines, log-lines, monorails, harvesters and walking machines in view of environmental protection.

Sixty percent of forest roads in Turkey have been completed but according to Acar and Şentürk (1993), an important part of forest roads still remains to be constructed so as to achieve a minimum production and harvesting level in forest areas in Turkey each year. These operations and investigations must be considered more carefully in order to protect the natural environment.

Forest roads are the most important foundation for sustainable forestry operations. At the same time, forest roads are the first step in providing forest fire-protection in the shortest time and consequently they play an important role in the environmental protection.

## 2. Forest roads and environmental protection

Apart from damages caused by forest road planning, environmental damages appear on seed stands, natural regeneration areas, rocky-mountains, landslide regions, etc. In the phase of forest road planning, road slopes must be carefully taken into consideration because otherwise environment can be seriously affected.

Moreover, insufficient number of built roads and poor road maintenance has been causing erosion and landslides on forest roads. Therefore, natural conditions are especially important for the selection of the type of road construction.

Rolling down of the remnant material from the forest road after construction causes the most important damage during the construction of forest roads. This is particularly unpleasant in mountainous regions and the damage increases with rocky materials (Bayoğlu 1989). These phenomena affect adversely the nature resulting in the annihilation of natural regeneration, damage of insects and trees, soil compaction and of course the decrease of productive forest areas.

**Figure 1** The slope damages during construction of forest roads

The construction of 1 km of forest road requires the excavation of 8,000 $m^3$ on unrocky areas and 3,000 $m^3$ on rocky areas on a 70% slope and 4 m wide forest road as stated by FAO.

Development of forest road construction has been restricted in Turkey. But, this must be discussed from technical and ecological point of view. Nowadays, the productive forest areas are covered with 125,000 km of forest roads. By the time the construction of all forest roads will have been completed, productive forest area will have decreased by approximately 250,000 ha. This is 1.25 percent of Turkish forest area (Acar 1999-Kütahya). That is why it is very important to minimise the loss of the forest area by rational forest road planning.

The value of the actual forest roads in Turkey is approximately US $ 1 billion milliard. The construction of forest roads is expensive but also necessary for forestry. This is why it is very important to plan the right forest road networks so as to cause minimum damage to environment during construction of forest roads.

Flowing of sand and gravel on forest roads is an important problem for natural soil structure in the stand. They cause finger and carve erosions especially in runny regions of unsuitable slope and inadequate ditch width etc., i.e. unsuitable environment for road construction (Acar 1993).

In the process of road construction, mechanisation has an adverse effect (noise, vibration etc.) on wildlife and chemical residues destroy the soil structure.

Insufficient annual road maintenance jeopardises road structures and causes erosion and landslide at the same time. So far only 15 % of forest road constructions and superstructures has been completed in Turkey. This affects adversely the natural environment.

## 3. Effects of forest harvesting operations on natural environment

In Turkey, approximately 10 million $m^3$ of industrial wood and 15 million $m^3$ of fuel-wood are produced annually. Generally these activities cause damage of the environment.

Forestry production mostly affects regeneration and other trees upon felling. These damages have been causing deaths or loss of quality or infestation by insects.

Forest transportation activities include the extraction within the forest and transport by trucks on forest roads. The extraction stage is more damaging for the environment. Out-of-date forestry techniques such skidding by manpower, controlled or uncontrolled sliding, rolling, etc. have been causing the damages to plants, animals and soil.

Skidding by animals is a better-controlled transport technique. For this reason, the skidding technique causes less damage apart from the erosion on skidding routes.

The wrong route selection during tractor operations is very bad for skidding on the forest road or cable pulling. These damages have been severely affecting regeneration and trees causing soil and water erosion on the route upon harvesting.

Skyline is the least damaging method for the environment but it requires cutting of a large corridor to provide transport by air. This corridor causes considerable loss of the productive forest area. Skidding by skyline causes regeneration damage and erosion on the route.

Other extraction methods such as log-line, rail system, transporting by water, balloon and helicopter are suitable natural techniques and give better results as far as environment is concerned.

## 4. Environmental protection during forest road construction and harvesting operations

Constructions of new forest-roads must continue in accordance with new plans, which take into consideration ecological, technical and forestry conditions. If it is necessary, wrong road network plans must be revised.

It only takes time and care to revise the road plans. It is, however, very difficult and high costing to implement those changes.

Functional values of forests must be determined first and then functional plans must be developed. After that, forest road network plans must be prepared. It must be remembered that unnecessary road planning will cause the loss of productive forest area. The forest road network planning must take into consideration the environmental protection. Consequently they must take into account topographic conditions, silviculture methods, transportation possibilities. The concrete and asphalt roads must be only applied for necessary and short distances, because they are expensive and damaging.

Generally, Lucci and Yoshimura met erosion and material flowing on skidding roads. There are a lot of factors, such as topography, road slope, road age and road maintenance, which can cause erosion on forest roads. This is why, Packer proposed the use of drainage ditches and protection bands.

Plans for superstructure, ditches, road buildings and bridges must take into consideration technical and natural aspects. The road slopes must be in accordance with the nature and constructed soundly, if it is necessary. The maintenance of forest roads and buildings must not be neglected.

Forest road construction must be carried out by use of a combination of excavators and dumpered trucks as practised in developed countries. Dozers must only be used on soft soils. Only highly qualified operators must be engaged. Temporary measures must be taken to decrease the environmental damages during road construction. Explosive materials and exposing methods for mining the rocks must be carefully chosen in order to cause the least possible damage.

The most important environmental damage in forestry takes place on regeneration and trees upon felling. For this reason, as a rule only qualified operators and workers should be engaged. The felling route must be determined so as to cause minimum environmental damage. In addition modern machines must be used, if possible.

**Figure 2** Log-lines method

Nature viable transportation techniques cause minimum environmental damage in harvesting operations. Transport by tractors should be realised on natural tracks. The skylines are the best method for forest transportation, but they require good route selection and transport planning.

Transportation by log-line, rail systems, river system, monorail, helicopter and balloon are high costing methods. But, they give positive results regarding the environment in comparison with the others. Harvesting operations on snow must be supported.

**Figure 3** Extraction by Urus M III

Transport possibilities must be taken into consideration when selecting the silvicultural methods. Machines must support harvesting operations on difficult topographic and regeneration areas.

A transport plan developed by Bayoğlu was aimed at developing rational harvesting methods and decreasing the damages of forest soil and stand.

## 5. Results and recommendations

A lot of damages at differental figures has come into being on natural environment during forest road planning, construction and maintenance with forest harvesting operations. The most important damages has been the losses of forest areas, wounding after insects, erosion and landslipes, felling and skidding damages.

The forest road net plans must be planned with ecological, technical and all other forestry conditions, the forest functional values must be taken into consideration, difficult terrains, and should be carefully evaluated unnecessary forest road net should not be planned.

The forest roads must be constructed with excavator and dumpered truck. Bridge and road building's planning should take into consideration the technical and natural. The maintenances of forest road and buildings must not be neglected.

It must be basic to work with qualified operators and workers during all harvesting operations. They give the possitive results skidding on snow, transporting by rail, log-line or river methods which are natural methods.

As a result, the forest roads are the most important infrastructure for forestry and a piece of country road net at the same time, it is very important that the environment damages occur during the forest road planning, and construction and forest harvesting operations. For this, shortly; it is necessary qualified workers, to work with modern machines and methods using nature during the forest road construction and forest harvesting, to establish the add buildings for minimum environmental damage and especially to evaluate as natural the succsesfull during all forest operations.

## 6. References


Acar, H. H., 1993: The effectives on forest transportation and damages at the forest roads on Macka region after 1999 erosion. Ecology Journal, Year:2, No:7, 14 – 17s., İzmir.

Acar, H. H., 1999: Forest Roads and harvesting operations in forestry, 1 st international symposium on protection of natural environment. Dumlupinar Univ, 23– 25sept. 1999, 8p., Kütahya.

Acar, H., Şentürk, N., 1993: The effects on forest ecosystem forest operations, İ. Ü. Forestry Faculty Journal, Vol 43, Serie B, No.1– 2, 103– 110 p., İstanbul.

Ata, C., 1992: Silviculture, KTÜ O. F. Publications, 101 p., Trabzon.

Bayoğlu, S., 1989: A unharmfull building technique on steep terrain, Forest Eng. Journal, Year: 26, No:12, 6 – 9 p., Ankara.

Bayoğlu, S., 1996: Planning of forest transportation, Ý.Ü. Publ. No:3941/8, 169p., İstanbul.

FAO, 1985: Logging and Transport in Steep Terrain, Forestry Paper 14 Rev. 1, ISBN 92-5-102218-6, 333 p., Rome.

Lucci, S., 1989: Logging on Steep Terrain in Relation to Soil Conservation: A Case Study In Southern Italy, Proceedings of The Seminar On The Impact of Mechanization of Forest Operations to The Soil, 11-15 September, 299 – 310 p., Brussels.

Packer, P. E., Christensen, G. F., 1977: Guides for Controlling Sediment from Secondary Logging Roads, USDA Forest Service, 42 p. USA.

Yoshimura, T., Miyazaki, H., Acar, H. H., 1997: Application of A Tank Model to Forest Road Surface Flow, Proceedings of The XI. World Forestry Congress, 13 – 22 October 1997, p. 204., Antalya.



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# Skidding technologies in Croatian mountainous selection forests – actual situation and possible future development

**Tomislav Poršinsky, Ante P. B. Krpan, Marijan Šušnjar, Željko Zečić**

***Abstract***

*Due to the impact of slopes and stand conditions of Croatian selection fir-beech forests the choker skidder and cable yarder are the most common means of extraction. This paper analyses the performance of the LKT-80 choker skidder while skidding long fir-tree roundwood in three different situations with or without secondary openness achieved through a network of strip roads and under different slopes. It also gives a survey of results of research on cable yarding beech logs with a mobile tower yarder KSK 16 as a possible alternative to the choker skidder (Variant 4). Daily efficiency, standard times and costs per unit were determined for extraction distances of 300 m for each variant:*

*Variant 1: skidding with the LKT-80 choker skidder in a stand without secondary openness and with a slope gradient of 19–38%: 79.5 $m^3$/day; 6.04 min/$m^3$; 22.5 kn/$m^3$*

*Variant 2: skidding with the LKT-80 choker skidder in a stand with secondary openness and with a strip road slope gradient of max. 36%: 97 $m^3$/day; 4.95 min/$m^3$; 18.3 kn/$m^3$*

*Variant 3: skidding with the LKT-80 choker skidder in a stand with secondary openness and with a strip road slope gradient of max. 25%: 127.7 $m^3$/day; 3.76 min/$m^3$; 14.0 kn/$m^3$*

*Variant 4: cable yarding with the KSK 16 mobile tower yarder in a stand without secondary openness and with a slope gradient of 50–90%: 80.6 $m^3$/day; 5.96 min/$m^3$; 47.3 kn/$m^3$*

*The load volume was the highest in Variant 3 (6.8 $m^3$) and then in Variant 2 (5.2 $m^3$), Variant 1 (4.1 $m^3$) and Variant 4 (2.1 $m^3$). The allowance of 20 % and 24 % of the effective time was applied for the LKT-80 skidder and the KSK-16 cable yarder, respectively.*

***Key words:*** *choker skidder extraction, cable yarding, slope, secondary openness, selection forest*

## 1. Introduction

The complexity of terrain conditions for carrying out forest works determines the accessibility of vehicles and people (Mellgren.1980, Conway 1984, Berg 1992). In timber skidding in the Croatian mountainous selection forests, the most important factors of forest off-road accessibility are slope gradient, surface obstacles and soil bearing strength. Due to high impact of terrain slope gradient on the Croatian selection fir-beech forests, the choker skidder and cable yarder are the only choice for wood extraction.

Today in such severe work conditions, choker skidders prevail and since 1970 they have practically eliminated the use of yarders for operational purposes. Further reasons for the current sporadic use of the yarder in Croatia are primarily its high purchase price, high operating costs in comparison with the skidder and its requirement for highly organized and trained group of operators.

However, the ecological and esthetic elements of up-to-date forest management pave the road for the comeback of cable yarding (Wasterlund 1996, Krpan 1997), as it causes no soil compaction and generally no damage to trees in the stand.

This paper shows some results of investigation of timber skidding by the LKT 80 skidder in the stands of more or less equal slope gradient, with or without secondary openness provided through a network of strip roads of different slope gradient and timber yarding by mobile tower yarder, the Steyr KSK 16, in fir-beech selection forests.

## 2. Methods and sites of investigations

The performance of the skidder and mobile tower yarder was investigated by use of work and time study. The operating time of both means of extraction was split into three operating elements with some constants determined in advance in accordance with the set goal of research. Time consumption of operating elements was recorded by use of repetitive chronometry timing method along with recording the working day. The distances of unloaded and loaded travel were measured by use of tape, slope gradient of the terrain and of strip roads was measured by clinometer and the load data were collected by measuring the diameter and length of each piece of roundwood.

The obtained data were processed by mathematical-statistical methods with the use of personal computers. After having processed and analyzed the data, the results of research were synthesized and they are presented further in the text.

### 2.1. Skidding wood by cable skidder LKT 80

The investigation of skidding long fir roundwood by the LKT 80 cable skidder was conducted in mountainous conditions of fir-beech selection forests in the area of Delnice Forest Office, Delnice Forest Administration. The investigation was carried out in two stands with the slope gradient of maximum 40 %, with terrain obstacles made of stones and stumps, on dry soil and skidding downhill. A chokersetter assisted the tractor driver by pulling out the rope from the winch and attaching and removing logs.

In the first stand (Delnice Management Unit, Compartment 39) the second openness had not been carried out and consequently the tractor drove off-road through the forest (Variant 1). The growing stock of the Compartment was 368 $m^3$/ha, of which the share of fir was 71% and the rest was beech. Harvesting density of selection felling was 92 $m^3$/ha, i.e. 58 trees/ha. The volume of the average mean cubic tree was 1.59 $m^3$ and the average distance between felled trees was 13 m.

In the second stand (Podvodenjak Management Unit, Compartment 21) with secondary openness provided through strip roads built with a density of 90 m/ha, the skidder used them in its operations. Strip roads were split into two slope classes and namely maximum 36 % (Variant 2) and maximum 25 % (Variant 3) in order to investigate the impact of slope gradient on the skidder work efficiency. The growing stock was 396 $m^3$/ha, of which the share of fir was 81 % and the rest was made of beech. Harvesting density of selection felling was 119 $m^3$/ha, i.e. 45 trees/ha, and the volume of the mean cubic tree was 2.64 $m^3$. The average difference between felled trees was 15 m.

### 2.2. Yarding wood by mobile tower yarder – Steyr KSK 16

The investigation of yarding beech wood by the Steyr KSK 16 cable yarder was conducted in the area of Drežnica Forest Office, Ogulin Forest Administration in a strictly beech even aged stand (Compartment 23 of Bitoraj Management Unit). The growing stock of the Compartment was 369 $m^3$/ha and the average breast height diameter of trees was 32 cm. Due to the slope gradient of the stand ranging between 50 and 90 % felling was carried out with the intensity of 59 $m^3$/ha, i.e. 21 trees/ha. The volume of the average mean cubic tree was 2.80 $m^3$ and the distance between felled trees was 22 m.

The driving unit is installed and anchored on the forest road widening constructed above the felling site. The Compartment area is covered with two stands from which eight lines are distributed in a fan-shaped arrangement.

**Figure 1** Cable skidder LKT 80

**Figure 2** Truck Yarder Steyr KSK 16

Felling of trees is performed by use of chain saw and then branches, thinner than 10 cm, are delimbed. Thus reduced treetop is separated from the stem and the stem is sawn in two or three pieces depending on its diameter. In this way the balance iss achieved between the mass of pieces of larger trees and the bearing capacity of the cable yarder.

After finishing the unloaded travel, the carriage of the yarder stops above the loading site, the pulling rope is lowered, it is fetched by the worker who drags it to the load. The load is attached with chokers. When the load is attached it is skidded vertically or at an angle towards the yarder route and then it is partly or completely raised and yarded along the bearing rope to the unloading platform. The load is lowered and released on the unloading platform and the rope is then raised and the new cycle begins. After skidding wood from the unloading platform, additional processing is carried out in the landing and commercial wood is separated from fuelwood. Four workers operate the yarder. Two of them prepare and fasten the load in the felling site, the third one unfastens the load on the unloading platform and the forth one operates the machine. They communicate among themselves and coordinate their work by portable radio receivers.

## 3. Results of investigation

A short survey of average work characteristics of investigated means of extraction is shown in Table 1. Travel speed of loaded yarder carriage is 5.4 km/h and by 47.7 % lower than the travel speed of unloaded carriage (10.33 km/h).

The average speed of unloaded skidder is the function of the skidder travel on off-road slope, i.e. skidder travel on strip roads of different slope gradient. The lowest average travel speed of unloaded skidder (3.26 km/h) was achieved when the vehicle drove on the strip road with the slope gradient of 36 % and the highest (3.52 km/h) was achieved when the vehicle drove on the strip road with the slope gradient of 25 %.

The average travel speed of the loaded skidder is by 9 % to 21 % lower than the average travel speed of unloaded skidder and apart from the above said factors it is also affected by load volume.

The impact of off-road slope and slope of strip roads affected the average load volume (Fig. 3). The lowest skidder load volume (4.1 $m^3$) was realized in the stand without strip roads with the slope gradient of 19 % to 38 % and the highest (6.8 $m^3$) was realized in the stand with secondary openness provided through strip roads with the slope gradient of 25 %.

**Table 1** Some investigation results

| | Yarder KSK 16 | Cable skidder LKT 80 | | |
|---|---|---|---|---|
| | stand without secondary oppeness terrain slope | | strip road density 90 m/ha slope of strip road | |
| | 80 % (50–90 %) | 19–38 % | <36 % | >25 % |
| Some results of extraction investigations | | | | |
| Unloaded travel speed, km/h | 10.33 | 3.42 | 3.26 | 3.52 |
| Loaded travel speed, km/h | 5.40 | 3.07 | 2.57 | 3.20 |
| Felling site work, min/cycle | 4.41 | 6.27 | 5.00 | 6.48 |
| Roadside landing work, min/cycle | 1.20 | 3.35 | 4.08 | 4.74 |
| Allowance, % of effective time | 1.24 | 1.20 | 1.20 | 1.20 |
| Load volume, $m^3$/cycle | 2.1 | 4.1 | 5.2 | 6.8 |
| Pieces per load | 2.7 | 5.0 | 4.1 | 5.5 |
| Mean volume per piece, $m^3$/pcs | 0.79 | 0.82 | 1.27 | 1.24 |
| Piece mean diameter, cm | 34 | 39 | 51 | 50 |
| Length of piece, m | 8.7 | 6.5 | 6.2 | 6.2 |
| Standard time, daily efficiency, and cost of extraction for extraction distance 300 m | | | | |
| Effective time, min/cycle | 10.69 | 20.75 | 21.61 | 21.96 |
| Total cycle time, min/cycle | 13.25 | 24.90 | 25.93 | 26.35 |
| Extraction efficiency, $m^3$/h | 9.5 | 9.9 | 12.0 | 15.5 |
| Standard time, min/$m^3$ | 6.31 | 6.07 | 4.99 | 3.88 |
| Cost per unit, DM/$m^3$ | 13.2 | 5.9 | 4.9 | 3.8 |

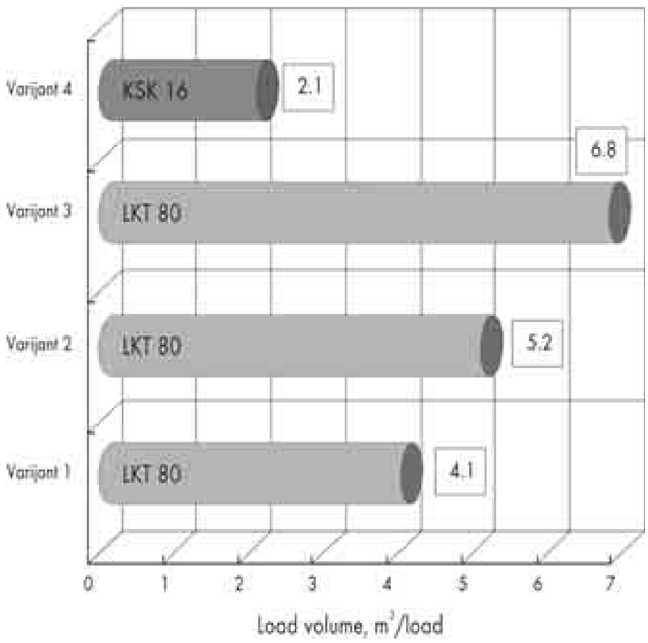


**Figure 3** Load volume

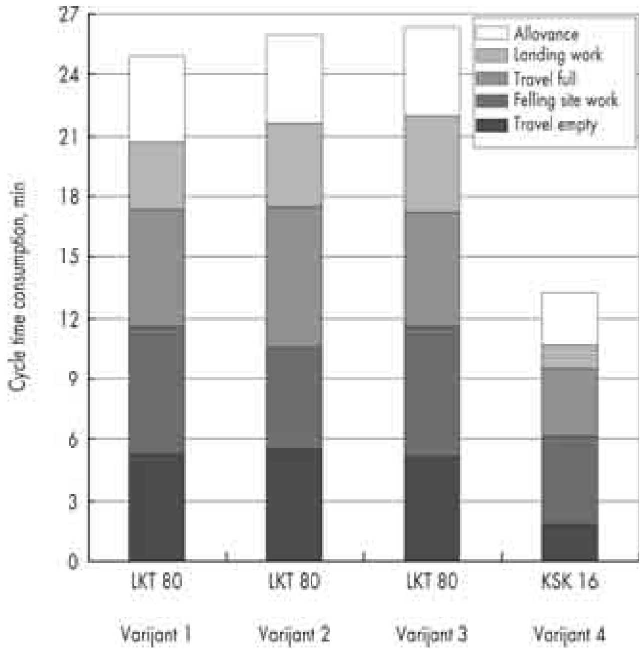


**Figure 4** Cycle time consumption (extraction distance 300 m)

The yarder load volume of 2.1 $m^3$ is the effect of its limited bearing capacity.

Time consumption of the investigated variants of skidder performance in the felling site and landing ranges between 9.08 and 11.22 min/cycle. The yarder requires almost half of that time for this group of working operations.

Allowance of 20 % and 24 % of effective time was established for the LKT 80 skidder Steyr and the KSK 16 yarder, respectively.

The structure of modeled cycle time consumption of the investigated means of extraction, over an extraction distance of 300 m, is shown in Fig. 4.

For the considered research variants of the LKT 80 skidder, over a skidding distance of 300 m, total cycle time consumption ranges between 24.9 min and 26.35 min.

With the same extraction distance, cycle time consumption of the KSK 16 yarder (13.25 min/cycle) is half the time required by the skidder.

The analysis of the data of conducted research variants of the LKT 80 skidder show little difference between time consumption of cycles. The average load volume, however, shows considerable differences depending on whether the felling site was with or without secondary openness provided through a network of strip roads and depending on different slope gradients of strip roads.

Slope of 19 to 38 % with no strip roads was the cause of the lowest skidder load volume (4.1 $m^3$/cycle). At the skidding distance of 300 m it resulted in the standard time of 6.07 min/$m^3$, which is very close to the standard time of the investigated yarder (6.31 min/$m^3$).

It can be concluded that the impact of the secondary openness with different slope gradients of terrain and strip roads on the efficiency of the LKT 80 skidder performance can be seen through realized load volumes. The dependence of the KSK 16 yarder efficiency and of a variant of the LKT 80 skidder on extraction distance is shown in Figure 5.

In the stand with secondary openness provided through strip roads with the density of 90 m/ha, at the extraction distance of 300 m, the efficiency of the LKT 80 skidder is by 5.6 $m^3$/h higher when timber is skidded on the strip road with the slope gradient of max. 25 % than on the strip road with the slope gradient of max. 36 %.

When comparing the efficiency of the LKT 80 skidder and the KSK 16 yarder operating in the stands without strip roads, at the same extraction distance, a slight difference in efficiency (0.4 $m^3$/h) can be observed in favor of the skidder.

The planing calculation of direct costs developed by the public enterprise »Hrvatske šume« was applied for establishing the extraction costs of investigated means of work. According to the said calculation, the cost of work of the LKT 80 skidder operated by an additional worker (chokersetter) amount to DEM 60.3 per hour and the costs of work of the KSK 16 yarder operated by four workers amount to DEM 123.8 per hour.

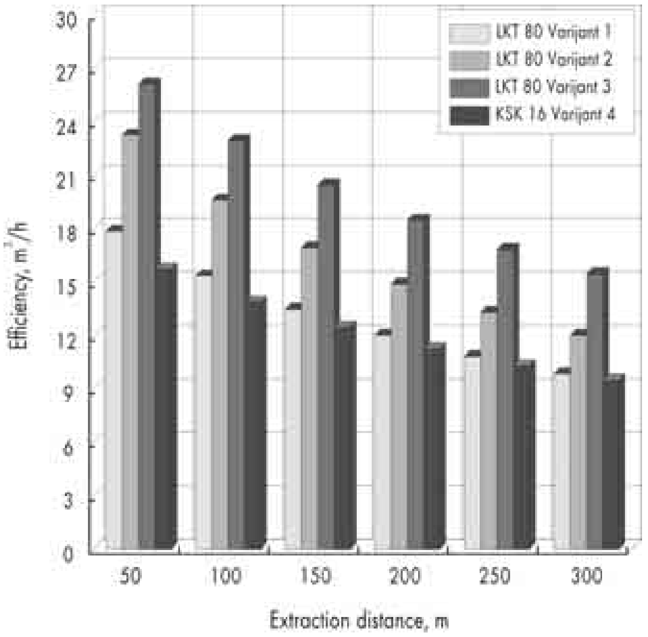


**Figure 5** Dependence of efficiency on extraction distance

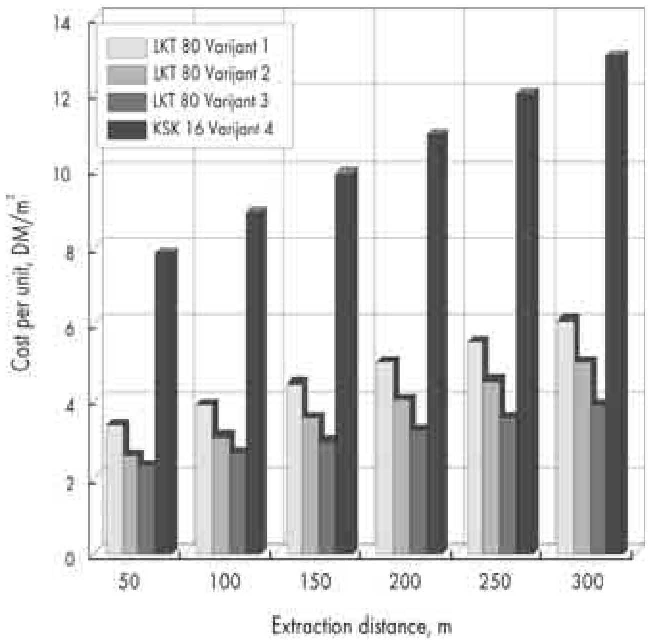


**Figure 6** Dependence of the unit cost on extraction distance

Based on work efficiency (Fig. 5) and planing calculations for skidders and yarders, the extraction costs for all investigated variants were calculated (Fig. 6).

The difference in the efficiency of the investigated variants of skidder performance affected the extraction costs. It should be noted that in the comparison of skidder performance (Variants 2 and 3) direct costs of timber skidding are shown (Fig. 5), without the costs of stand recovery after completing the works and the costs of strip roads construction. According to past experience (Grammel 1988) aggregate costs of extraction carried out by use of skidder and yarder are more or less the same.

Furthermore, the construction of secondary forest roads should not be considered as a one-time cost at the moment of harvesting the felling unit. It should rather be considered as the medium-term investment in view of selection management of these forests and 10-year rotation cuts.

General awareness of higher costs of the yarder in relation to skidder has been confirmed by this research. In spite of almost the same efficiency of the yarder and skidder in the felling unit without secondary openness (Variant 1), the cost of skidding is lower by 55 % than the cost of yarding. The reason for double operating costs lies in the high purchase price of the yarder as well as in the cost of four-member group of workers required for operating the yarder, which makes 53 % of total operating costs.

## 4. Conclusions

This paper presents the results of investigation of the performance of the LKT 80 skidder and the Steyr KSK 16 mobile tower yarder in the Croatian mountainous forests.

Comparison has been made between the skidder performance in felling sites with secondary openness (88 m/ha density) and in felling sites without secondary openness. Strip roads have been split into two slope classes (max. 25 % and max. 36 %). Comparison has also been made between work efficiency of the mobile tower yarder and skidder in the felling site with no strip roads.

The following harvesting characteristics have been investigated: load volume, average travel speeds, time consumption in the felling site and landing, and allowance.

In skidding fir roundwood the LKT 80 skidder achieved the load volume of 4.1 $m^3$/cycle (in the stand without secondary openness) to 6.8 $m^3$/cycle (in the stand opened through strip roads with the slope of 25 %) and the Steyr KSK 16 yarder achieved the load volume (beech) of 2.1 $m^3$/cycle.

Travel speed of unloaded skidder ranged between 3.26 km/h and 3.52 km/h and with the Steyr KSK 16 yarder the travel speed of unloaded carriage was 10.33 km/h. With loaded skidder, travel speeds ranged between 2.57 km/h and 3.20 km/h, and with loaded yarder carriage the travel speed was 5.4 km/h.

The Steyr KSK 16 yarder required half consumption time for the felling and landing work (5.61 min/cycle) than the skidder. With skidders time consumption for this group of work elements ranged between 9.08 min/cycle and 11.2 min/cycle.

For all operating variants of the LKT 80 skidder the same allowance of 20 % of the effective time has been determined and for the Steyr KSK 16 yarder it is 24 %.

The analysis of skidder work efficiency at the same skidding distance showed that load volume is the most important factor of the difference in efficiency and skidding costs in investigated work variants.

The performance of the Steyr KSK 16 mobile tower yarder and the LKT 80 skidder in the felling site without strip roads shows no particular difference in the efficiency and the costs of yarding are double in comparison with the costs of skidding.

In spite of higher unit costs of yarding, yarders as the means of extraction have their future in Croatia, especially in the stands, where due to slope gradient or some other characteristics, any other system is not possible. Yarding is an environmentally friendly technology of wood harvesting as it causes no soil compaction and generally no damage to trees in the stand.

## 5. References

Baldini, S., Pollini, C., 1998: Interaction between network of services: Forestry and Wood harvesting systems. Proceedings of the Seminar on environmentally sound forest roads and wood transport, 17–22 June 1996, Sinnaia, Romania, FAO Rome, 337–341.

Berg, S., 1992: Terrain Classification System For Forestry Work. Forest Operations Institute »Skogsarbeten«, 1–28.

Bojanin, S., Beber, J., 1990: Ovisnost učinka o terenskim uvjetima kod privlačenja drva traktorom. (Merchantable timber skidding output with tractors depending on terrain conditions.) Mehanizacija šumarstva 15(5–6): 83–86.

Bojanin, S., Krpan, A.P.B., Beber, J., 1988: Komparativno istraživanje privlačenja drva zglobnim traktorima u jelovim prebornim sastojinama sa sekundarnim otvaranjem i bez sekundarnog otvaranja (Comparative research of round timber skidding, by frame steered skidder, in fir selection forests, opened by skid trails, and without skid trails). Mehanizacija šumarstva 13(1–2): 3–13.

Conway, S., 1986: Logging practices, Principles of timber harvesting systems. Miller Freeman Publications, 1–432.

Grammel, R., 1988: Holzernte und Holztransport. Verlag Paul Parey, Hamburg – Berlin, 1–242.

Heinrich, H., 1998: Recent developments on environmentally friendly forest road construction and wood transport in mountainous forests. Proceedings of the Seminar on environmentally sound forest roads and wood transport, 17–22 June 1996, Sinnaia, Romania, FAO Rome, 366–376.

Krpan, A.P.B., 1997: Poredba djelotvornosti žičare STEYR KSK 16 na brdskom terenu i ravnici (Vergleich der Wirksamkeit des Seilkrans STEYR KSK 16 am Steilhang und in der Ebene). Mehanizacija šumarstva 22(2): 83–93.

Mellgren, P.G., 1980: Terrain Classification for Canadian Forestry. Canadian Pulp and Paper Association, 1–13.

Schlaghamersky, A., 1993: Feinerschliessung. Fachhochschule Hildesheim/Holzminden, Fachbereich Forstwirtschaft in Göttingen, 1–146.

Staff, K.A.G., Wiksten, N.A., 1984: Tree harvesting Techniques. Martinus Nijhoff/DR W. Junk Publishers, Dodrechts/Boston/Lancaster, pp. 371.

Trzesniowski, A., 1996: Forest engineering and technology in private forest enterprises. Proceedings FAO/Austria seminar on the economics and management of forest operations for countries in transition to market economies, 27 June – 3 July 1994, Ort/Gmunden, Austria, FAO Rome, 53–67.

Trzesniowski, A., 1998: Wood transport in steep terrain. Proceedings of the Seminar on environmentally sound forest roads and wood transport, 17–22 June 1996, Sinnaia, Romania, FAO Rome, 405–424.

Wasterlund, I., 1996: Environgentle forestry operations – possible or must. Proceedings of the seminar Progresses in Forest Operations, 8 May 1996, Ljubljana, Slowenia, 9–14.

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# Relationship Between Terrain Conditions and Operating Condition of Forest Skidders

**Milan Mikleš, Jozef Suchomel**

***Abstract***

*A model of a probability of operating conditions describes running of the examined unit od special forest vehicle in form of conjucted occurence probabilities of monitored operating factors. These operating factors can be stochastically dependent or independent. Operating factors will divide, in order to the oportunity of the monitoring, on the quantification of the probability model of the forest skidder, in two parts: terrain conditions (micro- and macro-relief of the terrain) and operating conditions (line of operation, load, distance). On this paper are sought oportunities of a relationship between terrain conditions and operating conditions in the defined signification. A field of the application is in a monitoring of operating conditions, planning and organise of the experiment.*

***Key words:*** *skidding, skidders, model of probability*

## 1. Introduction

Probability model of operation conditions describes operation of the examined machine in the form of conjugated occurrence probabilities of particular operation factors. Operation factors can be either stochastic dependent or independent.

While quantifiying the probability model of operation of a skidder the operation factors have been due to the examination possibilities divided into two categories:

– terrain conditions (terrain micro- and macroprofile)
– operation conditions in a narrower sense (operation period, load, distance).

## 2. Probability model of operation conditions

Probability model of operation conditions is to be deduced from the following discussion. Let the operation factors $x_1, x_2,.......x_n$ describing operation conditions be random/arbitrary functions of the argument $l$ and the operation of the machine be the simultaneous realisation of these factors. Then, the effect that »the machine is situated« (works) in the j-th operation conditions is equivalent to the effect where the operation conditions is equivalent to the effect where the operation factors $x_1, x_2,.......x_n$ are from $n$-dimensional space $D_j$. In words formulated relation can be in the form of probability written as:

$$P\text{ (operation conditions are in the state } j) = P\{(x_1, x_2,.......x_n) \subset D_j\} = \iint \ldots \int f(x_1, x_2,.......x_n)\, dx_1, dx_2, \ldots dx_n\ (D_j)$$

In this expression $f(x_1, x_2,.......x_n)$ means the conjugated probability density of the random vector $(x_1, x_2,.....x_n)$.

Becoming acquainted with the description of the probability model of operation conditions of the actual operation (whether in the form of the complete description of the law of probability distributions, or only in the form of its several characteristics), the term »hypothetical unit of operation duration« can be quantified as an alternative of operation conditions of the actual operation for frame durability adjustment and demonstration purposes.

Let us define a hypothetical unit of machine operation duration represented by the »matrix«:

$$l_b \sim \begin{vmatrix} v_1 \ldots\ldots v_2 \ldots\ldots v_j \ldots\ldots v_q \\ x_{11} \ldots\ldots x_{12} \ldots\ldots x_{1j} \ldots\ldots x_{1q} \\ x_{21} \ldots\ldots x_{22} \ldots\ldots x_{2j} \ldots\ldots x_{2q} \\ x_{i1} \ldots\ldots x_{i2} \ldots\ldots x_{ij} \ldots\ldots x_{iq} \\ x_{n1} \ldots\ldots x_{n2} \ldots\ldots x_{nj} \ldots\ldots x_{nq} \end{vmatrix}$$

Matrix is such a sample (made on the basis of the knowledge of appropriate description of the law of their distribution) of the operation factors ($x_{1j}$, $x_{2j}$..... ...$x_{nj}$) and with them corresponding occurrence probabilities $v_j$, $j$ = 1, 2...$q$, that with its utilisation the counted adjustment of technical life $L_{vyp} = \lambda \cdot l_b$ will with the probability approaching one either equal to the technical life of the actual operation under the operation conditions, or for the durability demonstration the extent of damage after the examination duration $L_{sk} = \lambda \cdot l_b$ with the probability approaching one will equal to the extent of damage of the actual operation under the operation conditions and during the same operation period.

## 3. Terrain macroprofile

Terrain macroprofile, particularly represented by its grade, has an influence primarily on the level (it is the »source« of load, mainly its quasi-static central part) of engine, transmissions and undercarriage load, i. e. the load of those parts of the machine that are the sources of energy and that transmit energy from the source to the contact place of the machine wheels with the ground.

The influence of grade on the outer performance of the machine, its skidding power $P_H = F_H \cdot v \ / \ 3.6$ can be conveniently pursued through its tension characteristic.

Under the tension charactersitic it is understood the plotted relation (observed or computed) between the towing power $P_H$ (kW), operation speed $v$ (km/h), hourly fuel consumption $M_P$ (kg/h), specific fuel consumption during skidding $m_H$ (g kW$^{-1}$h$^{-1}$) and gradient $\delta$ of the tractive force $F_H$ (kN) for all speed gears $i$ = 1, 2... $n$, i.e. a group of relations:

$$P_H, v, M_P, m_H, \quad d = f(F_H)$$

Under the tractive force $F_H$ a man understands the component of the resulting tractive force $F$ in the direction of tractor movement (in case of the movement on plain – a horizontal component, in case of descent drive – a component paralell with slope grade).

The complete computed tension characteristic can be constructed if the following characteristics are known:

- the course of skid in relation to the tractive force $F_H$
- revolution characteristic of the engine with regulator, i. e. the relation:

$$P_{er}, M_{ekr}, m_{epr} = f(n) \ P_j = \sup \{ P_{er}(n) \}.$$

- complex transmissions for particular speed gears, effective radius $r_h$ (m) of driving wheels, tractor weight $G$ (kN), mechanical efficiency $\eta_t$, rolling coefficient $f$ and aggregate structure represented by the angle of resulting tractive power inclination from the direction of tractor movement (angle $\beta$).

In tension characteristic it is possible to follow the influence of slope grade and ground type on tension qualities of a tractor.

In can be stated that:

- in a number of works, the coefficient of tyre adhesion utilisation has been proved not to change a lot in a wide range of tyres radial load
- if the course of relation $d = f(\mu)$ or $\mu = f(d)$ of a particular tractor on plain is known and this relation is presumed not to change substantially with the change of driving axial load, the course of tractor skidding during the slope movement can be relatively precisely determined

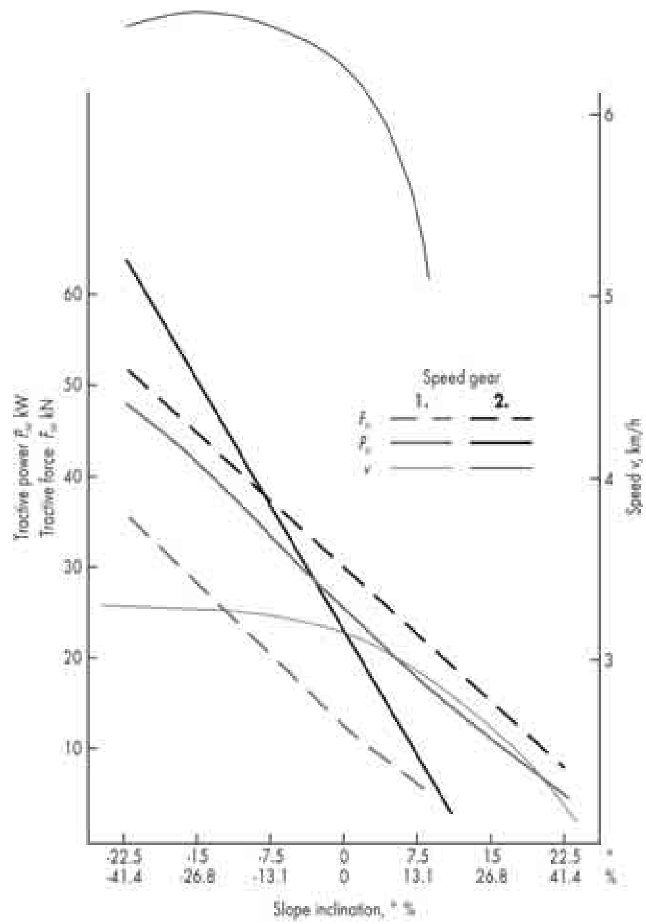


**Figure 1** Dependence of the tractive power $P_H$; tractive power on the hook $F_H$ and speed $v$ on the angle of ground climb (LKT 81, compact topsoil, $\beta$ = 30°, descent drive)

**Table 1** Maximal values of tractive power and responding values of tractive force on the hook and speed depending on the angle of ground climb and the type of ground, LKT 81, descent drive, angle of power in the rope $\beta$ = 30°

| Type of the ground | Speed gear/ Gear ratio | Slope inclination | | Tractive power | Speed | Tractive force |
|---|---|---|---|---|---|---|
| | | $\alpha$ | | $P_H$ | $v$ | $F_H$ |
| | $i$ | ° | % | kW | km/h | kN |
| compact top soil | 1. $i_1$ = 150 | 22.5 | 41.4 | 5.03 | 2.18 | 8.21 |
| | | 15.0 | 26.8 | 11.36 | 2.65 | 15.42 |
| | | 7.5 | 13.1 | 18.11 | 2.91 | 22.42 |
| | | 0 | 0 | 25.69 | 3.19 | 29.01 |
| | | -7.5 | -13.1 | 33.22 | 3.24 | 36.88 |
| | | -15.0 | -26.8 | 40.71 | 3.27 | 44.74 |
| | | -22.5 | -41.4 | 47.99 | 3.29 | 52.46 |
| | 2. $i_2$ = 81.77 | 22.5 | 41.4 | 1) | - | - |
| | | 15.0 | 26.8 | 1) | - | - |
| | | 7.5 | 13.1 | 9.63 | 5.25 | 6.60 |
| | | 0 | 0 | 22.45 | 6.35 | 12.73 |
| | | -7.5 | -13.1 | 36.65 | 6.46 | 20.42 |
| | | -15.0 | -26.8 | 50.93 | 6.57 | 28.28 |
| | | -22.5 | -41.4 | 64.95 | 6.49 | 96.00 |
| concrete asphalt | 1. $i_1$ = 150 | 30.0 | 57.6 | 7.02 | 2.69 | 9.39 |
| | | 22.5 | 41.4 | 13.18 | 3.24 | 14.63 |
| | | 15.0 | 26.8 | 20.50 | 3.29 | 22.41 |
| | | 7.5 | 13.1 | 28.54 | 3.53 | 29.09 |
| | | 0 | 0 | 36.92 | 3.59 | 36.99 |
| | 2. $i_2$ = 81.77 | 30.0 | 57.6 | 1) | - | - |
| | | 22.5 | 41.4 | 1) | - | - |
| | | 15.0 | 26.8 | 8.06 | 5.41 | 5.36 |
| | | 7.5 | 13.1 | 21.43 | 6.27 | 12.30 |
| | | 0 | 0 | 36.73 | 6.75 | 19.59 |
| | 3. $i_3$ = 49.72 | 30.0 | 57.6 | 1) | - | - |
| | | 22.5 | 41.4 | 1) | - | - |
| | | 15.0 | 26.8 | 1) | - | - |
| | | 7.5 | 13.1 | 11.19 | 9.30 | 4.33 |
| | | 0 | 0 | 35.58 | 11.22 | 11.41 |

1) insufficient engine power

- theoretical solutions and practical experiments proved the tension qualities of a tractor on a slope (in the direction of slope grade as well as of contour line) to be determined on the basis of the knowledge of its tension characteristies on a plain with sufficient accuracy
- tractor towing performance on the slope declines ca. 2 to 6 % on one slope grade.

Based from the above-cited, the tension chracteristics of the skidder LKT 81 moving in the direction of the slope grade were conted for standardized conditions. Chosen results of the calculation are in Table 1 and Figure 1.

## 4. Terrain microprofile

Deriving from the facts that:

- from the point of relation betwen terrain and vehicle the microprofile is defined as such a group of ground unevenesses that causes vibrations

– from the deformation aspect the tyre that is of the lowest stiffness is that tyre which is simultaneously / at the same time the member of the part where the largest amount of mechanical energy of terrain vibrations is being changed into thermal energy, the influence of terrain microprofile can be examined as the relation of power losses in a tyre to the dimensions of ground microunevenesses.

A particular machine – skidder LKT 81 is going to be examined. First, some necessary tyre characteristics will be inspected.

Since no load characteristics of the tyre LKT 81 have been measured so far, their parameters will be determined from available catalogue data. Thus, we will utilise the measured geometric characteristics of the tyre 16,9/14–30 of Czech production and catalogue values of the same type of the tyre manufactured by the firm DUNLOP, that are listed in Table 2.

Damping force $T_{tl}$ for viscous damping is given as:

$$T_{tl} = k\mathrm{d}h/\mathrm{d}t = h_o\omega_o\cos\omega_o t$$

Work per a period $L_T$ and power $N$ is to be expressed as:

$$L_p = \int_0^T T_{tl}\,\mathrm{d}h = \int_0^T k\omega_o^2 h_o^2 \cos^2 \omega_o t\mathrm{d}t$$

$$N_1 = L_T/T = \frac{1}{T}\int_0^T k\omega_o^2 h_o^2 \cos^2 \omega_o t\mathrm{d}t$$

where $T = 2\pi/\omega_o$

After integration

$$N_1 = k\omega_o^2 h_o^2 / 2 = K\omega_o h_o^2 / 2$$

The results of the calculation for values $h_0 = 3; 5; 7.62$ cm are written in Table 3. The value $h_0 = 7.62$ cm corresponds wth the state when the wheel rebounces from the soil. For four tyres the total lost power is derived from the relation:

**Table 2** Chosen parameters of the tyre 16.9/14–30

| | Tyre pressure | Tyre diameter | Static tyre radius | Tyre width | Tyre load | Tyre height |
|---|---|---|---|---|---|---|
| Manufacturer | $p_i$ | $d$ | $r_s$ | $b$ | $T$ | $h_b$ |
| | MPa | m | m | m | kN | m |
| BARUM | 0.196 | 1.475 3 | 0.674 2 | 0.416 | 20.643 | 0.326 |
| DUNLOP | 0.196 133 | 1.473 2 | 0.660 4 | 0.429 2 | 24.222 | 0.325 |

$$N_\Sigma = 4 \cdot N_1$$

From the table it can be seen that:

– absolute value of the lost power is in comparison with tractor power small,

– although relative differences between the values of lost power during the movement through various unevenesses are significant,

In the table and the text the following symbols are used:

$d$ – maximal tyre diameter
$r_s$ – static tyre radius (radius at static load)
$b$ – tyre width
$T$ – tyre load
$h_b$ – tyre height (spacing between the rim and the outer perimeter).

These values were counted:

$c = 0{,}3697 \cdot 10^5$ N/m
$K = 5{,}2155 \cdot 10^4$ N/m
$\omega_o = 13{,}2547$ rad/s
$k = 3{,}936 \cdot 10^3$ N s/m

The next step after the examination of the tyre characteristics is to determine the power »lost« in the tyre during the movement on terrain unevensses. For harmonical mass movement on the elastic face for forces oscilation of frequency $\varpi_0$ the relation for the deformation $h$ (compression) is following:

$$h = (t) = h_o\sin\omega_o t$$

where $h_o$ is maximal vibration amplitude.

**Table 3** Values of absorbed power in one ($N_1$) and four ($N_\Sigma$) tyres depending on the height of unevennessi ($h_0$)

| Height of unevennessi | Absorbed power in one tyre | Absorbed power in four tyres |
|---|---|---|
| $h_0$ | $N_1$ | $N_\Sigma$ |
| m | kW | kW |
| 0.03 | 0.311 | 1.244 |
| 0.05 | 0.864 | 3.455 |
| 0.0762 | 2.006 | 8.025 |

their importance recedes in comparison with machine engine power, and thus, also their difference is in that case negligible since there will be no possibility for it to come out.

On the basis of the above – said, it can be, at least from the first sight, stated that the influence of terrain of microprofile on machine power losses is of little importance, practically negligible.

## 5. Conclusions

Probability model of operation conditions describes operation of the examined machine in the form of conjugated occurrence probabilities of particular operation factors. Operation factors can be either stochastic dependent or independent and have been divided into two categories: terrain conditions (terrain micro- and macroprofile) and operation conditions (operation period, load, distance).

Terrain macroprofile represented by its grade, has an influence primarily on the level of engine, transmissions and undercarriage load, i. e. the load of those parts of the machine that are the sources of energy and that transmit energy from the source to the contact place of the machine with the ground.

It is possible to determine tension characteristics of skidder as well as the influence of slope grade and ground type on tension qualities of a tractor on the basis on known skidding characteristics and technical characteristics of skidder.

Terrain microprofile, from the point of relation betwen terrain and vehicle, is defined as a group of ground unevenesses that causes vibrations. The influence of terrain microprofile on power loss on the skidder tyre can be examined based on tyre charcteristics and values of tyre vibrations caused by ground microunevenesses.

The influence of terrain microprofile on machine power losses is in comparison with machine engine power, of little importance, practically negligible.

## 6. References

Mikleš, M., Danko, B., Holík, J., 1999: Teórija mobilných strojov. Tehnická univerzita vo Zvolene, 1–204.

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# Forest skylines in Turkish forestry

**H. Hulusi Acar, Özgür Topalak, Habip Eroğlu**

***Abstract***

*Forest area in Turkey covers 20.2 million hectares, out of which only about 8.5 million hectares are productively managed. These productive forest areas have been retreated to steep terrain. In Turkey, the forest areas are located on high and very steep mountainous lands. This causes complex logging problems. Therefore, mobile skylines have generally proved suitable for use in forest operations on steep terrain.*

*URUS M III mobile skylines, which can be set up for longer distances, were found stronger but also more expensive than Koller K 300. The Gantner forest skylines were found more productive for logging over 600 m but they require more time for setting the line than other skylines.*

*The average output of Urus M III for conifers has been found as 3.724 m³/hour. The average output of Urus M III skyline in logging operations of beech logs has been found as 3.432 m³/hour. As for logging carried out by Koller K 300 yarder, the productivity values for transportation of softwood and hardwood have been determined as 4.997 m³/hour and 4.755 m³/hour, respectively. Average time and productivity for Gantner have been determined to be 4.969 m³/hour.*

*According to the results of this study; it is very important to establish good work organization, to raise the number of working days with machines in a year, to work 8 hours a day on the average after setting the camping organization and provide insurance and adequate equipment for operators.*

**Key words:** *Turkey, steep terrain, forest transport, forest skylines*

## 1. Introduction

The forests, which cover 39.7 percent of the world, consist of 3,604 billion hectares of productive forest areas and 1,696 billion hectares of unproductive forest areas. 38 % and 62 % of the forests are found in developed and developing countries, respectively. Industrial wood production in the world has reached 3,506 billion m³ in 1990. It is estimated that it will reach 5,498 billion m³ in 2010 (DPT 1995).

Turkey's forests cover about 20.2 million hectares, of which about 8.5 million hectares are productive forest areas. These productive forest areas have been retreated to steep terrain.

The necessity of raw wood material in Turkey has been increasing, but on the contrary the forest area has been rapidly decreasing. In forest management, transportation stage involves a rather difficult, expensive and time-consuming activity. Transport of forest yield, from forest to the landing, have been practiced in various forms. Forest transportation with minimum loss in quality and quantity and with minimum damage to itself and the environment is an important issue.

The most difficult and high costing problems are forest road construction, the assurance of the necessary transport machines and technical and economical obstacles to operate these machines. Furthermore, other negative effects are the increasing damage of regeneration and trees during the transport of raw wood material, the erosion during transport, frequent work accidents, the topographic and climatic obstacles and especially frequent interruptions of the work flow.

Harvesting in forestry is a very important and difficult operation and it has greatly benefited from technical development of forest tractors and skylines recently. It is necessary to use technology effectively in forestry transport operations because of increasing work difficulty as well as hard land conditions.

## 2. The transportation types in forestry

In Turkey forest harvesting operations have been realized generally by using human and animal powers. The level of harvesting mechanization in developed countries is higher than in Turkey. In Austria 86 % of harvesting is carried out mechanically and in Turkey only 9% although the forests of the two countries have very much in common (Acar 1998).

Mechanization, as a result of technological development, brings new opportunities to transportation of forest products and forest exploitation. Machines have been used for skidding in forestry of developed countries while animals are not used anymore (Topalak 1998).

Manual gravity skidding on ground is carried out as ground skidding, sliding and dropping. Sometimes, the wood is transported by forest workers.

Animal skidding is carried out simply by skidding with the use of a pulling chain with a hook. The hook of this chain is nailed to the log and other point of the chain is attached to the animal's yoke. Thus, the logs are skidded on the ground.

The method of extracting from compartment by using farm tractors is mostly cable logging. Both forest and farm tractors realize uphill logging. In addition there is skidding on forest roads and logging with trailer.

Forest skylines are quite different from other harvesting techniques. Manual ground skidding is limited regarding the volume. Sliding can be done downhill on sloping areas. Downhill skidding by animal should not be done on steep terrain. Logging downhill can not be realized by tractor and cable distance is shorter than skidding by tractor.

Forest skylines are used to transport the forest products between 300 and 2000-meter distances. According to yarding distances, these are classified as follows:

- short distance (less than 300 m),
- middle distance (between 300–800 m),
- long distance (more than 800 m).

On the other hand, this technical development requires certain economical and productivity conditions. There are also simpler systems such as cableway and plastic log-line.

## 3. Forest skylines in Turkey and discussion

Problems of extraction of forest products from compartment have appeared because of the extreme increase of the necessity for forest production after Second World War. Researches were begun as a result of this development and the necessity for mechanization was increased.

The committee of FAO came to Turkey for a research in 1960. Then, this committee suggested the skylines for Turkey's mountainously areas. Thus, German, Swiss and Austrian Firms had come to Turkey and The Forest Ministry of Turkey had brought the skylines from Baco, Wyssen and Hinteregger firms (Acar 1998).

Extraction from compartment after increasing the forest road network would not give good economical and technical results because of high and steep slopes in mountainous areas. Skylines with mobile winches are more useful for extraction from compartment on high and steep slopes.

Today, Koller K 300 as short distanced forest skyline, Urus M III as middle distanced forest skyline and Gantner as long distanced sledge forest skyline are used on the forest areas of Turkey. Koller K 300 and Urus M III forest skylines transport raw wood material mostly uphill. Gantner forest skyline is used for downhill logging and hanger logging with gravity system.

Koller K 300 generally transports fuel wood from short distance and Urus M III carry out the industrial wood from middle distance in forest. Gantner skyline, which has sledge and transports generally hard wood and partially softwood from long distance. The road constructions for Gantner are more expensive and unnecessary sometimes. These forest skylines can be used consecutively or side by side when necessary.

The results of some investigations on these three skylines for Turkey are the following.

Downhill transport had been done with Koller K 300 for differential ground and slopes on the harvesting areas. The operations had been done on the skyline cable corridors where average ground slopes are among 45–60 % and average line slopes are among 20–25 %. The productivity values were determined as 4.997 $m^3$/hour, 4.755 $m^3$/hour and 6.60 ster/hour (4.620 $m^3$/hour) in transportation of softwood, hardwood and fuel wood, respectively for Koller K 300 yarder (Eroğlu 1997).

The productivity values were determined as 3.724 $m^3$/hour for Urus M III on 60 % slope during the extraction from compartment. Operations were realized by one skyline operator and two forest workers. Average product value was determined as 0.836 $m^3$/shift. Average productivity value was determined as 3.432 $m^3$/hour during the beech transportation from compartment by Urus M III.

Average productivity values were determined as 2.269 $m^3$/shift (4.969 $m^3$/hour) downhill on 80 %

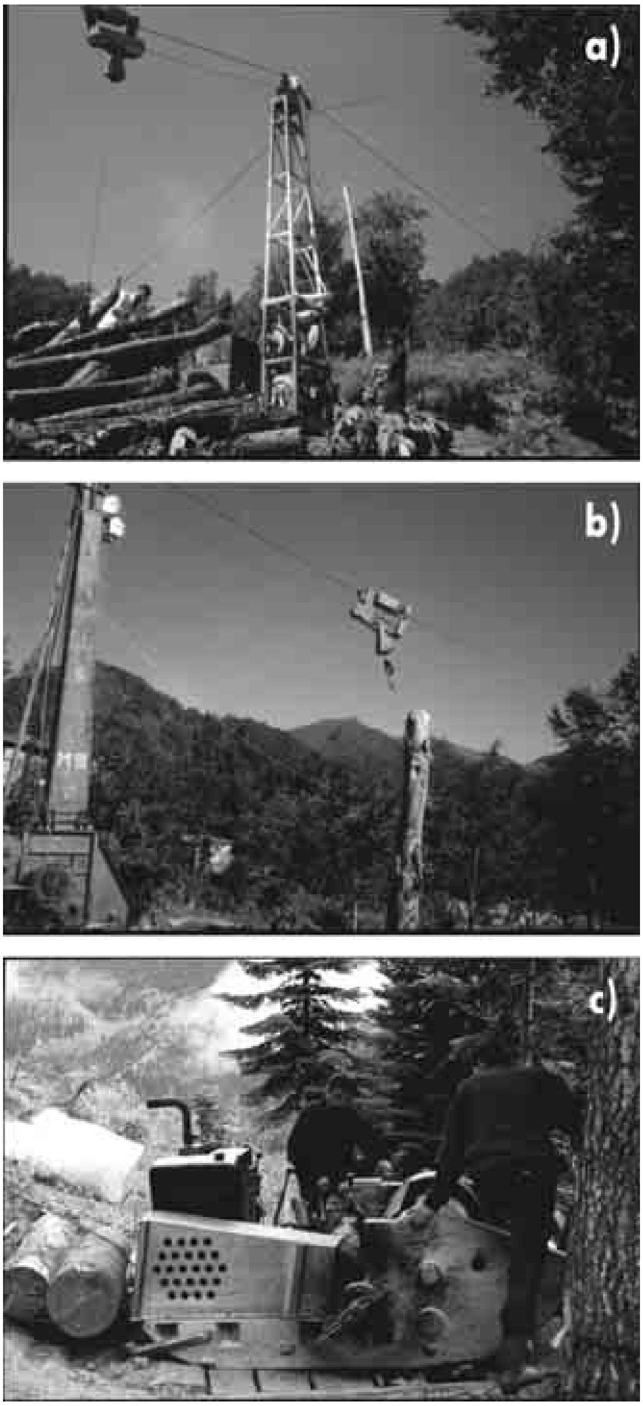


**Figure 1** Forest Skylines Used in Turkey: a) Koller K 300, b) Urus M III, c) Gantner

slope and 1,400 m distance during the transportation operations with Gantner. Five workers made of one skyline operator, one operator assistant, two workers at the loading station and one worker at unloading site realized these works. Cable yarder's skyline was supported by 4 supports between the valley station and mountain station. The distance between two supports was 250–300 m on the average and the support heights ranged between 10 and 40 meters (Acar and Erdas 1992).

Gantner skylines are powerful and productive. It is an important machine for forest transportation at long distances. These machines are used as double or consecutive where the transport distance is long or the road density is low. The cable line must be well selected and must be upon narrow corridor. The skyline must be installed to sufficient height. Carriage and cable line are maintained periodically.

Each of these forest skylines should be discussed for itself. But, Urus M III is more powerful than Koller K 300. Therefore, it was determined that Koller K 300 is more suitable for the transportation of fuel wood and Urus M III for logs.

## 4. Conclusions and recommendations

Forest skylines are necessary for Turkish forestry where steep terrain is typical. But, these machines are used only in some mountainous regions especially Artvin region.

Productivity of forest skylines in Turkey is adequate when they work. But, annual productivity values are low for these machines. Therefore, the work should be carefully planned for skylines before the operations.

Generally, Urus M III mobile skylines can be set up for longer distance. It was found stronger and more expensive than Koller K 300.

The advantage of Gantner forest skyline is that it can be set up for longer distances and requires low road density. But, the setting time for these machines longer.

According to these results, the following suggestions have been prepared:

- Felling plan and felling direction must be determined during the extraction from compartment and work organization must be done firstly and absolutely.
- Before extraction from compartment by skylines, the operations should be finished on the bottom of tree-stump. The skyline must not wait for preparation operations.
- The products in the skyline corridor should be transported firstly. After that, 20 m distance from skyline corridor both on the right and on the left should be transported.
- The number of workers for loading and unloading operations should be increased for achieving productivity of forest skyline. More chokers should be used for the productivity of these machines.

- The machine should be selected very well. The stocked logs on the side of the forest road must not obstruct the machine's work or should be transported by trucks loaded by loaders.
- The staff problem must be solved for these skyline operators using the expensive machines. These operators should repair the skylines in winter months. They should be informed about working technique with the skylines out of harvesting times.
- When purchasing skylines, machines having downhill and uphill transport advantages should be chosen.
- The impact of skylines on sustainable forestry should be established by increasing their ecological and economic investigations.

## 5. References

Acar, H., 1998: Transport Teknigi ve Tesisleri Ders Notlari (Transport Techniques and Foundations), KTU Forest Faculty Publication 56, p. 240.

Acar, H., Erdas, O., 1992: Artvin Yöresinde Uzun Mesafeli Vinçli Hava Hatlari ile Orman Yollari Alternatiflerinin Bölmeden Çikarma Açisindan Kiyaslanmasi (Comparison on the Transport from Compartment of Forest Products by the along Distance Winch Skylines and the Forest Road Alternatives in Artvin Region), TUBITAK Journal of Agriculture and Forestry 16, p. 549–558.

DPT., 1995: VII. Bes Yilik Kalkinma Plani Özel Ihtisas Komisyonu Raporu (VII. The Report of Specialization Commission for the Seventh Plan for Five Years), Ankara.

Eroğlu H., 1997: Artvin Yöresinde Bölmeden Çikarma Çalismalarinda Koller K 300 Kisa Mesafeli Orman Hava Hattinin Teknik ve Ekonomik Yönden Incelenmesi (Technical and Economical Analyses of Short Distance Koller K 300 Yarder for the Studies on Transport of Compartment in Artvin Region), KTU Graduate School of Natural and Applied Sciences, 132 p., Trabzon.

Topalak, Ö., 1998: Torul Orman Isletme Müdürlügü Alacadag Orman Isletme Sefliginde Mekanizasyon Ihtiyacinin Belirlenmesi (Torul Directorate of Forest District, Alacadag Forest District, Definition Level of Mechanization During The Production Operation), KTU Graduate School of Natural and Applied Sciences, p. 118, Trabzon.

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# State, problems and prospects of forest harvesting operations in mountainous conditions in Ukraine

**Anatoliy Sabadir, Sergiy Zibtsev**

***Abstract***

*This paper gives a survey of age and structure of species of Carpathians exploitable forests, volumes of annual cutting, kinds of forest operations, legislative and normative base for forest management in mountain forests, technology and machines used for timber harvesting. The ways of reforming mountain forest management in this region are discussed. Further steps in the development of sustainable use of mountain forests in Ukraine should be considered such as: introduction of economic incentive measures for applying environmentally sound technologies, development of industrial manufacturing of specialised technical equipment for mountain conditions, modification of rules related to the import of forest machines, reduction of sales tax and profits tax for the period of development of advanced technologies, development of the legislation and monitoring system for providing environmental protection during forest operations.*

***Key words:*** *Ukrainian Carpathians, harvesting operations, mountain forest*

## 1. General characteristics of mountain forests in Ukraine

Carpathians is the largest mountain forest region in Ukraine with an important role in the industrial sector. Forestland in the region covers 37 % of the territory, ranging between 40 % and 96 % in different areas. Forests grow at an altitude of 400 m to 1600 m above sea level. The prevailing part of the growing stock is located on 12–35 % slopes.

An important feature of the climatic conditions of the region is the superfluous humidity reaching 600-–2000 mm of deposits per year. A part of these deposits drops out as downpours of high intensity causing soil erosion, landslides and floods. In these conditions the function of water protection of mountain forests has an extremely important role and it is directly dependent on the observance of the environmental protection requirements during forest operations.

The forests of Ukrainian Carpathians have a large economic and social importance at regional, national and international levels. On a rather small area of mountain forests of Ukrainian Carpathians – 17.7 % from the total forest area of Ukraine, about 40 % of technically mature forests are concentrated. Carpathian mountain forests cover an area of 1,392 thousand ha, of which 862.6 thousand ha are exploitable forests (both 1-st and 2-nd groups). The most important mountain forest areas (oblasts) are Zakarpatska and Ivano-Frankivska – 349.3 and 240.4 thousand ha of forests respectively, Lvivska – 180 thousand ha and Tchernovitska oblasts – 92.5 thousand ha. The

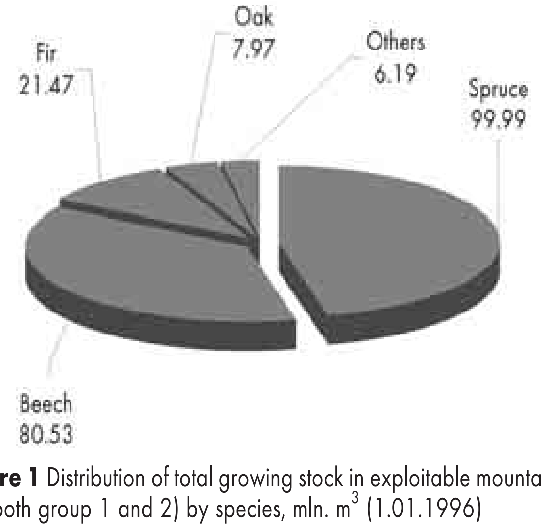


**Figure 1** Distribution of total growing stock in exploitable mountain forest (both group 1 and 2) by species, mln. $m^3$ (1.01.1996)

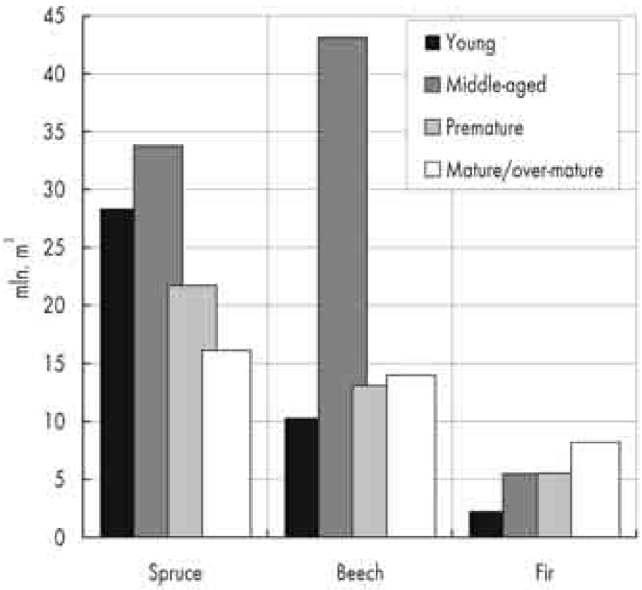


**Figure 2** Distribution of total growing stock in exploitable mountain forests (both group 1 and 2) by age groups

growing stock in exploitable forests, which make about 62 % of the Carpathian forests, is mostly made of spruce (46%), beech 37%, fir (10%) and oak (4%) (Figure 1).

In the age structure of spruce and beech forests young and middle-aged stands prevail – 62–67%, while the share of mature and over-mature stands is only 16–17%. It is the result of intensive felling (up to 2–3 annual allowable cut (AAC)) during the militaries and post-militaries years till 1960 (Figure 2). In 1970s and 1980s the volumes of final felling corresponded to AAC, which has improved the age structure of mountain forests.

## 2. Volumes and structure of forest harvesting in the region

In the past the annual cut was not completely used – 83–85 % (Table 1). The basic reason is the absence or lack of material and technical maintenance caused by economic instability and reforming of budget financing cycle. First of all easily accessible

**Table 2** Realisation of wood by economic section, thousand. $m^3$

| Region | Economic section | | | | Total |
|---|---|---|---|---|---|
| | Spruce | Beech | Fir | Oak | |
| Zakarpatska | 607.9 | 578.1 | 27.0 | 19.0 | 1241.9 |
| Ivano-Frankivska | 347.7 | 159.2 | 30.3 | 18.2 | 637.7 |
| Tchernovitska | 354.4 | 103.0 | 0.0 | 35.5 | 794.0 |
| Lvivska | 163.7 | 89.8 | 0.0 | 26.6 | 563.2 |
| Total | 1473.7 | 57.3 | 99.3 | 930.1 | 3236.8 |

**Table 3** Distribution of annual cuts by area and woodstock

| Type of felling | Actual volume of fellings | | | |
|---|---|---|---|---|
| | By woodstock | | By area | |
| | thousand $m^3$ | % | thousand ha | % |
| | Final felling | | | |
| Clear cutting | 1010.3 | 67.3 | 4.28 | 70.0 |
| Partial and selective | 491.9 | 32.7 | 1.83 | 30.0 |
| Total | 1502.2 | 100 | 6.11 | 100 |
| | Fellings, related to forest management | | | |
| Sanitary selective | 381 | 35,2 | 36.6 | 56.6 |
| Maintenance of young stands | 20.5 | 1.9 | 15.5 | 24.0 |
| Maintenance of middle-aged and of premature stands | 180.8 | 16.7 | 9.9 | 15.3 |
| Sanitary clear | 355.2 | 32.8 | 1.8 | 2.8 |
| Regeneration | 144.9 | 13.4 | 0.9 | 1.4 |
| Total | 1082.4 | 100 | 64.71 | 100 |

and inexpensive cutting units at foothill or lowland areas are harvested. The harvesting in hard-to-reach mountain forest areas, with a rare road network as a rule is economically unprofitable and hence carried out in the last turn.

In all mountain areas timber for sale is mostly obtained from spruce and beech (Table 2) – 91–96 %. The rest is obtained from fir (Zakarpatska and Ivano-Frankivska region) and oak.

The impact of forest harvesting on environment depends on the type of felling. The area and woodstock depending on various types of felling are shown in Table 3.

**Table 1** Dynamics of timber harvesting during final felling in state forest enterprises, mln. $m^3$

| Indexes | 1970 | 1975 | 1980 | 1985 | 1990 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|---|
| Annual Allowable Cut (AAC), mln. $m^3$ | 5.49 | 5.39 | 5.39 | 6.00 | 6.00 | 5.16 | 5.22 | 5.26 | 5.29 | 5.27 |
| Annual Cutting, mln. $m^3$ | 6.03 | 5.38 | 5.64 | 5.92 | 5.79 | 4.66 | 4.42 | 4.49 | 4.34 | 4.41 |
| % from AAC | 110 | 100 | 105 | 99 | 97 | 90 | 85 | 85 | 82 | 84 |

In final felling clear cutting prevails – 67–70%, causing enormous damage to the environment. In 1999 the area on which clear cutting was carried out was 4.28 thousand ha or about 0.4 % of the exploitable mountain forest area. Other final felling – about 30 % was carried out by partial and selective felling. Among other types of felling, related to forest management, the most frequent are sanitary felling (60––68 %) and maintenance of stands of various kinds (18–39 %). In other forest areas regeneration and reconstruction felling is applied.

## 3. Legislation

The most important documents, related to the regulation of mountain forest harvesting are:

1. Order for distributing forests into groups, determining their categories of protection and earmarking species of the growing stock (1995);
2. Regulations on main felling in the forests of Ukraine (1995);
3. Regulations on forest renewal and planting (1996);
4. Regulations on laying down secondary wood raw materials and using of non-wood material in the forests of Ukraine (1996);
5. Regulations on tree felling related to forest management and other types of felling (1996).

The basic requirements concerning harvesting in mountain forests are the following:

- all users of complex forest harvesting operations are obliged to carry them out so as to exclude or limit negative impact on trees, soil, reservoirs and other natural objects;
- on 21–350 slopes partially suspended and fully suspended ways of extraction should be applied along with animal skidding. Full-tree method of extraction in mountain conditions is forbidden;
- at present operations for forest viable regeneration are carried out in the snow period of the year. After the end of felling, the cutting unit area with the damaged ground should not exceed 15 %.

The basic lack of working normative documents results in applying clear cutting and extraction by caterpillar tractors in non-snow period. It causes destruction of forest environment and reduction of forest productivity. Imperfect system of distribution of the sanctions for forest harvesting in mountain forests, absence of an effective system of control above meeting the environmental protection requirements during forest operations and sanctions for the admitted infringements also play an important negative role.

Catastrophically high water in the Zakarpatska oblast in November 1998 drew attention of the public and of the authorities to the methods of harvesting in mountain forests. As a result in 1999 the Law on »the moratorium on clear cutting in fir-beech forests on mountain slopes of the Carpathian region« was passed by Ukraine Parliament (Verhovna Rada).

The law forbids carrying out the final felling in forests above 1100 m above sea level, in areas with risks of avalanches and mud-streams as well as in forest water protection zones. Clear cutting in fir--beech forests on 210 slopes is also forbidden. On slopes up to 210 only selective, gradual and narrowly clear cuttings can be carried out on the area of the cutting unit from 3 (group 1of forests) to 5 ha.

The width of narrowly clear cutting should not exceed 50 m. The length of the cutting unit location is measured horizontally. The law also provides complete transition to wheel, animal and cable transport by 2005. By 2010 the density of forest road network with improved firm covering should achieve 10 km per 1000 ha.

## 4. Planning of forest operations in mountain forests

The planning of forest operations is carried out in accordance with the »Rules on final felling in forests of Ukraine« (1995). According to this document pre--logging planning should consist of the following stages:

- volumes and character of preparatory works, technology of forest operations and clearing of cutting unit, way of reforestation of the cutting unit, amount of regeneration of valuable species to be kept during forest harvesting are previously defined;
- felling and long side of cutting unit should be directed against prevailing or dangerous winds blowing upwards with the long party across the slope;
- the technological card is developed containing the technological cycle of forest operations on a cutting unit, providing data on equipment, skid trails, kinds of forest operations (felling, limbing, extraction, bucking, sorting, decking, loading, clearing cutting unit), sequence of operations on different cutting sections, measures concerning safety at work, prevention of soil erosion and other negative phenomena.

In practice these rules are not implemented completely in mountain forest harvesting. The reason why lies in an unsatisfactory financial position of forest users and the lack of environmentally sound forest machines.

New technique of pre-logging planning in mountain forests based on computer technology is now being developed in Ukrainian State Forest and Techniques University. It includes a complex estimation of natural conditions of a cutting unit and environmental effects of felling, making it possible to create a computer database on the basis of Arc View GIS 3.0 and to optimise a network of wood roads, skidding corridors, ways of timber extraction (Bibluk *et al*. 2000).

## 5. Technology of forest operations in mountain forests

The changes of forest harvesting technologies in mountain forests during the last century have affected seriously the ecological and industrial functions of forests. Historically, the technology usually applied for forest operations in mountain forests till 1950s was based on animal and human force, use of weight and had little impact on stands, soil, mountain streams and rivers. It consisted of horse skidding, manual loading and sorting, descent of wood up to a road on specially equipped lines: chutes and sledges, transport of wood on narrow-gauge railways, alloy on rivers.

Since the fifties, for the purpose of transition to an industrially based forest management in the region of Carpathians, the establishment of complex wood enterprises – forest combinates began. In forest combinates reforestation, growth, harvesting and wood processing and non-wood production were combined. It has resulted in the transition from traditionally low productive forest operations in the region to new heavily mechanised harvesting system.

The most progressive of them was the environmentally friendly cable yarding system. However in the '70s–'80s the amount of working cable systems in mountain forests has considerably decreased. In the last decades the method of skidding by crawler tractors has prevailed and nowadays 85 % to 100 % of all timber is extracted in that way (Table 4).

**Table 4** Structure of timber extraction techniques (1950–95), % (Badera *et al*. 1997)

| Extraction technology | 1950 | 1960 | 1970 | 1980 | 1990 | 1995 |
|---|---|---|---|---|---|---|
| Tractors | 10 | 21 | 45 | 63 | 73 | 87 |
| Cable systems | 20 | 48 | 40 | 27 | 17 | 3 |
| Horse, manual | 70 | 31 | 15 | 10 | 10 | 10 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 |

In 1995 instead of reforming 3 forest industry associations, 3 regional directions of forest management in State regional administrations and state forest management enterprises were created. All state-owned forests were transferred to state forest enterprises. The main functional goals of new forest enterprises are the growth of forests, hunting and non-wood production management, protection of forests. The final felling is not an obligatory kind of their activity.

Due to a sharp deterioration of the economic situation in the transition period, state forest enterprises were unable to ensure complete harvesting cutting fond. As a way out from this situation final felling was allowed to others – non-state forest users. Now, as a result of this, final felling harvesting is mostly carried out by non-state forest users in the Carpathians region. In 1999 they performed more than 90 % of the cutting fund in Zakarpatska oblast and 60–70 % in Tchernovitska and Ivano-Frankivska oblasts.

Non state forest users can be divided into 2 categories: 1) Joint-stock companies, developed after privatisation from the former forest combinates. They are characterised by the presence of qualified staff, strongly worn out forest harvesting engineering, mainly domestic manufacturing; 2) Organisations not specialised for forest harvesting, employing temporary workers, renting specialised engineering. The workers of all categories of the enterprises get special training. Then they get the licence for state supervision of protection of harvesting operations.

In both cases over normative damage to stands and environment takes place in cutting units after harvesting, as a consequence of applying unfriendly forest engineering operations.

Non state forest users often fail to meet the environmental protection requirements in carrying out their forest operations. Among such infringements it is necessary to specify the absence of pre-logging planning, realisation of felling in periods without snow cover, prevalence of skidding by crawler tractors. All this results in the damage of about 83–96 % of regeneration of the main species, infringement litter, and soil cover. The use of crawler tractors for extraction in clear cutting causes ablation of 150–500 $m^3$/ha of fertile soil layer. The adverse effect after harvesting cleaning of a cutting unit interferes with natural regeneration of forest.

The degree of impact of forest operations on environment depends directly on the density of the road network in the mountains. At present, the road network in the region is absolutely insufficient. Thus, the forest road density in Zakarpattia is 0.6–0.7 km per 100 ha of forests, and the optimum parameter for the given conditions would be 1.5–2 km per 100 ha.

Nowadays the following technologies are applied in final felling and clear sanitary felling in mountain forests:

- Full-stem method. Motor-manual felling – manual limbing – skidding by crawler tractor (full-stem or full tree) – landing – loading by auto crane – transporting by stem carrying trucks;
- Assortment method. Motor-manual felling – manual limbing – bucking by chain-saw – skidding by crawler (on slopes up to 12–140 – by wheel) tractor or by animal or by cable yarding system – loading by auto crane – transporting by log trucks.

For the maintenance of middle-aged and premature stands and selective sanitary fellings in mountain forests the following technologies are applied:

- Motor-manual felling – manual limbing – bucking by chain-saw – skidding by crawler (rarely by wheel) tractor or by animal on skidding corridors – landing – loading by auto crane – transporting by log trucks;
- Motor-manual felling – manual limbing – bucking by chain-saw –extraction by cable yarding system – transporting by log trucks.

For clearing and thinning in mountain forests the following technologies are applied: motor-manual felling – manual or animal extraction – landing.

Currently used technologies of forest operations, forest harvesting engineering and ways of felling in mountain forests mostly have a negative impact on trees, soil, regeneration, hydrological condition of mountain streams and rivers. Many are the reasons for such a situation but the following ones should be pointed out: the economic crisis, middle-of-the-road institutional reforms in Ukrainian forest branch, infringement of interstate trade connections with the manufacturers of specialised forest harvesting engineering, reduction of the level of state control of forest harvesting in mountain condition and others.

At the same time the theoretical base for the application of environmentally sound forest operations in mountain forest and for the system of machines for sustainable mountain forest management is well developed in Ukraine. The leading organisations in this area are Ukrainian Research Institute of mountain forestry, Ukrainian Design Institute of forest industry, both Ivano-Frankivsk, Lviv Design Institute of Forest Industry, Ukrainian State Forest and Techniques University, Lviv, the research-and-production enterprise »Ukravtramash«, Lviv engineering -design consortium.

## 6. Forest harvesting engineering in mountain conditions

In state-owned forest enterprises specialised forest harvesting operations in mountain forests must be carried out with the equipment, which meets the requirements of environmental protection, as these enterprises carry out the entire volume of felling related to forest management and about one tenth of the final felling. For example, in 1999 state forest enterprises carried out the forest operations in Carpathians on an area of about 66–67 thousand ha. The presence of forest machines in state forest enterprises is shown in the Table 5. The given data testify that the forest operations in mountain conditions are based on the use of crawler tractors and chainsaws (25–50 % made in Germany and Sweden).

Among crawler tractors the most widely applied is TDT-55 with 10–12 t in weight, loading capacity of 65 kN and specific pressure on the ground of 52 kPa. TDT-55 can operate on the majority of slopes in the Carpathian mountains. On flat slopes wheel tractors are used, such as LKT–80, LKT–120, T–157. However their share is low. The tractor fleet is strongly worn out – 40–76 % of tractors of this brand are more than 8–10 years old.

**Table 5** Volume by harvesting equipment in state forestry enterprises in 1999 (absolute, piece and specific, piece on thousand. m$^3$ of a AAC)

| Type of equipment | Areas units | | | | | |
|---|---|---|---|---|---|---|
| | Lvivske | | Ivano-Frankivske | | Tchernovicke | |
| | units | units on thousand m$^3$ | units | units on thousand m$^3$ | units | units on thousand m$^3$ |
| Crawler tractors | 771 | 2.52 | 92 | 0.25 | 75 | 0.19 |
| Motor chain-saw (including import) | 715 (360) | 2.34 | 391 (127) | 1.08 | 228 (50) | 0.56 |
| Logging truck | 104 | 0.34 | 68 | 0.19 | 85 | 0.21 |
| Electric chain-saw | 37 | 0.12 | 14 | 0.04 | 18 | 0.04 |
| Cable systems | 3 | 0.01 | 1 | 0.00 | - | - |
| Winches | - | - | 3 | 0.01 | - | - |

Cable systems and winches are rare and do not play an important role. From four cable systems two were manufactured in Austria and two are domestic ones TL–4, LS–2–500. In Zakarpatska oblast TL–5 and UCT–3.2 are working. Some of the reasons why cable systems are used so rarely in the total amount of forest harvesting are the following:

- the productivity of extraction is 2–3 times lower than with tractor skidding;
- large distances of extraction in Carpathians. In final feelings the average distance of extraction ranges between 1.5 and 2.5 km, on average – 1.3–2.2 km. In remote areas with a rare road network the distance of extraction can reach 5 km;
- lack of industrial manufacturing of cable systems. In our estimation 210–240 cable transport systems are necessary for mountain regions of Ukraine. One third of them are stationary, the others are mobile cable transport systems. In our estimation forest users of cable systems require 19–23 million griven (US$3.5–4.2 million). The average cost of cable systems manufactured in Ukraine is less than 100 thousand griven (US $ 18.2 thousand), and the price of the imported ones amount to US $ 80–120 thousand;
- lack of qualified staff for cable system operation;
- wide introduction of mobile cable systems is restricted by the absence of a road network, which would allow the delivery of the cable systems directly to the cutting unit and extraction of wood without reloading.

At present a number of specially designed technical equipment providing environmentally friendly operations in Ukrainian mountain-forests have been developed:

- chain-saw »Motor – Sich« with the frequency of 200 $s^{-1}$ (12000 $min^{-1}$) and 7.8 kg in weight;
- tractor assembly TL-30, 9 kN, 4×4, 2700 kg in weight;
- a forest industry tractor;
- mobile cable systems for the transportation of full-stems and logs, on the basis of tractors MTZL--82, T–150K, with the line length of 400–500 m, loading capacity of 16, 32 and 50 kN;
- tower cable systems for transportation of logs, with the line length of 1000 m and lateral skidding of 50–75 m;
- combined cable systems with the line length of up to 2000 m, loading capacity of 32 kN and productivity of 80 $m^3$;
- timber forwarding (models 4×4 and 6×6) with hydro-cranes with the loading capacity ranging between 35 and 110 kNm;
- mobile systems for preventive maintenance aimed at fire protection and protection from insects. Super-light plane with useful carrying capacity of up to 400 kg and a 2-man crew has been designed and has passed the test flights for the control of fire stability and performance of the basic fire-prevention operations in Ukraine.

By special decision of the Government the introduction of 155 wheel tractors, 95 cable systems and 95 specialised machines for timber transport is planned for forest harvesting in Zakarpattia by 2010, at the cost of 32,4 mln. griven.

The key tasks in the field of restructuring aimed at ensuring sustainable forest management in the mountains are as follows:

- introduction of the system for providing economic incentives for the application of environmentally sound forest technology;
- assuring cancelling of customs duties and value added tax, and reduction of profit tax for the period of development of high technologies.

It is necessary to solve a number of legislation problems, to make the investments attractive and to be specific in terms of financial expenses for the maintenance of the protective functions of the Carpathian forests. These problems can only be solved together by experts of the European continent.

## 7. References

Bibluk, N., Stiranivski, A., Adamovsky, M., *et al.*, 2000: Bases of planning of technological processes forest harvesting with use of computer technologies. Wood business, N 1, 2000, 14–17.

Badera, I. S., Martinciv, M. P., Udovickiy, A. N., 1997: Development of environmentally sound forest technologies and mechanisms for harvesting mountain forests. Wood business, N 3, 1997, 14–16.

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# The state of art of ergonomics in forestry

**Marjan Lipoglavšek, Frits J. Staudt**

***Abstract***

*Needs for applied ergonomics in forestry are very different worldwide. They depend on the state of technological development of forestry work but also on the living standard of the whole population in a country. Somewhere ergonomics has to solve the energy consumption and nutrition problems at different hand work-methods, elsewhere the psychical loads of operator at computer supported highly mechanised work can make the work impossible. The ergonomic research must help solving all these different problems. In the past ergonomics often worked independently but nowadays it must be included in technological and organisational design of work and not be only related to machines. Ergonomics must have economical long-term effects upon employees and employers and not only upon wellbeing of people. International co-operation is prevalently needed in three fields: to prepare a handbook on ergonomic work design, to elaborate new methods for assessment of mechanisation and to promote the certification of work force.*

***Key words:*** *ergonomics, work design, mechanization*

## 1. Introduction

Since the beginning of this century ergonomics has gradually been introduced into the forestry sector. It started after the First World War with physiological and productivity studies in relation to saw design and walking and extracting of timber from the forest. Particularly after the Second World War ergonomic research in forestry developed considerably in its different disciplines, including work organisation and work psychology. Now, on the verge of a new millennium the question has to be raised whether ergonomics has still a role in forestry and which one? This question is not simple to answer. It might be convenient to define ergonomics first:

> *Ergonomics covers the study, design, improvement and implementation of a working situation, in particular of working tools, methods, tasks, working environment and work organisation, in order to create optimum efficiency, safety, health and wellbeing for workers in operating and maintaining social-technical systems.*

Looking at this definition it can be concluded that there is still a great mission for ergonomics in the coming millennium regarding the aspects of wellbeing, occupational health, safety and efficiency.

But the ergonomic problems and solutions vary greatly from country to country, depending among others on the living standard of the population and the availability of technology and capital.

## 2. Regional trends

### 2.1. Developing countries

In a lot of developing countries many of the present problems will continue in the foreseeable future. Nutrition of forest workers and their health will still be a problem. In many tasks forestry work will still be too heavy and the physical fitness of many forest workers will leave much to be desired. Ergonomic tasks will be the development of nutritional supplementary programs, better organisation of the work and the introduction of tools and equipment, which make the forest work easier and safer. In this respect attention should be given to the development of personal protective equipment (PPE), like helmets, clothing and leg protectors. The PPE in use nowadays has been developed in northern countries and is not suitable for use in the tropics. For instance better ventilation of helmets and leg protectors should be considered. In Australia and South Africa research has been carried out in this field and it should be continued.

### 2.2. Industrialised countries

In the industrialised countries of Europe and America improvement of the characteristics of the chain saw, which has been the scope of many research studies in the past, will still go on and will focus specifically on environmental, safety and health aspects. However, research will increasingly focus on logging machines and on the whole social-technical system. There are two reasons for these development trends. The first reason is the law of diminishing returns, meaning that improvements on chain saws are ever more expensive. The second reason is the need for mechanisation; as a result of higher wages and the need for higher capacity, chain saws will be replaced by logging machines. Still from the point of view of ergonomics and safety, need could arise for the development of a simple remote controlled chain saw.

As far as logging machines are concerned, the research will focus more and more on computer supported highly mechanised machinery. Work with these machines can cause several problems. On one hand restricted movements of the whole body can cause overweight and on the other hand too many movements of a few limbs can cause repetitive strain injury (RSI). Furthermore single repetitive (monotonous) tasks, which ask for high levels of concentration, can cause psychological stress. Stress can also be caused by long working days, low earnings, high machine costs and the extra responsibility the operator often has in a one-man enterprise. In future the design and implementation of the whole work system will pay much more attention to problems of noise and vibration than to the technical ones.

### 2.3. East-European countries in transition

A third category of countries to consider when speaking of the future role of ergonomics in forestry is the group of East-European countries in transition. In these countries forestry conditions are characterised by many new small enterprises and old and new forest owners operating in the forest without knowledge, appropriate tools and protective equipment. How to escape the »downwards spiral of bad ergonomics and safety« (Staudt and Lipoglavšek 1998) is also a problem to be solved by ergonomics. In the first place it will be the concern of the government to introduce new laws, regulations and the labour inspection to uphold them. The workers, employers and other non-government organisations (NGO's) will also have to follow them up. This means good co-operation between government and NGO's. The forest enterprises also have the duty to develop an ergonomic and safety policy. Finally there will be a large responsibility for research, education, training and extension. For the coming millennium all the protagonists mentioned above will have to set up an efficient organisation of occupational health and safety services in these countries in transition.

## 3. Important future research topics

### 3.1. Single and complex working systems

In the seventies and eighties many ergonomic and safety research dealt with the improvement of working tools and machines on single man-task systems. But when working systems become more complex social-technical systems with group work, overlapping shifts, etc., becoming increasingly dominant, ergonomics gets a broader definition. Ergonomics must be involved in technological and organisational design of entire work processes. Ergonomics must contribute to all new technologies and on the other hand technological solutions are not suitable without ergonomic inputs. This makes the implementation of ergonomics expensive and may discourage employers to invest in ergonomic measures.

### 3.2. Analysis of cost effects

Do ergonomic measures pay? In certain (starting) phases of the process of »ergonomisation« it is clear that ergonomics pays. Theoretically there will come a phase in which further ergonomic developments will not pay, because of too luxurious concepts. In forestry in most of the countries this is far from reality yet. Nevertheless practice shows that employers and employees have to be convinced that ergonomic pays. Therefore one of the new tasks of ergonomics is to elaborate the methods of cost-benefit analyses to prove the short-term and long-term profits and benefits of ergonomic measures to government and enterprise policy makers. Ergonomic models have to be developed to predict the benefits of ergonomics. The present models are not very reliable. Only costs can be determined quite precisely but the benefits cannot be defined yet (Morssink 1996).

### 3.3. Risk analyses

The complexity of working systems also affects the risks and safety regarding people and processes. Increasing attention should be paid to the study of risk analyses and the causes of accidents in forest enterprises in the new millennium.

Three types of failure can be distinguished in operational systems – technical, organizational and operational failures. Technical and organizational failures are relatively easy to solve by applying technical and organizational solutions. Operational or human factor however is unpredictable and unreliable. Near Miss Reporting (NMR) is a technique, which can be used to get better grip of the human factor and of the exposed risks. Due to the higher frequency in the occurrence of near misses against real accidents, NMR contributes better to the process of risk analyses.

Van der Schaaf (1992) worked out a classification model of system failure, which can be very useful for risk analyses in forestry. This classification model has also been discussed by Staudt (1998).

## 4. Important future actions to undertake

Forest work differs quite considerably from traditional industrial work. The outdoor working environment and climate are never optimal and are subject to changes over short periods of time. Moreover forest workers use forest tools and machinery under very different forests conditions all over the world. Consequently, a special handbook for ergonomics in forestry should be written – a handbook on research methods and one on work design. A handbook cannot give concrete solutions in every case, but must describe simple and sometimes sophisticated ergonomic methods for analyses and design of tools and working conditions for forestry work and should give suggestions for possible solutions.

Ergonomic check lists in use so far, which make distinction between »yes« or »not« suitable, are not accurate enough for assessment of new machines. A new step by step methodology for the evaluation of ergonomic characteristics is necessary involving more criteria than we have now (Gellerstedt 1995, 1996). Recently SkogForsk has published a revised edition of »Ergonomic Guidelines for Forest Machinery« (Frumerie 1999). This book could hopefully fulfil the lack of a good handbook for ergonomics in forestry.

Special attention should also be focused on methods for the assessment of mechanization in forestry.

Mechanization is a process with impacts on productivity of the enterprise, on wellbeing of workers and on sustainability of the forest ecosystem. As forests are very vulnerable and new big machines are very expensive and complicated the best-trained workers are necessary to avoid damage to forests, machines and workers themselves. A system of certification of work force and enterprises can contribute to the efficiency, safety and sustainability in forestry (Garland 1998). More actions should be initiated to promote certification in forestry, not only related to forest management, but also regarding ergonomically sound working conditions.

## 5. References


Anonymus, 1999: Ergonomic guidelines for forest machinery. In: Rev. ed., Frumerie, G. (ed.). Skogforsk, Uppsala, p. 58.

Garland, J. J., 1998: Accreditation, certification and licensing of the forestry workforce. In: Caring for the forest: Research in a changing world. Proc. of the ergonomic papers and posters presented during the XXth IUFRO World Congress in Tampere, Finland 1995, Sub-department of Forestry, Wageningen University.

Gellerstedt, S., 1996: Ergonomic guidelines for forestry machinery. IUFRO P.3.03.00 Work-Shop, Garpenberg.

Gellerstedt, S., 1998: Revision of the ergonomic checklist for forest machinery. In: Caring for the forest: Research in a changing world. Proc. of the ergonomic papers and posters presented during the XXth IUFRO World Congress in Tampere, Finland 1995, Sub-department of Forestry, Wageningen University.

Morssink, J. C. M., 1996: Arbeidsomstandigheden en ergonomie: Kosten of investeringen. Tijdschrift voor Ergonomie 1996.

Staudt, F. J., 1998: Participation in ergonomics and safety. In: Caring for the forest: Research in a changing world. Proc. of the ergonomic papers and posters presented during the XXth IUFRO World Congress in Tampere, Finland 1995. Sub-department of Forestry, Wageningen University.

Staudt, F. J., Lipoglavšek, M., 1998: Ergonomic research in a changing world. In: Improving working conditions and increasing productivity in forestry. Seminar Proceedings of Joint FAO/ECE/ILO Committee on Forest Technology, Management and Training. Banska Stavnica.

Van der Schaaf, T. W., 1992: Near miss reporting in the chemical industry. Dissertation thesis, Technical University University of Eindhoven.



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# Environmental and Ergonomic Stress During Logging with Woody 110 and Belt GV 70 Skidders

**Robert Robek, Mirko Medved**

***Abstract***

*In the key study the comparisons between two forestry skidders operating on deep brown soils under controlled conditions and during logging performance were conducted. During compaction experiment both tractors caused significant alterations in soil physical properties. The impact of hydrostatically driven skidder – Woody, equipped with narrow tires was after 8 passes insignificantly lower compared to the ordinary skidder – Belt. In the logging operation the CO, $CO_2$, NO, and $NO_2$ gas emissions were monitored on both tractors and the operator heart beat rate was monitored simultaneously. The average fuel consumption and gas emissions per operation and per logged quantity with Woody were significantly lower than the ones with Belt. In the same operations the operators heart beat rate was higher when the Belt skidder was used. Simultaneous analysis confirmed that the performance of Woody was environmentally and ergonomically more suitable regarding the analyzed parameters and conditions.*

***Key words:*** *environment, harvesting, skidders, soil, gas emission, ergonomy, heart rate*

## 1. Introduction and investigation objectives

Forestry skidders are designed for hauling and skidding wood assortments in skid trails and off-road areas. In these operations the remaining trees must be left intact, the forest soil must be preserved as much as possible and work must be performed with minimum fuel consumption and low level of exhaust gas emissions. Some of the stated requirements can be achieved by introducing modern engines and others by developing appropriate working procedures and adequate training of workers (Košir 1994).

Machine operator, who operates a skidder and performs the work, has an exceptional position within this system because the way he operates the machine has an influence on the machine itself as well as the environment. The wiser the operation and work are performed the better are the results. Since the quality and quantity of the work performed greatly depend on operator stress, the study of the influence of work, machines and working environment upon the operator have to be included into the investigation of individual aspects of technologic processes. Timber skidding is physically very demanding therefore the study of operator's heart rate is a promising method to study operator stress (Martinić 1994). Operator stress, expressed by a heart rate, is a result of a variety of different ergonomic characteristics of a skidder, efforts at work and the influence of working conditions (Bilban 1999). Therefore a simultaneous consideration of different work aspects in timber skidding is often a precondition for integral estimation whether it is appropriate to introduce new machines in forest production.

The Woody 110 forestry skidder was designed and produced in Slovenia. In its development, much emphasis was put on ecological and ergonomic requirements. Due to high mobility of the vehicle, hydrostatically-driven shafts and a remote control possibility of the entire skidder, it is especially suitable for thinning operations in stands during their optimal stage. The older Belt GV 70 skidder, which is compared with Woody in the investigation, is also a skidder produced in Slovenia yet its production has already been stopped. Within the extensive study of the skidder operation the objective of the investigation was as follows:

- to study the alterations in external and internal morphology of soil and greenhouse gas emissions in the operation of the Woody 110 forestry skidder in forest work in actual conditions,
- to establish the average operator stress per working day by individual work operations and the causes generating it,
- to compare the stress of the same operator in operating different skidders.

## 2. Working methods

The measurements regarding skidder performance and operator stress were performed in thinnings in logging units in state forests on the high karst (SW Slovenia). Based on the available possibilities and in order to be able to compare ecological indicators, the Belt GV 70 skidder was selected and two directed trials were performed: a soil compacting trial and a gas emission monitoring of carbon monoxide (CO) and nitrogen monoxide (NO) in tractor exhaust in different operation methods and at different engine load.

The soil compacting trial was carried out in commercial forests in Snežnik massif in the Leskova dolina forest management unit, Section 9a. Altogether ten passes of an empty tractor on a prepared testing ground were performed in two steps: first two passes and after the soil sampling subsequent eight passes. Each tractor had its separate testing grounds, half of them stretching over natural forest soil and the other half along an old skid trail. The skid trail had not been constructed. It emerged due to driving on a roadless area in timber skidding in the 80s. The measurements were carried out on selected profiles, where before, during and after the trial the terrain's relief and the maximum wheel rut depth, were recorded and soil core sampling was performed at a depth of 10–15cm. In the laboratory the soil samples were established as to moisture (vol. %) and bulk density (g/cm$^3$) and total porosity and coarse pore share in a soil sample were determined.

The measurements of exhaust temperature (°C), CO (ppm) and NO (ppm) were performed at the end of the exhaust tube at controlled increasing of revolutions of tractors in idle position and in five cycles of uphill timber skidding for each tractor with the MRU – Vario plus emission gauge according to the method of continuous measuring and recording emissions every 5 seconds (MRU 1998).

Heart beat rate monitoring was performed continuously throughout the entire working day by means of the Polar gauges; data were recorded every 15 seconds. Since the heart rate is the index of physical capability of an individual, the value of heart rate and the achieved working heart rate were taken into consideration in the investigation as the basis of the stress during work performing. A permanent burden of an operator in professional work should not exceed the permitted working heart rate limit, which is one third of the difference between the maximum heart rate and the heart rate of a person at rest (Bilban 1999). The value we got when the age of an

**Table 2** Basic data on machine operators included in the investigation

| Data / Machine operator | R | L |
|---|---|---|
| Year of birth | 1956 | 1954 |
| Age at the time of monitoring (years) | 43 | 45 |
| Weight (kg) | 74 | 70 |
| Height (cm) | 173 | 176 |
| Experience as machine operator (years) | 18 | 14 |
| Heart beat rate at rest (beats per minute) | 68 | 66 |
| Anticipated maximum heart beat rate (beats/min.) | 177 | 175 |
| Permitted working heart beat (beats/min) | 104 (68+36) | 102 (66+36) |

**Table 1** Basic data on working conditions in logging units (*directed trials site)

| Working day | Operator | Tractor | Skidding direction | No-load distance (m) | Load distance (m) | Bunching distance (m) | Mean load (m$^3$) | No. of pieces in a load | Mean piece (m$^3$) | No. of cycles with heart rate monitored |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | R | W110-S | down | 524 | 569 | 10 | 4.9 | 6.8 | 0.72 | 5 |
| 2 | R | W110-S | down | 797 | 810 | 12 | 5.1 | 7.5 | 0.69 | 6 |
| 3 | L | W110-IB | up | 146 | 165 | 10 | 2.9 | 12.3 | 0.23 | 6 |
| 4 | L | W110-S | up | 57 | 50 | 10 | 2.7 | 7.1 | 0.38 | 10 |
| 5 | R | W110-S* | down | 450 | 450 | 12 | 4.0 | 5.0 | 0.80 | 5 |
| 6 | R | BELT* | down | 450 | 450 | 12 | 3.9 | 3.4 | 1.14 | 5 |
| 7 | R | W110-S | up | 466 | 453 | 6 | 4.1 | 6.1 | 0.66 | 9 |

operator was subtracted from 220 was taken as the maximum heart rate. Heart rate monitoring was performed in logging units described in Table 1.

The samplings were performed in favorable weather conditions with no precipitation. Two operators, reliable and high quality machine operators, were involved in the investigation. They have had much experience in performing this type of work (14 and 18 years respectively). They both go in for sport, their psycho-physical characteristics are presented in Table 2.

## 3. Results

### 3.1. Ecological consequences of the work with the skidders

#### 3.1.1. Soil compaction in the soil compaction trial

The soil compacting trial was conducted on May 25th 1999 (Woody) and May 26th 1999 (Belt) on deep brown non-skeletal forest ground, in *Abieti fagetum dinaricum* spruce, fir and beech stands in their optimal stage. In the immediate surroundings of the testing grounds the Norway spruce prevailed, therefore the soil was intertwined with many roots on the surface. Soil moisture at the time of the trial was a little less than field moisture, which was not favorable as to compaction but from the aspect of stand conditions, that is the prevailing situation in the vegetation season. With such moisture the highest compaction is easily obtained and followed by evident wheel ruts. The mean wheel root depth in compacting trial after ten passes on undisturbed soil amounted to 4.1 cm with Woody and 4.9 cm with Belt. The difference was not statistically characteristic.

The results of laboratory analyses of soil samples in undisturbed situation are shown in Figures 1 and 2. They present the average and interval values of the parameters for individual treatments. For each treatment there were 6 repetitions. The left side shows the results for the Woody testing ground and the right one for the Belt testing ground. The first three treatments for each machine represent the situation before the trial, the situation after two passes on undisturbed soil and the situation after 10 passes on undisturbed soil. The other three treatments refer to the drive on the old, not constructed road, with a number of passes noted.

No significant differences have been established between the two machines as to soil compaction. Bulk density (Figure 1) with both machines increases significantly already after two passes on natural soil and after ten passes it differs significantly from the original situation. The first two passes over an old trail caused decreased bulk density, which may be the consequence of the subsurface vibrations of the roots. After ten passes of a machine over the profile the achieved soil compaction is not characteristically more compact than before the drive along the old road. The soil compaction achieved on the old trail is similar to that after ten tractor passes on previously undisturbed soil.

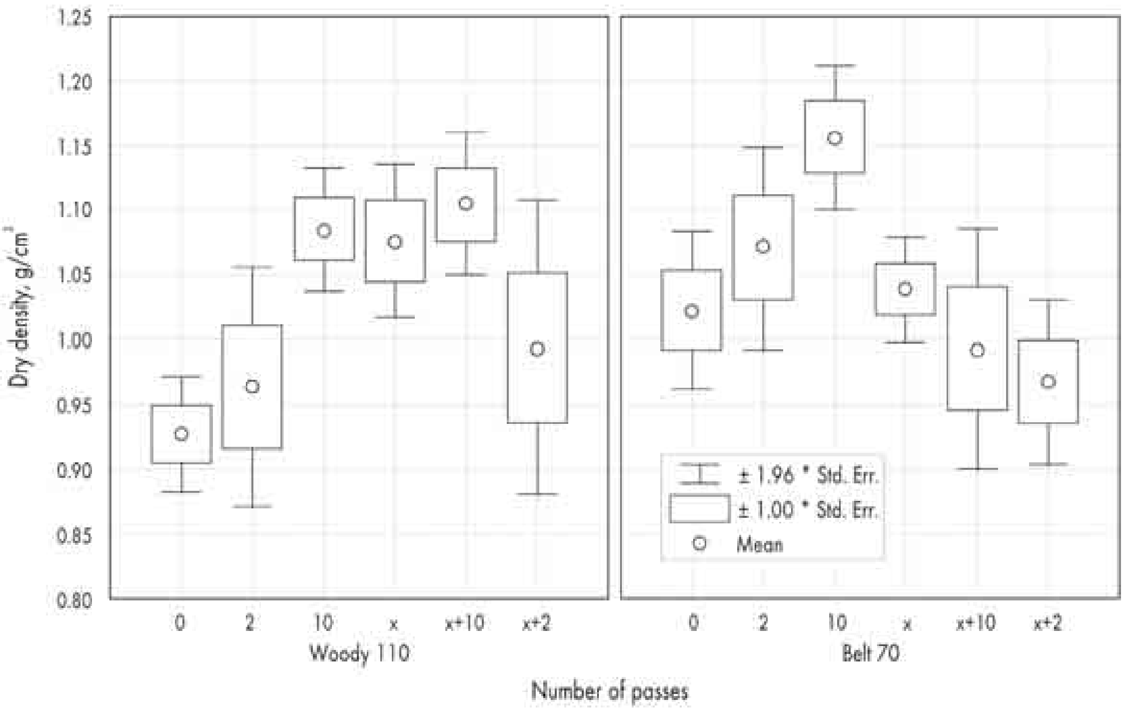


**Figure 1** Bulk density of mineral soil samples in a soil compaction trial

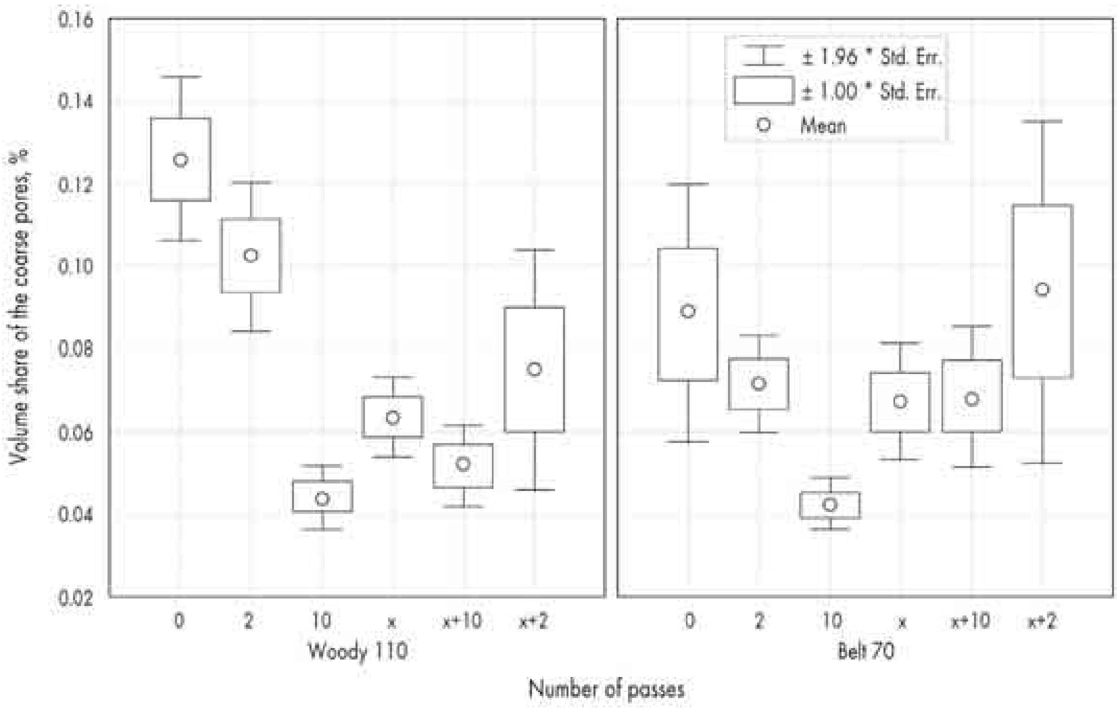


**Figure 2** Coarse pore volume share of mineral soil samples in a soil compaction trial

Figure 2 shows a significant decrease in coarse pore share when driving on natural soil. An anaerobic conditions (a share of the coarse pore under 5%) were obtained in most cases on previously undisturbed soils as well as on the old trail.

#### 3.1.2. CO and NO emissions at different engine revolutions of the skidder in the idle position

Figure 3 presents tractor emissions monitoring at programmed increase of the engine revolutions. The upper part gives the results for Woody and the lower one for Belt. Motor revolutions (n/min) are written in italics. When a cool engine is started high values of CO emissions can be established in both engines, which soon fall and remain at a similar level regardless of the number of engine revolutions of a tractor in idle position. CO emissions are with Belt 4 times higher than with Woody. NO emissions are by 30% higher than with Woody.

#### 3.1.3. CO and NO emissions during logging

For each engine the total sampling consisted of 5 cycles of timber skidding and approximately 1800 emission samples (continuous monitoring at the end of the tractor exhaust every 5 seconds). The total skidded quantity (for a distance of 450 m) amounted to 20.0 $m^3$ with Woody and 19.5 $m^3$ with Belt. Fuel consumption totaled 5.9 liter/operation hour with Woody and 7.9 liter/operation hour with Belt.

A comparison of the mean emission values by working operations in uphill skidding (the mean longitudinal grade of a skid trail was 17%) is shown in Table 3 for the purpose of a tractor study. The differences between the mean emission values by working operations have been expected. The reason for surprise are great differences between the tractors despite the fact that Belt is an older tractor, which had been more in use and with a technologically out-of-date engine. The results of the mean emissions in working operations are shown in Table 3. Woody can operate at lower revolutions, with lower temperatures and significantly lower mean emissions in all working operations. Figure 4 gives a dynamic image of emissions for two typical cycles for each engine, with the data on revolutions (Woody) and their estimate (Belt). In Slovenia the emission limit values regarding CO for diesel engines are 4500 ppm. This value was often exceeded by Belt when driving uphill (skidding along a skid trail).

From the point of view of the parameters studied, Woody 110 skidder gave better ecological results than Belt 70 skidder in the analyzed operations and studied working conditions yet mostly due to a better engine and not smaller soil damage.

### 3.2. Operator stress in timber skidding

#### 3.2.1. Operator stress in timber skidding with Woody 110 skidder

Based on operations and their duration, the mean heart beat rate was calculated by working elements in an individual working day. Time structure by op-

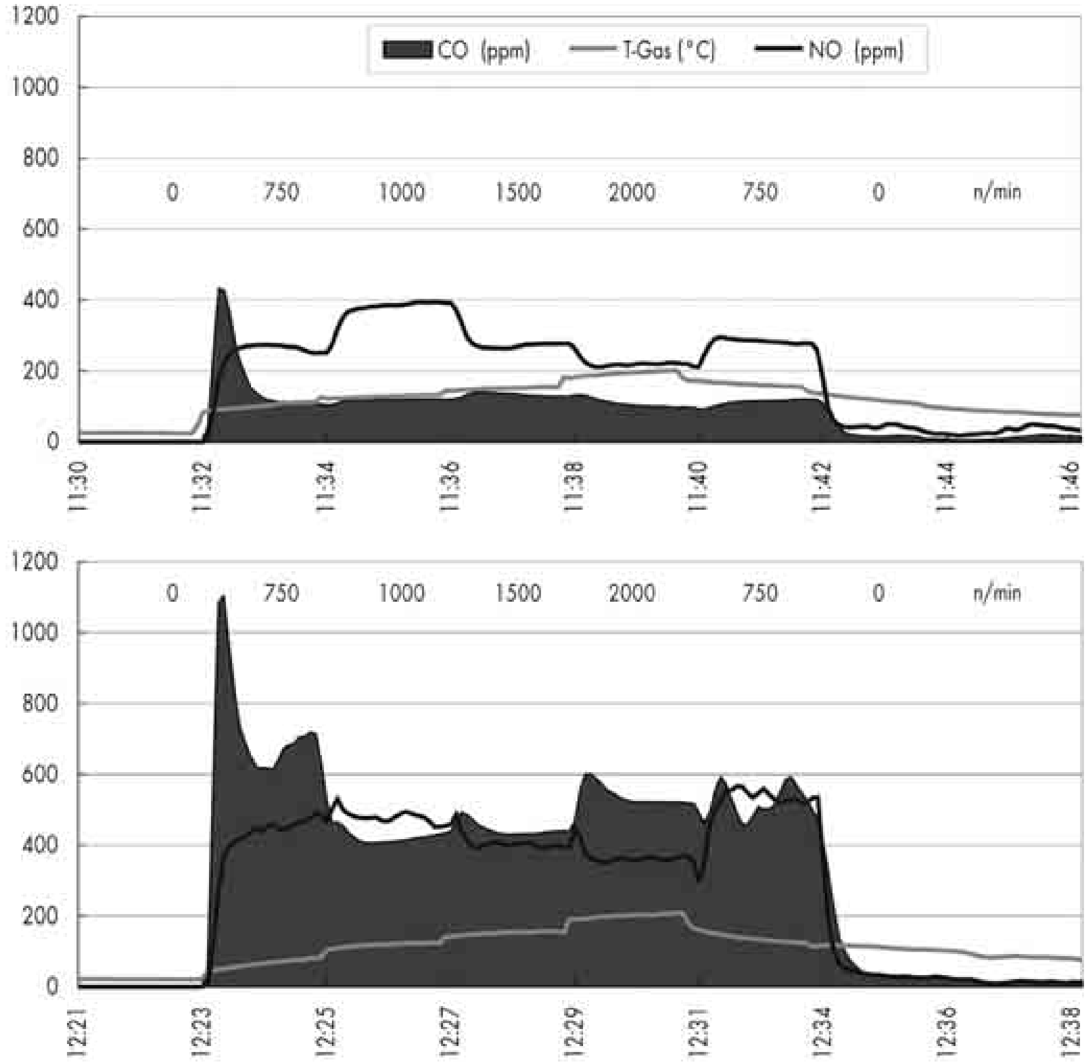


**Figure 3** 16-minute emissions monitoring with tractors in idle position at programmed revolutions (Woody – the upper part, Belt – the lower part)

eration cycles is shown in the lower part of Figure 5. There are also the data on the mean working time structure (AStr_T) of all the sampled operation cycles during the time studies and performance elements (Košir and Krč 2000).

A comparison with the data on stress in skidding with the adapted agricultural tractor (Lipoglavšek and Kumer 1998) has indicated very similar principles regarding stress, the latter being systematically a little higher in all working elements within the present investigation. This was also due to the structure of the working day since, on the average, 45% of all working time was performed during bunching and wood leveling in this investigation, where stress is the highest. In the literature compared, the sampling during these operations only took up one third. Following the sequence of working elements, the heart beat rate curve indicates a typical sine oscillation, reaching its maximum in binding and hauling. In spite of the fact that pulling of rope is probably the hardest operation, the resulting higher heart beat rate is seen only later in load binding and also in hauling. This is especially interesting because of the fact that an operator uses a winch with remote control in hauling and thus stress during this time could be expected to be lower. When investigating the rate of effort required for performing the work of machine operators (Lipoglavšek and Kumer 1998), lower stress was established in hauling with an oldest type of winch than in load binding. The difference may also be due to the fact that operators, when working with winches, which have a remote control system in the cabin, usually sit during this operation phase.

Relatively small differences have been established between the stress on an actual and the average working day. They are considerably higher between individual working days; they occur due to different working conditions and first of all due to working

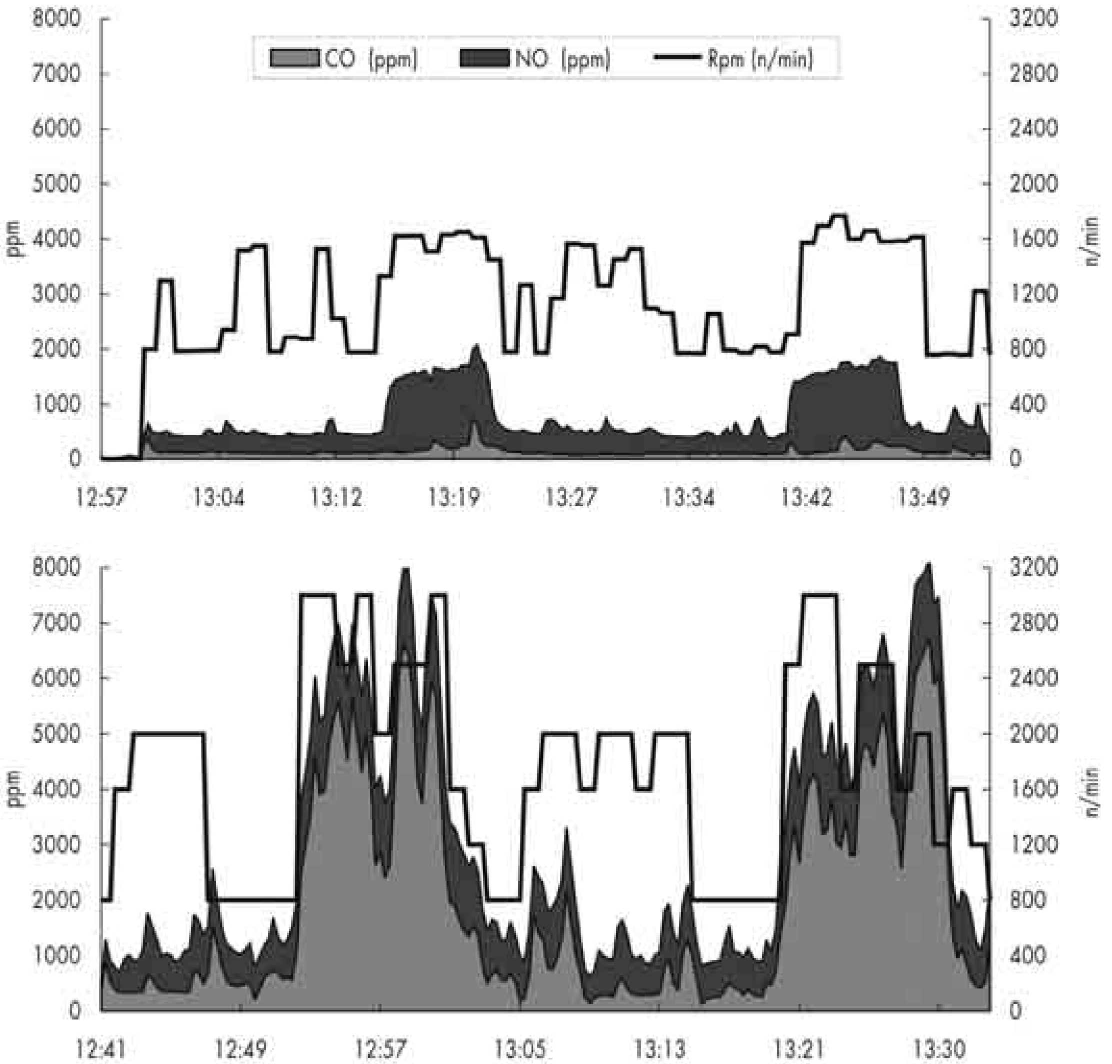


**Figure 4** Monitoring of emissions, revolutions and exhaust gas temperatures with tractors in timber skidding

**Table 3** The mean values of emissions and engine characteristics in 5 timber skidding cycles

| No. | Working element | CO (ppm) | | NO (ppm) | | RPM (n/min) | | Exhaust gas temp. (°C) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Belt | Woody | Belt | Woody | Belt | Woody | Belt | Woody |
| 2 | Slack drive on forest road | 1129 | 125 | 1070 | 585 | 2000 | 772 | 324 | 321 |
| 3 | Slack drive on skid trail | 492 | 100 | 730 | 368 | 1804 | 1053 | 284 | 203 |
| 5 | Pulling of rope | 828 | 115 | 781 | 372 | 1040 | 1076 | 243 | 200 |
| 6 | Binding of logs | 390 | 118 | 714 | 372 | 800 | 1179 | 210 | 196 |
| 7 | Hauling | 462 | 113 | 662 | 313 | 800 | 861 | 187 | 183 |
| 9 | Load drive on skid trail | 3717 | 187 | 1347 | 1171 | 2311 | 1433 | 548 | 401 |
| 10 | Load drive on forest road | 4076 | 268 | 1402 | 1434 | 1800 | 1651 | 613 | 478 |
| 11 | Unbinding | 2172 | 224 | 1127 | 631 | 1257 | 1219 | 458 | 356 |
| 12 | Sorting of logs | 1589 | 142 | 903 | 433 | 1000 | 1337 | 387 | 323 |
| 13 | Timber storage | 786 | 133 | 939 | 476 | 1457 | 915 | 321 | 291 |

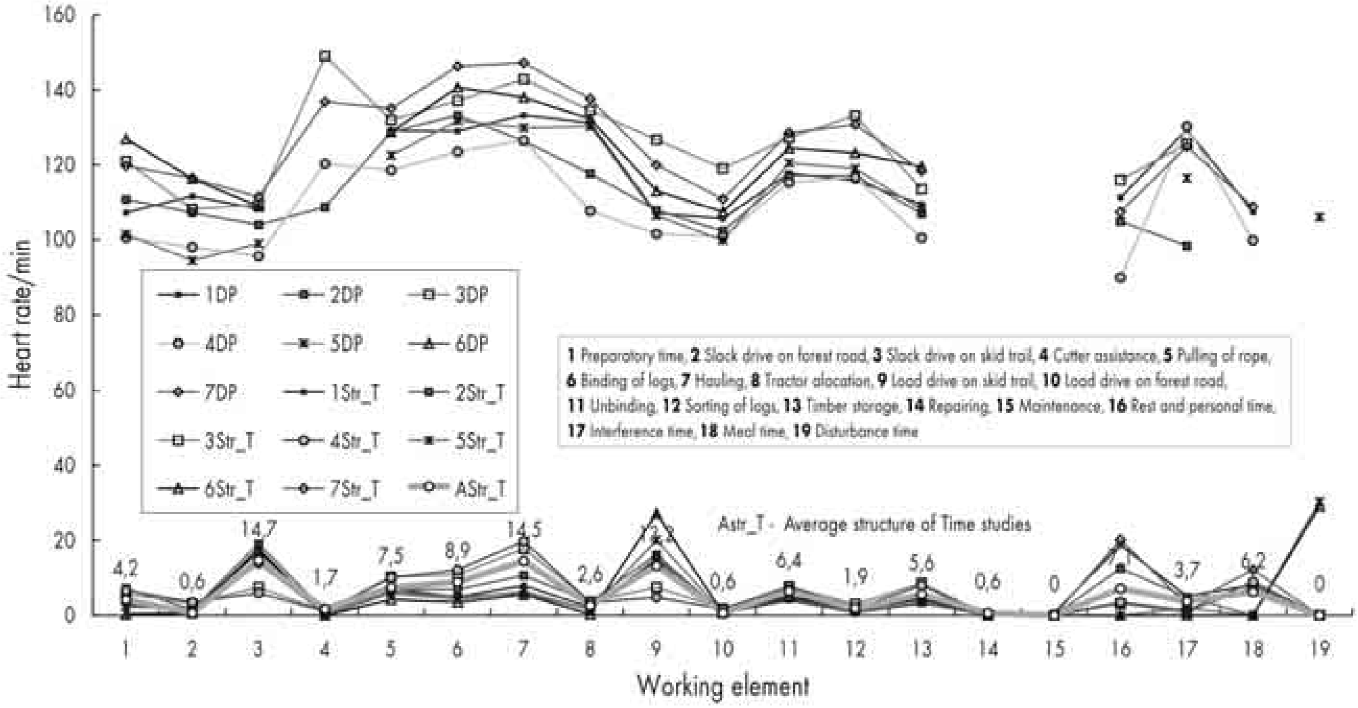


**Figure 5** Mean heart beat rate by working elements for all working days and time structures (Legend: 1CP – The first day of heart rate monitoring – the mean of all cycles, 1Str_T – Time structure for the first working day)

time structure. A great variety regarding both facts can be seen in Figure 6. Total stress of operators in individual cycles is presented there in such a way that heart beat rates after all working elements within the productive time have been summed up.

Due to a great variety of working conditions and different duration of working operations the stress also differs considerably. Figure 7 presents the average stress in a working cycle, individualy for each operator. There are several data in the graph, requir-

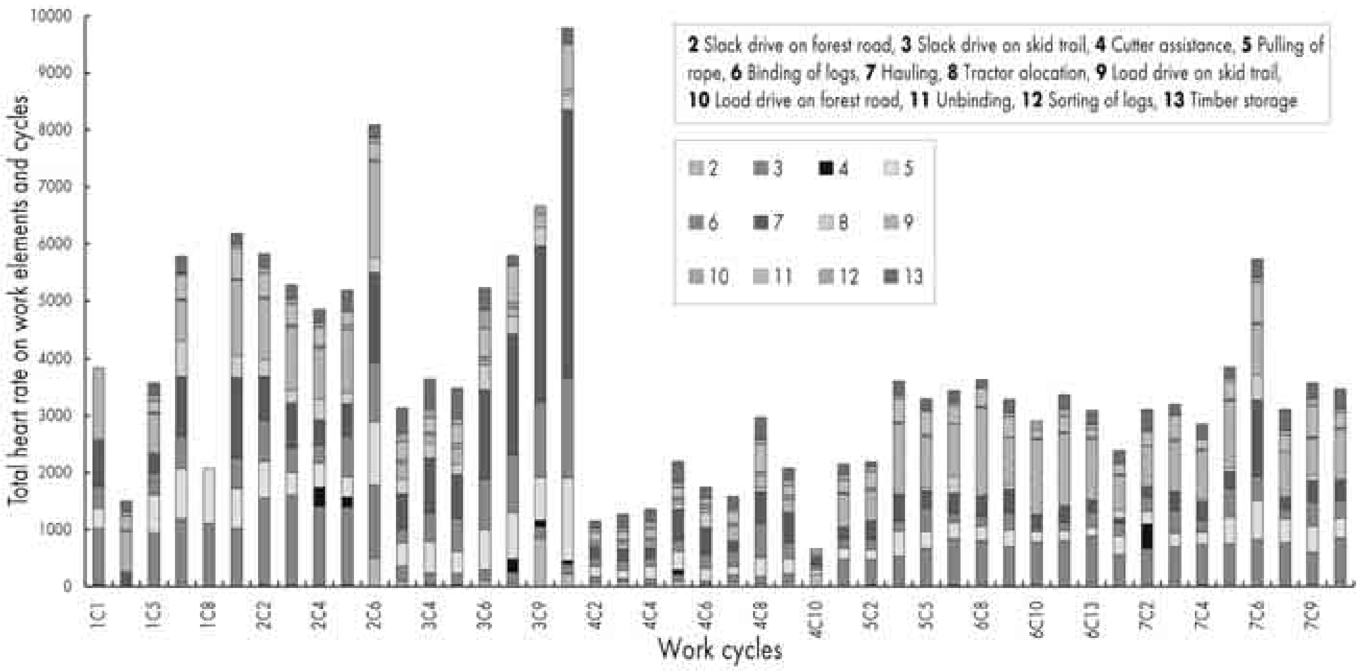


**Figure 6** Total operators' stress (heart beat rate sum) by cycles and working elements

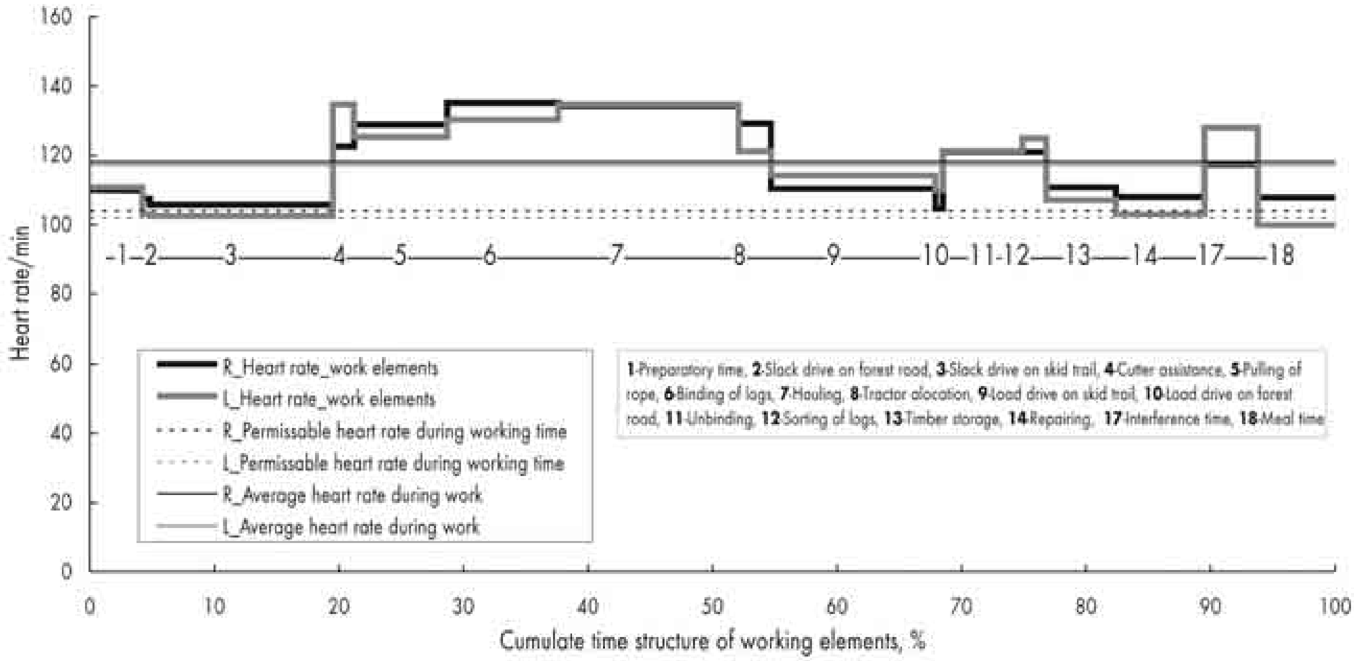


**Figure 7** The mean heart rate of operators in skidding with Woody regarding the average structure of working days

ing additional explanation. On the abscissa there is a sum total of the duration of all working elements, as they are performed in a sequence from 1 to 18 (at first 1 – preparatory-finishing time, 2 and 3 – slack drive through a timber yard on forest road and along a skid trail,… to the last element 18 – meal time). The two bold lines indicate the curve of the mean heart rate in both machine operators by working elements. The thin line made of dashes represents the two working heart rate limits and the non-intermittent line the achieved mean heart rate during work. While sampling both operators were similarly overburdened during work because the difference between the permitted working heart rates is similar to that between the average ones. If the average structure of a working day is taken into account, the stress of operators with the average heart rates practically becomes equal, provided a different concept regarding working heart rate limits is taken into consideration.

### 3.2.2. A comparison of the operator stress in skidding with the Woody 110 and Belt GV 70 skidders

In a directed trial, where ecological parameters of the two tractors – Woody and Belt – were monitored, operator stress at work was also monitored. Systematically higher values were established for Belt tractor (Figure 8). The same principle of presentation was used for a heart rate curve during work as shown in Figure 7 and the calculation was made on the basis of the average working day structure. Another difficulty in heart rate sampling emerged due to lacking data on heart rate. Soon after the engine started to work with high revolutions it interfered with data transmission between the transmitter on the belt and the receiver. Thus the data on the mean heart rate for these working operations were calculated on the basis of the samplings from the beginning and the end of working operations.

Based on the comparison of operator stress by means of heart rate, Woody proved to be ergonomically more appropriate because the overburdening level of the operator during work was much lower. Besides, in the tractor cabin of the older tractor (Belt), electromagnetic oscillations emerged, which interfered with the transmission of the data on heart rate. The temperatures in the cabin of the tractor were much higher, the same holds true of the noise. Consequently, a part of the stress heart rate when operating a tractor could be ascribed to working environment. Yet the work outside the cabin is also strenuous, which is most probably due to the pulling of rope, which demands a lot of effort, and the mass of load binders. Furthermore, sitting in Belt when hauling also did not contribute to lower stress in this working operation. The differences between the heart rates during unproductive time were insignificant. Therefore the conviction that the differences between the heart rates in productive working operations indicate higher stress when work is performed with the older and ergonomically less appropriate tractor Belt is even more relevant.

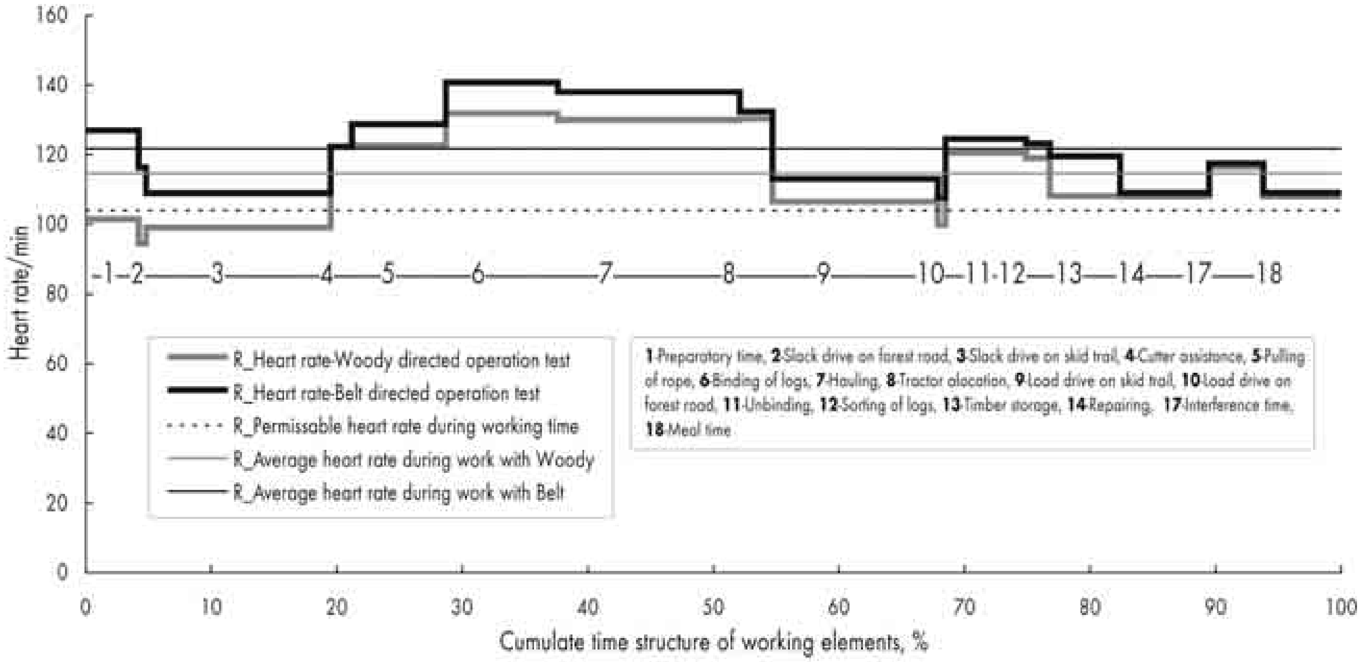


**Figure 8** Directed trial – the mean operator heart rate in skidding with Woody and Belt in relation to the average working day structure

## 4. Discussion and conclusions

From the point of view of soil damage in a compaction trial no significant differences have been established between the two engines. The changes in bulk density and volume coarse pore share are statistically significant in both tractors studied as regards the initial situation. In spite of the fact that the engine mass was higher with Belt, Woody had narrower wheels, which made the static pressure upon the soil amount to around 90 kPa in both engines. The wheel rut depth after ten passes was more than 4 cm in all measured profiles. Hydrostatic drive has no influence on soil alterations unless ground pressure is reduced by wider tires and/or slash mat.

The CO emissions in timber skidding were up to 10 times higher with Belt 70 skidder and NO emissions to 5 times higher than with Woody 110 skidder. At the same engine rotations, the emissions in logging operations were significantly higher on both analyzed skidders than in programmed engine revolutions in idle position of the skidders.

Both operators involved in the investigation exceeded heart rate stress limits while working. Taking into account the actual structure of a working day during monitoring, the heart rate stress limit was exceeded in operator R – 42% and operator L – 36%. Supposing that both operators had the same working day structure – the average of all the samplings – the daily stress limit would be exceeded in R by 39% and in L by 42%. Based on the results of the heart rate studied, it can be concluded that both operators were exposed to approximately the same overburdening in their work. The difference between the permitted working heart rate and the heart rate at rest is the same with both operators (36-heart rates/min). The actual difference achieved between the heart rates during work totaled 49 to 51 heart rates/min. Work performance as well – totaling 113% with operator R and 121% with operator L (source: the Postojna FE) – gives a similar image as regards the efforts during work.

The ergonomic suitability of Woody tractor was also tested comparatively with the older and more out-of-date Belt tractor. The same operator – R – operated both tractors in two subsequent working days in similar working conditions. The average heart rate during work with Woody totaled 115 and with Belt 122. As to the working heart rate limit the former was exceeded by 30% with Woody and 50% with Belt.

## 5. References

Bilban, M., 1999: Medicina dela. Zavod za varstvo pri delu, Ljubljana, 605 p.

Lipoglavšek, M., Kumer, P., 1998: Humanizacija dela v gozdarstvu. Učbenik, Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive gozdne vire, Ljubljana, 214 p.

Košir, B., Krč, J., 2000: Študij časa pri spravilu lesa Woody 110. Zaključno poročilo projekta razvoj in promocija gozdarskega zgibnega traktorja Woody New, Polikopija, Ljubljana, 18 p.

Košir, B., 1994: Work preparation as a tool to avoid soil disturbances. In: Proccedings of IUFRO P3.08.00 seminar on soil, tree, machine interactions, 4.–8. July 1994, Feldafing, LMU-Freising, Germany, 4 p.

Martinić, I., 1994: Ocjena fizičkog opterećenja radnika na privlačenju drva. Mehanizacija šumarstva, Zagreb, 19, 3, p. 151–160.

MRU emissionstechnik, 1998: Bedienungsanleitung für Abgasanalysator Varioplus. MRU GmbH, Heilbronn, Deutchland, pp. 55.

Robek, R., Medved, M., 1999: Some environmental and ergonomic stresses during logging with skidders Woody 110 and Belt 70. Paper in IUFRO Symopsium, Divisions 3.04.00, 3.06.00, 3.07.00: Emerging harvesting issues in technology transition at the end of the Century, Opatija; Croatia, 27. 9–1. 10. 1999. pp. 101–102.

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# Ergonomic Features of Woody 110 Skidder

**Marjan Lipoglavšek**

***Abstract***

*Within the research project of the technological development of hydrostatically driven Woody skidder, its ergonomic features have also been determined. Comprehensive ergonomic assessment showed that the skidder meets 77 % of the requirements, which is similar to other tractors used for timber skidding in Slovenia. The equivalent noise level in the cabin is 72 to 87 dB(A) and the noise stress of the tractor driver calculated in productive time was 79.8 dB(A). The seat vibrations in productive skidding time were about 1 ms$^{-2}$ in simple directions and the tractor driver's stress was within the allowed limits during time of work. No concentrations of carbon monoxide were recorded.*

***Key words:*** *timber skidding, ergonomic features, Woody 110 skidder*

## 1. Introduction

Within the research framework of applicability of hydrostatically driven WOODY 110 skidder for wood skidding in Slovenian forestry-economic conditions, its ergonomic features have also been investigated. The research was made in 1999 by Biotehniška fakulteta Ljubljana, Gozdarski institut Slovenije, Gozdno gospodarstvo Postojna and tractor manufacturer – Vilpo Grosuplje and co-financed by Slovenian Ministry of Science and Technology. The development of this skidder was presented at the meeting in Delnice (FORMEC 99). In the area of Postojna forest management in Leskova dolina (unit – Snežnik) pilot measurements of noise and carbon monoxide (CO) concentration in the cabin during 4 cycles of timber skidding and with the skidder at idling were carried out. In Leskova dolina, but in different conditions, a comprehensive ergonomic assessment of skidders was made as well as recommendations for its improvement. In the forest management unit Ilirska Bistrica, in the area of Gomance, again only pilot measurements were carried out of the skidder seat vibrations during 4 (2 incomplete) cycles of timber skidding. We also tried to estimate the tractor driver's noise and vibration load in single work operations and in a whole working day. The collaborators of Slovenian forest institute also measured the emission of carbon monoxide and the work effort of the tractor driver by means of a heart-rate. The results of their measurement were compared with those obtained for the BELT GV 70 skidder and they were published in another article (Opatija IUFRO 1999).

## 2. Noise

The noise of the WOODY 110 skidder was measured by an accurate microphone – Brüel et Kjaer 4155 and sound level meter – B et K 2231 in the tractor cabin with different engine rotation frequencies while tractor doesn't move and during 4 skidding cycles. With two rotation frequencies (at idling speed and at working rotation frequency 1 200 min$^{-1}$) the noise level was measured over a distance of 0 to 12 m from the tractor. In all measurements the microphone was attached to the helmet by the right ear at the eye height of the tractor driver, directed toward the ground. During skidding operations, the instrument's memory recorded the extreme values and the equivalent noise level at 30 second intervals. The measured values could be presented visually on the digital display all the time. Timber skidding was also monitored by a video camera, so that later on, for each 30 second interval, the work operation prevailing in that interval could be determined. The data were entered into the computer during the on-site recording and later on they were processed by use of MS-Excel program. When the tractor driver came out of the tractor, the helmet with the microphone was left in the cabin and continued measuring the noise but it was not taken into consideration in calculating the noise stress of the tractor driver. The cabin was only partly closed, as the window was partly opened during the whole operation of timber skidding and even the door was opened during the operation of timber gathering.

### 2.1. Skidder noise at idling

While the skidder was standing, unloaded on the road, the noise level in the tractor cabin was from 73.5 to 88.2 dB(A). It was measured at different engine rotation frequencies ranging between 760 and 2 250 min$^{-1}$, achieved by throttling up and reading the engine rotation meter. The noise level with the maximum frequency of 1 700 min$^{-1}$, otherwise irregular, had an almost linear growing trend and then dropped to start going up again at the frequency of 1 900 min$^{-1}$.

The noise ranging between 77.2 and 53.9 dB(A) was measured at idling speed and engine rotation frequency of 760 min$^{-1}$ outside the cabin. Measurement was performed right by the tractor and behind it, where the tractor driver spends most of his time, at each meter distance from the tractor exit and at ear height of the standing tester. Similarly, at the same points, the noise was measured at the engine rotation frequency of 1 200 min$^{-1}$. Maximum noise of 81 dB(A) was measured right by the engine and minimum noise of 57.5 dB(A) at the distance of 12 m behind the tractor. The noise level decreases with the increase of the distance between the operator and the tractor.

The measured noise level of 60 dB(A) over a distance of 7–8 m, assessed as the distance at which the tractor driver spends most time during timber gathering, was used in calculating his daily noise load.

### 2.2. Working conditions during noise measurement in timber skidding

Noise level was measured in timber skidding from a mixed stand of beech, fir and spruce in the area of Leskova dolina. The tractor driver gathered timber at different spots of a 405 m long skid trail so that the skidding distance was between 255 and 405 m. Skidding was carried out downhill and the skid trail slope was mostly slight – max. + 4%. However, in its central part there was a counter-slope with the highest measured slope gradient of 31%, 15 m long. Tractor loads were, therefore, small: from 0.59 to 3.26 m$^3$ – 2.16 m$^3$ on the average, made of coniferous and beech logs and other beech small-size round wood. The tractor driver (R. R.) had a 27 year work experience, of which 20 years as a tractor driver. He was 43, 174 cm tall and weighing 73 kg. He came to the place of work by his own car crossing a distance of 16 km. Some other details regarding work-

**Table 1** Noise loads of tractor driver operating the Woody 110 skidder

| Working site | LESKOVA DOLINA | | | | | GOMANCE | |
|---|---|---|---|---|---|---|---|
| | Noise load of tractor driver | | | Noise load of tractor driver with other recording of time | | | |
| | Single cycle Noise level | Average | | | | | |
| | | share of time | noise $L_{ekv}$ | share of time | load $L_{ekv}$ | share of time | load $L_{ekv}$ |
| Work element | dB(A) | % | dB(A) | % | dB(A) | % | dB(A) |
| Unloaded travel | 83.3–84.8 | 17.8 | 84.1 | 22.8 | 83.3 | 17.1 | 83.3 |
| Turning | 78.8–80.5 | 0.4 | 79.7 | 34.5 | 60.0 | 46.0 | 60.0 |
| Gathering wood | (77.8–79.3) | 40.9 | 60.0 | | | | |
| Moving | (78.9–81.1) | 0.4 | 60.0 | 24.9 | 84.4 | 18.2 | 85.2 |
| Skidding | 84.9–85.8 | 19.4 | 85.2 | | | | |
| Unbinding | (72.6–76.8) | 10.1 | 66.0 | 8.9 | 66.0 | 7.9 | 66.0 |
| Sorting | (79.9–83.7) | 4.9 | 66.0 | 2.3 | 66.0 | 2.8 | 82.0 |
| Storaging | 82.0–83.0 | 6.1 | 82.5 | 6.6 | 82.5 | 8.0 | 82.5 |
| Productive time | | 100 | 79.8 | 100 | 81.1 | 100 | 80.7 |
| Non-productive time | (72.8–79.8) | | 50.0 | *(3.5 h)* | 50.0 | *(2 h)* | 50.0 |
| Working time (8 h) | | | | | 78.6 | | 79.5 |
| Duration of productive time, min/cycle | 18–29 | 24.7 | | 47 | | 56 | |
| Gathering distance, m | | | | 11 | | 12 | |
| Skidding distance, m | 255–405 | | | 514 | | 403 | |
| Average load, m$^3$ | | 2.16 | | 4.08 | | 3.72 | |
| No. of pieces | | 7.5 | | 7.7 | | 8.8 | |
| m$^3$/piece | | 0.29 | | 0.74 | | 0.54 | |
| Number of cycles | | 4 | | 87 | | 77 | |

ing conditions, especially the structure of working time in skidding, can be seen in Table 1.

Table 1 shows that the average equivalent noise levels were 8o do 85 dB(A) when the tractor driver was in the tractor's cabin. The measured load of the tractor driver ($L_{ekv}$) in total productive time in these 4 cycles was only 79.8 dB(A) on the average, as he spent 56 % of the productive time out of the skidder. In Table 1 noise load of the tractor driver was measured taking into consideration the structure of productive and working time, which had been established in comprehensive time studies (87 and 77 skidding cycles).

Based on such calculations, the load of the tractor driver is 81.1 dB(A) in productive time and 78.6 dB(A) in an 8 hour working day. It has been taken into account that only 270 minutes or 4.5 hours are productive time in a tractor driver's working day, which was established by analyzing only 4 working cycles. On the basis of some assumptions, the noise load was also calculated for the other tractor driver in Gomance working site, who can only operate the winch and not the tractor, by means of remote radio control commands. It is slightly lower in productive time (80.7 dB(A)), as more time is required for timber gathering in more difficult terrain conditions. However, in a working day it is slightly higher (79.5 dB(A)), as 350 minutes or about 6 hours represented productive time in his working day (calculated on the basis of only two skidding cycles).

Noise load of the tractor driver of approximately 80 dB(A) in productive time is considerably lower than the stress established in Slovenia several years ago in timber skidding with other tractors (Table 2).

It is much lower, as the engine causes lower noise in the cabin at considerably lower working rotation frequency and also because the remote control winch enables the tractor driver to work outside the tractor, where the noise is much lower. Noise loads of the Woody 110 skidder in a working day are within the allowed limit of 85 dB(A) for most physical activities and therefore no damage to the sense of hearing is expected. Noise exceeding 60 dB(A) only makes the work difficult, as it reduces the working capability of workers. When making comparisons, it should bear in mind that the reduction of equivalent noise level of 3 dB(A) means the reduction of the load to a half. It could be said that the load of tractor drivers in skidding by Woody is 4 to 6 times lower than in skidding by other tractors.

**Table 2** The stress established in Slovenia in timber skidding with other tractors

| | Productive time $L_{ekv}$ – dB(A) | Working time $L_{ekv}$ – dB(A) |
|---|---|---|
| Skidder – TBJ 208D | 98.0 | 97.2 |
| Skidder – BELT GV 50 | 93.0 | 92.2 |
| Skidder – BELT GV 70 | 96.7 | 95.1 |
| Wheel tractor IMT 560 | 94.2 | 93.3 |
| Track tractor FIAT 605 | 91.9 | 91.1 |

## 3. Vibrations

Seat vibrations of the Woody 110 skidder *were* measured at the working site Gomance (unit Ilirska Bistrica, GG Postojna). Three-axes accelerometer Brüel et Kjaer was attached to a special board installed on the seat and connected by cables to the B et K 2231 meter equipped with B et K 2522 for measuring vibrations. During timber skidding, at 30 second intervals, the meter recorded simultaneously the extreme and mean vibration accelerations in all three directions: up – down, left – right and forward – backward. For each half-minute interval, the simple vector acceleration sum was calculated. In order to be able to compare these vibrations with previously measured vibrations of other tractors, the vibrations were measured linearly in the frequency area of 1–180 Hz. Again 4 skidding cycles were recorded, of which two were measured only partly due to their duration and limited memory capacity of the *vibration's* meter (only unloaded travel and gathering). Skidding was recorded by video cameras, so as to provide later on the possibility of determination of the prevailing work element for each 30 second interval. Our attention was particularly focused on moments when the tractor driver was leaving the seat and coming back to take it. The measured acceleration for the first two cycles was read from the memory on-site and the data for the other two were later transferred by interface directly to PC. By use of MS-Excel program, all data were entered, codes for work element were added and the vibration level in the recorded time was drawn. For establishing the *levels* of vibrations in *third-octave* frequency *bands* and for the assessment of vibration load of the tractor driver on his seat, another test was carried out in which the tractor driver drove the skidder forward and backward on one side over a 10-cm high obstacle. The accelerations on the seat were then measured with the same accelerometer but with another *vibration's* meter: B et K 2511 and B et K 1621 filter. Only vertical direction was measured, as the accelerations in this direction were the highest during skidding. Linear and *frequency band* accelerations were recorded on the recording paper of B et K 2306 printer. Filter frequency *bands* were selected manually in mid-thirds-octave from 0.20 to 50 Hz. The measured test accelerations were lowered proportionally to average accelerations in vertical direction, measured *linearly* in skidding productive time. Thus corrected accelerations were compared to the *allowed* limits for a 6 hour daily exposure to vibrations, which are transmitted to the whole body (WB ISO 2631).

### 3.1. Work conditions during vibration measurement in wood skidding

The seat vibration level was measured in the area of Gomance on a stony but smooth and dry skidding road, 360 m long. As the tractor driver gathered timber on different places, the skidding distance was 300 to 360 m. Karst terrain was steep and stony and therefore very inconvenient for gathering wood. The skidding road was mostly inclined in skidding direction with the slope gradient of up to –24% and at the very beginning it had an 84 m counter-slope with the maximum slope gradient of +18% (12 m long). On that section of the skidding road, the tractor drove in reverse when it was unloaded, as there was no enough space for turning at the end of the skiddind road. The tractor driver skidded simultaneously long thick round wood and thinner timber. The loads were from 3.20 to 4.63 $m^3$ i.e. 3.86 $m^3$ on the average and they consisted of 8.25 pieces. Additional details on work conditions, especially on the structure of the skidding working time can be seen in Table 2. The tractor driver was an experienced worker of 45, 177 cm tall and weighing 68 kg.

### 3.2. Skidding vibrations

The level of linearly measured seat vibrations during four skidding cycles was very changeable. Instantaneously (2 msec) measured acceleration peaks in single direction were in direction x (forward – backward) max. 15.2 $ms^{-2}$, y (left – right) max. 20.3 $ms^{-2}$ and vertical z (up – down) max. 25.6 $ms^{-2}$. Maximum average acceleration level of one second duration was 2.9 (forward – backward), 4.7 (left – right) and 5.4 $ms^{-2}$ (up – down). Mean level of acceleration in 30 second intervals, measured as the square means and used for the assessment of the skidder vibrations and load of the tractor driver, ranged horizontally (x) between 0 and max. 1.98 $ms^{-2}$, sidewise (y) max. 1.85 $ms^{-2}$ and vertically (z) max. 3.3 $ms^{-2}$. All these figures imply that low-frequency seat vibrations achieve the highest intensity in vertical direction. This probably means that their main source is the uneven skidding road and not the machine's drive, as forward-backward vibrations have the lowest accelerations.

On the basis of 30 second accelerations, square means were calculated for individual productive work operations and weighted square means were calculated for total skidding time, where weighted items were the duration of work elements. Table 3 shows the results of 4 recorded skidding cycles as well as skidding time recorded in other investigations. The vibration's meter calculated the vector sum for each second and for each half-minute based on the acceleration in single directions. From these values, mean vector sums for individual work elements were calculated and they varied quite seriusly. They were the highest in unloaded travel (2.28 $ms^{-2}$), a little lower in skidding and still lower in storage operations (1.44 $ms^{-2}$). In hauling the load to the skidder and in sorting timber on the road, while the tractor driver is sitting on his seat they are the lowest (approximately 0.80 $ms^{-2}$) and during gathering and unbinding operations the tractor driver is not under vibration stress, as he is not in the skidder then. In total time the tractor driver spends on his seat, the average measured accelerations in single directions were around 1 $ms^{-2}$ and the vector sum averaged 1.98 $ms^{-2}$. In total productive time, the stress of the tractor driver in single directions ranged (linearly) between 0.57 and 0.64 $ms^{-2}$ and the vector sum was 1.17 $ms^{-2}$. Assuming that in an eight-hour working day 6 hours are productive time, the average seat acceleration sum within the working time is only 1.01 $ms^{-2}$. For the time structure based on broader recording of required working time, the vibration loads of the tractor driver were also calculated for the area of Gomance. They are slightly higher due to longer skidding distance. Vector sum in productive time is 1.40 $ms^{-2}$ and in working time 1.21 $ms^{-2}$. A similar calculation for the working site in Leskova dolina, not quite reliable, as the characteristics of the working site where time was recorded are not known, gives a slightly higher vector sum of 1.59 $ms^{-2}$ for productive time. It is higher because the share of travel duration is higher than in Gomance and this is the time when the vibrations are the highest.

When the vibrations of the Woody 110 skidder are compared to vibration measurements in skidding performed by other tractors, it can be seen that in productive time the Woody 110 skidder achieves the lowest results. Only the BELT GV 50 skidder showed lower vibrations for the time the tractor driver spent on his seat. This skidder, however, was very slow in its work due to a weak engine and the travel speed on skidding road has a serious impact on vibrations. Seat vibrations with the Woody 110 (in 37 % productive time – Table 4) are 2 to 3 times lower than with other tractors (BELT GV 70, IMT 560 or FIAT 505). It is not possible to make direct comparison with the allowed limits, as the accelerations

**Table 3** Vibration stresses of tractor driver of the Woody 110 skidder

| Working site | Tractor driver on the seat | Average skidding cycle | | | | | Broader investigations of work operation's duration | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | GOMANCE | | | | | GOMANCE | | | | | LESKOVA DOLINA | | | | |
| | | Acceleration $ms^{-2}$ | | | | Share of time | Share of time | Acceleration $ms^{-2}$ | | | | Share of time | Acceleration $ms^{-2}$ | | | |
| Work element | | *X* | *Y* | *Z* | Vect. | % | % | *X* | *Y* | *Z* | Vect. | % | *X* | *Y* | *Z* | Vect. |
| Unloaded travel | yes | 1.20 | 0.98 | 1.29 | 2.28 | 11.3 | 17.1 | | | | 2.28 | 22.8 | | | | 2.28 |
| Timber | yes | 0.35 | 0.30 | 0.30 | 0.78 | 3.3 | | | | | | | | | | |
| gathering | no | | | | | 54.6 | 46.0 | | | | | 34.5 | | | | |
| Skidding | yes | 1.25 | 1.04 | 1.24 | 2.21 | 11.6 | 18.2 | | | | 2.21 | 24.9 | | | | 2.21 |
| *Unbinding* | no | | | | | 8.3 | 7.9 | | | | | 8.9 | | | | |
| Sorting | yes | 0.34 | 0.30 | 0.55 | 0.85 | 1.6 | 2.8 | | | | 0.85 | 2.3 | | | | |
| *Storage* | yes | 0.54 | 0.98 | 0.57 | 1.44 | 9.3 | 8.0 | | | | 1.44 | 6.6 | | | | 1.44 |
| Productive time | yes | 1.01 | 0.94 | 1.05 | 1.92 | 37.1 | 46.1 | 1.10 | 0.92 | 1.14 | 2.06 | 54.3 | 1.16 | 1.01 | 1.20 | 2.16 |
| | no | | | | | 62.9 | 53.9 | | | | | 45.7 | | | | |
| 6 hours | total | 0.61 | 0.57 | 0.64 | 1.17 | 100 | 100 | 0.75 | 0.62 | 0.77 | 1.40 | 4.5 h | 0.86 | 0.74 | 0.89 | 1.59 |
| *Work. time*, 8 h | | 0.53 | 0.49 | 0.55 | 1.01 | | | 0.65 | 0.54 | 0.67 | 1.21 | 8 h | 0.64 | 0.56 | 0.66 | 1.19 |
| Durat. of prod. time, min/cycle | | 28.5–31.0 | | | | 30.2 | 56 | | | | | 47 | | | | |
| Distance of gathering, m | | | | | | | 12 | | | | | 11 | | | | |
| Skidding distance, m | | 300–360 | | | | | 403 | | | | | 514 | | | | |
| Average load, $m^3$ | | 3.68 | | | | | 3.72 | | | | | 4.08 | | | | |
| Number of pieces | | 8.25 | | | | | 8.84 | | | | | 7.67 | | | | |
| $m^3$/piece | | 0.47 | | | | | 0.54 | | | | | 0.74 | | | | |
| Number of recorded cycles | | 2 + 2 | | | | | 77 | | | | | 87 | | | | |

**Table 4** Comparison between seat vibrations in productive time – linearly measured accelerations, $ms^{-2}$ with different tractors

| | Linearly measured accelerations, $ms^{-2}$ | | | |
|---|---|---|---|---|
| | forward-backward *X* | left-right *Y* | up-down *Z* | vector |
| WOODY 110 | | | | |
| tractor driver on seat | 1.01 | 0.94 | 1.05 | 1.92 |
| total productive time | 0.61 | 0.57 | 0.64 | 1.17 |
| BELT GV 50 | 0.78 | 0.92 | 0.64 | 1.37 |
| BELT GV 70 | 4.38 | 3.63 | 1.96 | 6.02 |
| TBJ 208 | 1.48 | 1.83 | 1.47 | 2.77 |
| IMT 560 | 2.73 | 1.42 | 2.62 | 4.04 |
| FIAT 505 | 2.73 | 2.82 | 1.72 | 4.29 |

were measured linearly, and the exposure limiting values are set for frequency values adapted to human sensitivity. The measurement was carried out linearly so as to provide the possibility of comparison of this tractor with other skidding tractors, the vibration intensity of which had already been measured. However, during skidding in Gomance, the frequency weighted acceleration sum was also measured and it did not differ considerably from the linear vector sum. If this linear sum is taken as the right one instead of the frequency weighted sum, it can be established, in compliance with ISO 2631 standard, that the seat vibrations of the Woody 110 skidder, after two hours of work, are a serious health threat to lumbar part of the back (Ergonomic guidelines for forest machines). This assumption, however, is not quite true.

### 3.3. Frequency analysis of seat vibrations

In driving the skidder over the obstacle on the road maximum vibration accelerations were measured in vertical direction in third-octave frequency bands from 0.20 to 50 Hz. It was assumed that a similar distribution of mean vibration levels in the frequency bands occurred with timber skidding, only at a much lower level. The measured accelerations in the test were lowered proportionally to the coefficient between linearly measured vibrations in skidding and in jumping over the obstacle. This was performed for the productive time spent by tractor driver on his seat and then for total productive time. All measured values with frequency analysis in the bands were multiplied by coefficients 1.05/8.22 = 0.127737 and 0.64/8.22=0.077860, respectively. The figures were taken from Table 3 for vertical vibration direction in skidding i.e. as the average value of linear measurements in the test.

The calculated load of the tractor driver by frequency bands is compared to exposure limits pursuant to ISO 2631 for 6 hours a day (productive time). The load of a tractor driver, sitting on his seat for 6 hours, exceeds the internationally set limit of work capability. His actual load with vertical vibrations is within the set limits, as he spends a lot of productive time on the ground. These vibrations only make him less comfortable in his work. Other skidders cause stresses, which are much higher than those of the Woody 110 skidder. Only with the BELT GV 50 skidder slightly lower accelerations were measured by frequency bands during time the tractor driver spends on the seat, but the Belt tractor driver spends much more time on his seat. Adapted farming tractors, wheeled and tracked, cause such seat vibrations that they jeopardize the health of tractor drivers.

## 4. Exhaust gases

During timber skidding in Leskova dolina i.e. during noise measurement, the meter for measuring the concentration of carbon monoxide, Dositox manufactured by Compur Munich, was attached to the right part of the chest of the tractor driver. In four skidding cycles no concentration of CO was recorded by the meter in spite of its 1 ppm sensitivity. The same occurs in skidding with other tractors, as the muffler directs all gases above the tractor cabin and air circulation in the forest carries away and dilutes all exhaust gases very quickly.

## 5. Comprehensive ergonomic assessment of skidders

Comprehensive ergonomic assessment has been made for the Woody 110 skidder by use of German ergonomic questionnaire (Mitteilungen des KWF, B. 19, 1977) for working machines. This questionnaire was chosen because it had already been used for assessing the ergonomic features of other skidders. In this way the possibility of making comparison between them was provided. The German questionnaire has a much lower number of general questions and therefore it is possible to assess details and make recommendations for improvement.

During winter parking in Leskova Dolina the skidder was assessed by a group of 7 forestry experts from GG Postojna, Gozdarski inštitut Slovenije and Biotehniška fakulteta, Ljubljana. They answered 86 questions out of 92, comprised by the questionnaire. Six questions were considered inadequate for the assessment of this skidder. As required by the questionnaire, their answers were mostly based on its objective criteria and they were as follows: ergonomically favorable (+), partly favorable (0) unfavorable (–).

The questionnaire covers 11 areas of ergonomic assessment. Complete satisfaction was not achieved with ergonomic design of the Woody 110 skidder in any area, except visibility. According to the number of negative answers, control instruments, which are not of utmost importance due to relatively slow operation of working machines, were assessed as the worst, along with operating instructions and maintenance performed by tractor driver himself. The number of different answers is shown in Table 5 70 % of the answers were favorable and 7 % partly favorable. 23 % of the answers were negative, as the skidder does not meet, to a certain extent, one or more out-of-date and mild German criteria of ergonomic suitability.

When the ergonomic features of other tractors were assessed several years ago, the suitability criteria were established for tractors in Slovenian forests, requiring a minimum of 70 % of favorable or partly favorable answers. The Woody 110 skidder meets these criteria, similarly as some other skidders: FIAT 605 with cabin, Timberjack 208, BELT GV 50. However, the Woody 110 skidder does not meet some essential work safety requirements or there is no evidence that it does. Consequently, in compliance with the Slovenian currently applied criteria, it could not get a positive expert judgment of work safety. The deficiencies are: only one exit from the cabin, sharp edges in the cabin, which can be the cause of injury of the tractor driver, unprotected hydraulic pipes in the cabin and the lack of the cabin strength test.

Along with the assessment of ergonomic features, recommendations for improvement were made for those unsatisfying. Some ideas for improvement also appeared with some positive answers. Some of them were not only ergonomic but also technical and technological. There were 34 recommendations in all for the improvement of the skidder features. Their complexity and importance for improving the ergonomic suitability varies quite considerably. Many of them can be carried out by minor design changes e.g. by moving the handle for the entrance into the tractor for a few centimeters. Others, however, require serious changes e.g. changing the shape and size of the cabin. These recommendations have been submitted to the manufacturer together with the de-

**Table 5** Comprehensive ergonomic assessment of the Woody 110 skidder

| Area of ergonomic assessment | | Total number of questions | Favorable answers + | Partly favorable 0 | Unfavorable answers – |
|---|---|---|---|---|---|
| 1 | Entrance and exit | 8 | 5 | 1 | 2 |
| 2 | Working area (cabin) | 6 | 5 | 0 | 1 |
| 3 | Seat | 9 | 6 | 1 | 2 |
| 4 | Control instruments | 9 | 4 | 1 | 4 |
| 5 | Operating elements | 11 | 9 | 1 | 1 |
| 6 | Visibility | 6 | 6 | 0 | 0 |
| 7 | ***Health damaging influence*** | 7 | 6 | 0 | 1 |
| 8 | Physical and psychic. stress | 8 | 7 | 0 | 1 |
| 9 | Safety | 10 | 7 | 2 | 1 |
| 10 | Operating instructions | 3 | 1 | 0 | 2 |
| 11 | Maintenance and repair | 9 | 4 | 0 | 5 |
| Total assessment, n | | 86 | 60 | 6 | 20 |
| % | | 100 | 70 | 7 | 23 |

scription of changes, some of them detailed graphically on tractor photos. Many of them will be certainly adopted in the production of further Woody 110 skidders.

## 6. References

Gellerstedt, S. et al., 1999: Ergonomic guidelines for forest machines, SkogForsk

ISO 2631: Guide for the evaluation of human exposure to whole-body vibrations

Košir, B., Lipoglavšek, M., 1999: Entwiklung des forstlichen Knickschleppers Woody mit hydrostatischem Antrieb in Slowenien, 33.Internationales Symposium »Mechanisierung der Waldarbeit« Sammelbuch, Zagreb 1999, s. 123–128.

Košir, B. et al., 2000: Razvoj in promocija gozdarskega zgibnega traktorja Woody new, Zakjučno poročilo raziskav, BF Ljubljana

Rehschuh, D., Tzschökel, D., 1977: Checkliste für die ergonomische Beurteilung von Forstmaschinen, Mitteilungen des KWF, Band 19.

Robek, R., Medved, M., 1999: Some Environmental and Ergonomic stresses during logging with skidders Woody 110 and Belt 70, Emerging harvesting issues in technology transition at the end of century, IUFRO meeting, Opatija.

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# Cannabis use among forestry workers

**M. D. Musson, R. N. O'Reilly**

*Abstract*

*The use of drugs by silvicultural or logging workers on the job is a concern for employers as well as safety and health personnel. To determine the extent of cannabis use by New Zealand forestry workers, a questionnaire survey was carried out in the North Island of New Zealand. 165 workers and trainees were included in the survey, and the results indicate that 77 % of the silvicultural workers, and 54 % of the loggers, reported having used cannabis in the previous 12 months. 25 % of the silvicultural workforce surveyed had used the drug at the workplace, while only 14 % of the loggers had done so. The trainees reflected this trend, with 41 % of silvicultural trainees indicating they had used cannabis while on the job, compared to only 24 % of the harvesting trainees. Results also indicate that the workers with high rates of cannabis use had high rates of workplace accidents, and, in the silvicultural sector, increased duration of lost time accidents. Absenteeism was also higher for both silvicultural and logging workers with increased cannabis use. The implications of the results and the responses by forestry employers are discussed.*

**Key words:** *cannabis, silviculture, logging, accidents, absenteeism*

## 1. Introduction

Forestry companies and the Occupational Safety and Health Section of the Department of Labour have concerns about the use of drugs by forestry workers in New Zealand. In order to determine the extent of cannabis use, a questionnaire survey was carried out in silviculture and harvesting operations in the central North Island plantation forests.

As well as determining the extent of use, the survey questioned workers' attitudes toward the use of cannabis on the job and towards random drug testing of forestry workers. Information on lost-time accidents related to drug use was also collected.

## 2. The Survey

A sample questionnaire was drawn up and tested initially on 14 silvicultural trainees, and modified in order to ensure readability and improve understanding. The survey was conducted on a person-to-person basis both individually and in a group situation. In total, 165 individuals were surveyed, including 43 workers from seven silviculture crews, 53 loggers from three harvesting crews and 45 trainees and 24 students enrolled in the New Zealand Diploma in Forestry, a ranger-type qualification.

52 % of those surveyed were Maori, 14 % were Pacific Islanders, and 33 % were European New Zealanders. 2 respondents were of other ethnic backgrounds. 95 % of those surveyed were male; the 5 % who were females were from the trainee or student groups only.

The average age and the range of ages for the different working groups was: harvesting 32 (22–53), silviculture 21.6 (16–38), trainees 18.3 (15–32).

## 3. Results

### 3.1. Use

77 % of the silvicultural workers and 54 % of the harvesting workers indicated that they had used cannabis in the previous 12 months. Of the trainees involved in silviculture, 94 % had used cannabis in the previous 12 months, while 76 % of the logging trainees, and 63 % of the students, indicated the same.

Only 14 % of the total harvesting workers surveyed indicated that they had used cannabis while on the job, compared to 27 % of the silvicultural workers surveyed. 24 % of the harvesting trainees, 41 % of the silvicultural trainees, and 8 % of the students, stated they had used cannabis on the job.

For all respondents, the average age when initially using cannabis was 15.5 years, and there was not a great deal of difference between working groups (silviculture 14.7, harvesting 16.1, trainees and students 15.8), although the individual replies ranged from 10 years to 22 years.

Heavy users (once or more per day) had an average age of 20 years. The average age of regular users (less than once per day but more than once per month) was 22, while recreational users (less than once per month but more than once per year) had an average age of 24. The average age of non-users was 27.

Of the survey population, those of Maori ethnicity showed the highest proportion of heavy cannabis users followed closely by Pacific Islanders. Those of European ethnicity showed the highest rate of recreational and regular users; all three groups had approximately equal percentages of non-users.

Those workers with up to four years' experience had the highest mean per worker use per week (approximately 10 times per week); those with 6 years' experience had a mean per worker use of 8 times per week, and those with 8 years' experience had mean per worker use of only 3 times per week. Those with more than 8 years' experience had an average cannabis use rate of less than 0.2 times per week.

### 3.2. Attitudes

Workers who indicated that they had used cannabis in the previous twelve months were asked to complete a series of questions on their attitudes toward cannabis use in the workplace. These questions ranged from their perception of cannabis use on accident rate and work quality to the reasons for using the drug at work.

The responses indicated considerable difference in attitudes between the silviculture and harvesting workers who had used cannabis in the previous 12 months towards drug use on the job.

For example:

- 80 % of harvesting workers in this category believed that »a cannabis user on the job is more likely to have an accident« compared to less than 50 % of silviculture workers.
- Not one harvesting worker agreed that »using cannabis on the job helps one relax«, while 40 % of silviculture workers replied in the positive.
- 80 % of harvesting workers disagreed that »one could do the job while using cannabis if one was experienced« (10 % agreed), compared to silviculture workers, 40 % of whom agreed with the statement and only 25 % disagreed with it (the rest were in the »didn't know« category).
- 100 % of harvesting workers disagreed with the statement that »sharing a joint is friendly and accepted on the job«, compared to 60 % of the silviculture workers; 15 % of silviculture workers agreed with this statement.
- 65 % of harvesting workers disagreed, and none agreed, that »cannabis helps break the boredom of the job«, while 44 % of silviculture workers agreed with this statement and only 30 % disagreed.
- 50 % of the harvesting workers disagreed (and only 5 % agreed) with the statement that »cannabis helps cope with the physical pain of the job, while only 25 % of silvicultural workers disagreed and 40 % agreed.
- 85 % of harvesting workers disagreed that »you do a better quality of work when using cannabis«, and none agreed, while 42 % of the silviculture workers agreed and only 35 % disagreed.
- Only 15 % of harvesting workers indicated that they would object to drug testing in the workplace, compared to over 30 % of silviculture employees. On average over all the sectors, 74 % of respondents would not object to drug testing in the workplace. Of those who would object, 92 % were cannabis users and 68 % were classed as heavy cannabis users.

### 3.3. Relationship between Cannabis Usage and Lost-Time Accidents

Every surveyed worker was required to estimate the number and duration of lost time accidents they had had in the twelve-month period prior to the survey. The number of report lost-time accidents within each cannabis use group (non-users, recreational, regular and heavy) was divided by the number of in-

**Table 1** The average number of lost-time accidents per worker

| Sector | Frequency of cannabis use | Accident rate per worker |
|---|---|---|
| Silviculture | Non-User | 0.17 |
| | Recreational | 0.27 |
| | Regular | 0.33 |
| | Heavy | 0.39 |
| Harvesting | Non-User | 0.17 |
| | Recreational | 0.19 |
| | Regular | 0.31 |
| | Heavy | 0.41 |

**Table 2** The average duration of the lost-time accidents

| Sector | Frequency of cannabis use | Average lost-time duration, days |
|---|---|---|
| Silviculture | Non-User | 0.2 |
| | Recreational | 1.2 |
| | Regular | 1.4 |
| | Heavy | 2.1 |
| Harvesting | Non-User | 1.0 |
| | Recreational | 0.5 |
| | Regular | 0.3 |
| | Heavy | 0.4 |

**Table 3** The average duration of the absenteeism

| Sector | Frequency of cannabis use | Average absenteeism, days |
|---|---|---|
| Silviculture | Non-User | 3.6 |
| | Recreational | 3.8 |
| | Regular | 3.0 |
| | Heavy | 5.6 |
| Harvesting | Non-User | 1.6 |
| | Recreational | 1.0 |
| | Regular | 5.0 |
| | Heavy | 4.4 |

dividuals within each group to give a value for the average number of lost-time accidents per worker (Table 1).

It can be clearly seen that in both harvesting and silviculture sectors, increasing cannabis use was accompanied by increasing accident rate. There is a statistical difference between the accident rates of the four cannabis groups. The average duration of the lost-time accidents was also calculated for each cannabis group (Table 2).

For silviculture workers there is a definite positive relationship between the time lost and the cannabis use group. For the harvesting workers, there appears to be a negative relationship, but this is strongly influenced by one 12 day lost time accident for a non-cannabis user.

### 3.4. Relationship between employee absenteeism and cannabis use

All surveyed workers were asked to indicate the approximate number of sick days they had had off in the past 6 months. These results were totalled based on cannabis usage and divided by the number of workers in each group to give a figure for average absenteeism per worker (Table 3).

The table shows that those employees who were regular and heavy cannabis users had higher absentee rates than those who were not. Heavy cannabis users within the silviculture sector had the highest rate of employee absenteeism while it was the regular users who had the highest absenteeism rate in the harvesting sector. Overall, the heavy cannabis use group had twice the absenteeism of the non-user and recreational user groups.

## 4. Summary and Discussion

The results show that a majority of silviculture and harvesting workers surveyed had used cannabis in the previous 12 months. Only a small proportion (approximately 20 %) of those surveyed had used the drug on the job.

There was a strong correlation between use and age and experience, with the younger age groups indicating heavier use. A marked difference in attitude to cannabis use between silviculture workers and harvesting workers is evident, perhaps also a reflection of age.

Most workers surveyed would not object to drug testing on the job; those who would object tended to be the younger, heavier users of cannabis.

A relationship was found between the frequency of cannabis use and the rate of lost-time accidents for both harvesting and silviculture workers. For silviculture workers, there was also a relationship between the duration of lost-time accidents and frequency of use. Considerable interest has been focussed on the relationship between cannabis use and accident rate. However, it must be clearly understood that this study was not designed to show cause and effect, and the results should not be interpreted as such. Age may be the main factor in determining the frequency of cannabis use, the accident rate and the rate of absenteeism, or it may be that those who are the heaviest users of cannabis are so because they have had more accidents or have had more sick days. Whatever the situation, it is not correct to conclude from this study that increased frequency of cannabis use has caused the higher accident rate.

There are a number of lessons for industry and organisations that are concerned about drug abuse in forestry:

- First, any attempt to reduce cannabis use must take into consideration that most cannabis use by the surveyed forestry workers occurred off the job, and so a lifestyle or cultural change is called for; education would seem to be a required means of achieving success.

- Secondly, since the younger workers and trainees were the ones exhibiting more frequent use of cannabis, programs targeting the newer or prospective workers instead of all of the workforce, may be more cost-effective.
- Thirdly, because of the differences in attitude toward cannabis use between harvesting and silviculture workers, a program focussed at the silviculture workforce seems to be called for.

The New Zealand forestry industry has responded positively to the problem of drug use in a number of ways.

A national »ForestSafe« Campaign, supported by the New Zealand Forest Owners' Association, has been launched to emphasise the need for individual forestry workers to take care of their health so that they remain alert on the job. ForestSafe is aimed at changing habits both on and off the job. As part of this, cannabis and alcohol are targeted as factors placing workers at risk.

As well, because of concerns about the health and safety of their employees, larger forestry companies have instigated an educational campaign to inform employees how drugs and alcohol affect people. They have also instigated a three-pronged drug testing program:

- Pre-employment testing, which identifies those with an impaired level of drugs or alcohol;
- »Reasonable cause« testing, which is carried out if the employer feels that there are strong grounds to suspect on-the-job- use of drugs or alcohol;
- Post-incident testing which may be done as part of the normal investigation into the causes of accidents where drugs and alcohol are suspected to have contributed.

Employees who do test positive in the last two cases are offered counselling and the chance to rehabilitate, with the bulk of the cost paid by the Company. Further positive testing by the employee, following completion of the rehabilitation, could lead to dismissal.

Forestry contractors to these companies are being encouraged to set up similar programs, but there are difficulties due to insufficient facilities and ready access to counselling services.

The recent adoption of this policy has not only the backing of the companies and the unions involved, it has, for one company at least, resulted in a completely different attitude to drugs and no lost time injuries since its adoption three and a half months ago.

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# Productivity and work loads of natural forest harvesting in Turkey

**H. Hulusi Acar, Tetsuhiko Yoshimura**

***Abstract***

*General characteristics of forest workmanship can be outlined as working in heavy conditions, working in high elevation, rough and vast areas, the necessity of accommodation in forest as the working site is far from social environment, the obligation of working generally in day-time hours, taking care of silvicultural treatments, large number of tentative workers, high accident risks resulting from working in open air conditions, lower labour pays than other labour branches.*

*According to their annual working intervals, forest employees can be categorised into three different groups as follows: permanent workers, seasonal workers and tentative workers. Forest workers in Turkey generally work during spring, summer and autumn. Most of forest workers are tentative and seasonal forest workers and the rest are permanent. The job is not considered as a very attractive one because of catering, education, housing and walking problems. There are approximately 30 thousand forest workers in Turkey. These workers work on logging, cutting, skidding and transporting of logs.*

*Forest areas in Turkey are generally located in mountainous regions. Therefore, the shape and conditions of the field affect forest labour. The demand for forest labour has been decreasing because of forest workers' health problem, unsatisfying payment, high risks of getting injured and their hard working conditions. These bad conditions affect negatively the forest workers productivity.*

***Key words:*** *forest worker, health, steep terrain, eastern Black Sea region, Turkey*

## 1. Introduction

The forest is made of trees that represent sustainable resources. In the world, man and nature seriously affect the potential forests in the mountainous areas. Day by day, despite the increasing environmental awareness, as a result of economic wishes this negative situation can not be avoided. Although the potential forests in the world are natural forest areas, they are reduced, day by day, affected by human beings and fire and consequently the importance of silviculture increases in forestry.

Generally, forestry operations can be summarised as planning, silviculture, protection and marketing. Very different studies such as forest roads, nurseries, wildlife, national parks and forest surveying are considered. These different studies are carried out on large and scattered lands. Shortly, in different geographic and climatic areas, in areas exposed to nature, forestry workmanship is investigated under adverse physical and physiological conditions.

Forestry workmanship is subject to adverse conditions more seriously than other industrial branches. This is caused by heavy work, rustic work sites, unhealthy and unsafe work conditions, limited mechanisation, physiologic and economic deficiencies. Shortly, the conditions such as the obligation of working at certain time intervals and the palliative position at work, limited education and training, social insufficiencies, obligation of group work, problem of catering, health problems, distance to the work site and walking as well as deficiency of control, reduce the interest for forestry workmanship.

The health of forest workers should be checked-up periodically, mobile bureau should be ready in case of emergency where needed and first aid materials should be kept ready to use in order to increase forest workers' productivity. In our country, it has been established that many forest workers suffer from rheumatism, back, shoulder, arm and leg injuries as well as from liver, lung and hearth problems. The forest workers should be paid more and social security should be provided for them in order to motivate them and increase their productivity.

In this study, the general forest workmanship in Turkey, especially the position of production workmen, is showed. Furthermore, the health problems common in these activities are investigated.

## 2. The position of forest workmanship in Turkey

Ninety nine percent of the forest areas in Turkey are managed by the state. In forestry the private management is so little that we can say that it is meaningless. The number of workers employed by the Ministry of Forests in 1998 was the following: 2,677 permanent employees, 11,234 seasonal, 11,000 fire protection employees, making in total 24,911. These workers are classified as permanent, seasonal and tentative (Orman Genel Müdürlügü 1998).

The demand for forest labour has been decreasing because of forest workers' health problems, unsatisfying payment, high risks of getting injured and hard working conditions. These unwanted conditions affected adversely the forest workers productivity.

The following examples are typical for these workmen, depending on their different working time: for permanent workers – the national park workers, for seasonal worker – the fire-protection workers, for tentative workers – the production workers. Most of the forest workers in Turkey are the production workers and fire-protection workers. The number of permanent workers is lesser than the other two groups together.

Most of the workers in Turkey are male. But in nurseries, the number of female workers increases. This arises from the work sites, heavy labour and work organisation. Furthermore, the conditions of work sites, the organisation, insurance, lack of clothes and safety at work are also an important issue. Workers do not use simple work equipment, such as the helmet and gloves. In practice, the syndicates could not solve these problems either.

Work conditions of the forest workers are partially better. Providing accommodation in caravans, shanties and tents the distance to the work site is minimised. The increase of productivity can be obtained by providing daily food requirements in time. With the provision of special requirements, such as psychological comfort and enough economic earnings, the work productivity increases.

The catering of the forest workers is a problem since it is not organised. This often causes the lack of food. Furthermore, workers themselves have to provide the work clothes as well as the essential work equipment.

There is a serious lack of education and training in forestry workmanship, which is mostly based on experience. In the past, there were workers training camps. These camps left their place to experience. Short courses are still organised for some special machines but this is far from enough.

The check-ups of the worker's health are too few. There is a periodic control and first aid crew but there is no immediate presence of the health stuff.

Some of forestry workers are insured and some of them are not. Especially among the production workers, the work conditions without insurance are out of question. According to the syndicate workers should continue to work under negative conditions. The salary is raised due to heavy work conditions in winter and due to harder labour but earnings like those cannot improve the worker salaries.

## 3. Investigation of the worker's health problems in forest engineering

### 3.1. Material and method

In this study, reports of the investigation carried out on the group consisting of heavy production workers were considered. Studies have been done on production workers in East Black Sea Region during the last three years.

This study was conducted on the workers who work at Yusufeli and Iskenderun Forest Enterprises. The workers were chosen at random and the questionnaire forms, which had been prepared before, were filled by individual conversation with workers. First of all, the workers were classified into groups according to their age: 15–30, 30–45 and older than 45. At the same time, the worker's body size and physical structure suitable for forestry workmanship was determined taking into consideration the width of shoulders, spade and wrist.

The questions prepared for the questionnaire have the same intention but they contain different topics according to their contents. To obtain the integrity of the questionnaire, questions must be answered in accordance with the determined general topics. These general topics are the following:

- The questions that can determine the worker's social economic position, and the questions about the living standard of forest workers of the region

- Worker's health position, the questions that can be asked to determine the forestry workmanship operations, which cause health problems as a result of work conditions
- The effects causing health problems, these effects can be caused by work conditions in forest and by worker's individual properties.

The results of the questionnaire are evaluated by simple statistical methods. At least 30 workers are referenced for the evaluation.

### 3.2. Results and discussion

After the evaluation of the questionnaire results, the following results came forward. Questionnaire was done over 35 production workers in the Directorate of Yusufeli Forest Enterprise and 30 production workers in the Directorate of Iskenderun Forest Enterprise (Acar and Sentürk 1997).

It is observed that the workers working in Yusufeli have weak body structure at young age while in Iskenderun there is no weak body structured young worker. The marriage ratio increases depending on the age.

When examining the production workers for their health problems, 59.67 % of the workers in Yusufeli and 80.27 % of workers in Iskenderun had normal blood pressure. The ratio of varicose-vein diseases of the workers in Yusufeli is low but it increases depending on age. But in Iskenderun only the group older than 30 have varicose-vein diseases and their ratio is very low (11.25 %). As far as diseases accompanied with pain are conserned, in Yusufeli region 40.46 % of the workers have rheumatism and 33.38 % of workers have backache. In Iskenderun region, the most frequent disease is backache with 68.67 % and then rheumatism with 32.83 %. The number of workers in Yusufeli who have nape-shoulder and arm/leg aches is lower than the number of the workers in Iskenderun. 51.27 % of the workers working in Yusufeli suffer from tiredness and weakness and 51.10 % suffer from hand/leg coldness. 63.83 % of the workers working in Iskenderun suffer from tiredness and weakness.

The workers working in Yusufeli region have psychological problems such as nervousness – 38.66 % and fatigue – 39.53 %. The situation in Iskenderun for nervousness is 44.97 %. On the other hand, in Yusufeli region, the most serious observed problem is the lung problem and then bronchitis and flue. In Iskenderun the ratio of bronchitis and flue is higher with 45.18 % and then the problem of stomach sickness with 12 %. The ratio of problems such as eczema-itching, fungus disease, foot and arm injuries, back and head injuries, bruise and twisting met in Iskenderun is higher than in Yusufeli region.

The finger whiteness can be observed on workers working with power saws for a very long time. As a result of pulsation the colour of fingers and hands changes into candle yellow. Young workers usually use the power saw because they are strong.

The physiological problems do not arise only from the forestry work. The negative social/economical position, family problems and poor adaptation to social environment have a serious effect on the workers. Forest workers are always face to face with danger as a result of their job and the lack of economic earning makes them deeply depressed. Therefore physiological disorders such as fatigue, insomnia and headache appear quite often.

Forest workers are always face to face with each other. This characteristic of their job is sometimes the reason why they suffer work accidents. Work accidents cause body injuries. The main reasons for these injuries are the personal faults of workers, environmental effects, lack of equipment, lack of attention and the faults arising from the working environment.

The general results of the evaluation show that the production workers were mostly males.

In this study the reason for the observed diseases such as eczema, itching and fungus diseases is sweating, not changing the sweaty clothes and wearing airless footwear.

As far as the worker's habits are concerned, it can be seen that the two groups are serious consumers of cigarettes and alcohol. The habit of alcohol drinking changes depending on the region. A high ratio of drinking alcohol is met in Iskenderun region. The habit of tea and coffee drinking is very common with both groups of workers and workers do not have the habit of exercising. Generally the workers have habits of smoking and drinking alcohol as a result of limited social opportunities.

According to the evaluation, the forestry workmanship in Turkey is performed as an economic obligation and it is not an optimal industrial branch. The economic and social work conditions are very bad. These are heavy work, no insurance, not organized catering and adverse physiological conditions. Bad work conditions increase the possibility of work accidents. Again the technological development in forestry brings negative effects.

## 4. Conclusion and recommendations

In Turkey, forest workmanship is the main labor branch. But there is not enough involvement and engagement so that it is not at a satisfying level. It is facing a lot of problems, the most important of which is the health problem.

From the standpoint of health evaluation results, in forestry workmanship, the most common ache-pain diseases are nervousness, fatigue and insomnia and other diseases include bronchitis-flue, eczema and itching. They are caused by heavy work, lack of regular feeding and clothing and other negative work conditions.

It is observed with forest workers who had some of these diseases that at an older age these diseases develop further. In forest workmanship the reasons why these health problems are not solved are the distance to the work site, lack of economic security and no social insurance.

Therefore, the following rules must be implemented to improve the forest workmanship in Turkey:

- Feeding, accommodation and work clothing to be solved by syndicates;
- Provide social insurance for all workers;
- Organize regular health services and mobile health crews for workers;
- Organization of the work site, discipline, worker's psychology and education and training must be improved;
- The development of mechanization and ergonomics must be applied to workers.

## 5. References

Acar, H. H., Sentürk, N., 1997: An Investigation on Forest Worker's Health in Yusufeli and Iskenderun. Journal of I. U. Forestry Faculty, A, 47, 2, pp. 95–109.

Anon., 1998: Orman Genel Müdürlügü (Data of General Directory of Forestry). Ankara.

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# »Hrvatske šume« Inc. Zagreb today (1991–1999) and tomorrow (in 21st century)

**Ivan Tarnaj, Josip Dundović**

***Abstract***

*The Republic of Croatia is ranked as the country with considerable forestland per capita in Europe (except Scandinavia) with 0.51 ha of forest per head of population. Forestland covers 43.5 % of the Croatian area. »Hrvatske šume« Inc. Zagreb manages 80 % of it, private owners have a share of 19 % and other governmental institutions 1 % of a total of 2.49 million ha of forestland.*

*This paper shows the basic characteristics of the Croatian forestry today as well as business results of »Hrvatske šume« Inc. Zagreb – the only enterprise managing forests and forestland in Croatia. After eight years, it is necessary to revise the set goal and the organization of the Enterprise. The general goals have been achieved, the Croatian State has been established and the war is over and now the public enterprise »Hrvatske šume« should go through adequate economic changes, as it is not a company nor institute since it is not financed from the budget. This duality is devastating. When making decisions, political opinion must be asked for and when settling its liabilities it acts as a real trade company.*

*Being a large system, the enterprise »Hrvatske šume« is often difficult to adapt. The countries of market oriented economy have a harmonized market system. We have turned things the other way round and we think that market is the lack of coordination and this has brought us into chaos. The effect is that nothing is worth producing and the untrue exchange rate of kuna has buried the export. Wood industry, as the biggest exporter and the most important buyer of »Hrvatske šume«, is not competitive, which also affects us severely in many ways. In addition to our home difficulties there are also the foreign ones. The countries with economy in transition offer wood to the West market at lower prices, as their government supports their export. »Hrvatske šume« and wood industry have no such support.*

*Where is the way out from this situation? We think that the owner, the state, should finally determine what it wants from forestry. Whether it should be profitable and the lever for activating the rest of industry, which would ultimately multiply the effects of forestry through export of highly finished products. However, there is no such determination. At the same time, the Enterprise cannot go on like this and it will have to be transformed from a public enterprise into a state-owned trade company. Since actually the Enterprise acts in accordance with the Law on Forests and not pursuant to the Law on Trade Companies, legal prerequisites must be established for restructuring it into a capital-based company. As a result, forestry with a modern organizational structure should follow as is common in Mid-Europe. The Enterprise must be equipped for carrying out its core business so as to provide production and technology development. The future of »Hrvatske šume« lies in investments in production equipment, which is old and inefficient. The loan will be necessary for such a step forward.*

*As far as wood industry is concerned, the enterprise »Hrvatske šume« has put off payment of some wood assortments at its own expense, thus trying to give its contribution to the rehabilitation of wood industry, because only market competitive wood industry can guarantee a safer life to forestry.*

*Hence, the enterprise »Hrvatske šume« is now at a turning point and is looking for the best options for forest management. It will have to be transformed from a public enterprise into a* *state-owned trade company. Restructuring should bring the optimum organization of forestry, provide decentralization and create conditions for motivating forestry experts and other employees in the Enterprise.*

***Ključne riječi:*** *»Hrvatske šume«, restructuring, process of production, organization of forestry, decentralization, motivation*

## 1. »Hrvatske šume« today, 1991–1999

*Under the Constitution* forests are proclaimed as *goods of general benefit and of special interest for the Republic of Croatia* and the relationships in forest management are regulated pursuant to the *Law on forests* (purified text from the Official Journal: NN 52/90, 61/91 and 71/93). In Croatia 95 % of forests are of natural structure and only 5 % are artificially grown forests or forest plantations. The enterprise »Hrvatske šume« has been entrusted with the task of managing this significant resource primarily with the purpose of its preservation and enhancement for future generations. It provides simple and extended biological regeneration of forests.

Forestland in the Republic of Croatia consists of a forest-economic area of 2,485,300 ha, which makes 44 % of its continental area. »Hrvatske šume« manages 80 % of forests and forestland, private owners 19 % and other governmental institutions only 1 %.

»Hrvatske šume« Inc. Zagreb is a public enterprise for managing state-owned forests and forestland. The Enterprise is in the ownership of the state. It was founded by the decision of the Parliament of the Republic of Croatia on 5$^{th}$ October 1990 and started functioning on 1$^{st}$ January 1991. The enterprise »Hrvatske šume« plays a significant economic and social role in Croatia, a country rich with forests.

The Enterprise is organized *functionally* (departments in the Headquarters and departments in forest administrations) and *regionally* (the Headquarters in Zagrebu, 16 forest administrations and 171 forest stations with pertaining districts) as a single enterprise in the whole Republic of Croatia.

The Enterprise is governed by an Executive Board composed of nine members, six of who are appointed by the Government of the Republic of Croatia and three are elected by the employees of the Enterprise. The Managing Director, nominated by the Government of the Republic of Croatia following the proposal of the Minister of Agriculture and Forestry, represents the Enterprise. The group »Hrvatske šume« employs full-time 10,000 employees, of whom approximately 1,200 are university graduates and about 1,230 employees are employed in companies with limited liability.

On an area of 1,991,573 ha, managed by the enterprise »Hrvatske šume«, there is a growing stock of 278 million m$^3$ with an annual increment of 8.1 million m$^3$, of which 4.9 million m$^3$ of wood can and must be felled. In the growing stock the most frequent are *broad-leaved species*: beech – 37 %, pedunculate oak – 16 %, sessile oak 10 %, hornbeam – 8 %, ash 4 %. The share of *coniferous species* is only 14.5 %, of which fir – 10 %, juniper – 2 %, black pine – 1%.

The most valuable forest stands – seed species, make 64 %, coppice and bushes 32 %, and different degraded forms 3 % of forest-covered area. Plantations make only 1 % of all areas covered with forest.

The enterprise »Hrvatske šume« produces annually 30–35 million of seedlings on an area of 484 ha of its own nurseries, of which 15–18 million *seedlings* are cultivated on site, and on 379 stands, covering an area of approximately 18,000 ha, *forest seed***s** are selected and collected.

On an area of more than 263,872 ha the enterprise »Hrvatske šume« manages quite a number of protected natural resources, such as parks of nature, special forest reserves, park-forests, significant landscapes, etc. Apart from protecting forests located in parks of nature, there is also an area of 51,163 ha of protecting forests as a special category. Protecting forests and special purpose forests make 16 % of all forest area managed by »Hrvatske šume«.

The enterprise »Hrvatske šume« manages 32 *hunting grounds* and 8 *game preserves* on a total surface of 386,646 ha. In the hunting grounds of the Enterprise the most numerous game species are: pheasant, common hare, common roe, wild duck, wild boar, common deer, fallow deer, bear, mouflon, lynx, etc.

The enterprise »Hrvatske šume« supports publishing of scientific studies and papers as well as preparing and holding scientific conferences and symposiums (e.g. IUFRO 99 in Opatija).

It also provides scholarships for quite a number of pupils and students. Each year a considerable number of employees are sent to post-graduate studies or other forms of additional professional education.

The enterprise »Hrvatske šume« provides funds for the *Program of scientific and research work* of the Faculty of Forestry Zagreb and the Forestry Institut in Jastrebarsko (annually HRK 8.0 million in average).

The most important business goals of »Hrvatske šume« Inc. Zagreb are as follows:

- uniform forest management in the whole Republic of Croatia in accordance with general interests,
- continuous investment in forest renewal and increase of the ecological value of forests,
- maintaining forest sustainability and general protection,
- rational production in market oriented economy,
- high-level quality of products and better utilization of forest biomass,
- optimum openness of forests through forest roads,
- promoting the significance and role of forest and forestry,
- promoting all undertaken international obligations (all resolutions of Ministerial Conferences in Strasbourg, Helsinki and Lisbon, etc.),
- participating in all international researching projects (COST and others).

Managing is carried out in accordance with the Forest-Economic Basis of this area to be in effect up to 2025. Forest management covers the following activities:

1. *simple and extended biological regeneration of forests;*
2. *harvesting of forests* and forestland, plantations and forest side products (crops, medicinal herbs, humus, moss, etc.), excavation of sand, stone and gravel as well as transport of forest products;
3. use of generally beneficial forest functions;
4. building and use of forest roads and other facilities with the purpose of forest management.

The volume of the realized production is shown in Table 1, 2 and 3.

In order to achieve rationalization, efficiency, profitability and market oriented business activities, the enterprise »Hrvatske šume« engages private contractors for carrying out a considerable part of work, choosing the best among them.

The development of entrepreneurship is one of the basic guidelines of »Hrvatske šume«, as defined by the *Development Program* (1991–2025).

Private contractors carry out more than 50 % of the work required in forest harvesting and civil engineering. Private contractors and local people perform 40 % of wood felling and cutting, 50 % of wood skidding and 60% of wood transportation (see Table 4 an 5).

It should be noted, however, that as far as technical, technological and organizational aspect is concerned private entreprenurship largely lags behind in quality and as a result the quality of services performed is not at a satisfactory level. The reason for this situation is that the contractors work with old and obsolete equipment mostly bought from »Hrvatske šume«. Therefore »Hrvatske šume« must give this problem serious thought in future.

**Table 1** Planned and realized production in the period from 1991 to 1999 in thousand. m$^3$

| Year | Planed | | | Realized | | |
|---|---|---|---|---|---|---|
| | Round-wood | Cord-wood | Total | Round-wood | Cord-wood | Total |
| 1991 | 2 005 | 1 850 | 3 855 | 1 649 | 1 323 | 2 972 |
| 1995 | 1 387 | 1 414 | 2 801 | 1 399 | 1 205 | 2 604 |
| 1996 | 1 496 | 1 528 | 3 023 | 1 468 | 1 403 | 2 871 |
| 1997 | 1 682 | 1 594 | 3 276 | 1 597 | 1 517 | 3 114 |
| 1998 | 1 645 | 1 725 | 3 370 | 1 638 | 1 434 | 3 072 |
| 1999 | 1 611 | 1 606 | 3 217 | - | - | - |

**Table 2** Realized, planned and specified operations related to simple biological forest regeneration in the period from 1995 to 1999 in ha

| Name of operation | 1991 | 1995 | 1996 | 1997 | 1998 | Plan 1999 | Prescript ŠGOP |
|---|---|---|---|---|---|---|---|
| Preliminary operations in forest regeneration | 6 891 | 9 258 | 7 295 | 6 206 | 6 478 | 7 483 | 9 298 |
| Planting and sowing in stand | 1 600 | 2 373 | 2 145 | 1 266 | 2 145 | 781 | 1 586 |
| Filling up in stand | 1 687 | 2 386 | 2 123 | 1 410 | 1 424 | 1 299 | 1 743 |
| Cultivating young growth and plantation | 13 752 | 14 492 | 14 381 | 13 041 | 15 286 | 16 487 | 14 326 |
| Cleaning the stand | 5 945 | 6 726 | 6 280 | 7 511 | 7 366 | 7 170 | 8 587 |
| Other operations (cultivating plantations) | - | 1 212 | 760 | 1 448 | 630 | 1 132 | 1 625 |
| Resurrection of degraded forests | - | 18 | 56 | 75 | 71 | - | 5 |

**Table 3** Realized, planned and specified operations related to extended biological forest regeneration in the period from 1995 to 1999 in ha

| Name of operation | 1991 | 1995 | 1996 | 1997 | 1998 | Plan 1999 | Prescript ŠGOP |
|---|---|---|---|---|---|---|---|
| Preliminary operations on soil and in stand | 337 | 2 025 | 1 374 | 1 170 | 4 045 | 5 326 | 1 561 |
| Resurrection | 209 | 100 | 62 | 95 | - | - | - |
| Conversion | – | 178 | 314 | 516 | 174 | 146 | 271 |
| Afforestation | 847 | 1 496 | 1 275 | 1 620 | 1 791 | 1 846 | 2 152 |
| Rehabilitation | 198 | 538 | 975 | 615 | 441 | 812 | 271 |
| Filling up | – | 398 | 277 | 216 | 460 | 323 | 382 |
| Cultivating young plantations up to 1/5 of rotation | 3 537 | 2 462 | 2 942 | 2 617 | 2 458 | 4 016 | 3 147 |

**Table 4** Production structure broken down by service suppliers for felling and cutting wood assortments in thousand $m^3$

| Year | Self-performed work | Service Ltd. Company | Services others | Self-perfomed cutting | Total (1 do 4) | Share (%)of self-performed work and Ltd.C. |
|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1994 | 1 700 | - | 682 | 437 | 2 818 | 60.3 |
| 1995 | 1 610 | - | 607 | 388 | 2 604 | 61.8 |
| 1996 | 1 784 | - | 502 | 584 | 2 870 | 62.2 |
| 1997 | 1 878 | - | 504 | 733 | 3 114 | 60.3 |
| 1998 | 1 950 | 45 | 419 | 658 | 3 072 | 64.9 |
| Plan 99 | 2 260 | - | 353 | 604 | 3 217 | 70.3 |

**Table 5** Production structure broken down per service supplier for skidding and removal of wood assortments $m^3$

| Year | Self-performed work | Service Ltd. Company | Services others | Total (1 do 3) | Share (%)of self-performed work and Ltd.C. |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |
| 1994 | 1 120 | - | 1 253 | 2 373 | 47.2 |
| 1995 | 1 060 | - | 1 089 | 2 149 | 49.3 |
| 1996 | 1 215 | - | 1 005 | 2 220 | 54.7 |
| 1997 | 1 201 | - | 1 213 | 2 415 | 49.7 |
| 1998 | 638 | 658 | 1 115 | 2 411 | 53.7 |
| Plan 99 | 759 | 657 | 1 186 | 2 602 | 54.4 |

»Hrvatske šume« manages 14,500 km of *forest roads* (as of 31 December 1998); 400 km of asphalt-covered roads, 12,100 km of macadamized roads and 2 000 km of roads without the lower layer, of which 1,700 km are fire-protection roads with elements of forest roads.

Constructed forest roads affect considerably the development of forestry and they are also significant for the entire economy and »accessibility« of the country. Fire-protection roads are an important contribution to the preservation of our forest eco-systems together with all other safety measures.

**Table 6** Sales broken down per groups of wood assortmentas in period 1995–1998

| Year | Logs | Thin roundwood | Pulpwood | Fuel wood | Total |
|---|---|---|---|---|---|
| | $m^3$ | | | | |
| 1995 | 1 275 000 | 56 000 | 440 000 | 859 000 | 2 630 000 |
| 1996 | 1 388 000 | 46 000 | 357 000 | 1 143 000 | 2 934 000 |
| 1997 | 1 491 000 | 37 000 | 436 000 | 1 168 000 | 3 132 000 |
| 1998 | 1 515 000 | 38 000 | 386 000 | 1 029 000 | 2 968 000 |
| Plan 1999 | 1 545 000 | 66 000 | 498 000 | 1 108 000 | 3 217 000 |
| As of May 31 | 714 000 | 11 000 | 118 000 | 368 000 | 1 211 000 |

**Table 7** Sales broken down per ways of selling logs in period 1995–1999.

| Year | Contract | | Domestic public tender | | International public tender | | Cash desk | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ |
| 1995 | 732 000 | 59 | 359 000 | 28 | 103 000 | 8 | 81 000 | 7 | 1 275 000 |
| 1996 | 952 000 | 69 | 234 000 | 17 | 73 000 | 5 | 129 000 | 9 | 1 388 000 |
| 1997 | 1 131 000 | 96 | 105 000 | 7 | 74 000 | 5 | 181 000 | 12 | 1 491 000 |
| 1998 | 1 101 000 | 93 | 295 000 | 19 | 76 000 | 5 | 43 000 | 3 | 1 515 000 |
| May 31 '99 | 563 382 | 65 | 77 698 | 16 | 52 361 | 34 | 20 107 | 46 | 713 548 |

The funds for the management of forests and forestland are mostly provided by *wood sale* (Table 6 and 7).

Taking as a starting point the management based on Forest-Economic Basis of the area within the Republic of Croatia, taking into consideration the necessity to meet the demand for wood, the development of other economic activities, significance and role of forests in arranging our territory and achieving its natural balance as well as the importance of forests in realizing their functions of general benefit, with special care for forests and forestland in the karst region, *the permanent goal and task of commercial business is to provide funds for simple and extended biological regeneration of forests by sale of forest products* in base of rational production in forestry, *focusing the sale towards finishing end products in domestic wood industry*, choosing high-quality buyers of good credit rating, solvent in relation to the Enterprise, taking into account the market and achieving maximum income by sale of main forest products as well as forest side products.

The managing body of the Enterprise is the Executive Board also authorized to determine business and commercial policy of the Enterprise. The Managing Director of the Enterprise together with his Assistant, other assistants and heads of forest administrations or persons with special authority implement the business policy and take responsibility for the success of business activities.

In the Enterprise, uniform commercial activities have been established, implemented at the level of the Enterprise through the Commercial Department in the Headquarters and commercial departments in forest administrations, where contractual relationships have been set up.

The implementation of the applicable Croatian Standards for wood – HRN, in wood manufacturing and trading are the integral part of the business policy of the Enterprise with the permanent aim and task of keeping in line and passing Croatian Standards in accordance with European Standards for wood – CEN, EN and International Standards for wood – ISO.

The sale of wood assortments is carried out in the following way:

**1. *Agreement without invitation to tender (5-year contract i.e. annual contract)***

1.1 Areas of special governmental interest
Wood industry on that area is supplied with logs from that area

1.2 Export oriented segment of finished products industry (furniture, parquet, building timber, etc.)
1.3 Part of primary processing
 1.3.1 Wood assortments with higher supply than demand (veneer logs and peeler logs, thin roundwood, cellulose wood, wood for wood boards, part of sawmill logs and fuel wood)
 1.3.2 Areas where primary processing is of special significance due to impossibility of development of other activities.

***2. Public tender***

2.1 Domestic public tender
For other wood assortments for which the demand is higher than supply
2.2 International public tender
Only for those wood assortments for which there is no interest on the domestic market.

***3. At cash desk***

Sale of wood assortments for the needs of population.

The issue of wood assortment sales:

- Low sale of poplar, hornbeam, turkish oak, locust, chestnut and ash logs and demand for oak, fir, juniper and particularly beech logs,
- As a result of closed factories in Plaško (Croatia), Maglaj and Banja Luka (B&H) and also owing to the reduced production of the factories in Slovenia, the sale of small-size industrial broad-leaved timber went down. We increase the export each year and now it amounts to 230,000 t and we are trying to adapt ourselves to the market in order to keep this increasing export trend of low-size industrial broad-leaved timber.

The situation is also affected by introduction of gas in Croatian villages causing the decrease of demand for fuel wood. Wood assortments are exported to Italy, Austria, Slovenia, Hungary and Greece.

In the last several years the enterprise »Hrvatske šume« Inc. Zagreb has managed to cover its expenses and to finance by itself its business activities with its income in spite of increasing general (post--war) economic difficulties. Further development will largely depend on the trend and economic situation of the Croatian companies dealing with wood processing, which cause serious concern lately and affect severely the state and business activities of »Hrvatske šume« Inc. Zagreb.

As a result of war operations, 12 % of forest areas (approximately 244,000 ha) and 10 % of the specified annual cut (about 489,000 $m^3$) managed by »Hrvatske šume« Inc. Zagreb are mine contaminated.

## 2. »Hrvatske šume« tomorrow, in 21$^{st}$ century

By the decision of the Government of the Republic of Croatia of July 1998 the initiative was brought up on restructuring »Hrvatske šume« Inc. Zagreb from a public company into a capital-based company pursuant to the Law on Trade Companies.

To implement this initiative some legal prerequisites must be established, i.e. the Law on Forests must be modified, this being under the authority of the Ministry of Agriculture and Forestry of the Republic of Croatia. By restructuring »Hrvatske šume« Inc. Zagreb into a capital-based company, prerequisites will be made for it to become profitable and to start acting as a lever for activating the rest of the industry, which will then multiply the forestry effects through the export of highly-finished products. Since the Enterprise acts pursuant to the Law on Forests and not in accordance with the Law on Trade Companies, there is no room for restructuring it into a capital-based company from which a modern organization of forestry should develop, as the case usually is in European industrial countries. Upon being restructured, the enterprise »Hrvatske šume« Inc. Zagreb must by all means retain the principle of *forest management sustainability*, which grants ecological, economic and industrial values, and open the possibility of profitable business activities, through the increase of *production of the main forest products*, better *utilization of forest side-products* and the development of *secondary activities* in the Enterprise, as well as the reduction of production costs and the increase of investments.

After eight years of its being »Hrvatske šume« Inc. Zagreb, must assess what has been done and what has not:

1. It must establish *the standards* of the required number of full-time employees at the level of organizational units of the Enterprise (forest stations, operational units, limited liability companies, forest administrations and Headquarters).
2. The established *surplus of employees* must be efficiently employed through the increase of production of the main forest products and forest side-products and development of secondary activities in the Enterprise.
3. Special attention must be paid to *additional professional education* of the employees of »Hrvatske šume«, particularly those directly taking

parts in production, as well as contractor's employees. All this in order to provide protection for the employees and the forest eco-system.

4. Development must be provided for *the companies with limited liability* owned by »Hrvatske šume« through investments in their production equipment and full utilization of their capacities.
5. Measures must be implemented for the *development of entrepreneurship* aimed at undisturbed carrying out of forestry operations by specialized technical departments of »Hrvatske šume«.
6. The ratio must be established *of the work* carried out by the employees and equipment of »Hrvatske šume« against services provided by third parties and contractors. The necessity of issuing licenses and certificates for working equipment for forest operations must be considered.
7. The guidelines of the Program of Efficient Employment must be introduced in the BUSINESS CONCEPT of the *new enterprise »Hrvatske šume«* restructured in a company based on capital, which will continue a 234-year long principle of sustainable forest management and grant the ecological, economic and industrial aspects.

It will be possible to achieve the above said objectives if »Hrvatske šume« Inc. Zagreb becomes a capital-based company, and forest administrations profit centers or if »Hrvatske šume Inc. Zagreb becomes a stock company and forest administrations companies with limited liability. The final organization will come out of the *business concept*, which should be developed by the Committee of the Ministry of Agriculture and Forestry of the Republic of Croatia, consisting of the representative of the Ministry, the Faculty of Forestry Zagreb, Forest Institute Jastrebarsko and »Hrvatske šume« Inc. Zagreb.

## 3. References

Anon, 1990: Law on Forests, Official Journal NN, 52/1990 – purified text. Narodne novine, Zagreb.

Anon, 1993: Development Program 1991–2025 of »Hrvatske šume« Inc. Zagreb, »Hrvatske šume«, p. o. Zagreb.

Anon, 1993: Law on Forests, NN 9/91 and 6/93. Narodne novine Zagreb

Anon, 1996: Forest-Economic Basis of the area (in effect from 1996 to 2005), Zagreb.

Anon, 1999: Business report of »Hrvatske šume« 1991–1998. »Hrvatske šume«, p. o. Zagreb.

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# Scientific research in Croatian Forestry on the eve of the 21st century

**Joso Gračan**

***Abstract***

*Scientific research and scientific thought in Croatian forestry have a long and abundant history. The first Forestry Research Institute was founded within the Agriculture and Forestry Faculty in Zagreb on March 24, 1921. During July 1945 a decision of the then Ministry of Agriculture and Forestry founded the Institute for Practical Forestry Research in Zagreb. Today's institutional basis for forestry and wood technology research are the Forest Research Institute, Jastrebarsko, the Department of Forestry Research and the Department of Wood Industry Research of the Faculty of Forestry, University of Zagreb, the Forestry Department of the Institute for Adriatic Cultures and Karst Melioration in Split, the Scientific Centre in Vinkovci, the Arboretum Trsteno which are a part of the Croatian Academy of Sciences and Arts in Zagreb.*

*Forestry and wood technology scientific research is at the very top of scientific research in Croatia not only quality-wise but also by the status of scientists and researches. The scientific research program in the period from 1996 to 2000 is composed of scientific projects (17) and supporting projects (7) financed by the Ministry of Science and Technology, 2 scientific projects with 8 sub-projects financed by »Hrvatske šume« Inc. Zagreb and international projects in the framework of co-operation with Slovenia, European Union and bilateral co-operation with a large number of European countries and associations (IPGRI, FAO, IUFRO, EFI).*

*Forestry and wood technology scientific research results up to now are a very good basis not only for the development of these two branches of economy but for the country as a whole on the eve of the 21st century.*

***Key words:*** *scientific research, forestry, wood technology*

## 1. Introduction

Science and research activities in Croatian forestry have a long and abundant history. The first research in forestry began in Križevci at the Agriculture and Forestry School in 1860. The first Institute for forest experiments was founded at the Faculty of Agriculture and Forestry in Zagreb on March 24, 1921.

Organized scientific research in Croatian forestry begins in 1945 with the establishment of the Institute for practical forestry research in Zagreb. In the period between 1945 and 1974 Croatian forestry has frequently changed the organization and financing structure of scientific research.

Croatian forestry is at the very top of forestry in Europe in its organization, expertise and the level of forest preservation. Forests and forestland cover almost 2.5 million ha or 43.5 % of the total area of the Republic of Croatia. In the development of Croatia, forests had, have had and will have great significance.

Scientific and educational institutions, as well as professional associations (Croatian Forest Association, Academy of Forestry Science) in the field of forestry and wood technology are at among the leading in Croatia not only quality-wise but also by the status of scientists and researches. The scientific research program is composed of scientific projects (17) and supporting projects (7) financed by the Ministry of Science and Technology, 2 scientific projects and 8 sub-projects financed by »Hrvatske šume« Inc. Zagreb, international projects in the framework of co-operation with Slovenia, European Union and bilateral cooperation with a large number of European countries and associations (IPGRI, FAO, IUFRO, EFI).

Forestry, higher education and scientific research have been active continuously for the last 139 years. The Croatian Forestry Association has been active for over 150 years (founded in 1846), the scientific publication Journal of Forestry has been published continuously for 123 years, Annales pro experiments foresticis has been published for 73 years, Forestry Mechanization for 22, Wood Industry for 50 years, and Works (Radovi) for 40 years.

## 2. The state of Croatian forests

Since 1987 the Republic of Croatia has been involved in the program of monitoring and assessment of the state of European forests. The assessment is conducted in accordance with the methodology adopted through the International Co-operative Program of Assessment and Monitoring of Air Pollution Effects on Forests. Results of a 10-year research of the effects of air pollution on European forest eco-systems conducted within the framework of the Pan-European program have shown a general defoliation of the crowns of the main forest tree species in Europe. This trend is especially present in broadleaf species such as beech and several types of oak as well as the Mediterranean pines. Only the Scots pine and the Maritime pine have shown recovery in some areas.

At the same time the spreading of soil acidity in Europe arises great concern. Extremely acid forest soil is generally present in Central Europe, an area also seriously affected by air pollution and tree defoliation.

According to the Pan-European program, monitoring is conducted in two ways: extensively and intensively. A total of 5700 plots placed in systematic rings – level I, are included in the extensive monitoring program. This level of monitoring is conducted annually and gives a good insight into the trends of the state of the crowns of forest trees, which are in turn solid indicators of the general state of forest. Nevertheless, these conditions are not sufficient or detailed enough to give an accurate state of the forest. For this reason, intensive monitoring has been introduced on 860 permanent plots – level II. These plots serve to conduct intensive research of stands and stress factors as well as biological and ecological conditions of forest eco-systems. The established state of damage to forests is the result of a combination of complex stress factors (natural, which are linked to the defoliation of crowns, for instance draught, and insects which played a significant role in oak trees in the past decade). On the other hand, stress caused by human action (air pollution effects, ozone layer damage) destabilizes the forest ecosystems.

Because of the very complex processes, which characterize forest ecosystems, the future level II monitoring and analysis of results shall be the main course and priority in the research. Level I monitoring shall also be a priority. Because of the importance of monitoring and assessment, Table 1 gives an overview of the activities conducted in level I and II:

According to the UN/ECE an EC data for 1998 the state of defoliation of crowns is shown in Figure 1 individually for every EU member country totally for Europe, and for coniferous and broadleaf species, and also for Norway spruce, Scots pine, Beech and Oak. In 1998 approximately ¼ (23.1 %) of all monitored trees in Europe were assessed as significantly

**Table 1** Surveys carried out at Level I and Level II

| Activity | Level I | Level II | |
|---|---|---|---|
| Crown conditions | annually | annualy | all sites |
| Foliar conditions | only once to date[1] | every 2 years | all sites |
| Soil chemistry | only once to date[2] | every 10 years | all sites |
| Soil solution chemistry | – | continuous | 10 % of sites |
| Tree growht | – | 5 years | all sites |
| Ground vegetation | – | 5 years | 10 % of sites |
| Atmospheric deposition | – | continuous | 10 % of sites |
| Meteorological conditions | – | continuous | 10 % of sites |
| Phenology | – | being debated | |
| Remote sensing | – | being debated | |

[1] on 1441 plots; [2] on 5289 plots

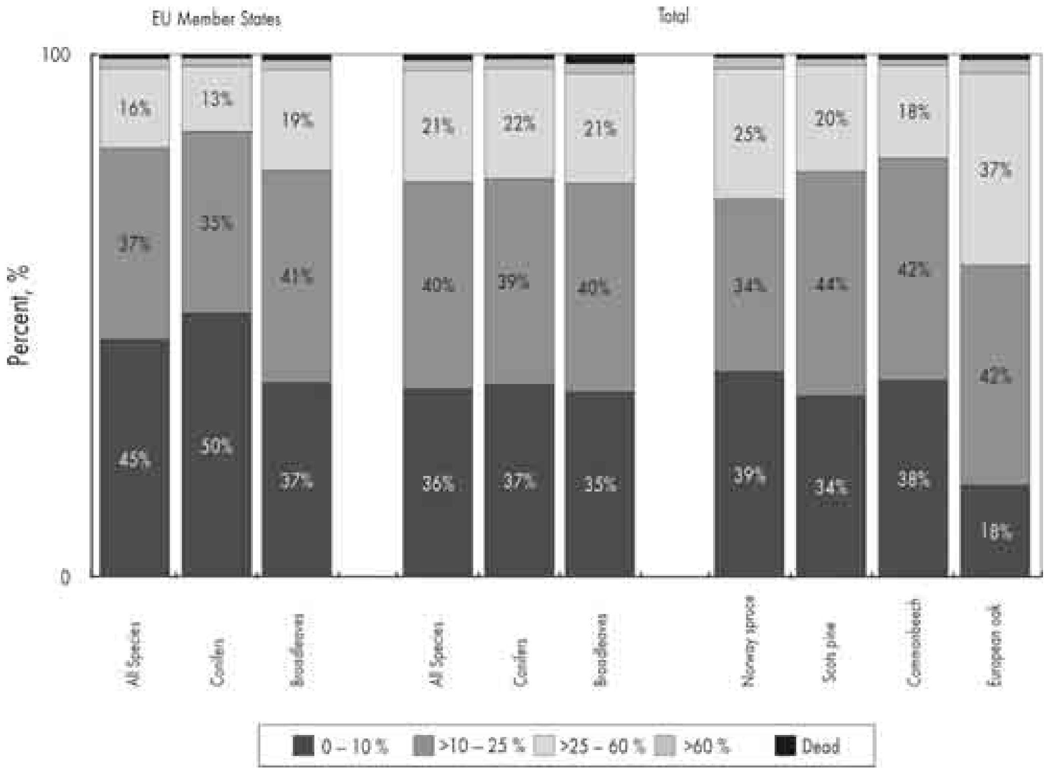


**Figure 1** Defoliation of crowns of several tree species in EU member states and in Europe as a whole (*Executive Report for 1998*)

and severely damaged, 0.9 % were dead, 39.8 % were slightly defoliated and only 36.2 % were classified as healthy.

The assessment of defoliation in Croatia 1n 1998. revealed 19.4 % as severely defoliated trees, which shows an improvement of 4.2 % in comparison with 1997. The severe defoliation trees fall under categories 2, 3 and 4. The results of the assessment for broadleaf species is very similar to the results for all species since the proposition of broadleaf species amounts to 91.9 % in the total number of trees. Figures 3, 4 and 5 (Potočić and Seletković 2000) give the percentage of severe damaged common fir trees (Figure 3), pedunculate oak (Figure 4) and common beech trees (Figure 5) in comparison to the severe damaged trees of the same species in Europe. The comparison to the state of damage in 1998 in Croatia shows a small reduction in significant damage for all species, while the damage to coniferous species increased significantly in comparison to 1997. Since damage was assessed on only a small number of trees of coniferous species (fir, Norway spruce and others), it is necessary to increase the number coniferous plots in the level I monitoring program.

Since the very beginning of this research, scientists of the Faculty of Forestry, Forest Research Institute and experts from the »Hrvatske šume« Inc. Zagreb have been involved. Well-known and recognized scientists and experts coordinated the research. The Forest Research Institute Jastrebarsko was nominated as the national center for Croatia in 1998. Over 3000 ha of test areas, the pertaining facilities, test plots and seed orchards are used for educational purposes and scientific research.

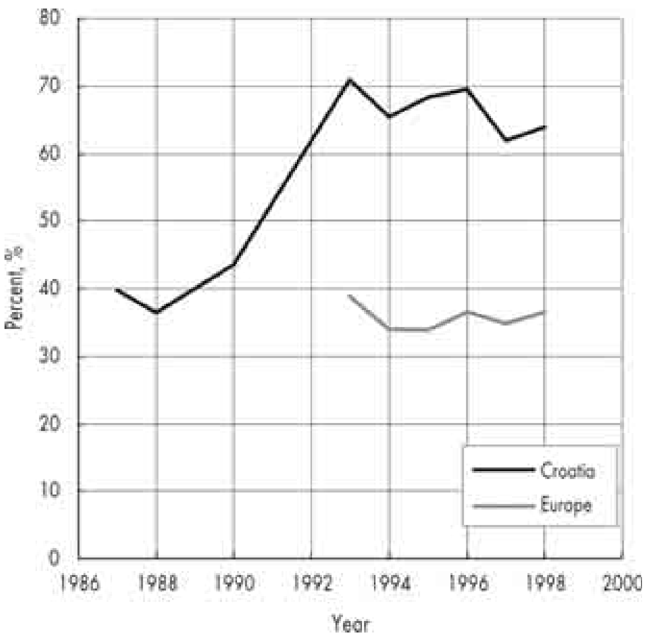


**Figure 2** Comparison of percentage of moderately to severely damaged silver fir trees in Croatia and Europe

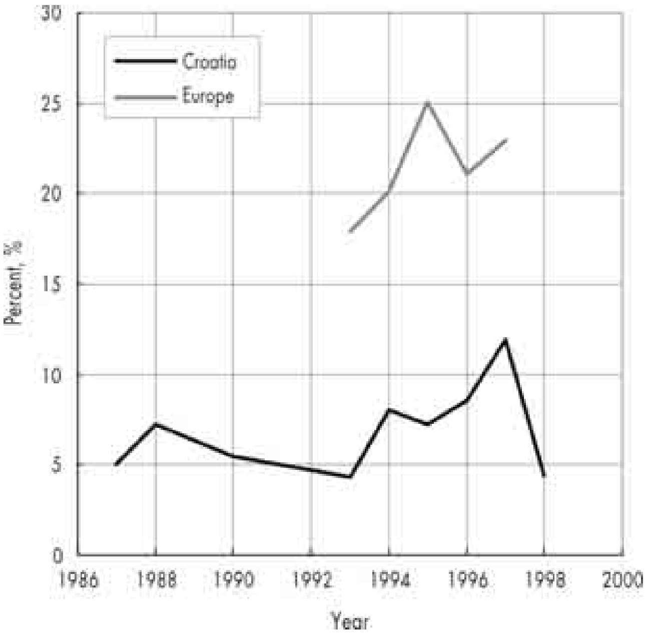


**Figure 3** Comparison of percentage of moderately to severely damaged beech trees in Croatia and Europe

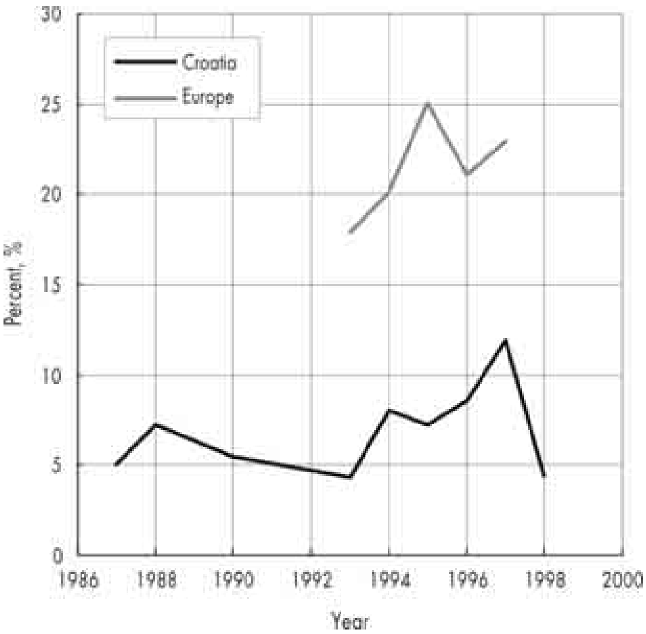


**Figure 4** Comparison of percentage of moderately to severely damaged pedunculate oak trees in Croatia and Europe

## 3. Scientific institutions in Croatian forestry

Today's institutional basis for Croatian forestry scientific research activities lies in the following institutions:

- *Forest Research Institute, Jastrebarsko* (founded on January 1, 1974 by the merger of the Institute for forest research, Zagreb 1945, the Institute for forest seed control, Rijeka 1959 and the Institute for conifers, Jastrebarsko 1961);
- *The Department for Forestry Research* and the *Department for Wood Industry Research* of the Faculty of Forestry, University of Zagreb;
- *Forestry Department* of the Institute for Adriatic Cultures and Karst Melioration in Split;
- *Scientific Center in Vinkovci* and the *Arboretum Trsteno* which make part of the Croatian Academy of Sciences and Arts

The new Law on Scientific Research and the Law on Higher Education are a good basis for the development of scientific research and higher education in Croatia. These legal regulations also require paying special attention to employment and involvement of young assistants. However, the need to provide larger financial resources for capital investment into the construction of new facilities (Faculty of Forestry, Forest Research Institute), purchase of modern laboratory and IT equipment as well as professional training of scientists and researchers has to be emphasized.

For a more successful development of forestry and wood technology scientific research another HRK 7 million have to be provided for the construction of a new building for the Department of Forestry at the Faculty of Forestry in Zagreb (budget, Faculty funds, forestry support). In this way the existing facilities in the main building would be sufficient for the Wood Industry Department, and HRK 4 million for Forest Research Institute, Jastrebarsko.

The Faculty of Forestry has at its disposal 600 ha of land adjacent to the Faculty buildings (forest garden, Dotrščina Forest, Mokrice Lug Forest and part of the Maksimir Forest), and outside this location another 3000 ha (Sljeme, Zalesina, Velika, Lipovljani). The Forest Research Institute has at its disposal 28 ha of land adjacent to its facilities (nursery, other facilities), field experimental plots and seed orchards covering an area of approximately 400 ha, and 3000 experimental plots. All these forests, field experiments and plots are used for the training of students and research.

## 4. Scientists and researchers

High school and University level education in Croatia has been active continuously for 139 years (1860). During this period about 4000 forestry engineers and 300 wood industry engineers have graduated. 258 postgraduate students have acquired the Master of Sciences degree. The first doctoral thesis was presented at the Faculty of Forestry in Zagreb in

**Table 2** The number of scientists and researchers in 1999 in relation to 1991

| Institutions | Scientists | | | Researchers | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1999 | % | 1991 | 1999 | % | 1991 | 1999 | % |
| Forest Research Institute | 10 | 5 | 50.0 | 24 | 21 | 87.5 | 34 | 26 | 76.5 |
| Faculty of Forestry | 36 | 44 | 122.2 | 46 | 32 | 69.5 | 82 | 76 | 92.5 |
| Department for forestry | 1 | 1 | 100.0 | 1 | - | 50.0 | 2 | 1 | 50.0 |
| Department of HAZU Vinkovci and Trsteno Arboretum | 0 | 1 | - | 2 | 1 | 50.0 | 2 | 2 | 100.0 |
| Total | 47 | 51 | 108.5 | 73 | 54 | 74.0 | 120 | 109 | 90.8 |

1922, and 150 doctorates have been awarded up to now. This period is characterized by many academicians and globally recognized and renounced experts in the field of silviculture, forest genetics and forest tree development, forest management, forest protection, dendrometry, wood science, wood technology and processing.

The number of scientists and researchers in Croatia as of June 30, 1999 in comparison with 1991 is presented in Table 2.

The average age of scientists at the Forest Research Institute is 59 and of the researchers 33, while the average age of the scientists at the Faculty of Forestry is 48 and of researchers 29. This proves that the age structure at the Forest Research Institute is less favorable than that at the Faculty of Forestry and the total number of scientists and researchers is 10 % lower than in 1991.

All the scientists have the required scientific degrees and experience although their total number is not satisfactory with regard to the institutions and research program. The total number of scientists and researchers is 109 i.e. 47.8 % of the total number of employees (228).

## 5. Research programs and tasks

Organized scientific research in forestry and wood industry commenced in 1945. At that time there were no clear programs and tasks. Since 1951, financing for scientific research has been defined and long-term research programs have been drafted. In these first programs emphasis was placed on tending natural stands, establishing cultures and plantation of the Poplars and introduction of fast growing conifers, melioration of degraded forests, vegetation research and mapping and the research of wild life biology and breeding.

After the unification of scientific research, achieved by the merger of research institutions (1974), joint projects were developed, research teams were established, new equipment was purchased, education and training of young researchers was improved through training abroad and in the country. This period lasted from 1976 to 1990. It is characterized by the following: preservation of the forest stand and improvement of its quality, reduction of forest management costs, increase in the stand biomass production, forest protection and research of the structure and stability of forest ecosystems. The most significant projects of this period are the pedology and vegetation maps of Croatia, protection of human environment, research of the structure and functioning of forest ecosystems, research and mapping of forest types and forest natural sites, improvement of seed hushbandry, nursery production and silvicilture, forest protection, research of the organization and economics in forestry and wood technology, forest harvesting, forestry mechanization and forest roads, research in the karst regions of Croatia, the detrimental effect of forest fires on vegetation, bio-type and environment as well as the detrimental effect of pollution of forests and forest soil.

Since 1990, regardless of the war destruction and the devastating effect it has had on our forests, national parks and despite the occupation of almost 1/3 of our country, forest management and organized scientific research have been uninterrupted. Through the establishment of »Hrvatske šume« Inc. Zagreb, the public enterprise for forest and forest-land management in the Republic of Croatia (1991) and the transition of scientific institutions into state property (1993), good foundations were set for the undisturbed development of scientific and research activities in the field of forestry and wood technology on the eve of the 21st century. During this period the Ministry of Science and Technology financed and evaluated 14 scientific projects, and »Hrvatske šume« Inc. Zagreb did the same for 3 projects with 9 subprojects and 88 research topics.

The planned scientific research activities for 1996–2000 consist of 17 scientific and 7 supporting projects financed by the Ministry of Science and Technology, 2 scientific projects and 8 sub-projects financed by »Hrvatske šume« Inc. Zagreb and international projects in the framework of cooperation with Slovenia, European Union, International Plant Genetic Resource Institute (IPGRI), World Bank and FAO, European Forest Institute (EFI) and the International Union of Forest Research Organizations (IUFRO).

List of projects and subprojects according to cooperation and financing type:

- Ministry of Sciences and Technology

**068001** Silvicultural management and sites of Croatian forests

**058002** Planning models for stability of forest ecosystems,

**068003** Protection and reconstruction of forest ecosystems,

**068004** The promotion of production in Croatian forestry

**068005** Ornamental dendroflora in Croatian urban forestry

**068006** Game management in Mediterranean region in Croatia

**068011** Model development of production systems

**068012** Durability and modifications of wood surface

**068013** Influence of wood characteristics on drying, protection and sawmill processing

**068014** Investigation of raw materials, processing, quality and use of boards

**068015** Lateral stability of saw circular

**068016** Energy investigations in wood processing

**0240101** Tree breeding and seed husbandry development in forest regeneration

**0240102** Improvement of nursery production and sylviculture of forest plantation

**0240103** Protection of forest ecosystems from biotic and abiotic factors

**0240104** Permanent monitoring of ground and surface waters in lowland forests

**0240105** Growth and development of the forests for special purposes

- Supporting projects

**068031** Silvicultural characteristics of narrow-leaved ash in Posavina

**068032** The structure and dynamics of Norway spruce stands

**068033** Mycorrhiza in different development stages of pedunculate oak forests

**068042** Forest shake of bitter oak (*Q. ceris* L.) in Croatia

**068043** Hybrids from four pine species and their determination

**024199** The relationships of the growth of the pedunculate oak forests in Bjelovar region

**024200** The growth pattern of crown structure of pedunculate oak and hornbeam with regard to age

- »Hrvatske šume« Inc. Zagreb

**Project 1:** Protection and improvement of biomass production with the aim of maintenance multiple forest functions

**Subproject 1:** Assurance of regeneration as a measure of stability and sustainable production of fitomass in natural ecosystems

**Subproject 2**: The support of effective increase of forest areas

**Subproject 3:** Exposure of the forests to harmful conditions and improvement of their protection

**Subproject 4:** Assurance of sustainable production assortment according to ecological and economical forest types

**Project 2:** Use and management of the capital in forestry

**Subproject 1:** The exploitation of biomass

**Subproject 2:** Development of technologies and use of ecological applicable ones

**Subproject 3:** Evaluation of capital resources and losses caused by harmful factors

**Subproject 4:** Establishmet of economical systems

## 6. International cooperation

- Slovenian – Croatian joint projects

Influence of raw materials quality on boards characteristics.

Breeding and protections of pedunculate oak from abiotic factors

- The World Bank and FAO

Coastal forest reconstruction and protection project

- ECE/EU

International cooperative programme on assessment and monitorig of air pollution effects on forests.

European network for the evaluation of the genetic resources of beech for appropriate use in sustainable forestry management.

- IPGRI

EUFORGEN – Network

Conifers (started as *Picea abies* Network)

Mediterranean oaks (started as *Quercus suber* Network)

*Populus nigra* and *P. alba* – Network

Noble Hardwoods – Network

Social Broadleaves – Network

- International meetings (IUFRO, EFI) and other cooperation

The cooperation with the international non-governmental organizations is shown also in international meetings, of which we would like to mention:

33rd international symposium »Mechanization of Forest Work – FORMEC« organized by the Department for Forest Harvesting of the Faculty of Forestry, University of Zagreb, held in Delnice from July 1–6, 1999.

International conference »Emerging Harvesting Issues in Technology Transition at the End of the Century«, Division, 3. Subject groups S3.04.00; S3. 06.00 and S3.07.00, held in Opatija from September 27 – October 1, 1999.

International conference »Improvement of Wood Quality and Genetic Biodiversity of Oaks« organized by IUFRO Division 1 and 2, to be held in Zagreb from May 20–25, 2000.

International meeting »Improvement of Agriculture and Forestry in Karst Region« organized by Scientific Board of the Croatian Academy of Sciences and Arts, to be held in Zagreb in March 2000.

The scientists and researchers from the field of wood technology have been holding, within the »Ambijenta« fair, the international symposium on wood technology management.

## 7. Cooperation with domestic organizations

A very successful and long cooperation of the forestry scientific organizations with »Hrvatske šume« p.o. Zagreb (Croatian Forests) should be emphasized. This cooperation takes place not only in the field of high education, but especially the field of scientific and research activities and application of the research results. The Faculty of Forestry and the Forest Research Institute have been performing the investigations of direct interest for the Croatian forestry for more than 50 year. Besides its basic character, these investigations have the qualities of applicability and development with the aim of transferring the results directly into practice.

We would especially like to stress the results of cooperation achieved after the Republic of Croatia gained its independence in 1990. The scientists and researchers, as well as the »Croatian Forests« experts, full members of the Croatian Academy for Science and Arts, assisted by the Ministry of Science and Technology, Ministry of Agriculture and Forestry, Croatian Forestry Association, Academy of Forestry Sciences have published a large number of books and monographs:

ŠUME U HRVATSKOJ, 1992. (Forests in Croatia)

HRAST LUŽNJAK U HRVATSKOJ, 1996. (Pedunculate oak in Croatia)

ŠUME MOJE HRVATSKE, 1996. (Silvae Nostre Croatie)

SLAVONSKI HRASTICI, 1996. (Slavonian oak Forests)

SKRB ZA HRVATSKE ŠUME, 1846.–1996. knjiga 1 i 2, 1996. (The Care for Forests in Croatia)

HRVATSKO ŠUMARSKO DRUŠTVO 1846–1996. (Croatian Association of Foresters)

NIZINSKE ŠUME POKUPSKOG BAZENA, Radovi Vol. 31, broj 1 i 2, 1996. (Low Land Forest of the river Kupa Basin)

BIBLIOGRAFIJA, 1986–1995, Šumarski institut, Jastrebarsko 1998. (Bibliography)

On the 100th anniversary of the university level of forestry education, the Faculty of Forestry University of Zagreb published 4 books – monographs:

*Vol. 1:* Šumarska nastava 1860–1898. na Kraljevskom gospodarskom i šumarskom učilištu u Križevcima, 1998. (Forestry educational program from 1860 to 1898 at the Royal High School of Economy and Forestry in Križevci)

*Vol. 2:* Sto godina Sveučilišne šumarske nastave u Hrvatskoj, 1998. (100 years of university forestry education in Croatia)

*Vol. 3:* Pola stoljeća drvnotehnološke nastave, 1998. (Half century of wood processing training)

*Vol. 4:* Nastavno-pokusni objekti Šumarskog fakulteta Sveučilišta u Zagrebu, 1998. (Training--testing facilities of the Faculty of Forestry in Zagreb)

The scientific and research institutions in Croatia have a very successful cooperation with many economic institutions, of which we would like to mention: water resources authorities, power supply authorities, agriculture, tourism, wood industry, civil engineering, »Exportdrvo«, Zagreb, INA.

We would like to stress the cooperation of scientific and research institutions with non-governmental organizations and associations (Croatian Association of Forestry, Croatian Ecological Society, Croatian Society for Soil Protection, Croatian Genetic Society, and others) with other scientific institutions (Croatian Academy for Science and Arts, Faculty of Agriculture. Faculty of Natural Sciences and Mathematics, Faculty of Electronics and Computing Sciences, etc.) and the state administration institutions (Ministry of Science and Technology, Ministry of Agriculture and Forestry, Ministry of Economy, Ministry of the Interior etc.).

## 8. Conclusions

Croatian forestry science and scientific research have a long and abundant history. Scientific research activities in forestry and wood technology are among the leading in Croatia not only with regard to quality but also to the status of scientists and researchers.

Forestry and forest science is among the leading in Europe in view of the organization, expertise and forest protection. Forests and forestland cover an area of 2,5 million ha. Forests have always had and shall continue to have great significance in the development of Croatia in the 21st century.

University level education in forestry and scientific research has been active for the past 139 years. For an even more successful development of science and scientific research forestry and wood technology it is necessary to build new and maintain the existing facilities and laboratories, as well as establish new and monitor the actual field research. In order to maintain and successfully enhance the existing level of scientists and other resources, we need approximately HRK 11 million of capital investment over the next 3–4 years.

The monitoring of forest damage in the past ten years has shown certain improvements (4,2 %) in 1998 as compared to 1997 although the damage to Fir forests is greater than in the rest of Europe.

The establishment of »Hrvatske šume« Inc. Zagreb and the new legal regulation in forestry as well as higher education and science have created a solid basis for the preservation of biological diversity and sustainable forest management. The Republic of Croatia has signed and actively implements all resolutions on protection and preservation of European forests (Strasbourg, Helsinki, Lisbon, etc.).

Our scientific research institutes have established a diverse and fruitful cooperation not only with the Croatian economic sector but internationally with most European countries as well.

## 9. References

Androić, M., 1963: Uvod. In: Šumarska nastava u Hrvatskoj 1860–1960. Šumarski fakultet, Zagreb.

Anon., 1998: Nastavno-pokusni šumski objekti Šumarskog fakulteta Sveučilišta u Zagrebu. In: Sveučilišna šumarska nastava u Hrvatskoj 1898–1998, Knjiga četvrta, Vukelić, J. (ed.). Forestry Faculty Zagreb.

Anon., 1998: Pola stoljeća drvnotehnološke nastave. In: Sveučilišna šumarska nastava u Hrvatskoj 1898–1998, Knjiga treća, Ljuljka, B. (ed.). Forestry Faculty Zagreb.

Anon., 1998: Sto godina Sveučilišne šumarske nastave. In: Sveučilišna šumarska nastava u Hrvatskoj 1898–1998, Knjiga druga, Matić, S. (ed.). Forestry Faculty Zagreb.

Anon., 1998: Šumarska nastava 1860–1898. na Kraljevskom gospodarskom i šumarskom učilištu u Križevcima. In: Sveučilišna šumarska nastava u Hrvatskoj 1898–1998, Knjiga prva, Meštrović, Š. (ed.). Forestry Faculty Zagreb.

Bastijančić, I., 1963: Zavod za šumarske pokuse. In: Šumarska nastava u Hrvatskoj 1860–1960. Šumarski fakultet, Zagreb.

Fisher, F., 1999: Forest Condition in Europe. In: 1999 Executive Report. Federal Research Centre for Forestry and Forest Products, Hamburg.

Gračan, J., 1990: Problematika znanstvenoistraživačkog rada u šumarstvu SR Hrvatske. Glas. šum. pokuse 26:103–135.

Gračan, J., 1992: Znanstvenoistraživačke ustanove i istraživački rad. In: Monografija šume u Hrvatskoj. Forestry Faculty Zagreb, p. 263–272.

Horvat, A., 1955: Institut za eksperimentalno šumarstvo. Šumarski list 79: 526–531, Zagreb.

Hren, V., 1986: Postanak i razvoj šumarskih znanstvenih ustanova koje su prethodile Šumarskom institutu. Šumarski institut Jastrebarsko, p. 13–19.

Kauders, A., 1963: Šumarski odjel Gospodarsko-šumarskog učilišta u Križevcima 1860–1960. In: Šumarska nastava u Hrvatskoj. Šumarski fakultet Zagreb.

Krstinić, A., 1986: Istraživanje aktualnih problema u šumarstvu. Glas. šum. pokuse, posebno izdanje, 2:35–42.

Potočić, N., Seletković, I., 2000: Stanje oštećenosti šuma u Republici Hrvatskoj 1998. godine. Šumarski list (u tisku).

Rauš, Đ., 1985: Primjena šumarskih znanosti u šumarstvu Slovenije i Baranje. Šum. list 109: 329–339, Zagreb.

Šafar, J., 1995: Osvrt na desetgodišnji razvitak i rad Instituta za šumarska i lovna istraživanja, Šum. list 79: 582–558, Zagreb.

Vidaković, M., 1986: Uloga suvremenih znanosti u visokom obrazovanju i razvitku materijalne proizvodnje. Glas. šum. pokuse, posebno izdanje 2: 25–34.

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# Forest management in the Croatian Danube region with a high level of mine contamination

**Pavle Vratarić, Dubravko Krušarovski**

***Abstract***

*It is unthinkable to carry out the activities aimed at managing forests and game in the area highly contaminated with mines. Humanitarian mine clearance is much more demanding than the military one. Mine clearance activities are extremely high costing. Forestry is a low-accumulative economy branch and it can hardly cover the regular production costs with the expenses of forest regeneration, so that the calculation with mine clearance activities of all the area shows a highly negative balance. However, mine clearance could partly be carried out by use of funds intended for forest regeneration. Mine clearance of forest roads crossing the former war zone, i.e. the line of disengagement, which used to be mined, would make the whole area in the »hinterland« accessible for work activities. In such cases, the enterprise can assess feasibility of mine clearance activities and choose self-funding regardless their considerable cost. And still, a part of mine clearance activities could be carried out at the expense of the funds intended for regeneration.*

***Key words:*** *Croatian Danube region, mine contamination, forest management*

## 1. Introduction

Mines and other explosive devices are a great evil accompanying every war in the world and hence in our country, too. They are called »buried horror«, »death devices of $20^{th}$ century«, »devil arms«, etc. It is estimated that approximately 110 million mines are currently placed in war zones throughout the world and that »forgotten« unexploded mines, a continuous threat, can be found in 64 countries (Mikulić 1999). Mines kill almost 26,000 people each year and at least the same number get injured. Approximately 3 million mines are laid annually and about 150,000 are removed. Canada raised the issue of passing the *Convention on Banning the Use of Anti-Personnel Mines*, signed by 122 states in Ottawa in 1997, including the Republic of Croatia.

## 2. Mine contamination of the Republic of Croatia

It is estimated that in the Republic of Croatia 1–1.2 million mines have been laid on an area of about 6,000 $km^2$, i.e. on about 10% of the Croatian continental territory. The Republic of Croatia is ranked as one of the most highly mine-contaminated countries in the world. The Government of the Republic of Croatia established the Croatian Center for Mine Clearance Activities (HCR) by its Order of 19 February 1998 with its registered office in Sisak. HCR tasks are the following: to keep the database; to submit the plan for mine clearance to the Government; to develop mine clearance projects; to organize public tenders, surveillance, marking; training about mine risks; first aid to mine casualties, to pro-

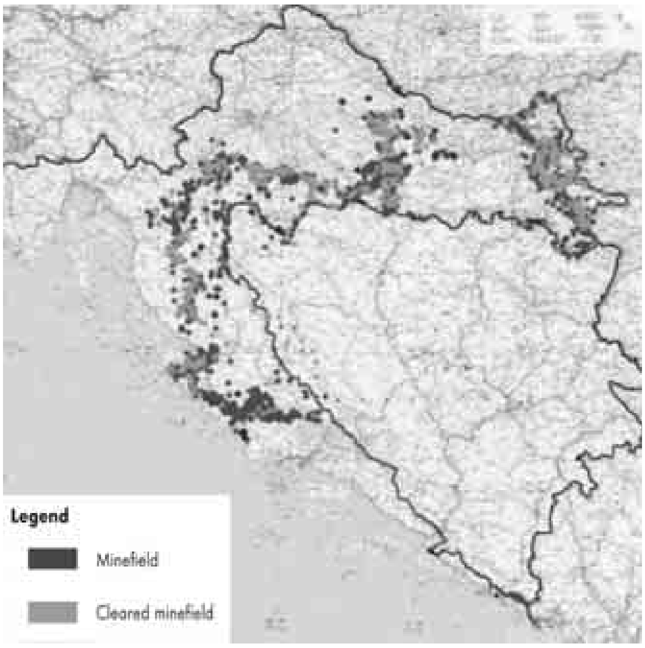


**Figure 1** Minefields in the Republic of Croatia

vide support to the development of domestic technology; to co-ordinate activities of international experts for mine clearance and other related activities.

»Hrvatske šume« Inc. Zagreb manages about 80% of all forests in the Republic of Croatia. A total of 243,693 ha or 12% of the total area and 1,212 km of roads are mined i.e. inaccessible for work activities. Within such an inaccessible area high damages occur due to impossibility of carrying out forest preservation and harvesting activities, non-use of annual cut, game damage, etc. Forests and forestland are ranked seventh among eight types of land classified in accordance with the purpose and mine clearance priority.

»Hrvatske šume« Inc. Zagreb manages the forests of Danube region through Vinkovci and Osijek Forest Administrations and local forest stations. Vinkovci Forest Administration has 8,413 ha or 12% of mine contaminated forests and Osijek Forest Administration 14,546 ha or 19%. These forests cover an area of 18 economic units and they are mostly made of: forests of white willow and black poplar with blue blackberries (*Salici-Populetum nigrae rubetosum caesii* Ratuš 1973), forests of black and white poplar (*Populetum nigro-albae*, Slav. 1952), field ash forests (*Leucoio-Fraxinetum angustifoliae* Glav. 1952), forests of pedunculate oak and large greenweed (*Genisto elatae-Quercetum roboris* Ht. 1938) and their sub-associations separated with reed and ill weeds, forests of pedunculate oak and hornbeam (*Carpino betuli--Quercetum roboris* /Anić 1959/ emend. Rauš 1969) and others.

**Figure 2** Machine thresher operating in the forests of Kopački Rit in Danube region

Any action aimed at managing forests and game is unthinkable on the area contaminated with mines and other explosive devices. Humanitarian mine clearance is far more demanding than the military one. Thorough removal of mines and explosive devices is required here in accordance with UN specification of 99.6% (*International Standards for Humanitarian Mine Clearance Operations*). It is considered that one pyrotechnist can search a 20 m$^2$ area a day (5 hours) and under very favorable conditions an area of up to 50 m$^2$. One machine thresher (e.g. MV2) can clean approximately 6,000 m$^2$ in one working day in two shifts. If the efficiency of the mine clearance machine is 85%, the difference to the required 99.6% can be achieved by methods using detectors and mine searching dogs. A group of 30 pyrotechnists who check the efficiency of mechanical clearance can examine and if necessary manually clear of mines 4,2000 m$^2$. The technology of mine clearance is adapted to the type of mined area depending on whether it is a village, road, plough-field, forest or something else.

## 3. Mine clearance in the Croatian Danube region

For mine clearance of an area of 22,959 ha in the Croatian Danube region, it would take 11,480 working hours or 57 years (with 200 working days a year). This simple calculation is made in base of three machines in two shifts and five teams made of 30 pyrotechnists working for five hours a day (with the efficiency of 2 ha a day). Such calculations do not stand well the calculations of expenses of forestry production. Forestry is a low accumulative branch of economy and it can hardly cover its regular production costs with the expenses of forest regeneration.

However, mine clearance could partly be carried out by use of funds intended for regeneration. There are two examples of such realization and several projects are now being prepared. Mines and explosive devices are mostly placed along the front-line, which was shifted 7 to 30 km from the border with Yugoslavia to the Croatian Danube region. Today, it is impossible to reach the forests in the »hinterland« of the front-line using public roads, which cross the areas of the former front-line due to mostly folded and swampy terrain particularly in the area of Kopački Rit.

»Hrvatske šume« Inc. Zagreb have ordered the project of »forest roads »mine clearance in the economic unit »Kopačevke podunavske šume« (Forests of Kopačevski Rit in Danube region) with HCR affiliate in Osijek. As a matter of fact this is an earth path, which makes accessible the area for felling ripe Euro-American poplar plantations and cultures with a growing stock of approximately 60,000 $m^3$ and 25 years old or older. In base of that project, mine clearance of the road was carried out (figure 4) – 3,530 m in length and 15 m wide. On places where a minefield was detected, additional mine clearance was performed so that ultimately 63,350 $m^2$ were examined and cleared. Total cost with additional operations amounted to 700,000 HRK i.e. 11 HRK per 1 $m^3$ in average. It is clear that these must be investment funds, as felling is going to be carried out in five years. Thus the work has been provided for the employees of Darda Forest Station for the next five years, the use of the annual cut has been secured and 60,000 $m^3$ of high quality wood mass of Euro-American poplar has been saved from decay (as well known if felling of poplar trees is not carried out in due time they are prone to decay). A wide area of approximately 2,000 ha has been made accessible for safety operations especially for fire protection (fires being very frequent here), for silvicultural and management activities as well as game management (which is very important since »Kopački Rit« is a park of nature).

Within the area of Vinkovci Forest Administration, the forest road and openings were cleared of mines in Debrinja economic unit, covering an area of 15,000 $m^2$ with the expenses amounting to 380,000 HRK. As a result, six departments of oak seed stands, old more than 1 hundred years, were opened, all necessary forestry and cultural operations were made available and an important wind-breaking area, which will be very soon used, was made accessible »HCM« Osijek affiliate carried out the mine clearance project in Topolovac economic unit and has or-

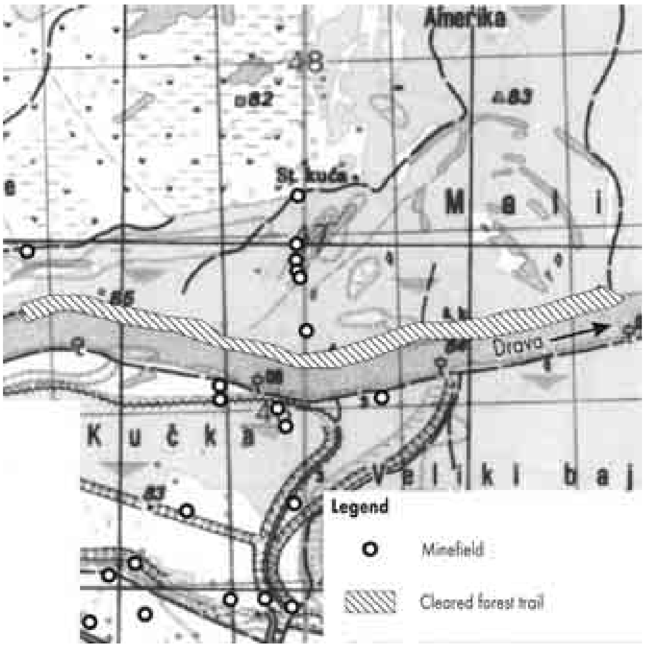


**Figure 4** Cleared forest trail in the management unit »Kopačevske podunavske šume šume«

**Figure 3** Drava region before mine clearance

**Figure 5** Drava region cleared of mines – earth path

dered the projects for mine clearance of roads and forest paths in economic units »Osječke nizinske šume«, »Valpovačke podravske šume«, Jagodnjačke šume«, »Zmajevačke šume« and »Tikveške podunavske šume«. However, a part of mine clearance activities could be carried out by use of the funds intended for regeneration.

## 4. References

Anon., 1997: Ne. Policijska akademija, Visoka policijska škola, MUP RH, Zagreb.

Barbalić, D., 1996: Zabrana mina, stvarnost ili utopija (II. dio). Problemi uklanjanja mina. Velebit 28. 6. 1996, str. 22.

Barbalić, D., 1996: Zabrana mina, stvarnost ili utopija (III. dio). Organizacija čišćenja mina. Velebit 28. 6. 1996, str. 23.

Barbalić, D., 1996: Zabrana mina, stvarnost ili utopija. Velebit 14. 6. 1996, str. 20–21.

Bonner, R., 1996: Pentagon razmišlja o zabrani mina. The New York Times, Vjesnik 19. 3. 1996.

Mikulić, D., 1999: Tehnika za razminiranje. Hrvatski centar za razminiranje. Sisak – Zagreb.

Tuličić, J. i Goršeta, D., 1998: Republika Hrvatska i mine. TIPOMAT.

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# For technological transformation in the development of Croatian forestry, psychological and sociological changes for forestry personnel are necessary

**Tomislav Starčević**

***Abstract***

*The basic characteristics of the past century as regards Croatian forestry development can be summarised into a intense life of forestry scientific and professional tought, based on the traditional almost religious relationship between the human expertise and the forests in this area but also on the lack of development of basic organisational forms and economically motivated working units (forestries).*

*Forestry higher education has for many years trained young forestry experts in the field of basic biological subjects while forestry economics, organisation, mechanics and especially market economy, marketing and business handling were pushed back to the level of basic information. An economic system without profit motivation where no value differentiation was made between labour and profit making as a result of expertise, quality work and effect contributed to all this. A relatively weak unmotivated economic status of Croatian forestry resulted in no investments into knowledge, technology and development and therefore the market and technology have surpassed the operational professional life.*

*The characteristics of today's Croatian forestry are very clear notions on the slowness of a large, centralised system as well as the aims and means that guarantee development and progress. But the necessary preconditions for the change is new knowledge in many fields and the courage of the professionals to initiate the changes wich will testify to the real profession in economic operations as well as a selection of personnel whose interests lie in the benefits for the whole organisation and not the individual. The major changes have to include the rigid regulations which freeze the otherwise dynamic life of the forest, as well as the development of technology and the market. Major changes have to be made in the control aspect in regard to competency, site and authority.*

*The ways of exiting this situation must be focused on decentralisation, creation of production freedom and responsibility, permanent education of a certain number of young professionals abroad in the fields of marketing, technology development, management, informatics and motivating work organisations and award system as is done in developed European countries. The said changes must first occur with the professionals, the society but also on a government level.*

***Key words**: decentralisation, organisation, education, technology transition, forestries*

## 1. Introduction

If we accept the assessment that the technological development of the Croatian forestry has been stagnating and that the changes have been too slow, I am sure that, among many other reasons for such assessment, there is one of not purely technical or financial nature. It pertains to the field of psychological and even sociological changes, which must occur in people dealing with forest management and those state authorities that regulate, perform surveillance, monitor and somehow affect or take part in the life of the Croatian forestry. This daring attitude is not an attempt to justify the actual situation, but rather a tendency to explain objectively the determined technological lagging and above all the incentive for changes that we, the present participants in the Croatian forestry, must undergo.

## 2. Historic survey

Organisation, welfare and development of forestry in Croatia is related to the fear of the effects that could arise due to excessive and non controlled felling and incompetent forest management in mid 19 century. By way of illustration, forest cover in Slavonia, where our most valuable oak forests are located, decreased from 70% to only 30% between 1750 and 1938. The awareness of the value and significance of forests for human survival, was the base for love and respect that people living in this area feel towards this resource.

Too frequent wars and then regularly accompanying economic crises caused excessive demands on forest, jeopardizing its sustainability as the basic economic principle of forestry. Only in the period from 1945 to 1951, felling of 6,237,000 $m^3$ was carried out annually, thus jeopardizing the survival of valuable forest species and destroying the principle of sustainability. This is the time when the moral profession comes into conflict with authorities. After that period, time comes for big actions of afforestation, reduced felling and systematic battle for forest preservation. Central administration system is in effect as well as controlled distribution of raw material, planned economy resulting in the absence of market oriented economy, serious professional and economic contacts with the world are extremely restricted and all this caused serious stagnation of economic growth and development of up-to-date technology. A considerable part of forestry revenue was transferred into governmental funds or funds of regional social and political associations.

Technological innovations or work rationalizations of some diligent forestry enthusiasts were absorbed by the averageness of the entire economic system. Frequent but inefficient reorganizations of the Croatian forestry suffocated and stopped every ambitious attempt for developing and implementing a longer-term program in accordance with development trends. Workers' self-management, the well-known introduction of OOUR-s (independent self-managing units) and the trend of the so-called functional organization of the Croatian forestry are only part of unnecessary and inefficient but high costing experimenting with the organizational structure of the Croatian forestry.

However, the period following 1960, when the forestry organization reintroduces forest harvesting, is marked as the time when significant breakthroughs were made in the direction of technological development. Forests are opened through the construction of roads and chain saws are introduced as well as agricultural tractors, skidders, hydraulic cranes as well as tractor and truck equipage. The first technical standards are recorded and serious efforts are made in order to develop an up-to-date technology. Regular manpower is introduced and trained, their transport to work is organized and their work and skills are stimulated through adequate payment incentives. However, the general climate of superficiality, lack of motivation and incompetence of the controlling function highly suppress and slow down the development.

As far as education is concerned, forestry high-education training provided thorough knowledge in many biological disciplines for young experts while the fields of economy, work organization, management, market economy and marketing as a whole lagged far behind their development in the West European industrial countries. By way of illustration, the following quotation and statement is given here from the book »Šumarska nastava u Hrvatskoj 1860–1960.« (Forestry training in Croatia 1860–1960), (Zagreb, 1963) which says: »By the foundation of the Faculty of Economy and Forestry in 1919, the chair for managing forests was established with the subjects forest management and calculation of forest value by use of forestry statistics. From the very foundation of the Institute there was a tendency to focus on economic issues of forest management.« After World War 2, the Institute changes its name into the Institute for forest management and forestry economy covering all economic and legal subjects. By the foundation of the Faculty of Forestry in 1960 the Institute was divided into two independent institutes: the Institute for Business Economics and Organization of Forest Economy and Wood Processing and the Institute for Forest Management. In accordance with the Articles of Association of the Faculty of Forestry of 1960 the Institute, as the educational organizational unit, covers the following subjects: basic law, forestry business economics, business economics of forest-economic organizations, organization and business activities of forest-economic organizations and wood trade. However, the inevitable conclusion remains: »As long as it existed the Institute always had minimum personnel.« Twenty-six years later, Prof. Dr. R. Sabadi in his textbook and manual of the Faculty of Forestry »Ekonomika šumarstva« (Forestry business economics) dedicates many pages to the calculation of forest value, so that the other chapters are shortened and some issues are completely omitted. As the author himself says in his preface (quote): »Thus, for example, highly important issues such as forestry planning or exchange of products have not been given the space they deserve regarding their significance.«, end quote. The confirmation of this statement lies in the book, (page 337) where marketing is defined as the process required when transferring goods from the manufacturer to consumer or where marketing and market research are considered as component parts in the process of getting insight into consumer's wishes.

## 3. Operational level

In operational-economic life, there are many proves of our lack of knowledge or even lack of awareness of the economic truth that goods are of no use unless they are made available to the consumer in the form, at the time and in the place where he/she is ready to pay their price for them. The reason for such course of events mostly lies in the entire economic system, the absence of sound income-based motives, lack of market oriented economy and devastating leveling of wages, without the presence of legal and controlled private interest in business and absolute lack of motivation and creativity. Hence, it is unfortunately possible and acceptable to find explanation for a poor economic situation in forestry and absence of investments in the development of technology and knowledge on market and marketing. Therefore, the operational life of forestry profession lags far behind the West European industrial economy as a whole in view of technological development and especially concerning market recognition. The example for such slow reactions of the profession is easy to find in non-occurring of the external service and entrepreneurship. As a matter of fact we wait for this development to happen instead of working on it. It is a fact that the economic function of forestry has been obviously neglected.

The concept of social (state) ownership, to which we were exposed for five decades, never became a reality in the wanted form. The reason maybe lies in the fact that we did not really have our own state for centuries so that the lack of care for it and even its plundering by foreign rulers was not considered as a crime but rather as »ingenuity« or even as a good deed.

## 4. Time of changes

Huge and multiple changes, wished for such a long time, which have occurred in the last decade of this millenium, are so radical that in my opinion all of them could not be implemented at the same time, not to mention their quality. It is hard to assume that a new European developed way of thinking and behaving in organizing all forms of legal state and all its bodies, of the entire economy, particularly the business economy and rational structure of forest economy can occur at once. And it is particularly difficult to achieve changes in the mind-set of people where stagnation and genetically distorted ideas of the trends of development, growth and acquiring goods reigned for so long. At the time of anomie, distorted morality, with no criteria regarding safety in view of legal protection, it is no wonder that we witness events in which, quite often, people emerge, who subordinate common interests to their personal ones.

The assumptions of such changes imply indispensable civic courage, organized battle and even victims in the process of implementing changes, in which people ready to put into practice all ideas they now proclaim and spread will take the leading role. The other area retaining old, obsolete and rigid frames is that of law and regulations accompanying the economic life. In the economic branch of forestry, a considerable part of legal regulations is obsessed with the protection (guarding) of forests from foresters, as if all records, almost two centuries old, on production and natural state of forests did not reflect well enough this relationship. What is more, the relation of the forestry profession itself, in its core, towards forests is enthusiastic, almost religious, and hence forestry and economy-based regulations are far from economical necessity, not to mention economic compromise. In this segment, the profession will have to change the priority of goals.

No wonder, then, that today we claim that we cultivate at high cost and with no reason the lowest degradation forms of sub-Mediterranean and Mediterranean stands on karst. However, through thinning and with silviculturally insignificant intensity, we also cultivate degraded and invaluable stands of minimum increment and quality in the continent with ultimately unidentifiable silvicultural economic effects. Adding to all this the truth that we are able to produce this wood mass, but that we know in advance that it cannot be confirmed on the market, every comment becomes superfluous. The economic truth is that only maximum production is the right orientation but we must be aware that every good, and hence wood too, has no expressed value unless the buyer is ready to pay the price for it.

It is obvious now that the management of forests and forestland is based on stiff and quite often silviculturally too ambitious and economically non-balanced long-term regulations. It is pretty difficult and complicated to change them and therefore they are one of the deterrents in the process of adaptation to the requirements of the market. Today, besides market whimsicality, forest eco-systems are also subject to frequent stresses caused by anthropogenetic impacts, climate excesses and changes of stand conditions. It is, therefore, obvious and sure that in the long run, forestry will focus its interest on a continuous and regular battle for regeneration and renewal of forests, preservation of their natural state, productivity, sustainability and self-regeneration. It is natural that such projected development trend implies new knowledge within profession, working technology, its planning and surveillance, but also suitable breakthroughs in legal regulations and very important breakthrough in the function and competence of control and surveillance.

After all these changes, the actual state of the Croatian forestry is marked with the excellent idea of a single enterprise, the idea conceived on uniformity of forestry policy, uniform forest management, basic guidelines of development strategy and marketing including market research. However, at the same time this system is too centralized, complicated and slow with clearly identifiable lack of profit interests of the basic organizational units (forest stations). A large number of people, who should be the initiators of creativity and rationalization, being at the very source of events, are not motivated and have no the necessary authority and responsibility.

## 5. Pathways of change

Pathways leading out of this situation are not unknown and still the whole system is not developing with the right dynamics, which could, in a reasonable time, grant a step forward towards the set goal. This is a time when we deliberately accept new things, but instinctively continue to work in the old manner. Production of freedom and responsibility at each point of life and work seems to be the basic prerequisite for making this step forward towards the set goal. Thus produced freedom will very soon require the internal reorganization of the Enterprise trying to find balance between authority and responsibility and the increased authority and responsibility will cause equally necessary personnel changes, where young and right-minded, qualified experts, enriched with up-to-date knowledge, will find their place. It is no secret that we need continuous training in the field of management, information technology, exchange of knowledge with the world, public relations, market research and marketing as well as simple models for stimulating innovations, profit effects and work. This, however, is not simple or easy but it is beyond doubt that there is no alternative to this trend.

Along with such changes in the Enterprise for forests, similar changes are inevitable in, at least equally important, component of this economic complex made of state institutions (Ministry of Agriculture and Forestry, Ministry of Economy, State Inspectorate, Administration of Justice, etc.). *The changes I am speaking about will start to take place only when all indispensable changes start occurring in ourselves, in the mind-set of people who live for the forest and from the forest and in the social setting of people and institutions of our country.*

## 6. References

»Hrvatske šume« p.o. Zagreb: Program razvoja (1991.-–2025. god.)

Klepac, D., 1965: Uređivanje šuma, Šumarski fakultet, Sveučilišta u Zagrebu, Zagreb.

Rauš, Đ., 1992: Šume i šumarstvo u obnovi istočne Hrvatske, Šumarski fakultet Sveučilišta u Zagrebu

Sabadi, R., 1992: Ekonomika šumarstva. Školska knjiga Zagreb, 1–280.

Savez inženjera i tehničara šumarstva i drvne industrije Hrvatske, Povijest šumarstva Hrvatske 1846.–1976., Zagreb 1976.

Starčević, T., 1999: Šumsko gospodarstvo Hrvatske; prijedlozi za raspravu, Šumarski list 3–4

Šumarski fakultet Sveučilišta u Zagrebu,: Šumarska nastava u Hrvatskoj 1860.–1960.

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# Regulation and management of selection forests in the management unit Belevine

Juro Čavlović, Mario Božić, Nikola Lukić

***Abstract***

*The Belevine management unit, which is part of the Educational-testing forestry facility Zalesina of the Forestry Faculty in Zagreb represents, more or less, the field of selection forests in Croatia and especially those in Gorski kotar with a long and complex management history.*

*This study gives a brief insight into the development of the relationship between forests and the methods for regulating selection forests in the framework of social, historic and economic changes as well as changes in ownership, on the example of the Belevine management unit. Three different periods with specific characteristics have been chosen. The period ending with 1870 was characterized by random forest felling. For 70 years after that period forests were managed based on the German model. The most significant period is that of the last 50 years when the Forestry Faculty has been continually managing the Belevine forest, implementing the set goals and management guidelines.*

*Furthermore, results are shown of recording the existing state of the selection stands and the whole forest in the framework of preparing a new management plan (state of growing stock and increment, state of natural regeneration and the relation towards the normal selection constitution).*

*Special emphasis has been placed on sustainability of natural regeneration (recruitment of trees to the stand) which is the basis for a permanent and stable selective structure.*

*On the basis of measured factors of the actual state and given management guidelines, the future behavior of the structural elements of selection stands and forests was shown in a SD simulation model.*

*The future management plan should include regulated management procedures aimed at sustaining a stable and natural forest with maximum potential for yielding general and other benefits. It should take into consideration the actual management and state of forests as well as changes in the natural process in the framework of significantly changed forest requirements.*

***Key words:*** *selection forest, regulating methods, recruitment, SD simulation model, guidelines for future management*

## 1. Introduction

Selection management plays a very important role in the forestry of Croatia. Within the area of selection forests, Gorski Kotar takes up a special place as the most forested part of Croatia boasting of beautiful selection forests of fir and beech. Gorski Kotar can be said to have a very long and complex history of managing its forests. As historical, social, economic and ownership relations changed, so did the treatment of forests, ranging from the initially incompetent and disorganised approach, through empirical to professional and scientific one. The beginning of the 20$^{th}$ century saw intensive professional and scientific activity concerning selection management (Kern 1898, 1909, Jovanovac 1925), which has been particularly intensified in the last 50 years (Klepac 1953, 1954, 1956, 1960, 1961, Križanec 1993, Matić 1983, Šurić 1933, Božić 1998). In recent times considerable changes resulting from man's influence have been noted in the constitution of selection fir forests (Klepac 1995, Čavlović and Marović 1997, Matić *et al*. 1996), as well as in the developmental stages (Korpel 1996).

The Management Unit Belevine, part of the teaching-experimental forestry facility Zalesina of the Faculty of Forestry in Zagreb, is a good representative of selection forests in Gorski Kotar. The aim of this paper is to present the management and regulation of selection forests and give a projection of future management using the selection forest Belevine as an example.

## 2. General characteristics of the Management Unit Belevine

The Management Unit Belevine is located in the area of Croatian selection forests in the region of Gorski Kotar and Forest Administration Delnice. It is situated along the north of the Kupjak plateau on three mildly sloping mountain peaks at an altitude of 720–870 m.

The prevalent climate in the area is temperate rainy (etesian), in which the mean monthly temperature in the summer months does not exceed 22 °C. Mean annual temperature is 6.7 °C. The vegetation period lasts for 140 days (mean daily temperature is over 5 °C). Air humidity is high over the whole year and reaches 81%. The quantity of precipitation ranges between 1,500 and 2,500 mm (2,074 mm), and the snow period lasts 188 days on average.

The forest lies on the silicate geological base with acid brown, brown to podzolic soils.

The mildly undulating and fan-shaped relief is furrowing towards the north eastern – southern west direction, with mostly sunny expositions with inclinations of up to 20°.

The dominant plant community is the forest of fir with fern (*Blechno-Abietetum*, Horv. 50), and the less represented is the forest of beech and fir (*Abieti fagetum croaticum*, Horv. 50).

The total area of the forest and forestland is 293.94 ha, of which 283.20 ha are under the forest, 5.88 ha are non-forested productive forestland, and 4.86 ha are infertile.

The area under the forest is divided into four management classes:

- Management class *Fir II* 266.24 ha
- Management class *Beech and fir* 9.93 ha
- Management class *Protective forest* 6.27 ha
- Management class *Park* 0.76 ha

## 3. The history of management

The forest in the Management Unit Belevine is a good representative of the area of selection forests in Gorski Kotar, with which it has shared a long and complex history of management.

A long historical period beginning at the end of the 12th century, when the first written documents on ownership relationships over these forests date, can roughly be divided into three periods. Each of them is characterised by specific relations towards the forests and the influences on the management and development of forest regulation within historical, social and economic changes.

### 3.1. The period to 1871

This period is characterised by Gorski Kotar being the home of virgin forests of beech with a low share of conifers. The first chaotic felling of beech forests began at the end of the 16th century. Since there were no roads and paths, charcoal was burned in the forest as well as potash for the production of glass, and simpler assortments were made (shingle, staves, oars, beams, cart-wright material and others). As new settlements were founded and expanded and metallurgy and manufacture developed in the 18th century, the forests were exploited even more intensively. Timber trade received its impetus when roads were built from the continental part of the country towards the sea. Of particular importance for these forests was the building of the Caroline road from 1726–1732 (Karlovac – Vrbovsko – Ravna Gora – Fužine – Kraljevica), and the Louise road from 1805–1809 (Karlovac – Skrad – Delnice – Rijeka). These roads had a particularly large influence on the forest of Belevine when increased exploitation of bigger beech assortments took place, and felling became more organised.

### 3.2. The period 1872–1931

The German families Thurn and Taxis, who owned this forest, left their mark on the management.

The event of great significance from the beginning of this period was the building of the railway Zagreb – Karlovac – Rijeka from 1873–1878, which led to almost complete disappearance of beech by the end of the 19th century. For example, in the former district Zalesina there was 67% of beech in 1867, 19% in 1930, and 10% in 1980.

In the first 20 years, the German model of forming pure conifer stands by removing beech was being introduced.

The first management treatments were carried out in 1891/92, when pure fir stands with decreased forest crop and broken canopy prevailed. To replace the wind-fallen trees, reforestation with spruce was prescribed until 1900. Only the sickest trees were felled, and the place, time and method of selecting and cutting trees – selection management – were set down.

In 1911/12, comprehensive regulation was carried out when all trees above 32 cm were measured and samples of tree heights taken. Data obtained from those measurements and data from the measurements in 1969 are compared in Table 1.

**Table 1** Comparision between 1911 and 1969 inventory

| Year of inventory | Number of trees | Growing trees | | Volume of average tree |
|---|---|---|---|---|
| | | $m^3$ | $m^3$/ha | $m^3$ |
| 1911 | $D_{>32cm}$ 33 698 | 56 744 | 202 | 1.69 |
| 1969 | $D_{>30cm}$ 42 029 | 115 029 | 431 | 2.75 |

Financial maturity bearing the lowest interest of 3% dominated management practices. On this basis, the dimension of cutting maturity of 56 cm and the average diameter increment of 6 mm were obtained. Since the maturity dimension of 56 cm corresponds to the age of 100 years, the forest was divided into 4 age classes (Figure 1). Different tree ages within each individual stand, accompanied with a long regeneration period of 40 years, were encouraged.

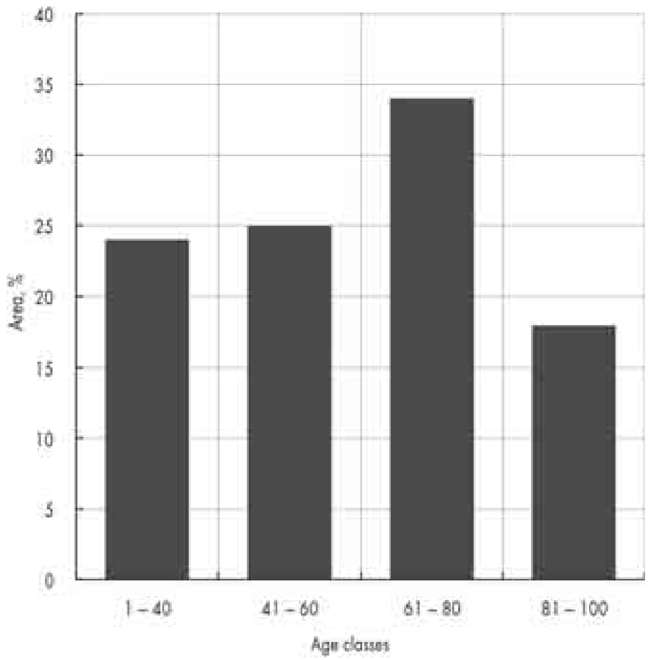


**Figure 1** Age classes distribution

The most important feature of this period was the idea to initiate and put into practice the notion of forming pure conifer stands.

### 3.3. The period from 1950

In 1950 the forest Belevine, then a part of the former Forest Office Zalesina, was given over to the Faculty of Forestry from Zagreb to manage and regulate for teaching and research needs. In the 50-year period, the Faculty of Forestry has continuously managed the forest Belevine in a unique manner, and has consistently applied the following management goals and guidelines set out at the beginning:

- to transform the even-aged and transitional structures into the selection structure,
- to reduce the basal area to the optimal one of 34 to 37 $m^2$/ha,
- to conduct selection cutting of maximal intensity of 25% in the stand every 10 years,
- to form mixed stands of fir and beech in the ratio 80 : 20 with a selection structure and group spatial arrangement of trees.

Management plans based on inventories were regularly drawn up. At the beginning, they included the total area, but later incorporated sample areas. The first management plan followed the Instruction from 1937, and the second involved the yield determined with Melard's formula. Since 1963 the forests have been managed using the New System method of selection management.

The principles of intensive management in biological and technical sense were applied.

Management results can best be seen in the trends of the growing stock, structure per tree species, increment, and prescribed and conducted felling over the last 50-year period (Figures 2, 3, and 4).

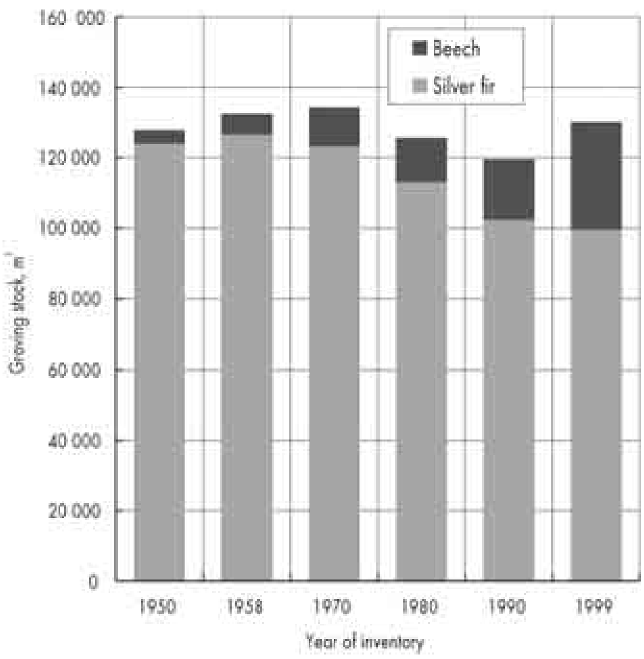


**Figure 2** Trends in growing stock per ha in period 1950–1999

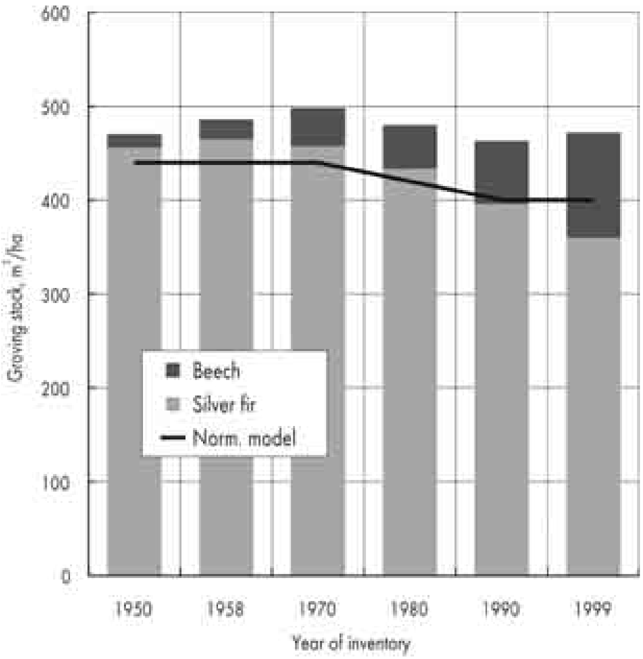


**Figure 3** Trends in growing stock per ha in period 1950–1999

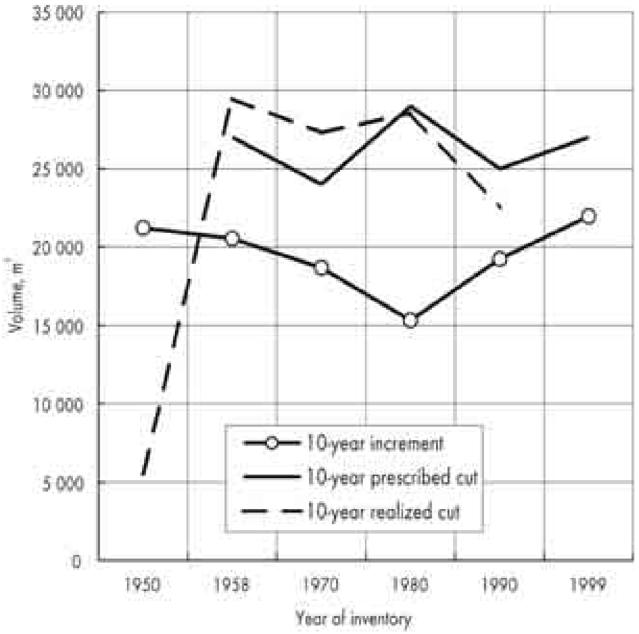


**Figure 4** Trends in 10-year increment, prescribed and relized cut in period 1950–1999

Trends in total and average growing stock per ha in the last six inventories show that the total growing stock has ranged from 120,000 to 130,000 $m^3$, or 460 to 500 $m^3$/ha. With regard to the constitution of growing stock in terms of tree species, there has been a constant decrease in the participation of fir in the last 30 years. On the other hand, over this period the participation of beech has increased from the initial 3% to 24% by the end of the period. This is a definite indication of the processes influencing the change in the internal structural relationships in stands.

The ratio between the measured increment in the 10-year period and the prescribed and conducted felling in the same period shows that the measured 10-year increment was roughly 15,000–22,000 $m^3$, the prescribed 10-year felling quantity ranged from 24,000 to 29,000 $m^3$, and the realised 10-year felling quantity reached 22,000–30,000 $m^3$. Over the whole period the prescribed and realised felling exceeded the measured increment with regard to the fact that the existing growing stock was being reduced to the normal stock. Aberrations from the prescribed and realised felling were within the allowed limit ± 20%.

Generally, in the course of the last 48 years 113,309 $m^3$ of the growing stock have been cut, which corresponds to the amount of the forest timber on the stump, which has been constantly present over this period. Assuming that the age of mature trees (»production cycle«) in this selection forest is at least 150 years, then in the course of one »production cycle« three growing stocks of mature and immature yields can be cut, which indicates a very high productivity of this selection forest.

## 4. The existing state of Belevine forest in preparing a new management plan

Preparatory activities aimed at drawing up the new management plan involved comprehensive measurement and recording of the existing state of the stands in the management unit, which was carried out in the summer of 1999. A square network with 90 metre sides was laid down in each compartment. At the network cross points, every 90 metres, square plots of 900 $m^2$ in size were staked out using semi-diagonals. The following activities were carried out in each plot: diameters of all trees above 5 cm breast height were measured, heights were measured at three points, increment cores from three trees closest to the centre of the plot were taken, an increment core from each tree reaching the thickness of 7.5 cm was taken, diameter and heights of two dominant fir trees gravitating towards the plot were measured, seedlings and young plants on the circular sub-plot of 4 cm in diameter were counted, plants at a younger and more mature stage on the circular sub-plot of 8 cm in diameter were counted, and site and stand elements in the part gravitating towards the sample plot were described.

The obtained mean height of dominant trees for the whole forest of 35.5 m corresponds to previous measurements. This date serves as a base for a mixed normal model of fir and beech in the ratio 80:20, with maturity dimension of 70 cm for the fir and 40 cm for the beech, which was also used as a base for management in the past period.

The present state of the stands and the whole forest can best be shown in relation to the prescribed normal model used in management.

The distribution of the number of trees and growing stock per diameter degrees (classes) in relation to the mentioned normal model (Figures 5 and 6) was shown for an average selection stand within the most important management class *Fir II*, which covers 91% of the total forest area. Two things are noticeable at first glance. There is a distinct surplus of the total number of trees and growing stock with dbh over 50 cm. Since the distribution of the number of trees and growing stock of beech mainly corresponds to the normal model, aberrations from the normal model are reflected in the distribution of trees and growing stock of fir. 93 $m^3$/ha, or 26% of the growing stock, are above the prescribed maturity dimension of 70 cm for the fir. A large part of this growing stock is over-mature and has a considerably reduced increment. On the other hand, there is a distinct shortage of trees with dbh of 30 cm among the trees with small to medium thickness.

With regard to the structure of an average selection stand in relation to a normal mixed model, it is of vital importance to determine the state of natural regeneration along with measured high transition times (poorer tree increment).

As was said before, young plants classified into four categories were counted in small experimental plots. The results of counting per compartments, transferred to the whole forest, are shown in Table 2.

**Table 2** State of natural regeneration

| | Number of plants per ha | | | |
|---|---|---|---|---|
| | 1-year plants | 2 year plants to 0.5 m height | 0.5–1.3 m heigt | 1.3 m height to 5 cm dbh |
| Fir | 7 498 | 2 808 | 416 | 165 |
| Beech | 620 | 3 236 | 413 | 157 |
| Total | 8 118 | 6 044 | 829 | 322 |

Data in the table show a very bad state of natural regeneration. With the exception of seedlings, which appear and disappear every year, the number of young plants and trees past the stage of the fight for survival is unsatisfactorily small. This refers especially to the fir.

The effects of the above on the annual inflow, that is, on the number of trees that enter the measurable part of the stand, are shown by the following:

**Recruitmenr**$_{\mathbf{Fir}}$ $= (N_{7.5} + N_{12.5}) / 2 \cdot t_{7.5} = (52 + 39) / 2 \cdot 31{,}2 = 1{,}5$ trees/ha · per year

**Recruitment**$_{\mathbf{Beech}}$ $= (N_{7.5} + N_{12.5}) / 2 \cdot t_{7.5} = (70 + 59) / 2 \cdot 24{,}6 = 2.6$ trees/ha · per year

**Recruitment**$_{\mathbf{Total}}$ **= 4.1 trees / ha · yearly**

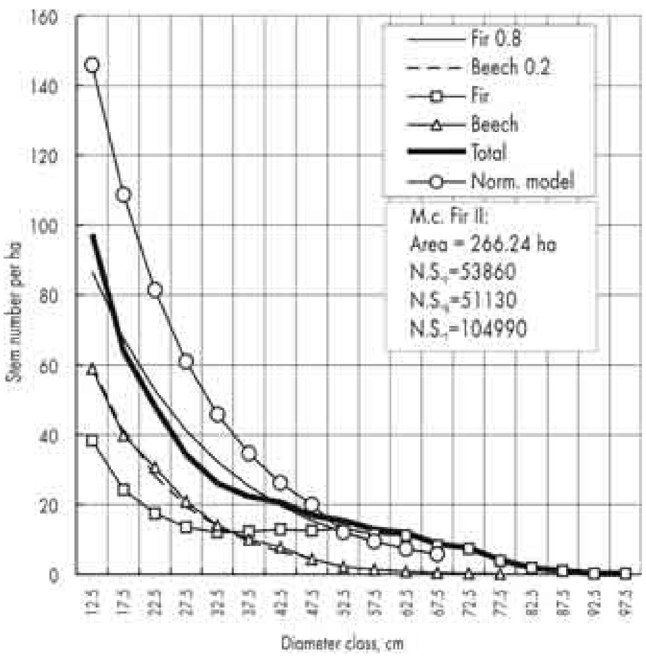


**Figure 5** Stem-numbers by diameter classes – Manag. class Fir II

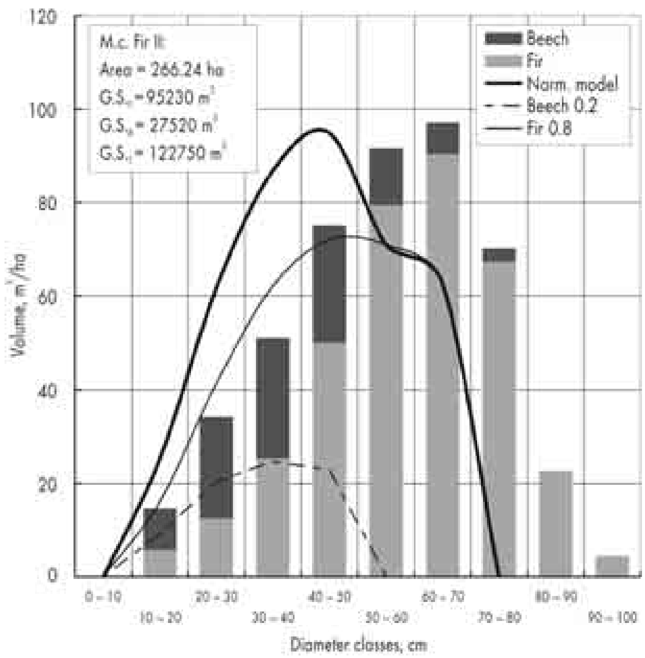


**Figure 6** Growing stock by diameter-classes – Manag. class Fir II

The annual inflow of 4 trees per hectare is far below the optimal. A steady and optimal inflow of trees into the stand is the basic prerequisite for the existence of a normal and stable selection structure. The affects of the inflow on the trends of the total number of trees for a normal pure fir model in the second site class were simulated using the SD model (Čavlović 1997)(Figure 7). For example, according to the picture, the inflow of 0 trees would result in a halved number of all trees in a selection stand in 50 years' time. Likewise, a constant inflow of at least 10 trees per hectare annually is a basic prerequisite for a stable balance of a normal selection structure.

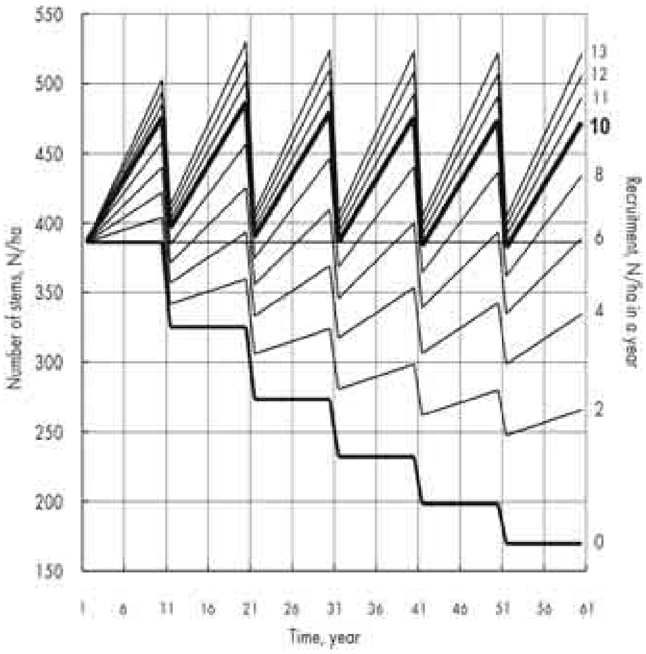


**Figure 7** Recruitment influence on stem-numbers – Normal non-mixed model – Fir II

## 5. Discussion on the future management

The key management procedures in the future period are determined by the state of selection stands and the whole forest, as well as by what our aims are. The existing state can be summarised by two unfavourable facts: the surplus of over-mature growing stock and poor natural regeneration. The primary goal is to invoke positive processes over a longer period that will result in a stable forest of a normal selection structure.

By using the SD model of a selection stand (Čavlović 1996, 1997) and the established basic conditions for the future management procedures, the results of a possible future development of an average selection stand structure have been obtained.

The model contains the following features and management procedures:

- there is a cause-consequence link and relationship between the mature growing stock and the inflow
- a normal mixed model of management used so far will be used in the future
- almost all growing stock with a dbh over 70 cm should be cut over the next 40 years
- the increase of fir and beech inflow from the initial 4 trees per hectare annually after the first

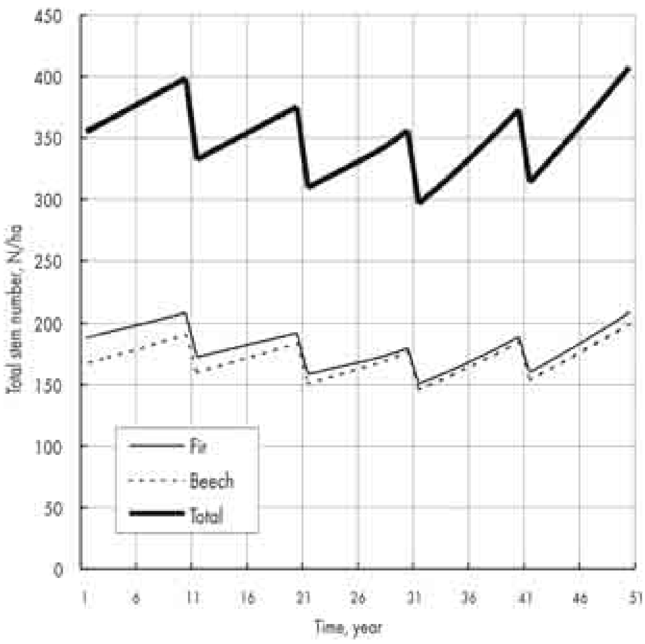


**Figure 8** Trends in total stem-numbers – Management class Fir II

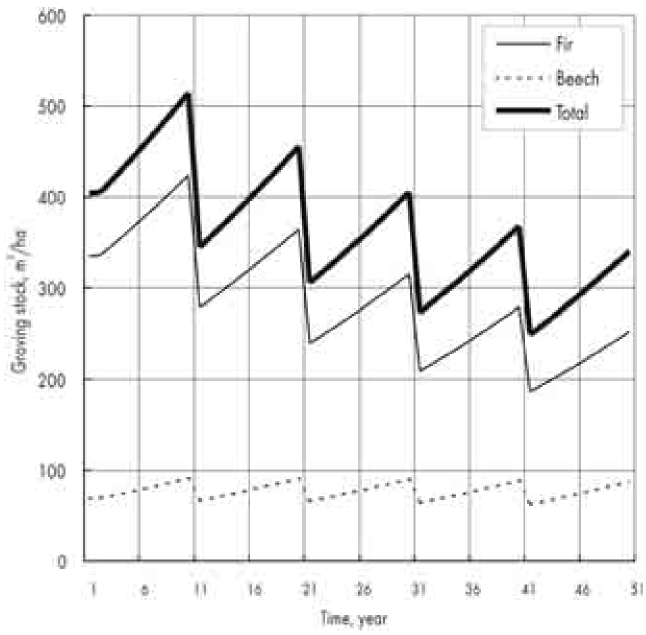


**Figure 9** Trends in growing stock – Management class Fir II

cut should reach the optimal one of 12 trees per hectare annually at the end of a 50 year period

- diameter increment should be increased, that is, shortened tree transition time ensured.

The simulation yielded the results of possible future trends in the total tree number, growing stock and yield (Figures 8 and 9), as well as the development of selection stand structure (Figure 10).

In the first 30 years, the number of trees per hectare will gradually decrease. A more rapid growth in the number of trees will follow as a result of the assumed increased inflow in the last two thinning cycles. The number of firs and beeches in the whole period remains the same.

The trends in growing stock per ha, showing the yield every 10 years, differ from the trends in tree numbers. Over the 50-year period there is a gradual drop in the total growing stock, faster at first faster and slower later. It is exclusively the consequence of a decreased growing stock of fir due to cutting down mature and over-mature fir trees with dbh exceeding 70 cm. In the beginning, the felling intensity is

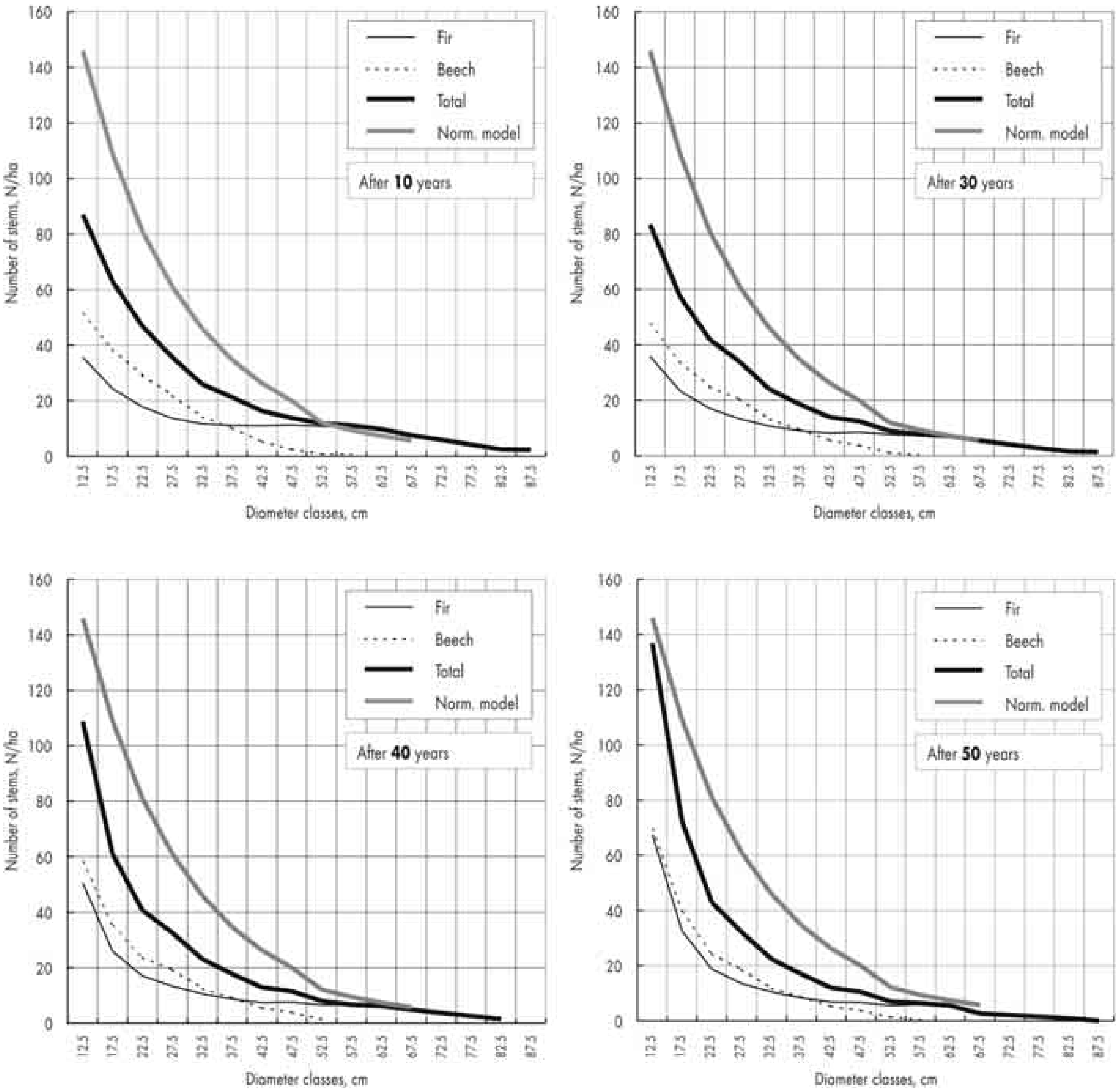


**Figure 10** Trends in diameter distributions over future 50-years period

high (about 35%), and later it gradually declines. The growing stock of beech has a constant value of about 80 $m^3$/ha over the whole period. This means that over the 50-year period such intensive felling treatments, aimed at removing over-mature growing stock, encouraging natural regeneration and improving the selection structure, will reduce the initial growing stock of 430 $m^3$/ha to 300 $m^3$/ha, or to 75% of the normal mixed model. As seen in Figure 9, if transferred to the whole forest, during the first thinning cycle a yield of 45,000 $m^3$ could be cut, then of 40,000 $m^3$, then 35,000 $m^3$, 31,000 $m^3$, and 26,000 $m^3$.

In total, in the course of the next 50 years, 177,000 $m^3$ will be cut within the presented management scenario, which exceeds the felled amount in the last 50 years by 56%.

Extremely slow changes in the development of an average selection stand structure are shown in Figure 10. Over the 50-year period there is a slow decrease in the trees with dbh above 50 cm, and an increase in the number of trees in the first two diameter classes. Even after 50 years, there is a large void relating to trees of medium thickness in relation to the normal model. The question remains whether another 50 years would suffice to achieve a satisfactory normal selection structure, that is, a satisfactory number of firs of medium thickness.

It should be pointed out that the results of the simulation model refer to a long period of time. In reality, such long-term planning should be complemented with continuous and more sophisticated planning of management procedures to reflect the feedback in the man-forest system. There is also the open question of the stability of the normal model and the possible need for changeable normal models with reference to the »developmental stage« of a selection forest.

## 6. Conclusion

Over the time, the selection forest in the Management Unit Belevine has gone through several developmental stages. They have been brought about by various management procedures in the framework of social, historical, economic and ownership relations, as well as by the changes in natural processes in the forest over a long period of time. Therefore, at a certain point in time it is important to note the positive natural processes and to follow them with adequate management procedures, regulation methods, dynamic normal models and technologies. However, these should always be subordinated to the preservation of a stable and natural forest with a maximal potential for both general and other benefits from the forest.

## 7. References

Božić, M., 1999: Modeli uređivanja jelovih šuma Gorskog kotara. Magistarski rad. Šumarski fakultet Zagreb, Hrvatska, pp. 140.

Čavlović, J., 1996: Simulacijski model dinamičkog sustava preborne sastojine. Unapređenje proizvodnje biomase šumskih ekosustava, Znanstvena knjiga I, Šum. fakulteta i Šum. instituta, Zagreb 1996, pp. 147–156.

Čavlović, J., 1997: Process-based model of a selection forest stand as a support to uneven-aged forest management. *Proceedings*, IUFRO Group 4.0., pp. 14, Oeiras, Portugal.

Čavlović, J., Marović, T., 1997: Odnos prirašćivanja stabala jele na NPŠO »Sljeme«. Šum. list 121(9–10), 473–478.

Jovanovac, A., 1925: Važnost »normale« kod uređivanja prebornih šuma. Šum. list 49(5), 288–299.

Kern, A., 1898: Uređenje prebornih šumah. Šum. list 22 (8–9), 300–326.

Kern, A., 1909: Preračunavanje drvne zalihe i prirasta u prebornim šumama. Šum. list 33(?), 142–151.

Klepac, D., 1953: O šumskoj proizvodnji u fakultetskoj šumi u Zalesini. Glasnik za šum. pokuse 11, pp. 181–238.

Klepac, D., 1954: Komparativna istraživanja debljinskog, visinskog i volumnog prirasta u fitocenozi jele i rebrače. Šum. list 78(2–3), 83–110.

Klepac, D., 1956: Funkcionalni odnos između godišnjeg volumnog prirasta i prsnog promjera za jelu u prebornoj šumu. Šum. list 80(1–2), 1–16.

Klepac, D., 1960: Prirasne tablice za jelu na području fakultetske šumarije Zalesine. Glasnik za šum. pokuse 14, pp. 359–382.

Klepac, D., 1961: O nekim normalama u jelovim prebornim šumama. Šum. list 85(3–4), 85–90.

Klepac, D., 1995: Dinamika kretanja drvne zalihe na panju u šumama Gorskog kotara tijekom 40 godina (1950–1990). Šum. list 119(3–4), 85–90.

Korpel, Š., 1996: Razvoj i struktura bukovo-jelovih prašuma i njihova primjena kod gospodarenja prebornom šumom. Šum. list. 120(3–4), 203–208.

Križanec, R., 1993: Uloga evidencije sječa u praćenju kretanja drvne zalihe preborne šume. Glasnik za šum. pokuse, posebno izdanje broj 4, pp. 111–120.

Matić, S., 1983: Utjecaj ekoloških i strukturnih činilaca na prirodno pomlađivanje prebornih šuma jele i bukve u Gorskom Kotaru. Glasnik za šum. pokuse 21, pp. 223–400.

Matić, S., Oršanić, M., Anić, I., 1996: Neke karakteristike i problemi prebornih šuma obične jele (*Abies Alba* Mill.) u Hrvatskoj. Šum. list. 120(3–4), 91–100.

Šurić, S., 1933: Preborne sječe u neuređenim prebornim šumama i šumama tipa prašume. Šum. list. 57(5), 339–347.

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# Quality of fir timber assortments from the forest of fir and hardfern (*Blechno-Abietetum* Ht.)

**Marijan Šušnjar, Ante P. B. Krpan, Željko Zečić, Tomislav Poršinsky**

***Abstract***

*The paper deals with the share of fir timber assortments by quality in the volume of processed timber. The sample consists of 1,404 trees, 20–82 cm in breast height diameter. A total of 4,319.29 m³ of timber assortments were processed and then categorized in 4 quality classes with regard to their dimensions and wood defects. Timber volumes of processed trees as well as absolute values of all quality classes increase with the increasing of the breast height diameter. In relative values, the share of »A« quality-class assortment ranges between 15.2 % and 20.2 %. »B« quality class prevails in diameter classes ranging between 32.5 cm and 47.5 cm, while the share of »C« quality class is the highest with the class of 52.5 cm in diameter and more. The percentage share of »D« quality class is the highest with 22.5 cm diameter class and it makes 80.4 %.*

***Key words:*** *fir, timber assortment, quality class, diameter class, timber volume*

## 1. Main issues

The forest is a regenerative natural resource, which performs its multifunctional role if managed and used rationally (Martinić 1996). The importance of the forest is shown through direct benefits (forest products) and indirect benefits (ecological, protective and social function of the forest). Forest products are divided into wood and non-wood products. Wood products are timber assortments. Non-wood forest products are litter, mushrooms, forest fruits and other live and non-alive substances, which are rarely exploited. From the economic point of view, timber assortments are the final products in forestry so that the aim of forest management is to achieve their highest quantity and best quality. The efficiency of forest management implies the efficiency of all forest activities. The aim of forest planning and silviculture is to establish forest stands, which will give the best possible quality of wood assortments at the time of felling.

Evaluation and classification of wood assortments by quality is based on size and frequency of wood defects, and it is carried out in accordance with standards, which specify the characteristics of forest products. Timber assortments are placed to the market classified into quality classes in compliance with a specific standardization system. Thorough knowledge of the share of wood assortments by quality classes depending on forest communities is, therefore, a very important economic, market and organizational factor in forestry.

Forest scientists emphasize the importance of knowledge of timber assortment quality all the time. Generally, scientists dealing with issues of economic possibilities of forests and forest management potential base their research primarily on timber volume and quality of timber production (Martinić 1996).

Lipoglavšek (1996) sets forth the importance of knowing the quality timber assortments and their classification by quality classes in forest harvesting and market economy. Bojanin (1960) emphasis the necessity of knowing the quality and quantity of timber volume because of better economical timber exploitation.

The paper deals with the research of the quality of fir assortments. Fir is one of the most valuable species in Croatian forestry. The share of fir is 9.4 % of the total growing stock in Croatia. The share of fir is about 28.2 mill. m³ or 10.1 % of the growing stock in the management of state forests. The share of fir is 20.2 % of growing stock in other state forests and only 1.8 % in private forests. The annual felling volume of fir is about 350 000 $m^3$. Furthermore, the demand for fir assortments is very high on the Croatian timber market.

Many scientists investigated the quality of fir timber assortments. They wanted to establish on which factors the quality of timber assortments depended and which fir breast height diameters gave the best economic effects.

Wood assortments are processed only from fir stem and the quality of assortments depends on the position in the stem. The lower half of the stem length is mainly the zone of better quality. Mean value of the assortment diameter decreases with the increase of the distance from the stump and the number and size of knots also increases from the beginning of the crown upward, which all results in a considerable decrease of the quality of assortments.

## 2. Area of research

Research was carried out in forest management unit »Belevine« of Forest Educational and Training Center »Zalesina« of the Faculty of Forestry Zagreb. The area of forest management unit is 293.94 ha, of which 283.20 ha are stocked area.

The forest management unit »Belevine« is situated on mild slopes at the altitude of 720–870 m above sea level, exposed to the sun with moderate inclination (up to 20 %). Zagreb – Rijeka highway makes its border to the south, southwest and southeast. According to Köppen's classification the forest is situated in C climatic zone – warm temperate and rainy climate, »Cfsbx« type. Depending on the ground basis, acidophilus geological structure, deep silicate soils, such as podsol, brown acid and brown podsol soil were developed.

The forest management unit »Belevine« is mostly covered by fir forest with hardfern (*Blechno-Abietetum* Ht.) on a second-rate quality site. These stands are a mixture of beech and fir high selection forest. In the ratio of the mixture fir and spruce make 86 % of the growing stock, and beech 14 % but according to the number of trees the share of fir is 57 %.

The principle of forest management sustainability has been acquired with 10-year selection cycle time and 70 cm felling diameter. The group selection felling is practiced. The stands are in the phase of thick trees since most of them have breast height diameter of over 50 cm. The total growing stock is 126,500 $m^3$ or 457.14 $m^3$/ha of which the growing stock of fir is 105,600 $m^3$ or 382.37 $m^3$/ha. 10-year felling volume is determined on the basis of the ratio between the actual and the optimum growing stock, previous annual cut, maturity dimensions, measured increment, state of regeneration, health conditions and purpose of the forest and it amounts to approximately 25,000 $m^3$ (23,000 $m^3$ of conifers). The sanitary felling volume is 2 $m^3$/ha per year.

## 3. Research method

Measured trees were felled and processed in main felling of the selection cycle volume. Sanitary felling trees made no part of the sample. Before felling, two breast-height diameters perpendicular to each other were measured on standing trees and then sorted into diameter classes. Timber assortments were processed in accordance with the Croatian timber standards (Standards for sorting and measurement of unprocessed and processed timber, Standards for coniferous veneer logs and sawmill-logs, mine timber and cordwood). Two mean diameters and length (with allowance) were measured on each timber assortment without bark (excluding cordwood).

For the purpose of the investigation of the total volume of processed fir-trees, timber assortments were distributed into 4 quality classes with regard to dimensions and wood defects. »A« quality class contains assortments with mean diameter value of more than 25 cm and very small wood defects (veneer logs or best quality sawmill-logs). »B« and »C« quality classes are made of sawmill-logs with different wood defects. Timber assortments with the mean diameter value lower than 20 cm are classified as »D« quality class. As the criteria of quality classification were based on the Croatian timber standards, these quality classes are not equal with the European timber standards.

In data processing, the volumes of timber assortments were calculated in accordance with the measured data. The volumes of timber assortments were classified in accordance with the quality and diameter classes and then total processed volume of the diameter classes was presented. Summary values of the assortment volumes by quality and diameter classes were divided with the number of trees of the pertaining class. In this way, mean values of the trees of diameter classes were determines as absolute and relative values of quality classes.

Absolute values of quality classes were regressed with second-degree curves for each quality class. The total processed timber volume of the mean diameter class tree represents the sum of regressed assortment volumes of this tree.

Relative values of assortment volumes by quality classes were calculated in accordance with the total timber volume of the mean diameter class tree established on the basis of regressed values of timber assortment volume.

## 4. Results of research

The quality of fir timber assortments in the forest of fir and hardfern on second rate quality site was investigated on the sample of 1404 trees with the breast height diameter ranging between 20–82 cm (22.5–82.5 cm diameter classes). The total volume of timber assortments was 4319.29 $m^3$. The sample shown in Figure 1 represents the number of trees and processed volume by diameter classes. The values of both indicators show the trend of normal distribution, with the arithmetic mean value with 52.5 and 57.5 cm diameter classes. The volumes of the processed assortments are presented by diameter and quality classes in Table 1. »A« quality class starts with 27.5 cm diameter class. Diameter class of 22.5 cm contains only assortments of »B« and »D« quality classes.

The share of »A« quality class in the testing sample is 17 %. Assortments of »B« and »C« quality classes make a major part of processed timber volume with the share of 34.4 % and 40.3 %. The share of »D« quality class is only 8.3 %.

The share of quality classes in absolute values is calculated by use of mean trees of diameter classes. Summary values of volumes of timber assortments by quality and diameter classes (data from Table 1) are divided with the number of trees of the pertaining diameter class. The obtained values are regressed with second degree-curves for each quality class. Equations and correlation indexes by quality classes are shown in Table 2. Correlation indexes indicate very strong link among data.

Table 3 and Figure 2 show regressed absolute values of the assortment volume by quality classes. Pro-

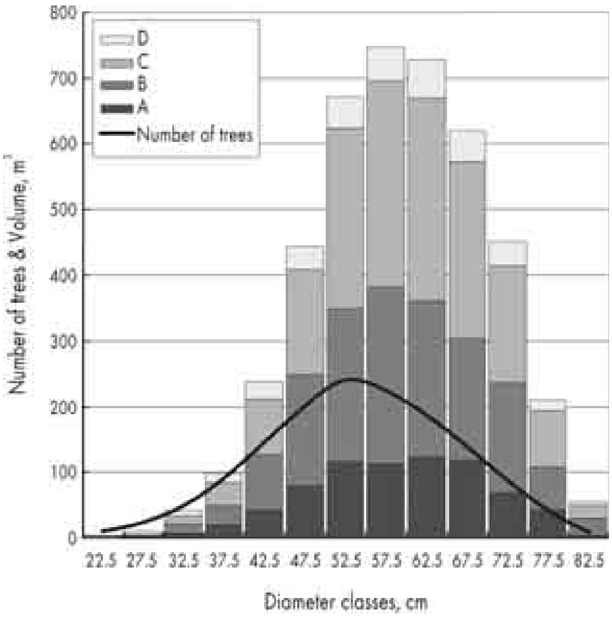


**Figure 1** The sample – Number of trees and processed volume by diameter classes

**Table 1** The sample – Number of trees and assortment volumes by quality and diameter classes

| Diameter class, cm | Number of trees | Volume | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | Total |
| | | $m^3$ | | | | |
| 22.5 | 10 | - | 0.65 | - | 2.67 | 3.32 |
| 27.5 | 19 | - | 2.37 | 2.13 | 5.59 | 10.09 |
| 32.5 | 42 | 6.20 | 15.21 | 11.42 | 9.24 | 42.06 |
| 37.5 | 79 | 19.27 | 30.77 | 34.67 | 14.79 | 99.50 |
| 42.5 | 140 | 41.52 | 86.49 | 83.75 | 27.47 | 239.22 |
| 47.5 | 202 | 80.04 | 168.47 | 159.62 | 35.04 | 443.17 |
| 52.5 | 244 | 116.26 | 233.22 | 273.41 | 48.45 | 671.35 |
| 57.5 | 224 | 113.21 | 268.27 | 313.90 | 52.01 | 747.38 |
| 62.5 | 182 | 124.23 | 235.62 | 310.32 | 58.19 | 728.37 |
| 67.5 | 133 | 118.89 | 184.43 | 268.98 | 47.82 | 620.11 |
| 72.5 | 86 | 69.27 | 168.10 | 176.57 | 35.94 | 449.88 |
| 77.5 | 35 | 42.27 | 65.67 | 86.53 | 15.26 | 209.73 |
| 82.5 | 8 | 3.97 | 26.01 | 20.23 | 4.92 | 55.12 |
| Total | 1404 | 735.13 | 1485.27 | 1741.52 | 357.38 | 4319.29 |
| Proportion, % | | 17.0 | 34.4 | 40.3 | 8.3 | 100.00 |

**Table 2** Equations and correlation indexes

| Quality class | Equation | Corelation index |
|---|---|---|
| A | $y = -1{,}16 + 0{,}047\,x - 0{,}0003\,x^2$ | 0.82 |
| B | $y = 0{,}38 - 0{,}024\,x + 0{,}0006\,x^2$ | 0.97 |
| C | $y = -1{,}01 + 0{,}035\,x - 0{,}0001\,x^2$ | 0.99 |
| D | $y = 0{,}66 - 0{,}022\,x + 0{,}0003\,x^2$ | 0.98 |

cessed timber volume of mean trees of diameter classes, as well as the share of all quality classes, increases with increasing of the breast height diameter of the tree. The share of »A« quality class increases very quickly from 37.5 cm diameter class to 57.5 cm (from 0.08 $m^3$ to 0.63 $m^3$) and then slowly to the value 0.83 $m^3$ with 82.5 cm diameter class. »B« and »C« quality classes increase considerably with increasing of the breast height diameter. »B« quality class achieves the highest volume values with mean tree in 32.5 cm diameter class. The next best values are achieved in the thickest diameter class of 82.5 cm. »C« quality class starts with 27.5 cm diameter class, but this quality class achieves the highest values of mean tree volume from 37.5 cm to 77.5 cm diameter classes. »D« quality class increases constantly with increasing of the breast height diameter from 0.30 $m^3$ to 0.59 $m^3$. Volume of »D« quality class makes the major part of mean tree volume in 22.5 cm and 27.5 cm diameter classes, while it has the lowest values of mean tree volume with all other diameter classes.

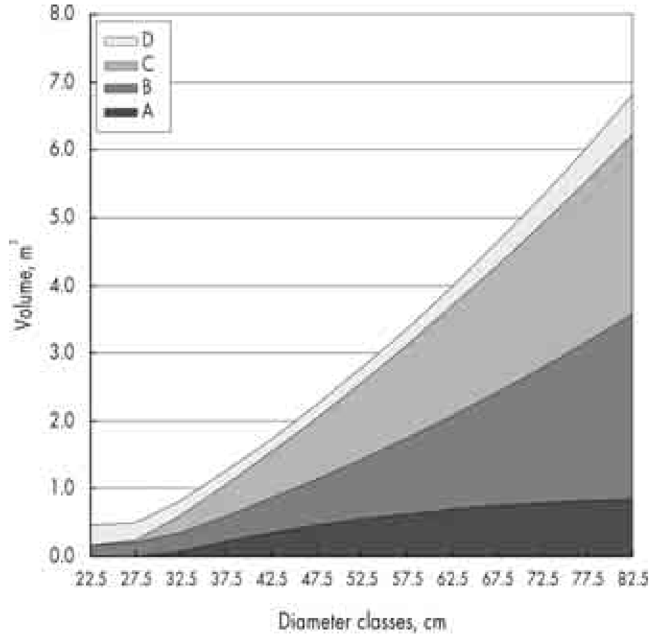


**Figure 2** Regressed absolute values of quality classes by diameter classes

Relative values of quality classes (Table 4 and Figure 3) were calculated on the basis of regressed, absolute values of the volume of quality classes by diameter classes.

Relative values of the share of »A« quality class assortment for 32.5 cm to 77.5-cm diameter class range between 15.2 % and 20.2 %. The high relative values of »A« quality class are noticed in 37.5 cm to 47.5 cm diameter classes (from 17.4 % to 19.4 %).

**Table 3** Regressed absolute values of quality classes by diameter classes

| Diameter class | Volume | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | Total |
| cm | $m^3$ | | | | |
| 22.5 | – | 0.17 | – | 0.30 | 0.46 |
| 27.5 | – | 0.21 | 0.04 | 0.25 | 0.50 |
| 32.5 | 0.08 | 0.28 | 0.25 | 0.22 | 0.82 |
| 37.5 | 0.21 | 0.38 | 0.46 | 0.20 | 1.25 |
| 42.5 | 0.34 | 0.51 | 0.68 | 0.19 | 1.73 |
| 47.5 | 0.45 | 0.68 | 0.91 | 0.19 | 2.23 |
| 52.5 | 0.55 | 0.88 | 1.14 | 0.21 | 2.78 |
| 57.5 | 0.63 | 1.11 | 1.38 | 0.24 | 3.36 |
| 62.5 | 0.70 | 1.37 | 1.62 | 0.29 | 3.98 |
| 67.5 | 0.75 | 1.66 | 1.87 | 0.34 | 4.63 |
| 72.5 | 0.79 | 1.99 | 2.12 | 0.41 | 5.32 |
| 77.5 | 0.82 | 2.35 | 2.38 | 0.49 | 6.04 |
| 82.5 | 0.83 | 2.73 | 2.65 | 0.59 | 6.80 |

**Table 4** Relative values of quality classes by diameter classes

| Diameter class | Relative proportion | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | Total |
| cm | % | | | | |
| 22.5 | | 19.6 | | 80.4 | 100.0 |
| 27.5 | | 23.5 | 21.1 | 55.4 | 100.0 |
| 32.5 | 14.7 | 36.2 | 27.1 | 22.0 | 100.0 |
| 37.5 | 19.4 | 30.9 | 34.8 | 14.9 | 100.0 |
| 42.5 | 17.4 | 36.2 | 35.0 | 11.5 | 100.0 |
| 47.5 | 18.1 | 38.0 | 36.0 | 7.9 | 100.0 |
| 52.5 | 17.3 | 34.7 | 40.7 | 7.2 | 100.0 |
| 57.5 | 15.1 | 35.9 | 42.0 | 7.0 | 100.0 |
| 62.5 | 17.1 | 32.3 | 42.6 | 8.0 | 100.0 |
| 67.5 | 19.2 | 29.7 | 43.4 | 7.7 | 100.0 |
| 72.5 | 15.4 | 37.4 | 39.2 | 8.0 | 100.0 |
| 77.5 | 20.2 | 31.3 | 41.3 | 7.3 | 100.0 |
| 82.5 | 7.2 | 47.2 | 36.7 | 8.9 | 100.0 |

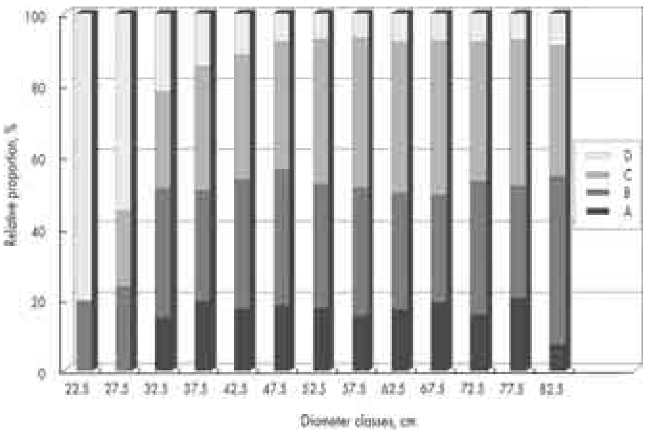

**Figure 3** Relative values of quality class of mean trees among diameter classes

However, they vary with the increase of the breast height diameter and achieve the maximum value of 20.2 % with 77.5 cm diameter class. The diameter class of 82.5 cm has the minimum relative value of »A« quality class (7.2 %). »B« quality class prevails in diameter classes ranging between 32.5 cm and 47.5 cm (from 30.9 % to 38.0 %) and it achieves the maximum value in 82.5-cm diameter class accounting for 47.2 % of the mean tree volume. The sample of 82.5 cm diameter class contains only 8 felled and processed trees, so that relative values of »A« and »B« quality classes of this diameter class are affected by the small number of data. »C« quality class prevails in 52.5 cm diameter class and higher with approximately 40 % of the mean tree volume. The share of »D« quality class is the highest in 22.5 cm diameter class (80.4 %) and 27.5 cm diameter class (55.4 %), but in 42.5 cm classes and higher it ranges unevenly between 7.0 % and 8.9 % of the mean tree volume.

The analysis of the relative values of quality class of mean trees among diameter classes shows the highest volume of »A« quality class, 20.2%, in 77.5 cm diameter class. In the same diameter class, the relative share of »B« quality class is 31.3 %, »C« quality class – 41.3 % and »D« quality class – 7.3 %. In 47.5 cm diameter class there is a slightly lower share of »A« quality class (18.1 %), while the ratio between »B« and »C« quality classes is more favorable (38.0 % and 36.0 %). The difference in the share of »D« quality class between these diameter classes is small (7.9 % instead of 7.3 %).

## 5. Conclusions

- The quality of timber assortments depends on breast height diameter.
- The amounts of all quality classes increase with increasing of breast height diameter.
- The »A« quality class starts with 32.5 cm diameter class and the relative value ranges between 15 and 20 % up to 77.5 cm diameter class.
- »B« quality class prevails in 32.5 cm to 47.5 cm diameter classes (from 30.9 % to 38.0 %) and it achieves the maximum value with 82.5 cm diameter class – 47.2 % of the mean tree volume.
- »C« quality class prevails with 52.5 cm diameter class and higher and accounts for 40 % of the mean tree volume.
- The relative values of »D« quality class are the highest in 22.5 cm and 27.5 cm diameter classes (80.4 % and 55.4 %), but in 42.5 cm diameter class and higher they range unevenly between 7.0 % and 8.9 %.

The acquired knowledge on the structure of fir timber assortments will be a considerable contribution to establish a better and more functional management of fir and hardfern forest. At the same time, with the purpose of developing the production of wood assortments, the research on the quality of timber assortments should also involve other fir forest communities in order to cover the quality of fir as a whole. Research should also be applied to other most represented tree species in the Croatian forestry (oak, beech and ash).

## 6. References

Bojanin, S., 1960: Učešće sortimenata i količine gubitaka kod sječe i izrade jelovih stabala u fitocenozi jele s rebračom. Šumarski list 84(1–2): 21–34.

Knoke, T., 1997: Economic aspects of timber production in uneven-aged forests: preliminary studies on forest management planning in the Kreuzberg municipal forest. Forstwissenschaftliches-Centralblatt. 116(3): 178–196.

Lipoglavšek, M., 1996: Določanje kakovosti proizvodov. Zbornik savjetovanja »Izzvi gozdne tehnike« Ljubljana, Slovenija, 67–72.

Martinić, I., 1996: Ekonomski i organizacijski kriteriji za oblikovanje šumskih radova. Glasnik za šumske pokuse 33, 215–299.

Plavšić, M., 1967: Istraživanje sadašnje najpovoljnije sječive zrelosti u jelovim prebornim šumama. Studija Zavoda za ekonomiku i organizaciju šumske privrede i drvne industrije. Šumarski fakultet Sveučilišta Zagrebu, 1–114.

Rebula, E., 1995: Tablice oblikovnega števila, debeljadi in količine izdelanih sortimentov za jelko. Gozdarski vestnik 53, 402–425.

Rebula, E., 1996: Sortimentne i vrijednosne tablice za deblovinu jele. Mehanizacija šumarstva 21(4): 201–222.

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# Expert bucking of wood assortments aimed at enhancing the utilisation of the annual cut and increasing the revenue from the sale of wood assortments

**Andrija Štefančić**

***Abstract***

*The paper shows the results of expert bucking and sorting of wood assortments in quality classes specified by Croatian Standards for forest harvesting products, achieved in the public enterprise »Hrvatske šume« Inc. Zagreb (»Croatian Forest« Inc. Zagreb), from January to June 1999.*

*In order to improve the utilization of the annual cut and increase profit from the sale of wood assortments in »Hrvatske šume« Inc. Zagreb, we have accomplished the following:*

- *In the plan for 1999, we determined the quantity and quality of wood assortments by use of unique wood assortment tables (HŠ-DOZ).*
- *We organized training of qualified personnel for working on bucking and sorting of wood assortments in quality classes as provided by Croatian Standards for forest harvesting products.*
- *We established the system for performing expert control of bucking and sorting of wood assortments in quality classes and determining justified deviations from the applied wood assortment tables.*
- *The profit from the sale of wood assortments was established as the base for stimulating remuneration at the level of forest administration.*

*The analysis of the effects of these measures in the period from January to June 1999, compared with the same period in 1998, shows a much higher share of more valuable wood assortments in the total volume of produced wood assortments and higher profit achieved by their sale. The share of veneer logs increased from 5.07% to 6.83%; of peeler logs from 2.40% to 3.17%; of I class saw logs from 13.70% to 16.10% and the share of II class saw logs decreased from 19.49% to 18.35%; of III class saw logs from 10.72% to 10.64%; of thin technical roundwood from 2.57% to 1.63% and of cordwood from 46.05% to 43.28%. The revenue achieved by sale of wood assortments increased from 473,130,312 HRK in 1998 to 508,229,667 HRK in 1999.*

*The results are shown in form of tables and figures.*

***Key words:*** *annual cut, wood assortment, share of wood assortments, logs, thinner technical roundwood, cordwood*

## 1. Introduction

»Hrvatske šume« – a public enterprise for the management of forests and forestland in the Republic of Croatia, manage the forests of a total area of 1,991,537 ha. Wood stock in these forests amounts to 278,324,000 m$^3$, the annual increment is 8,123,496 m$^3$ and the annual cut 4,934,199 m$^3$.

The main yield in total annual cut amounts to 2,084,747 m$^3$ or 42.25%, general yield to 1,343,904 m$^3$ or 27.24% and previous yield to 1,505,548 m$^3$ or 30.51%. The specified annual cut represents large resources and hence due attention should be paid to its harvesting.

By competent and dedicated work on bucking wood assortments and determining their quality pursuant to Croatian Standards for forest harvesting products, it is possible to achieve considerable improvement of quality of wood assortments and increase profit from their sale on the market. Therefore, in 1999 we, »Hrvatske šume« Inc. Zagreb, decided to find possibilities for better utilization of annual cut through improvement of wood assortment quality.

## 2. Scope of research

»Hrvatske šume« Inc. Zagreb, manage the forests and carry out harvesting operations throughout the territory of the Republic of Croatia. Forests are very different in view of the represented species of trees, silvicultural forms of stand age and quality of specified annual cut. It is, therefore, very difficult to determine in advance the volume and quality of wood assortments, which can be produced by use of the annual cut, at the level of »Hrvatske šume« Inc. Zagreb and at lower organizational levels. Bucking and sorting of wood assortments is carried out by more than two thousand forestry engineers and technicians, with different, earlier acquired habits and insufficiently trained and motivated to perform these jobs professionally and conscientiously.

The analysis of wood assortment production broken down by quantity and quality in the past years shows very different utilization of an average annual cut at the level of regional forest stations and forest administrations. Different utilization of the annual cut in regional forest stations and forest administrations partly derives from differences in structure and quality of the annual cut and partly from the difference in quality of performed bucking and sorting of wood assortments.

The structure and quality of the annual cut cannot be easily changed so we have decided to raise the level of competence and responsibility in carrying out bucking operations and determining quality of wood assortments.

## 3. Aims of research

The research is aimed at improving the utilization of the annual cut, through an increased share of more valuable wood assortments and achieving higher profit from their sale on the market compared to the results in the past years.

The set goal should be achieved in the course of 1999 by expert work on bucking wood assortments and determining their quality in compliance with the Croatian Standards for forest harvesting products.

## 4. Method of work

The analysis of the achieved production of wood assortments in the last several years (1995–1998) shows that that these results, related to volume and quality, are far from the results obtained by research of the structure of wood assortments for common oak, sessile oak, common beech and field ash. The deviations were very different in forest administrations implying that they mostly resulted from non-professionally performed bucking operations and inadequate sorting of wood assortments.

Consequently we became aware that better utilization of the annual cut could increase considerably the profit from the sale of wood assortments. Hence we fully focused our attention on better utilization of the annual cut in »Hrvatske šume« Inc. Zagreb undertaking the following:

- In 1998 we organized the training of qualified personnel for bucking and sorting wood assortments in quality classes pursuant to Croatian Standards for forest harvesting products.
- The volume and quality of wood assortments in the felling plan for 1999 was defined, from the department level upward, by use of unique wood assortment tables (HS-DOZ).
- We established the system for controlling the performance of bucking and sorting wood assortments and determining deviations from the applied wood assortment tables.
- The profit from the sale of wood assortments was the base for stimulating remuneration at the level of forest administrations.

## 5. Results of research

The actions undertaken in »Hrvatske šume« Inc. Zagreb showed good effects in improved utilization of the annual cut and increased profit achieved from the sale of wood assortments from January to June 1999.

In comparison with the same period in 1998, considerably higher share of valuable wood assortments was achieved in average net annual cut. The share of veneer logs increased from 5.07% to 6.83%, of peeler logs from 2.40% to 3.17%; of I class saw logs from 13.70% to 16.10% and the share of II class saw logs decreased from 19.49% to 18.35%; of III class saw logs from 10.72% to 10.64%; of thin technical round-

**Table 1** Production trends of wood assortments from January to June in several years

| Wood assortments | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | | 1996 | | 1997 | | 1998 | | 1999 | |
| | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ | % |
| Logs | 569 600 | 45.40 | 707 992 | 48.91 | 702 405 | 47.02 | 807 942 | 51.39 | 817 841 | 55.08 |
| Thin rounwood | 69 600 | 5.55 | 48 917 | 3.38 | 80 425 | 5.38 | 40 381 | 2.57 | 24 300 | 1.64 |
| Cordwood | 615 300 | 49.05 | 690 610 | 47.71 | 711 081 | 47.60 | 723 863 | 46.04 | 642 578 | 43.28 |
| Total | 1 254 500 | 100.00 | 1 447 519 | 100.00 | 1 493 911 | 100.00 | 1 572 186 | 100.00 | 1 484 719 | 100.00 |

**Table 2** Production trends of logs from January to June in several years

| Wood assortments | Year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1995 | | 1996 | | 1997 | | 1998 | | 1999 | |
| | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ | % | $m^3$ | % |
| Veneer and peeler logs | 93 100 | 16.34 | 110 443 | 15.60 | 88 747 | 12.63 | 117 451 | 14.54 | 148 363 | 18.14 |
| Thin rounwood | 476 500 | 83.66 | 597 549 | 84.40 | 613 658 | 87.37 | 690 491 | 85.46 | 669 478 | 81.86 |
| Total | 569 600 | 100.00 | 707 992 | 100.00 | 702 405 | 100.00 | 807 942 | 100.00 | 817 841 | 100.00 |

**Table 3** Comparison of wood assortment production broken down by wood species from january to june 1999 and 1998

| Wood species | Period | Wood assortment production from january to june 1999 and 1998 in $m^3$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Logs | | | | | Logs total | Thin technical roundwood | Cordwood | Total |
| | | F | L | I | II | III | | | | |
| Common oak | I-VI 1999 | 39 838 | | 44 380 | 47 356 | 44 999 | 176 573 | 1 246 | 42 645 | 220 464 |
| | I-VI 1998 | 22 875 | | 31 835 | 46 128 | 46 268 | 147 106 | 2 085 | 48 647 | 197 838 |
| | % 99/98 | 174.16 | | 139.41 | 102.66 | 97.26 | 120.03 | 59.76 | 87.66 | 111.44 |
| Sessile oak | I-VI 1999 | 3 724 | | 15 684 | 17 832 | 13 112 | 50 352 | 1 747 | 41 817 | 93 916 |
| | I-VI 1998 | 3 885 | | 13 649 | 24 902 | 12 135 | 54 571 | 1 336 | 46 854 | 102 761 |
| | % 99/98 | 95.86 | | 114.91 | 71.61 | 108.05 | 92.27 | 130.76 | 89.25 | 91.39 |
| Beech | I-VI 1999 | 33 476 | 39 550 | 80 716 | 83 450 | 56 386 | 293 578 | 2 541 | 255 289 | 551 408 |
| | I-VI 1998 | 28 934 | 31 411 | 78 454 | 103 848 | 58 911 | 301 558 | 19 352 | 291 208 | 612 118 |
| | % 99/98 | 115.7 | 125.91 | 102.88 | 80.36 | 95.71 | 97.35 | 13.13 | 87.67 | 90.08 |
| Ash | I-VI 1999 | 5 994 | | 12 994 | 20 360 | | 39 348 | 719 | 12 721 | 52 788 |
| | I-VI 1998 | 8 115 | | 13 715 | 23 295 | | 45 125 | 1 210 | 15 587 | 61 922 |
| | % 99/98 | 73.86 | | 94.74 | 87.4 | | 87.2 | 59.42 | 81.61 | 85.25 |
| Other broadleaved hardwood | I-VI 1999 | 1 162 | 136 | 10 327 | 18 909 | 123 | 30 657 | 1 299 | 211 641 | 243 597 |
| | I-VI 1998 | 984 | 260 | 10 151 | 20 805 | 900 | 33 040 | 1 474 | 214 134 | 248 648 |
| | % 99/98 | 118.09 | 68 | 101.73 | 90.89 | 13.67 | 92.79 | 88.13 | 98.84 | 97.97 |
| Broadleaved softwood | I-VI 1999 | 11 298 | 7 228 | 24 090 | 29 292 | | 71 908 | 3 290 | 31 629 | 106 827 |
| | I-VI 1998 | 10 709 | 6 123 | 19 171 | 22 126 | | 58 129 | 2 778 | 43 531 | 104 438 |
| | % 99/98 | 105.5 | 118.05 | 125.66 | 132.39 | | 132.7 | 118.43 | 72.66 | 102.29 |
| Conifer | I-VI 1999 | 5 843 | 114 | 50 861 | 55 203 | 43 404 | 155 425 | 13 458 | 46 836 | 215 719 |
| | I-VI 1998 | 4 165 | 50 | 48 479 | 65 331 | 50 388 | 168 413 | 12 146 | 63 902 | 244 461 |
| | % 99/98 | 140.29 | 228 | 104.91 | 84.5 | 86.14 | 92.29 | 110.8 | 73.29 | 88.24 |
| Total | I-VI 1999 | 101 335 | 47 028 | 239 052 | 272 402 | 158 024 | 817 841 | 24 300 | 642 578 | 1.484 719 |
| | I-VI 1998 | 79 667 | 37 784 | 215 454 | 306 435 | 168 602 | 807 942 | 40 381 | 723 863 | 1.572 186 |
| | % 99/98 | 127.2 | 124.47 | 110.95 | 88.89 | 93.73 | 101.23 | 60.18 | 88.77 | 94.44 |

**Table 4** Comparison of share of produced wood assortments in processed net wood mass from january to june 1999 and 1998

| Wood species | Period | Share of produced wood assortments in processed net wood mass in % | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Logs | | | | | Logs total | Thin technical roundwood | Cordwood | Total |
| | | F | L | I | II | III | | | | |
| Common oak | I–VI 1999 | 18.07 | | 20.13 | 21.48 | 20.42 | 80.09 | 0.57 | 19.34 | 100.00 |
| | I–VI 1998 | 11.56 | | 16.09 | 23.32 | 23.39 | 74.36 | 1.05 | 24.59 | 100.00 |
| | % 99/98 | 156.31 | | 125.11 | 92.11 | 87.26 | 107.71 | 54.29 | 78.65 | 100.00 |
| Sessile oak | I–VI 1999 | 3.97 | | 16.70 | 18.99 | 13.96 | 53.62 | 1.86 | 44.52 | 100.00 |
| | I–VI 1998 | 3.78 | | 13.28 | 24.23 | 11.81 | 53.10 | 1.30 | 45.60 | 100.00 |
| | % 99/98 | 105.03 | | 125.75 | 78.37 | 118.20 | 100.98 | 143.08 | 97.63 | 100.00 |
| Beech | I–VI 1999 | 6.07 | 7.17 | 14.64 | 15.13 | 10.23 | 53.24 | 0.46 | 46.30 | 100.00 |
| | I–VI 1998 | 4.73 | 5.13 | 12.82 | 16.97 | 9.62 | 49.27 | 3.16 | 47.57 | 100.00 |
| | % 99/98 | 128.33 | 139.77 | 114.20 | 89.16 | 106.34 | 108.06 | 14.56 | 97.33 | 100.00 |
| Ash | I–VI 1999 | 11.35 | | 24.62 | 38.57 | | 74.54 | 1.36 | 24.10 | 100.00 |
| | I–VI 1998 | 13.11 | | 22.15 | 37.62 | | 72.87 | 1.95 | 25.18 | 100.00 |
| | % 99/98 | 86.58 | | 111.15 | 102.53 | | 102.29 | 69.74 | 95.71 | 100.00 |
| Other broadleaved hardwood | I–VI 1999 | 0.48 | 0.06 | 4.24 | 7.76 | 0.05 | 12.59 | 0.53 | 86.88 | 100.00 |
| | I–VI 1998 | 0.40 | 0.08 | 4.08 | 8.37 | 0.36 | 13.29 | 0.59 | 86.12 | 100.00 |
| | % 99/98 | 120.00 | 75.00 | 103.92 | 92.71 | 13.89 | 94.73 | 89.83 | 100.88 | 100.00 |
| Broadleaved softwood | I–VI 1999 | 10.58 | 6.76 | 22.55 | 27.42 | | 67.31 | 3.08 | 29.61 | 100.00 |
| | I–VI 1998 | 10.25 | 5.86 | 18.36 | 21.19 | | 55.66 | 2.66 | 41.68 | 100.00 |
| | % 99/98 | 103.22 | 115.36 | 122.82 | 129.40 | | 120.93 | 115.79 | 71.04 | 100.00 |
| Conifer | I–VI 1999 | 2.71 | 0.05 | 23.58 | 25.59 | 20.12 | 72.05 | 6.24 | 21.71 | 100.00 |
| | I–VI 1998 | 1.70 | 0.02 | 19.83 | 26.73 | 20.61 | 68.89 | 4.97 | 26.14 | 100.00 |
| | % 99/98 | 159.41 | 250.00 | 118.91 | 95.74 | 97.62 | 104.59 | 125.55 | 83.05 | 100.00 |
| Total | I–VI 1999 | 6.83 | 3.17 | 16.10 | 18.35 | 10.64 | 55.09 | 1.63 | 43.28 | 100.00 |
| | I–VI 1998 | 5.07 | 2.40 | 13.70 | 19.49 | 10.72 | 51.38 | 2.57 | 46.05 | 100.00 |
| | % 99/98 | 134.71 | 132.08 | 117.52 | 94.15 | 99.25 | 107.22 | 63.42 | 93.98 | 100.00 |

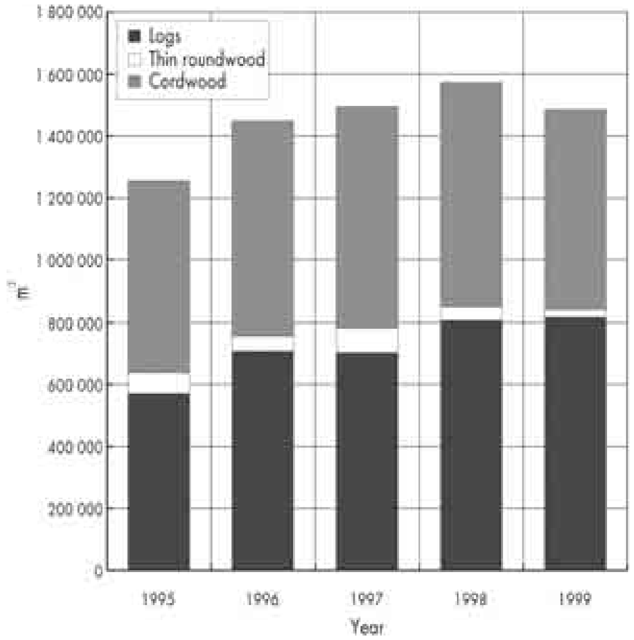


**Figure 1** Production trends of wood assortments from January to June in several years

wood from 2.57% to 1.63% and of cordwood from 46.05% to 43.28%.

The profit realized from the sale of wood assortments for the period January–June, increased from 473,130,312 HRK in 1998 to 508,229,667 HRK in 1999 amounting to 35,099,355 HRK or 7.42%.

The results are shown in Tables 1–4 and Figures 1–3.

## 6. Conclusion

In the period from January–June 1999, the utilization of the average annual cut was improved in »Hrvatske šume« Inc. Zagreb.

The utilization of more valuable wood assortment was increased by professional work on bucking wood assortments and determining their quality in compliance with the Croatian Standards for the products of wood harvesting.

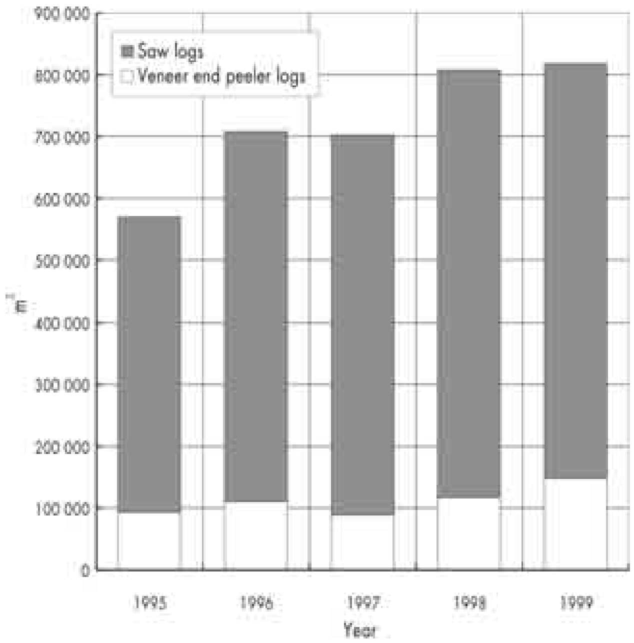


**Figure 2** Production trends of logs from January to June in several years

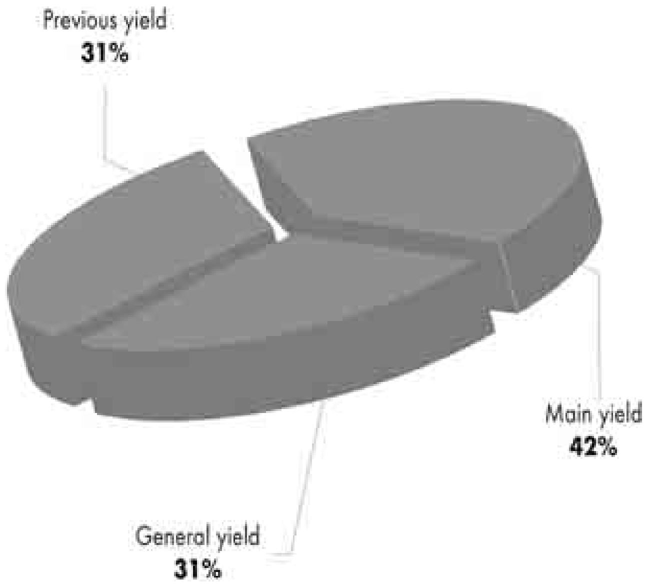


**Figure 3** Yield structure in the public enterprise »Hrvatske šume« Inc. Zagreb

Better utilization of the average annual cut resulted in the increase of the revenue from the sale of wood assortments by 35,099,355 HRK or by 7.42% compared to the same period in 1998.

These results were achieved by adequate training of qualified personnel for the operations of bucking and sorting wood assortments, better motivation for professional performance of these operations and by establishing efficient control over these activities.

These actions should be continued so as to maintain the achieved level and further develop the utilization of the annual cut in »Hrvatske šume« Inc. Zagreb.

## 7. References

Anon., 2000: Poslovna izvješća »Hrvatske šume« Inc. Zagreb 1995.–1999. »Hrvatske šume« Inc. Zagreb.

Anon.: Hrvatske norme proizvoda iskorištavanja šuma. II. izdanje. Državni zavod za normizaciju i mjeriteljstvo.

Meštrović, Š., Fabijanić, G., 1995: Priručnik za uređivanje šuma. Ministarstvo poljoprivrede i šumarstva Hrvatske, Zagreb.

Rebula, E., 1996: Sotrimentne i vrijednosne tablice za deblovinu jele. Mehanizacija šumarstva broj 4, Zagreb.

Štefančić, A., 1997: Udio drvnih sortimenata u volumenu krupnog drva do 7 cm promjera za hrast lužnjak, hrast kitnjak i poljski jasen – suši tip. Šumarski list 9–10, Zagreb.

Štefančić, A., 1998: Udio drvnih sortimenata u volumenu krupnog drva do 7 cm promjera za običnu bukvu u jednodobnim sastojinama. Šumarski list 7–8, Zagreb.

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# Croatian forest nursery production

**Milan Žgela**

***Abstract***

*Serious deterioration of the natural balance of our forest stands causes their complex reafforestation by giving an ever growing significance to seed collection and production of forest seedlings as one of the most important factors for regeneration and sustainability of forest stands. In addition, there are large areas of unstocked forestland, which represent considerable economic and ecological potential. As a result, forestry experts must seriously deal with the organization of forest seedlings production especially in the areas of our most valuable hardwood forests i.e. the Karst areas along the coast, which are barren or covered with degraded forests. These are the reasons why most of the nurseries are located in these areas. We have 44 nurseries (16 main and 28 auxiliary) active in nursery production covering a gross area of 484 ha, and producing 30–35 million seedlings and an annual supply of 14–17 million seedlings (2, 3, 4 year olds and one year olds grown in containers). The majority of the seedlings are grown traditionally in the ground: broad-leaved (11–14 mil. pcs) of which pedunculate oak covers 65%; 2–2.5 mil are coniferous seedlings (spruce 70%), while the production of seedlings with wrapped roots intended for the coastal area amount to 1–2 mil. Depending on the requirements for seedlings in the years to come, with only a minor investment, the annual delivery of forest seedlings would be further increased by 50% (21–26 mil.). Increased production with expert personnel (main nurseries are usually headed by graduated forestry engineers) and full-time employees (3–7 workers), and average nursery production equipment (slow mowed tractor equipped with basic and advanced tools for soil tilling, Rath and Egedal machines, plastic and glass greenhouses) will also enable the construction of a new nursery for modern seedling container production intended for planting in coastal areas (Piket near Zadar). Of course, increased production depends on long-term requirements, which have to be harmonized by forestry experts and defined by species, amount, age and areas of demand. With the establishment of managing structures for nursery production, the facilities that remain unreserved must be used for the production of export seedlings as well as decorative flower and bush seedlings for known buyers (domestic and foreign).*

***Key words:*** *nurseries, seedlings, seed, nursery mechanization*

## 1. Introduction

Nursery in the Republic of Croatia and the conditions and possibilities for seedlings production nowadays and in future should be taken into consideration and developed in accordance with the basic task of forestry profession and forestry experts: regeneration of forest stands and improvement of wood mass structure in them. Scientific theses, forestry conceptions and our legal regulations support natural regeneration of our stands so that our nurseries are left with the task of emergency seasonal supplying with seedlings of parts of our forestland where natural regeneration has not quite worked out or has completely failed.

Nursery must, by all means, provide seedlings of satisfying quality and quantity even for the land just brought into the forest stock (extended biological reproduction), i.e. for regeneration of forest stands of other forest owners.

Serious deterioration of the natural balance of forest stands and an increasing lack of regular regeneration of forest tree species gives an ever-growing significance to seed collection and production of forest seedlings. It requires very careful application of the acquired forestry knowledge and skills related to regeneration, preservation and development of the forest stock. The source of forest seeds of unquestionable quality is the very base of nursery activities.

Our natural stands and seed facilities located therein are the source of seeds from which nurseries are supplied.

Forest seed sources can (to a lower extent) also be broad-leaved and coniferous forest cultures, autochthonous or allochothonous tree species, grown as seed plantations.

Since the Republic of Croatia gained independence, seed supply of domestic tree species has mostly been carried out from our own seed facilities. Coniferous seeds are put through final processing stages in our new seed extraction plant, which makes part of the Forestry Institute in Jastrebarsko.

It should be noted that the aid of nursery in the renewal of our stands is 80% for broad-leaved forests, 12% for coniferous forests and 8% of nursery capacities are used for the production of coniferous and broad-leaved seedlings for our coastal area – the Karst area. The production of pedunculate oak seedlings makes almost half of all nursery activities (45%), 13% is related to the production of sessile oak seedlings, 16% to the production of ash seedlings, 3% to alder seedlings and 3% to other broad-leaved species.

Along with these figures all current and future issues relevant to forestry as a whole and nursery as part of forestry activities should be taken into consideration.

## 2. Survey of the present situation

The tradition of nursery in Croatia is very long. Its 100 anniversary has already been celebrated. It is true, however, that from its beginning to the end of World War II the production of forest seedlings mostly occurred in small nurseries, the so-called nurseries at hand. The tendency of opening a larger number of nurseries in Croatia could be seen in 1960's and these nurseries are still in use. Today, the public enterprise »Hrvatske šume« (»Croatian Forests«) have 44 registered nurseries covering a gross area of 484 ha (Table 1).

Broad-leaved and coniferous trees are produced in 26 nurseries and in 18 only broad-leaved trees. More than half nurseries cover an area of less than 10 ha, 8 nurseries cover an area of 11–15 ha, 4 nurseries 16–20 ha and 8 nurseries cover a gross area of more than 20 ha.

The largest nurseries of broad-leaved production are »Zalužje« (oak and ash) – Forest Administration Vinkovci; »Višnjevac« and »Topolje« (poplar and willow) – Forest Administration Osijek; »Limbuš« – Forest Administration Koprivnica; the nurseries »Hajdarevac« and »Cernik« for the production of broad-leaved and coniferous trees – Forest Administration Požega and Nova Gradiška; »Močile« – Forest Administration Koprivnica; exclusively for conifers: »Oštarije« – Forest Administration Ogulin, »Kuželj« – Forest Administration Delnice and »Franćeskija« – Forest Administration Buzet for the production of coniferous and broad-leaved trees for our coastal area.

The development of nurseries in Croatia is strongly affected by the results of investigation carried out in the nurseries of the Forest Institute Jastrebarsko and the Faculty of Forestry Zagreb.

Preliminary designs and feasibility studies as well as recommendations for the development of work techniques and technologies have been prepared for many nurseries in Croatia.

The Forestry Institute with its nursery has a direct impact on the development of the nursery production in Croatia and on meeting the demand of some forest administrations for seedlings.

Apart from being relatively well equipped with the basic machines (tractors) the nurseries are well equipped with the attachments for the basic and supplementary soil tilling.

Speaking of nursery mechanization, it must be said that nurseries are well equipped with complete groups of foreign products.

To tell the truth the mechanization is 10 years old or more (Rath) and modernized by purchase of new spare parts of »Egedal« nursery machines and Steyr tractors for all major nurseries where seedlings are produced traditionally.

As far as technology is concerned, all major continental nurseries, which produce broad-leaved trees traditionally in the ground (sowing in rows or in bulk) on seedbeds use the same group of machines (e.g. Rath) for nursery seedling production. These are Zalužje, Gajić, Hajderovac, Cernik, Močile, Lukavec, Limbuš, Oštarije, Kuželj.

The nursery Zdenački Gaj has purchased new Egedal machines and most of the above said nurseries use some parts of this group of machines (e.g. extractors, trimmers, etc.).

Most nurseries do not have enough water or water accumulation, for the necessary watering of forest seedlings.

Since most nurseries were developed from hand nurseries, by implementing various anthropological measures, as a rule the soil in nurseries is of low or average humus content (less than 2%) and of bad structure, this being one of the limiting factors of seedling quality together with water.

Only major nurseries have full-time and qualified personnel. Part-time employees are almost a

**Tablica 1** Survey of nurseries registered as producers of forest seedlings

| Nursery | Forest office | Total area ha | Production of: | |
|---|---|---|---|---|
| | | | Broadleaved species | Conifers |
| Zalužje | Vinkovci | 22.21 | + | |
| Višnjevac | Osijek | 27.80 | + | |
| Poloj | Beli Manastir | 4.93 | + | |
| Topolje | Valpovo | 15.75 | + | |
| Repnjak | Beli Manastir | 25.00 | + | |
| Biljski rit | Darda | 9.60 | + | |
| Šarkanj | Batina | 9.20 | + | |
| Tikveš | Tikveš | 13.41 | + | |
| Gajić | Našice | 7.50 | + | + |
| Lanik | Donji Miholjac | 6.07 | + | |
| Bobrovac | Slatina | 5.38 | + | |
| Cernik | Nova Gradiška | 19.50 | | + |
| Hajderovac | Kutjevo | 21.59 | + | + |
| Zdenački gaj | Grubišno Polje | 10.09 | + | |
| Jantak | Čazma | 3.52 | + | |
| Sjevernjaci | Ivanska | 3.81 | + | + |
| Grahovljani | Pakrac | 6.01 | + | + |
| Močile | Koprivnica | 12.75 | + | + |
| Limbuš | Kloštar Podravski | 15.31 | + | |
| Zelendvor | Varaždin | 16.68 | + | + |
| Drnje | Koprivnica | 11.76 | + | |
| Župetnica | Križevci | 3.00 | + | + |
| Travnik | Ludbreg | 1.00 | + | |
| Podturen | Čakovec | 5.00 | + | |
| Gaj | Kutina | 34.47 | + | |
| Lukavec | Velika Gorica | 23.96 | + | + |
| Brestje | Dugo Selo | 14.92 | + | |
| Oštarije | Josipdol | 32.56 | + | + |
| Kuželj | Skrad | 4.59 | + | + |
| Podbadanj | Crikvenica | 1.46 | + | + |
| Vujnović brdo | Gospić | 14.97 | + | + |
| Franćeskija | Buje | 19.15 | + | + |
| Šijana | Pula | 2.59 | + | + |
| Liskovac | Split | 1.30 | + | + |
| Svilaja | Sinj | 3.37 | + | + |
| Bočina | Metković | 2.05 | + | + |
| Piket | Zadar | 9.90 | + | + |
| Voštarnica | Zadar | 0.30 | + | + |
| III. Kono | Dubrovnik | 0.30 | + | + |
| Trolokve | Brač | 1.00 | + | + |
| Borak | Imotski | 3.20 | + | + |
| Slavinj | Split | 0.18 | + | + |
| Duboka dolina | Slatina | 5.27 | + | + |
| Lisičine | Voćin | 28.12 | + | + |
| Total | | 483.99 | + | + |

rule in nursery production. Taking in consideration the production volume (quantity) in the last 20 years, it can be seen that the average annual volume from 1971 to 1980 was approximately 5 million pieces of broad-leaved seedlings and 11 million pieces of coniferous seedlings and from 1981 to 1990 approximately 13 million pieces of broad-leaved seedlings and 6 million pieces of coniferous seedlings (meeting the requirements for the renewal of stands of the entire territory of the Republic of Croatia).

Upon the establishment of the public enterprise »Hrvatske šume« p.o. Zagreb for the management of forests and forestland in the Republic of Croatia, organized production and supply of forest seedlings has started for all our forest stations (Table 2).

The annual demand, i.e. the nursery supply, can be easily seen: 11 million pieces of broad-leaved seedlings, 2 million coniferous seedlings and more than 1 million forest seedlings for the plantation in the Karst region of our coastal area.

Considering the participation of individual forest species in these groups, we can see that the production and supply are based on approximately 7 million pieces of pedunculate oak seedlings, 1.3 million pieces of common spruce and 0.6 million pieces of black pine (of Mediterranean origin), which represents 2/3 of the total volume of seedlings produced in or supplied by nurseries.

The above figures refer to traditional production of seedlings, excluding nurseries on the coast, where seedlings are produced in containers as a rule. The share of seedlings with coated root system is less than 5% in total production of continental nurseries. Larger nurseries also produce horticultural trees and

**Tablica 2** Nursery delivery of forest seedlings (1991–1998)

| Species | Delivery (in 000 pieces) | | | | | | | | Total | Yearly |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | | |
| Pedunculate oak | 6 430 | 10 070 | 3 832 | 5 793 | 10 181 | 8 009 | 6 361 | 5 527 | 56 203 | 7 025 |
| Sessile oak | 1 321 | 2 516 | 355 | 1 867 | 1 784 | 2 034 | 2 062 | 1 667 | 13 606 | 1 701 |
| Field ash | 1 811 | 1 518 | 1 363 | 1 814 | 760 | 1 369 | 1 349 | 1 571 | 11 555 | 1 444 |
| Black alder | 284 | 225 | 90 | 754 | 471 | 737 | 470 | 459 | 3 499 | 437 |
| Euro-American poplar | 42 | 53 | 18 | 63 | 69 | 68 | 55 | 66 | 434 | 54 |
| Willow | 31 | 16 | 19 | 41 | 22 | 33 | 18 | 24 | 204 | 26 |
| Beech | - | - | - | 20 | 45 | 37 | 64 | - | 166 | 21 |
| Other broad-leaved species | 13 | 5 | 18 | 202 | 92 | 8 | 30 | 101 | 469 | 59 |
| **Broadleaved species** | **9 932** | **14 403** | **5 695** | **10 554** | **13 424** | **12 295** | **10 418** | **9 415** | **86 136** | **10 767** |
| Spruce | 1 243 | 1 706 | 1 089 | 1 878 | 1 369 | 1 050 | 1 100 | 1 014 | 10 449 | 1 306 |
| Black pine | 324 | 355 | 165 | 422 | 236 | 136 | 199 | 189 | 2 026 | 253 |
| Scots pine | 148 | 65 | 62 | 191 | 89 | 191 | 96 | 25 | 867 | 108 |
| Larch | 283 | 215 | 74 | 189 | 84 | 77 | 68 | 65 | 1 055 | 132 |
| Douglas fir | 88 | 72 | 24 | 105 | 45 | 26 | 56 | 53 | 469 | 59 |
| Fir | 34 | 15 | 36 | 30 | 79 | 20 | - | - | 214 | 27 |
| Other conifers | 28 | 11 | 6 | 19 | 9 | 3 | - | - | 76 | 10 |
| **Conifers** | **2 148** | **2 439** | **1 456** | **2 834** | **1 911** | **1 503** | **1 519** | **1 346** | **15 156** | **1 895** |
| Holm oak | - | - | 2 | 10 | 19 | 17 | 23 | - | 71 | 9 |
| Pubescent oak | 3 | - | 3 | 34 | 48 | 137 | 26 | 50 | 301 | 38 |
| Other broad-leaved species | 14 | 8 | - | - | - | - | - | - | 22 | 3 |
| Black pine | 78 | 85 | 180 | 794 | 687 | 847 | 820 | 1 100 | 4 591 | 574 |
| Cluster pine | 60 | 38 | 110 | 314 | 395 | 536 | 458 | 162 | 2 073 | 259 |
| Aleppo pine | 81 | 47 | 2 | 160 | 76 | 90 | 181 | 148 | 785 | 98 |
| Stone pine | 12 | 11 | 33 | 140 | 90 | 56 | 146 | 172 | 660 | 82 |
| Cypress | 5 | 7 | 25 | 173 | 144 | 376 | 60 | 176 | 966 | 121 |
| Cedar | 12 | 18 | 154 | 8 | 2 | 8 | 13 | 15 | 230 | 29 |
| Other Mediterr. species | 39 | 57 | - | 2 | 47 | 71 | 35 | - | 251 | 31 |
| **Mediterranean species** | **304** | **271** | **509** | **1 635** | **1 508** | **2 138** | **1 762** | **1 823** | **9 950** | **1 244** |
| **Total** | **12 384** | **17 113** | **7 660** | **15 023** | **16 843** | **15 936** | **13 699** | **12 584** | **111 242** | **13 906** |

bushes for arranging parks and other green areas. A vast range of decorative species of different market value is typical for this kind of production.

## 3. Projection of nursery activities in the enterprise »Hrvatske šume«

Past forestry experience and knowledge should give the projection of nursery activities in Croatia based on:

- the condition of natural regeneration of our stands and the demand for seedlings,
- possibility of investment in the extended biological reproduction,
- condition and need for renewal of private forest properties,
- condition and potential of our nurseries from technical – technological point of view.

The demand for seedlings for the period 1999–2003 was derived from the said assumptions (Table 3).

Based on the above said, the following should be done in future:

- complete the equipment and personnel of the main (central) nurseries,
- support the existing hand nurseries.

The main nurseries must have the following properties:

- sufficient area and favorable soil,
- qualified personnel employed full time,
- complete nursery equipment – West-European group of machines and other mechanization,
- sufficient quantities of permanently available water,
- properly enclosed nursery,
- agreed and contracted production.

**Tablica 3** The demand for seedlings for the period 1999–2003

| Species | Year | | | | |
|---|---|---|---|---|---|
| | 1999 | 2000 | 2001 | 2002 | 2003 |
| Pedunculate oak | 7 609 | 8 191 | 8 042 | 7 694 | 7 449 |
| Sessile oak | 2 151 | 2 222 | 2 360 | 2 490 | 2 264 |
| Field ash | 3 062 | 2 969 | 2 876 | 2 893 | 2 842 |
| Black alder | 554 | 652 | 665 | 473 | 476 |
| Beech | 47 | 38 | 43 | 54 | 42 |
| Cherry | 27 | 8 | 7 | 8 | 7 |
| Lime | 22 | - | - | - | - |
| Maple | 22 | 6 | 2 | 5 | 2 |
| **Broadleaved sp.** | **13 494** | **14 086** | **13 995** | **13 617** | **13 082** |
| Spruce | 883 | 911 | 891 | 952 | 811 |
| Larch | 93 | 85 | 105 | 81 | 79 |
| Black pine | 221 | 204 | 220 | 186 | 194 |
| Scots pine | 79 | 79 | 79 | 79 | 79 |
| Common fir | 8 | 9 | 8 | 8 | 8 |
| Douglas fir | 51 | 51 | 52 | 52 | 52 |
| White pine | 51 | 51 | 52 | 52 | 52 |
| **Conifers** | **1 335** | **1 339** | **1 355** | **1 358** | **1 223** |
| Black pine | 1 207 | 1 267 | 1 227 | 1 237 | 1 297 |
| Aleppo pine | 81 | 86 | 91 | 96 | 96 |
| Turkish pine | 35 | 35 | 35 | 35 | 35 |
| Cluster pine | 233 | 193 | 253 | 263 | 273 |
| Stone pine | 130 | 140 | 150 | 160 | 170 |
| Holm oak | 105 | 115 | 135 | 145 | 155 |
| Pubescent oak | 332 | 344 | 349 | 349 | 349 |
| **Mediterranean sp.** | **2 123** | **2 180** | **2 240** | **2 285** | **2 375** |
| ***Total*** | ***16 952*** | ***17 605*** | ***17 590*** | ***17 260*** | ***16 680*** |

Nine major nurseries are sufficient for providing the necessary quantity of seedlings for our even-aged forests. The nurseries are not necessarily connected to forest administrations so that some forest administrations have more than one nursery (Koprivnica) while Sisak and Karlovac are still without any.

The main nurseries are: Zalužje – Vinkovci, Višnjevac – Osijek, Gajić – Našice, Hajderovac – Požega, Cernik – Nova Gradiška, Zdenački gaj – Bjelovar, Limbuš i Močile – Koprivnica, Lukavec – Zagreb.

The main nurseries Oštarije – Ogulin and Kuželj – Delnice mostly cover the production for coniferous forests.

Consequently, all future production of seedlings is related to major nurseries, which develop their production concept in base of the specified (projected) quantity of seedlings, including in it a large number of the existing, small hand nurseries.

The Forestry Institute Jastrebarsko will provide its services to Karlovac and Sisak Forest Administration and partly Zagreb Forest Administration, in base of long-term rights and obligations of the parties.

If necessary, the possibility can be taken into consideration of including the nursery »Šljukingon« – Bjelovar (up to ten years ago the leading nursery for seedlings in Croatia as a business unit of Forest Economy Bjelovar and now making part of »Bjelovarski vrt« d.d. Bjelovar) in the contracted production of seedlings for Forest Administration Bjelovar and beyond.

For the Mediterranean area the most important nurseries would be: Franćeskija – Buzet, Podbadanj – Senj, and in Forest Administration Split: Liskovac, Bočina and the new nursery Piket – Zadar now in the designing phase (probably to be built soon).

Taking into account the actual annual production task of seedling supply, available expert and production staff, nursery area, new and old nursery mechanization, the potential of the nursery water supply, major nurseries focus their interests, in terms of modernization, to nursery conceptions of »Hrvatske šume« Inc. Zagreb:

- from a technical – technological aspect, the nursery area should cover about 20 ha, have a good soil structure and chemical content, the application of up-to-date nursery machines should be made possible and efficient (this does not apply to our coastal nurseries).
- major nurseries mostly have the usual equipment and nursery machines, (Rath and domestic production), pretty old but still capable for production. The coastal nurseries are an exception – Forest Administration Split., These machines will be supplemented or renewed depending of course on the production task and in some cases similar nursery machines will even be introduced (e.g. »Egedal« – Danmark), as well as other mechanization (equipment) meeting the production task (species and quantities of plants) not only in the »parent« – major nursery but in all smaller and hand nurseries under its control.
- without sufficient and continuous water supply, regardless its source, there is not and cannot be any major nursery. As a rule, each nursery of this kind shall have water accumulation of sufficient capacity, where water can be conditioned and always available for the usual and necessary watering or irrigation. If possible, the use of the municipal – public water supply system should be provided as an additional source of supply with obligatory water conditioning in accumulations. Hydrant network should be installed within the nursery.
- each major nursery will have a general task for the annual production of seedlings to be supplied in accordance with the requirements of its forest administration, i.e. pursuant to the quantities of seedlings provided by the contract entered for other forest administrations. Such annually »planned« production will introduce order and work in nurseries. It will be possible to prepare seedling rows, including unseeded areas (green or barren) as well as tables separated from each other by windshield belts. Thus the implementation of the latest technological achievements will be made possible involving IT monitoring and support as the integral part of such technology.
- the necessity of building cooling capacities for preservation of forest seedlings and seeds.

If the unit price, based on calculation-stimulation, of forest seedlings is added to the above said, major nurseries should not have problems in achieving the »reproduction capability«. By adopting these assumptions and determining the contracted production of forest seedlings, it will become clear how to use free nursery areas for a higher quality forest seedling production or, in some regions, for the production of horticultural trees and bushes.

## 4. Conclusions – Suggestions for future

To focus maximum forestry attention on natural regeneration of stands and as the alternative to rely on the fact that the nursery areas of »Hrvatske šume« can provide, with minor investments, the production of more than approximately 50% of the current one: the annual growth of seedlings for afforestation of approximately 40 million pieces in 2:1 ratio in favor of broad-leaved trees.

To organize adequate training and then to maintain in terms of quantity and quality such team of experts for seeding and nursery activities that will be ready to take over, modify and implement all generally acquired and practiced technologies in the world.

To pay attention to the production of soft broad-leaved trees (poplar-willow) exclusively as forestry-agricultural production and transitional phase in forming forest stand on specific agricultural or forest soils.

To define as soon as possible the production of forest seedlings of coated root system (in containers) by specifying: species, quantity, form and material from which the container is made as well as the age of the plant. In base of these data to adapt or purchase the necessary mechanization (machines for container production) and to refit the facilities.

To prepare as soon as possible the Croatian standards for the quality of seeds and seedlings.

To use pesticides exclusively as prevention measures, taking care of avoiding the use of higher quantities of herbicides in nurseries.

To develop IT forestry programs for providing technological support and monitoring seeding and nursery activities.

The projected, average annual production of seedlings in nurseries must be determined with specific purpose so as to provide the supply of the required quantities of seedlings of uniform quality (age, growth, size, width, condition). The quantity and quality of the selected seeds is, of course, determined with the same purpose.

To enrich the fertility of nursery areas by introducing seedling rows, green fertilization and other types of fertilization (to increase the percentage of humus to 5%) and along with providing sufficient quantities of irrigation water – rain-watering – bedewing, to produce, by conditioning, high quality forest planting material. Windshield belts should be carefully designed, planted and regularly maintained.

To determine the recourses (areas – technical machines – qualified staff), market condition and the demand for the production of horticultural trees and bushes in terms of urban forestry, which is planned to be one of the activity of the enterprise »Hrvatske šume«.

Without nursery organization in accordance with the above conclusions and suggestions and at least 10 years for testing and settling them into routine, there can be no talk of privatization of nurseries or their leaving the basic activity of »Hrvatske šume«, p.o. Zagreb.

## 5. References


Anon. 1999: Poslovno izvješće »Hrvatskih šuma«, p.o. Zagreb 1991–1998.g. (interna dokumentacija), Zagreb.

Dokuš, A., Gračan, J., Komlenović, N., Orlić, S., 1988: Stanje rasadničke proizvodnje u Hrvatskoj. Studija – dokumentacija Šumarskog instituta, Jastrebarsko.

Dokuš, A., Orlić, S., Orešković, Ž., Žgela, M., Matić, S., Oršanić, M., 1992: Šumski rasadnici. In: Šume u Hrvatskoj, 101–104, Zagreb.

Matić, S., 1990: Šume i šumarstvo Hrvatske – jučer, danas, sutra, Glas za šumske pokuse, 35–56, Zagreb.

Matić, S., 1994: Prilog poznavanja broja biljaka i količine sjemena za kvalitetno pomlađivanje i pošumljavanje, Šumarski list 3–4, 71–79, Zagreb.

Ocvirek, M., 1994: Kontejnerska proizvodnja četinjača, Radovi Šumarskog instituta, Vol. 29, broj 2, Jastrebarsko.

Orešković, Ž., Rath, V., Maradin, R., 1993: Proizvodnja šumskog sadnog materijala u rasadniku Šumarskog instituta, Radovi Šumarskog instituta Vol. 28, broj 1–2.

Regent, B., 1972: Šumsko sjemenarstvo. Poslovno udruženje šumarstva šumsko privrednih organizacija, Zagreb.

Žgela, M., 1994: Stanje i mogućnosti rasadničarske proizvodnje »Hrvatskih šuma«, p.o. Zagreb.



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# Actual tasks and a view of changes imposed by different forest management requirements in Bosnia & Herzegovina

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***Abstract***

*There are still many open questions in forest management of the Federation of Bosnia & Herzegovina waiting for answers from forestry science, profession and practice. Forest management is affected by recently overcome socialist self-management, consensus economics, coupled income relations of forestry and wood processing, non-functional and inefficient organization of forest management, out-of-date and insufficient forest mechanization and inadequate and devastated forest infrastructure. The actual tasks are a big burden for the present, already complex state of forest management, which is still expected to solve social and other issues and difficulties. The most actual task is by all means developing the right relationship toward and general awareness of the forest as an invaluable resource. Equally important is the task of forest management reorganization from the consensus and income economy to the market economy. The current legal regulations are inadequate for the present moment of overwhelming deep social and economic changes. This task should, therefore, be completed as quickly as possible by passing a modern and contemporary law on forests with all the accompanying regulations. The organization of forest management and operation should be adapted to a reasonable framework of an efficient and functional self-sustainable and durable managing. The development of forestry long-term strategy is a necessary guideline of the future relationship towards forests in the Federation of Bosnia and Herzegovina. Preserving of natural, self-regenerating and durable forest resources is a permanent and priority task of all foresters. Forests of the Federation of Bosnia and Herzegovina should be adapted to modern needs of today's generations giving the advantage to generally useful functions of forests over the economic ones. The new spatial and economic classification of forests is imposed as an imperative, and the foresters should realize it as soon as possible, together with carrying out the new inventory-making of all the forests. The reduction of the prewar extent of felling opens possibilities for protecting natural forests for different tasks of forest managing in accordance with all the world and European charters and conventions about forests. The introduction of modern methods in carrying out the forest inventory is necessary in the Federation of Bosnia and Herzegovina from different viewpoints*

***Key words:*** *forestry, Bosnia and Herzegovina, managing, tasks*

## 1. Introduction

In late 1980's of this century and at the verge of the second millenium, serious changes of social, industrial and economic aspects have occurred in many European countries and in Bosnia & Herzegovina, too i.e. in the Federation of Bosnia & Herzegovina. The said changes have inevitably brought changes in forest and forestry management of the Federation of B&H in general. War events speeded up the devastation of forests and forest facilities as well as of forestry infrastructure, insufficient anyway, and out-of-date forest mechanization. Forest management, previously based on totalitarian socialist self-management of socially owned forests, consensus economics, controlled market, coupled income relations between forestry and wood processing (wood industry) and inefficient organization of forest management, disappeared completely or almost completely for a while. Under such circumstances, forests and forestry of B&H Federation was left to irresponsible and completely incompetent individuals and groups of people who devastated the natural forest resources without the minimum professional knowledge, organization and responsibility greedily and shamelessly trying to achieve quick profit. Numerous forestry experts and scientist were, therefore, forced to leave their jobs, companies and communities. Consequently the education and training of forestry personnel became complicated, it decreased and almost disappeared as well as scientific work in forestry. Numerous forest economic policies, which expired or were about to expire, could not be renewed due to the above said reasons as well as because the institutions that used to deal with such activities ceased to exist.

But in spite of such difficult situation in the forests and forestry of B&H Federation, there was a number of individuals, a group of true forest lovers and proved experts, who found ways and power to organize professional and responsible forest management in most parts of B&H Federation.

When the general situation calmed down, forestry experts and scientists of B&H Federation had to face a very difficult task and challenge. They had to decide how to overcome the current problems in forestry, how to solve all the actual tasks, how to develop a view of the forestry in future accepting numerous changes imposed today by other functions of forest management. Fully aware that there are no ready solutions or prescriptions, forestry experts and scientists of B&H Federation confronted decisively the task of seeking the answer as to how to manage the forests in such changed circumstances, which imposed completely different and new tasks.

## 2. Actual forestry situation

The role and significance of forests can be assessed on the basis of different criteria, of which the most important for B&H Federation are physical, economic and social ones. Physical criteria are reflected in soil and water preservation; economic criteria are reflected in wood processing alimentation and social criteria in improving life conditions and providing some areas for recreation and leisure. It is necessary to achieve a certain balance between the above criteria so as to provide wood production, pasture, hunting, water protection and recreation at the same time. This could be the formula for multi-purpose use of forests. Furthermore, through our history, from its very beginning to the present day, forestland on earth has never stopped decreasing. This decreasing has been quicker than ever in the last century. It is largely considered that this phenomenon is related to social and economic progress in general. Due to the development of agriculture and demographic expansion forests found themselves under high requirements increased by additional excessive demands for building timber and firewood in the process of general post-war rebuilding and reconstruction. This progress of humanity development caused the change of forest and forestland borders. Nowadays, as well as before, forests are destroyed consciously and unconsciously throughout the world and especially on the territory of B&H Federation. However, the fact should be noted and accepted that the decrease of forestland can have long-term and very serious effects, as forest is not only the source for supplying wood but also provides other extremely useful benefits. It is well known that there is hardly a country in the world where a common, simple man could not identify huge areas that could be covered with forest and are deforested and unproductive instead.

One of the most important tasks of forestry experts and scientists, economic experts and federal authorities is to control forests. Federal programs of economic and social development should focus their interest on regeneration of forests in critical areas adopting it as the essential base of their programs.

The issues of the present forestry in this period of transition result from a series of changes, which impose different tasks to forest management oriented towards forestry development. The said issues are the following:

- the transition from self-management with consensus economics to capitalist market economy,
- transition from public ownership to private and state ownership,
- transition to new structure and organization of forestry,
- war destruction of property, casualties of employees in forestry and mined forests and forestland,
- the awareness of the actual environment in which forests and forestry can solve the issues of environmental protection on the whole forest area without adverse effects,
- frequent drying of trees i.e. dying off of forests,
- out-of-date equipment, lack of service market and forestry contractors and lack of IT system,
- too many employees in forestry and a large number of highly disabled employees in forestry, and
- lack of uniformity among factors that make a forestry enterprise.

The above situation results in frequent dissatisfaction of:

- forest owners (justified when their own unsuccessfulness is in question, but not when the authorities of B&H Federation determine the terms and conditions of their business activities);
- employees in forestry companies (irregular payment of salary, fieldwork bonus and holiday allowance, lack of personal protection kit or use of out-of-date personal protection kit written off several times already);
- domestic buyers of forest assortments (they ask for lower prices, deferred payment and higher quality of goods);
- suppliers of energy, working machines and services (they ask for timely and regular payment).
- Successful forest management is possible if the following four tasks are achieved:
- ownership (state ownership of B&H Federation and private ownership)
- authority (divided between B&H Federation and the counties)
- management (of forestry enterprises)
- surveillance – inspection (federal and county forestry inspectors).

All this is closely connected in planned economy and all above said derives from a wider area especially due to the following facts:

- Organization and management of state forests is an important task in all countries with a considerable share of such forests in entire forestry.
- Trying to harmonize forestry and environmental protection relationship is the task of the world community.
- General approach to forestry higher education should be as uniform as possible in view of forestry policy, forestry organization and forestry economy as well as regarding the efficiency of individual work.

Federal and regional authorities organize surveillance to assure that the low is observed. Problems arise because three component parts of forest management are not separated well enough (ownership, management and surveillance). If they were separated, it would be much easier to solve the problems arisen. If they cannot be separated otherwise, it must be done organizationally taking into account that one of the issues for successful management is the rationalization of work activities in forestry.

## 3. Starting points for different tasks in forest management

### 3.1. Actual tasks and prospects of changes

All forests, regardless of the ownership, should be managed on the basis of the latest achievements of forestry science, profession and practice. Forestry today has inherited different organizational structure as well as a series of non-forestry activities, which made part of former forestry enterprises with different status. Thus, in due time, regardless of the way and method in which non-forestry activities were introduced into former forestry enterprises, a reciprocal interaction was established between work and activities of non-forestry business units and basic activities related to forest harvesting. With regard to their basic aims and technology they were absolutely inseparable but they were associated in different ways with regard to the operating and management model. It is, therefore, necessary to separate all non-forestry activities from the basic forestry activities and hence to secure recognition for all forestry activities as well for forestry science, profession and practice.

For many years forestry suffered frequent and purposeless reorganizations and as a result its development was uneven and with different material and personnel policies. It all caused different development levels in certain areas, which must be taken into consideration in future forest organization of B&H Federation.

Apart from huge damage of our forests, premises and houses, bridges, nursery-gardens and other production facilities, a large number of work machinery and equipment was destroyed in war plundering and destruction. Since market–competitive relationship has not been established, our forestry is subject to blackmail and high prices for services without its own work machinery and equipment. Due to huge war damages and regarding our present possibilities and interests in near future, rehabilitation, reconstruction and building of new facilities should be carried out as well as the purchase of destroyed work machines and equipment necessary for implementing the set production plans. To achieve these goals, apart from forestry enterprise funds, loans of the bank for restoration and reconstruction will have to be used in compliance with the regulations on financing the restoration and reconstruction of B&H Federation.

Consequently, the actual tasks and prospects of changes in forest management are as follows:

- Forestry as a specific economic activity does not cope well with frequent reorganizations and requires the organization stability that must be continually developed through restructuring and improving the inner organization, which will in the end guarantee progress and efficiency of the forestry enterprise.

- For many decades, forestry in this area has been going through frequent and numerous but purposeless reorganizations, which must be avoided by a good and suitable selection of forest management organization.
- Regional self-confinement along with excessive requirements from forests caused uneven development of the forestry of B&H Federation and different, mostly unfavorable, conditions of our forests so that such relationship must be changed in near future.
- Wood processing plants were built above the possibilities of our forests – the supply of wood, the raw material, was insufficient and the adequate solutions to this problem must be found in near future.
- Forests on Karst were always neglected and they were never given forestry significance, which must be changed in near future especially because forests on Karst are invaluable for the life of people and economy in those areas.
- Insecurity of private ownership, as a rule small proprietors, brought private forests to the very edge of economic existence. In near future, therefore, all forests, regardless of the ownership, must have the same value and the same relation towards all issues.
- The development of industry, chemistry and agriculture in this area and wider, affects adversely the stability of forest eco-systems and the growth and development of forests is a long standing biological process highly sensitive to the effects of biophysical and abiotic factors. Therefore, in near future, these issues must be taken into consideration and B&H Federation should try to verify all international conventions, charters, declarations, etc. related to forests and environmental protection.
- Reasonable forestry policy everywhere and always must rely on well-considered expertise and continuous, permanent annual long-term investments. Therefore, in this area in near future, consistent forest policy and development strategy must be defined in order to achieve considerable development of forest management.

### 3.2. Actual tasks of forestry and wood industry and prospects of changes

The actual unfavorable condition of our forestry is the result of numerous factors within and outside the wood complex. The way out from the actual difficulties cannot be found by partial solutions of certain problems within the field of forestry. Forestry development goals and programs cannot be solved without simultaneous solution of economic relations between forestry and wood processing, without suitable up-to-date forestry organization, without reconstruction and privatization of wood-processing enterprises, without adequate systematic legal solutions and without proper political action. For getting insight into the condition of our forests and our forestry, some significant facts must be globally taken into consideration starting with the general forestry characteristics, production of forest wood products, placement of forest wood products, illegal felling, public (state) ownership of saw-mills, mobile saw-mills within some forestry enterprises and solution of common property of forestry and wood processing – the wood complex. The procedure and manner of separating forestry from wood processing must be carefully considered as they have been acting together so far in the same enterprises with income-based relations. Forestry, with its broad spectrum of generally beneficial functions and economic functions including timber production, and wood processing, as the majority user of wood mass in industry, have many things and interests in common. As a matter of fact, the base of their relationship lies in the fact that forestry achieves most of its income from the sale of wood and the production of primary wood processing is mostly based on domestic supply of timber. Permanent relationship between forestry and primary wood processing derives from the fact that wood production is not in contrast with tasks necessary to fulfill generally beneficial forest functions.

Wood processing is interested in:

- safe, continuous and sustainable source of wood supply of a determined quality,
- optimal ratio between quality and price, which provides market competitiveness of primary wood processing,
- conditions of timber supply known in advance.

On the other hand, unlike wood processing, forestry is interested in:

- having permanent and reliable buyers of timber,
- such structure of wood processing that can process all kinds and assortments of wood,
- being able to pay competitive prices within acceptable time limits.

On the basis of the above standpoints, similarities and differences as well as different interests, it is possible to determine, carry out and coordinate both development and business policy of forestry and wood processing, providing optimum effects to each party.

Therefore, in near future, the following should be accomplished in production and processing of wood from domestic potentials:

*A) in wood processing:*

- adapt the processing capacities for rational and profitable processing of all kinds and assortments of wood,
- adapt the processing capacities for purchasing all kinds and assortments at competitive prices and conditions,
- adapt the processing capacities so as to be competitive on the market selling wood products.

*B) in forestry*

- increase the production wood mass suitable for industrial processing,
- bring into line the annual production of assortments with wood processing regarding the time of processing and delivery terms,
- encourage and support new wood processing technologies of less valuable kinds and assortments with attractive prices and terms of sale,
- try to achieve as complete and as good as possible supply of raw timber and assortments for wood processing plants.

The measures of B&H Federation related to forestry and wood processing must secure recognition of their potentials, usefulness and significance for B&H Federation.

Taking into consideration the possible development trends of forestry in near future it should be emphasized that the work of the existing wood processing plants depends directly on the degree of forestry development. Forest natural potential controlled by B&H Federation was in the past and will be in the future a significant factor in its entire development. Although the share of forestland is considerable in the total surface of B&H Federation, it should be stressed that that the structure of forests is unfavorable considering high share of coppice forests, bare rocky areas that could be forested and unproductive areas in total surface of B&H Federation. Consequently, even though a large area is covered with forests, data show that the structure of forests, the structure of forest stock and the annual cut are unfavorable due to high share of non-coniferous trees having a high share of wood of low quality in the total wood mass. The fact should be taken into consideration that the natural forest potentials are mostly located on undeveloped areas of B&H Federation, which makes the importance of forests even greater.

Starting from reasonable production possibilities of our forests, optimum supply of the existing capacities of primary wood processing, i.e. saw-mills, with raw timber cannot be expected and this applies particularly to coniferous raw timber due to the fact that private saw-mills deal exclusively with processing coniferous raw timber. The fact that the capacity of plants for primary wood processing is highly above the forest production capacities is already well known as well as the fact that the reconstruction and modernization of the plants has not resulted in the increase of the existing capacities. This was emphasized by the fact that during war and in post war period many private sawmills were founded, most of which do not meet the essential technical and technological operating requirements. In near future, forestry science and practice must take into consideration the said relationships and tasks and offer the best possible solutions.

### 3.3. Prospects of changes imposed by different forest management tasks

In present very complex, ecological, economic and social relationships in our country and in the world, the phenomena affecting adversely the forests are dominant. The results of such effects can be seen in our forests, which loose stability and productivity and withdraw permanently from some centennial natural sites. The analysis of the current conditions in our forestry implies that in near future forestry should make its best to:

- develop forest stock, forest condition and structure,
- increase forest accessibility and modernize forest roads,
- develop technology, methods, work organization and technical equipment,
- improve supporting activities in forestry.

### 3.4. Prospects of changes imposed by forest protection

Systematic protection of forests through the establishment of guidelines for a sustainable forest management is of particular importance for the preservation of forests. Integral forest protection should be based on general guidelines for a sustainable forest management and on general guidelines for the protection of forest biodiversity. The purpose of establishing coordinated guidelines for a sustainable forest management is based on six criteria for achieving sustainable forest management:

- maintenance and proper use of forest resources and their contribution to global carbon cycles,

- maintenance of health and vitality of forest eco-systems,
- maintenance and incentives to provide forest productive functions (wood and general),
- maintenance, protection and increase of biologic diversity in forest eco-systems,
- maintenance and adequate incentives to provide protection functions in forest management (especially related to soil and water),
- maintenance of other social and economic functions and conditions.

Sustainability in forest management cannot be only focused on wood and other numerous products but on the entire array of forest eco-system functions. The right forestry approach to sustainability involves maintenance of various species, genetic diversity, space and time diversity in structure, maintenance of soil hydrology and climate protection, maintenance of natural soil fertility, health and productivity of forests and where possible their natural regeneration and their capability to meet physical and spiritual demands of man. Consequently all forest functions are significant for the society and they should be combined as much as possible by implementing forest management, which involves multi-purpose functionality of eco-system maintenance through the increase of their biodiversity. However, special forest conditions or social circumstances can arise requiring priorities for some forest functions. The priority given to a certain function should not cause the collapse of other function potentials. Natural forests are irreplaceable laboratories for researches. All other natural forests should be protected from excessive wood harvesting and new areas should be provided for all kinds of forest vegetation so as to provide monitoring of their development without the influence of man.

### 3.5. Prospects of environmental protection forest management

The use and adaptation of ecological processes in forest management is the essential means for a rational and profitable management. All forest activities must observe natural forest processes. This should also apply to afforestation and restoration of degraded forests (conversion). Doing so it is necessary to imitate the structure and dynamics of natural forests in order to provide, if possible, sustainability and profitable production. And finally forestry should no longer treat forests in the way agriculture treats harvesting. Natural forest management can be applied to all tree species and can start in all phases of stand development. Sustainability of all functions, including wood production and wood skidding from natural forests, can be well planned and controlled by use of suitable forest-economic technologies and technological processes.

## 4. Conclusion

All above said, related to actual tasks and the prospect of changes imposed by different forest management tasks in B&H Federation, implies the following conclusions:

- The actual tasks and the prospect of changes imposed by different forest management tasks in B&H Federation are burdened with numerous open questions waiting for quick answers and best solutions from forestry science, profession and practice.
- Forest management is still affected by remnants of totalitarian social relationships of socialist self-management, consensus economics, coupled income relations of forestry and wood processing, non-functional and inefficient organization of forest management, out-of-date and insufficient forest mechanization and equipment and insufficient and devastated forest infrastructure. All these should be improved in near future and properly established by finding optimal and well-chosen solutions.
- The most actual task is to develop the right relationship towards and awareness of all people about forests as a general and invaluable resource and at the same time to restructure forestry based on market principles.
- Drawing and passing of an up-to-date and modern Forest Law should be completed as soon as possible and forest management should be adapted to reasonable frameworks of an efficient and functional self-viable and sustainable forest management.
- Long-term forestry strategy should be developed as soon as possible as the necessary clue for determining future relationships in forest management through preservation of natural self-regenerative and sustainable forest stands giving advantage to generally beneficial forest functions over the economic ones.
- A new regional and economic forest division is required along with the implementation of a new inventory of forests and on this basis new forest-management policies should be developed. The general orientation should involve the decrease of pre-war volume of forest felling and give priority to the possibility of protection of natural forests. Long-term forest management tasks should be carried out by applying up-to-date scientific and pro-

fessional methods in implementing the inventory of forests in compliance with European and international charters, conventions and declarations on forests.

- Forestry as a specific economic activity does not cope well with frequent reorganizations and requires the organization stability that must be continually developed through restructuring and improving the inner organization, which in the end guarantees progress and efficiency of forest management.
- Regional self-confinement of the forestry of B&H Federation along with thže excessive requirements from forests caused uneven development and different, mostly unfavorable, conditions of our forests.
- The capacities of primary wood processing plants are much too high and our forests cannot possibly meet their demand for timber. Measures should be applied aimed at optimizing the potential, usefulness and significance in the relationship between forestry and primary wood processing.
- Forests on Karst have continually been neglected and their role was mostly but unjustly not related to forestry. However, they doubtlessly have an inestimable value for the life and economy of those areas.
- Insecurity of private ownership, as a rule small proprietors, brought private forests to the very edge of economic existence implying that in near future all forests, regardless of the ownership, must have the same management and value.
- Successful forest management can be implemented if four tasks are achieved through: ownership, competence, management and surveillance.
- Integral forest protection can be achieved by setting the guidelines for a sustainable forest management based on general guidelines for forest biodiversity protection.
- Ecological forest management is absolutely necessary and possible by use and adaptation of ecological processes in forest management as the essential means for a rational and profitable management along with implementing natural forest processes and providing production sustainability and profitability.

## 5. References

Federalno ministarstvo poljoprivrede vodoprivrede i šumarstva, 1997: Zbornik radova Savjetovanja »Šumarstvo Federacije BiH«, Sarajevo.

Federalno ministarstvo poljoprivrede vodoprivrede i šumarstva, 1996: Zbornik radova Savjetovanja »Šumarstvo u BiH«, Sarajevo.

Kopčić, I., et al. 1971: Razvoj šumarstva u SR BiH za period od 1971–2005. godine, Institut za šumarstvo, Sarajevo.

Matić, V., 1977: Metodika izrade šumskoprivrednih osnova za šume u društvenoj svojini na području BiH, Sarajevo.

Matić, V., et al. 1965: Stanje šuma u SR BiH prema inventarizaciji 1964–1965. godine, Institut za šumarstvo, Sarajevo.

Matić, V., et al. 1968: Inventura šuma 1964–1968., Sarajevo.

Rauš, Đ., 1991: Zaštita prirode i čovjekova okoliša, Šumarski fakultet Sveučilišta u Zagrebu, Zagreb.

Sabadi, R., 1992: Šumarska politika, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1994: Načela za tvorbu konzistentne šumarske politike, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1994: Prilog povijesti šumarstva i šumarske politike, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1996: Šumarstvo i drvna privreda SR Njemačke, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1996: Talijansko šumarstvo i prerada drva, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1997: Švicarska pregled šumarstva i prerade drva, »Hrvatske šume«, p. o. Zagreb.

Sabadi, R., 1997: Vrednovanje šuma u njihovoj ukupnosti, »Hrvatske šume«, Zagreb.

Statistički godišnjak SRBiH 1992. godine, Sarajevo.

Stefanović, V., 1983: Ekološko vegetacijska rejonizacija Bosne i Hercegovine, Šumarski fakultet u Sarajevu, Posebno izdanje br. 17., Sarajevo.

Šume i prerada drveta ex Jugoslavije, 1986, Savez inžinjera i tehničara šumarstva i industrije za preradu drveta, 169–177, Beograd.

Vratarić, P., 1993: Šumarstvo i prerada drva u Republici Hrvatskoj, »Hrvatske šume«, Zagreb.

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In gratitude for a forty-year cooperation
I devote this paper to the memory of my
metrology colleague Vojislav Bego
(1923–1999). – The author

# Formation of decimal and binary units of measurement[1]

**Marijan Brezinšćak**

***Abstract***

*This paper presents the equations and patterns used for the systematic development of monosemic formation of values, names and symbols of decimal and binary units of measurement. Special interest was focused on the formation of the Croatian names for compound units.*

***Key words****: units of measurement, decimal units, binary units, formation of the Croatian unit names.*

## 1. Ambiguous use of unit prefixes

Unit prefixes deci (0,1 = 1/10), centi (0,01 = 1/100) and milli (0,001 = 1/1000) were established by the French law in 1793, two entire ages ago. Two years later, the prefixes hecto (100) and kilo (1000) were introduced. Other 15 unit prefixes were introduced by international organizations for standardization, international conventions and national laws from 1870 to 1991 [11]. All 20 prefixes are defined *monosemically* [6, 7, 8, 11, 30, 31, 34, 35, 37], i.e. their three characteristics are defined: value, name and symbol (Table 1 and 2).

In the forties of the 20th century the information unit *bit* appeared in the electronic data processing and in the sixties the unit *byte* appeared. Bit is the name for the number one when it expresses the numerity (amount) of possible alternative decisions (*yes* or *no*, *0* or *1*) of the binary system. This is, for example, the information content of the message or computer, memory capacity, shortened: memory. The unit name *bit* (symbol: bit) comes from the English words **bi**nary digi**t**. Eight time greater unit is called byte, hence byte = $2^3$ bit = 8 bit. The English unit name byte (frequently the symbol: B) was developed in early sixties from three words: **b**inar**y**, digi**t**, bit**e**.

With the development of computer systems, the need arose for expressing the information contents by much greater units than bit and byte. As the system is binary, and not decimal, multiple numerical units are formed by the units bit and byte with the help of multiple $N = 2^r$. If $r = 10$ is chosen, the result is $2^{10} = 1024$. Conforming to the formation of decimal units in force for centuries, the information technology along with computer industry gave this binary prefix the same name *kilo*, but the symbol K (capital letter!).

Since in this area everything occurs quickly, the unit name *kilobyte* (symbol: KB), meaning 1024 bytes, soon spread throughout the world. Thus the **ambiguity** meaning of the prefix was born: the prefix *kilo* means 1000 (kilometre, km) and it also means 1024 (kilobytes, KB)! Then this ambiguity spread further: *mega* means $10^6$ (megawatt, MW) and also means $1{,}049 \cdot 10^6$ (megabyte, MB), *giga* means $10^9$ (gigawatthour, GWh), but also means $1{,}074 \cdot 10^9$ (giga-

[1] *Editor's note:* This study was written for the Proceedings of the International Conference *Emerging Harvesting Issues and Technology Transition at the End of the Century* held from 27th September to 1st October 1999 in Opatija. Editorial was pleased to allow the author to publish the study in Mjeriteljski vjesnik 18 (2000) 1–2: 3568–3586.

byte, GB), etc. **Confusion** arose and continues to be as the basic rule of valid standardization of units of measurement has been disrupted: *each unit must have a single value, a single name and a single symbol.*

The Croatian Law on Units of Measurement (1993) does not deal with the units bit and byte. They were not dealt with by the former, Yugoslav law, either [37]. They are not comprised by the relevant Guideline of the European Union (1971...1999). The unit *bit* is mentioned by the German Standard DIN in 1982, not as a unit of measurement but rather as the name and symbol: »names and symbols analogous to units« [26]. The International Electrotechnical Commission (CEI/IEC), the leading world standardization organization in the area of electric engineering and electronics, mention the unit *bit* in 1983 [22] in the note along with the units shannon and hartley: »In data transmission, the unit *bit* is used with the symbol *bit*, and the unit *baud* with the symbol Bd.« They refer to the practice of ITU – International Telecommunication Union.

The bodies taking part in the intergovernmental *Convention du Mètre* (1875) did not deal with information units until February 1995. Then the *Consultative Committee for Units* (CCU) [12] confirmed that the unit prefixes kilo, mega, giga, tera, etc. were exclusively powers of number ten, and in no way powers of number two [24]. CCU stated the example that »un kilooctet représente 1000 octets et non 1024 octets«, i.e. in English: »one kilobyte represents 1000 bytes and not 1024 bytes« [24, page 15, 48]. The French name *octet* means the same as English *byte* (in Croatian *osmak*). Moreover CCU also forwarded to its higher-ranked body, the International Committee for Weights and Measures (CIPM), the Recommendation U1(1995) in which it describes the arisen confusion and reminds that the prefixes represent only powers of number ten and invites the International Electrotechnical Commission to suggest the names and symbols for binary prefixes in information technology. CIPM held its meeting in early October 1995 and did not accept the U1(1995) of the Consulting Committee on Units. The refusal reads without much concern: »... the view of the CIPM was that it is now too late to influence the world of information technology and it decided to take no action in the matter«. [25, page 124]

By coincidence CCU had its next meeting as soon as spring 1996 [20]. Consistent with the standpoint of its Recommendation U1(1995), CCU wrote to CIPM a new, better-defined recommendation. In the competent language its title is *Recommandation U1 (1996): Multiples de deux pour les unités utilisées dans les techniques informatiques* [20, page 29]. At the adjoining page the English translation is given [20, page 63]. In September 1996 CIPM accepted the Rec-

**Recommendation U 1 (1996):**
**Binary multiples of units used in information technology**

**The Consultative Committee for Units,**

**considering**

- **that the Conférence Générale des Poids et Mesures has adopted a series of prefixes to be used in forming the decimal multiples and sub-multiples of SI units,**
- **that there is an increasing need in information technology to express multiples of units such as the bit and byte,**
- **that the use of the SI prefixes in information technology to express binary multiples of such units leads to confusion,**

**recalling that the SI prefixes represent strictly powers of ten,**

**noting that work is under way, notably within the International Electrotechnical Commission (IEC) but also in other organizations, aimed at finding alternative ways of expressing binary multiples,**

**strongly supports the IEC in its efforts to reach agreement on names and symbols for prefixes denoting powers of two for use in information technology world-wide.**

ommendation U1(1996) as its Recommendation 2(CI – 1996) [23, page 30 (Fr.), 146 (En.)]. Confirming that »the use of prefixes kilo, mega and giga in information technology to denote powers of 2, namely $2^{10}$, $2^{20}$ and $2^{30}$, continues to cause confusion«, in its recommendation the International Committee also says the following: »... CIPM strongly supports the IEC in its efforts to reach agreement on names and symbols for prefixes denoting powers of two for use in information technology world-wide.« With such support of the supreme executive body of the Meter Convention, assisted by the world leading organization for standardization – ISO and the Institute of Electrical and Electronic Engineers (IEEE; USA), IEC published in1999 a monosemic international standard [1] of binary names and symbols (see Chapter 3).

At the meeting of CCU in 1998 A. J. Thor, the Head of the Technical Committee ISO/TC 12, reported on the current state in IEC: »IEC has reached the final voting stage on the adoption of names and symbols for binary multiples and that here the symbols use upper case letters followed by lower case i, noting especially the symbol Ki for $2^{10}$.« [21]

## 2. Formation of decimal units of measurement

In compliance with two-century long experience of humanity, it is the recommendation of the International Organization for Standardization – ISO [31] to express the measurable quantities, as a rule, by applying the numerical value ranging between 0,1 and 1000. This can be achieved by *free choice* of the adequate unit of measurement for each set example. Observing this rule, the car engine power *P* shall not be expressed as $5 \cdot 10^4$ W or as 50 000 W, but rather in the form 50 kW. The electric plant power will be expressed as 620 MW and not as $62 \cdot 10^7$ W or 620 000 kW or even 620 000 000 W. The letter W denotes the power unit watt in the International System of Units (SI). The units kilowatt (symbol: kW) and megawatt (MW) are two of twenty available legal [37] *decimal units* for power. Their value is defined as follows: kW = $10^3$ W and MW = $10^6$ W. It can be seen from these examples why they are called *decimal units*. The origin is latin: *decem* means ten and *decimus* tenth; this explains the name *decimal system*.

**Table 1** Values and names of unit multipliers *N* and names and symbols of the relevant legally accepted prefixes [37] for the formation of decimal units of measurement. Columns include: *1* – powers of number ten, *2* – decimal numbers, *3* – number names, *4* – prefix names, *5* – prefix symbols

| *1* | *2* | *3* | *4* | *5* |
|---|---|---|---|---|
| Ten internationally standardized unit multipliers *N greater* than number one: | | | | |
| $10^1$ | 10 | ten | deca | da |
| $10^2$ | 100 | hundred | hecto | h |
| $10^3$ | 1 000 | thousand | kilo | k |
| $10^6$ | 1 000 000 | million | mega | M |
| $10^9$ | 1 000 000 000 | billion (US) [11] | giga | G |
| $10^{12}$ | 1 000 000 000 000 | trillion (US) | tera | T |
| $10^{15}$ | 1 000 000 000 000 000 | quadrillion (US) | peta | P |
| $10^{18}$ | 1 000 000 000 000 000 000 | quintillion (US) | exa | E |
| $10^{21}$ | 1 000 000 000 000 000 000 000 | sextillion (US) | zetta | Z |
| $10^{24}$ | 1 000 000 000 000 000 000 000 000 | quadrillion | yotta | Y |
| Ten internationally standardized unit multipliers *N less* than number one: | | | | |
| $10^{-1}$ | 0,1 | tenth | deci | d |
| $10^{-2}$ | 0,01 | hundredth | centi | c |
| $10^{-3}$ | 0,001 | thousandth | milli | m |
| $10^{-6}$ | 0,000 001 | millionth | micro | $\mu$ |
| $10^{-9}$ | 0,000 000 001 | billionth (US) [11] | nano | n |
| $10^{-12}$ | 0,000 000 000 001 | trillionth (US) | pico | p |
| $10^{-15}$ | 0,000 000 000 000 001 | quadrillionth (US) | femto | f |
| $10^{-18}$ | 0,000 000 000 000 000 001 | quintillionth (US) | atto | a |
| $10^{-21}$ | 0,000 000 000 000 000 000 001 | sextillionth (US) | zepto | z |

**Table 2** Formation of the decimal unit on the principle *D* = *N* × *J* and its name formation by joining two words into one *D* = *N* + *J*. The letters denote: *D* – decimal unit, *N* – multiplier (prefix), *J* – formative (starting) unit of measurement

| Multiplier | | Prefix name | | Decimal unit | | Note |
|---|---|---|---|---|---|---|
| Number | Symbol | Croatian | French | Example | Pronunciation | |
| Multipliers *N greater* than number one (multiples): | | | | | | |
| $10^1$ | da | deka | déca | dag = 10 g | dekagram | |
| $10^2$ | h | hekto | hecto | hL = 100 L | hektolitra | |
| $10^3$ | k | kilo | kilo | kW = 1000 W | kilovat | (*a*) |
| $10^6$ | M | mega | méga | MBq = $10^6$ Bq | megabekerel | (*b*) |
| $10^9$ | G | giga | giga | GPa = $10^9$ Pa | gigapaskal | (*c*) |
| $10^{12}$ | T | tera | téra | TWh = $10^{12}$ Wh | teravatsat | (*d*) |
| $10^{15}$ | P | peta | peta | Pm = $10^{15}$ m | petametar | (*e*) |
| $10^{18}$ | E | eksa | exa | EJ = $10^{18}$ J | eksadžul | (*f*) |
| $10^{21}$ | Z | zeta | zetta | Zg = $10^{21}$ g | zetagram | (*g*) |
| $10^{24}$ | Y | jota | yotta | Yg = $10^{24}$ g | jotagram | (*h*) |
| Multipliers *N less* than number one (submultiples): | | | | | | |
| $10^{-1}$ | d | deci | déci | dL = 0,1 L | decilitra | |
| $10^{-2}$ | c | centi | centi | cm = 0,01 m | centimetar | |
| $10^{-3}$ | m | mili | milli | mbar = $10^{-3}$ bar | milibar | (*i*) |
| $10^{-6}$ | $\mu$ | mikro | micro | $\mu$rad = $10^{-6}$ rad | mikroradijan | (*j*) |
| $10^{-9}$ | n | nano | nano | nm = $10^{-9}$ m | nanometar | (*k*) |
| $10^{-12}$ | p | piko | pico | pF = $10^{-12}$ F | pikofarad | |
| $10^{-15}$ | f | femto | femto | fm = $10^{-15}$ m | femtometar | |
| $10^{-18}$ | a | ato | atto | aC = $10^{-18}$ C | atokulon | (*l*) |
| $10^{-21}$ | z | zepto | zepto | zmol = $10^{-21}$ mol | zeptomol | (*m*) |
| $10^{-24}$ | y | jokto | yocto | yg = $10^{-24}$ g | joktogram | (*n*) |

***Notes*** accompanying decimal units in Table 2: (**a**) The power of a modern vehicle ranges between 45 and 90 kilowatts (Croatian: kilovat); (**b**) In raying the brain, one-photon tomography begins approximately ten minutes after intravenous injection of technetium radioactive isotopes with activity from 740 to 1110 megabecquerels (Croatian: megabekerel); (**c**) The testing machine crumbles the sample by applying pressure of more than one gigapascal (Croatian: gigapaskal) (= ten thousand bars); (**d**) The nuclear electric plant Krško, if it worked with its full capacity with no interruption, would produce 5,4 terawatthour (Croatian: teravatsat) of electric energy per year; (**e**) In a year, the light passes the distance of 9,46 petametres (Croatian: petametar) through vacuum; (**f**) In Croatia approximately 0,22 exajoules (Croatian: eksadžul) of primary energy was produced in 1996; (**g**) An ice cube with the edge 100 kilometres long would have the mass of one zettagram (Croatian: zetagram); (**h**) The Earth's mass is about 6 yottagrams (Croatian: jotagram); (**i**) The air pressure ranges between 980 and 1040 millibars (Croatian: milibar) (mbar = hPa); (**j**) One-fifth of the second of angle equals approximately one microradian (Croatian: mikroradijan); (**k**) The atoms of a solid body are one-tenth nanometre (Croatian: nanometar) apart; (**l**) The electric charge of electrons is 0,16 attocoulombs (Croatian:atokulon); (**m**) Unthinkably small lump of substance made of 602 molecules has the amount of substance of one zeptomole (Croatian: zeptomol); (**n**) The mass of the lightest, hydrogen atom is 1,67 yoctograms (Croatian: joktogram).

Essential bases for the formation of legal decimal units are shown in Table 1 and 2. Latin, Greek, Danish and Italian origins of unit prefixes are described in the paper [11]. The history of unit prefixes is described in the textbook [7] and article [10]. Additional international rules for the formation of decimal units are stated in the encyclopedic article [8]. The first of these rules says that for the formation of a decimal unit each of 20 prefixes can be used, but only one of them. This rule is provided by Croatian law, too [37].

Decimal units are formed in accordance with the international rules [6, 7, 8, 30, 31, 37]. At least three characteristics of the decimal unit are formed: value, name and symbol pursuant to equal features of the formative (starting) unit *J*. The unit of measurement has the following characteristics [9]: pertaining to the measurable quantity, value or/and definition, name, symbol, origin, (non)legality, restriction of use (time or/and regional) and other possible name or/ and symbol.

The ***value*** of each decimal unit *D* is determined by a general product

$$N \cdot J = D \qquad (1)$$

Here *N* denotes the value of any of twenty standardized unit multipliers shown in Tables 1 and 2, and the letter *J* denotes the formative unit, the one from which the decimal unit $D$ is formed in the actual example. Nowadays the formative unit $J$ usually belongs to The International System of Units (SI), and sometimes it is the unit exceptionally approved by law, for example the pressure unit bar (symbol: bar) [37]. The multiplier $N$ in the equation (1) is calculated by the equation:

$$N = 10^n. \quad (2)$$

Intergovernmental agreements, national laws and international standards allow at present the use of the following values of the exponent $n$:

$$n = \pm 1, \pm 2, \pm 3, \pm 6, \pm 9, \pm 12, \pm 15, \pm 18, \pm 21 \text{ and } \pm 24 \quad (3)$$

The ***name*** of the decimal unit of measurement $D$ is formed as the solid compound made of two names according to the pattern:

$$N + J = D. \quad (4)$$

Here the letter $N$ denotes the *name* of internationally accepted and/or legally determined decimal prefix pertaining to the appropriate multiplier in accordance with Table 1 and 2. The letter $J$ denotes the *name* of formative unit and the letter $D$ the *name* of the formed decimal unit. *The example of name formation*: for $N$ = mega and $J$ = watt the pattern (4) gives the *name* of decimal unit: $D$ = mega + watt = megawatt.

### Compounds

The formation of Croatian unit names in accordance with the pattern (4) gives *solid compounds*, i.e. new words made by joining two words into one [4]. If $J$ = vat (W) and $N$ = kilo (k), with the use of (4) the compound is formed: $D$ = *kilovat* (kW). Unit and prefix symbols are in the round brackets. If $J$ = vatsat (Wh) and $N$ = kilo (k), the new compound $D$ = *kilovatsat* (kWh) will be formed. If $J$ = voltampersat (VAh) and $N$ = kilo (k), the compound $D$ = *kilovoltampersat* (kVAh) will be formed in accordance with the principle (4). The formation of unit compounds in the Croatian language has been the subject of legal regulations since Austro-Hungarian times to the present days [13]. It can be seen in the Croatian orthography: *gigavatsat, kilogrammetar, kilovatsat, kilovoltamper* [5]. It can also be seen in the Croatian dictionary of foreign words [3]: *ampersat, kilopondmetar, vatsat, vatsekunda, voltamper, etc*. Some attempts of interrupting this tradition [18], i.e. using the form of compounds with a hyphen such as *kilovat-sat*, *kilovolt-amper-sat*, etc. do not have any orthographic justifications [16, 17], other than the part of English practice: *watt-hour*, *kilowatt-hour* [32]. The rest of this practice is formed as follows: *watt hour*, *kilowatt hour, newton meter, pascal second* (separated!) [35].

Unit names in the form of solid compounds are common in the German language: *Amperstunde* (Ah), *Kilovoltampere* (kVA), *Kilowattstunde* (kWh) [27]. In French there is a considerable variety of use: solid compounds such as *voltampère, wattheure, kilowattheure* [29], separated words such as *pascal seconde* and compounds with a hyphen such as *pascal-seconde* (Pa·s) and *kilowatt-heure* (kW-h) [14]. A consistent use of compounds with a hyphen is required by Russian regulations [19, 34]: *kilogramm-keljvin, mikronjuton--metr, voljt-amper, etc*. Czech orthography does not allow [14] the public use of unit compounds with a hyphen.

Endorsing solid compounds in the Croatian language is especially important with regard to the names of decimal units, as they are the most numerous. It must never be forgotten that twenty legally approved decimal units can be formed out of each formative (starting) unit. The examples stated herein and the observed differences are negligible formation problems compared to those met when trying to establish the system for names of complex units of measurement, particularly those containing an attribute [9], e.g. square, cubic, reciprocal, to the power of two, to the power of minus two, etc. The standard proposal [8] of some twenty years ago was in fact the beginning of a systematic solution. The widened proposal [17] might bring considerable improvement to word formation transparency and orthographic monosemy.

***Symbol*** of the decimal unit of measurement $D$ is also formed in accordance with the pattern (4). The letters $N$, $J$ and $D$ are respectively: the symbol of the chosen unit prefix (Tab. 2), symbol of the chosen formative unit, symbol of the formed decimal unit of measurement. *The example of symbol formation:* Pursuant to the pattern (4) the symbol is formed as follows: k + W = kW.

## 3. Formation of binary units of measurement

*Numerity* is the basic measurable quantity of information technology. It is used for expressing a large number of possible alternative decisions, information technology content of messages, computer memory capacity, etc. The bodies taking part in the international *Meter Convention* (1875) [6, 7, 8] have not still dealt with information units and quantities, anyway not as competently as with units of measurement for length, mass, time, etc. They are, how-

**Table 3** Values, names and symbols of binary prefixes for the formation of binary information units in compliance with the International Standard IEC, 1999 [1]

| Binary prefix value | Name | Symbol |
|---|---|---|
| $2^{10}$ = 1,024 · $10^{3}$ | kibi | Ki |
| $2^{20}$ = 1,048 576 · $10^{6}$ | mebi | Mi |
| $2^{30}$ = 1,073 741 824 · $10^{9}$ | gibi | Gi |
| $2^{40}$ = 1,099 511 627 776 · $10^{12}$ | tebi | Ti |
| $2^{50}$ = 1,125 899 906 842 624 · $10^{15}$ | pebi | Pi |
| $2^{60}$ = 1,152 921 504 606 846 976 · $10^{18}$ | exbi | Ei |

**Table 5** Conversion of binary prefixes into decimal prefixes. The letter $C$ denotes the constant, $C = 2^{10}/10^{3}$ = 1,024 (exactly). The values of decimal prefixes kilo (k) to exa (E) are shown in Table 1.

| Binary | Calculation | Decimal |
|---|---|---|
| kibi (Ki) | $= C \cdot$ k | = 1,024 kilo (k) |
| mebi (Mi) | $= C^{2} \cdot$ M | » 1,048 58 mega (M) |
| gibi (Gi) | $= C^{3} \cdot$ G | » 1,073 74 giga (G) |
| tebi (Ti) | $= C^{4} \cdot$ T | » 1,099 51 tera (T) |
| pebi (Pi) | $= C^{5} \cdot$ P | » 1,125 90 peta (P) |
| exbi (Ei) | $= C^{6} \cdot$ E | » 1,152 92 exa (E) |

ever, facing the problems of ambiguity when the information quantity *numerity* forms new quantities with standard quantities, for example *transmission speed* (through computer network) defined by the ratio *numerity/time*. This quantity uses the units: bit per second (symbol: bit/s), byte per second (symbol: B/s) and many others. It is obvious here that the confusion has arisen due to the *ambiguity of unit prefixes* and it is even more serious than the one mentioned in Chapter 1. There are other quantities, too derived by use of *numerity*, and in time there will be even more.

In this chapter it is described how the International Electrotechnical Commission – IEC solved the problem of ambiguity of information units for *numerity*, the basic information quantity in the area of data processing and transmission by the standard [1] in 1999. The summary of the solution is shown in Tables 3 and 4 and the link between binary and decimal prefixes is shown in Table 5.

**Table 4** Names, symbols and values of binary information units derived from the formative (starting) units bit and byte

| Name | Symbol | Value |
|---|---|---|
| Formative unit bit (symbol: bit) | | |
| kibibit | Kibit | $2^{10}$ bit = 1024 bit |
| mebibit | Mibit | $2^{20}$ bit = 1024 Kibit |
| gibibit | Gibit | $2^{30}$ bit = 1024 Mibit |
| tebibit | Tibit | $2^{40}$ bit = 1024 Gibit |
| pebibit | Pibit | $2^{50}$ bit = 1024 Tibit |
| exbibit | Eibit | $2^{60}$ bit = 1024 Pibit |
| Formative unit byte (symbol: B) | | |
| kibibyte | KiB | $2^{10}$ B = 1024 B |
| mebibyte | MiB | $2^{20}$ B = 1024 KiB |
| gibibyte | GiB | $2^{30}$ B = 1024 MiB |
| tebibyte | TiB | $2^{40}$ B = 1024 GiB |
| pebibyte | PiB | $2^{50}$ B = 1024 TiB |
| exbibyte | EiB | $2^{60}$ B = 1024 PiB |

Value, name and symbol of the *binary unit* are formed by use of the equation (1) and pattern (4) introduced in Chapter 2 for the formation of decimal units. Here, however, the letter $D$ denotes the value of *binary* unit, i.e. its name and the multiplier $N$ is not determined by the equation (2), but by *binary* definition

$$N = 2^{r}. \quad (5)$$

The exponent $r$ has only positive values. Binary multiplier $N$ is always greater than number one, i.e. it is exclusively the multiple (compare with the Tables 1 and 2; in their lower parts the multipliers are smaller than number one). At present those values of the binary exponent are sufficient:

$$r = 10, 20, 30, 40, 50, 60. \quad (6)$$

The names of binary prefixes are listed in the second column of Table 3. They are formed systematically from two syllables. The first syllable reminds of the decimal prefixes, e.g.. **me** of *mega* and the second syllable **bi** shows that what we have here is **bi**nary formation. Thus the following solid compounds have been formed:

ki + bi = kibi (Ki), me + bi = mebi (Mi),
gi + bi = gibi (Gi),

te + bi = tebi (Ti), pe + bi = pebi (Pi),
ex + bi = exbi (Ei).

The symbols are also formed systematically from two parts, made of two letters. The first letter is always a *capital* letter, the first letter of the name of decimal prefix (see Table 1 and 2). The second letter is a *small* letter »i«; it refers to *information technology*, it says that this is the prefix for information unit and it reminds of the word b**i**nary.

The described principle of formation of names and symbols of binary prefixes was proposed by the

Technical Committee 25 of the CEI/IEC: *Quantities and Units*. As the proposal got the required majority of votes of the national organizations for standardization – IEC, in January 1999 the formation principle was published as a table in the second part of Annex No. 2 to the international standard CEI/IEC 60 027-2 [1]. These standards are published bilingually in the same publication. The titles of the said table are: Article 14 – Préfixes pour les multiples binaires and Clause 14 – Prefixes for binary multiples. The table is the integral part of the standard.

French binary prefixes are (comp. Tab. 3): kibi, mébi, gibi, tébi, pébi, exbi. After removing the accents, the English version is left. The symbols are, of course, equal in all languages using the Latin alphabet. Both tables contain four *examples* of names, symbols and values of binary and decimal units formed by the units *bit* and *byte*. And they are as follows [1]:

*French*

| | |
|---|---|
| un kibibit: | 1 Kibit = $2^{10}$ bit |
| un kilobit: | 1 kbit = $10^3$ bit |
| un mébioctet: | 1 Mio = $2^{20}$o |
| un mégaoctet: | 1 Mo = $10^6$o |

*English*

| | |
|---|---|
| one kibibit: | 1 Kibit = $2^{10}$ bit |
| one kilobit: | 1 kbit = $10^3$ bit |
| one mebibyte: | 1 MiB = $2^{20}$ B |
| one megabyte: | 1 MB = $10^6$ B |

French unit name *octet* (in Croatian *osmak*, see Chapter 1 and Table 6) has the same meaning as English *byte* and the Croatian adapted name *bajt*. The symbol for octet is »o« and for byte »B«. Their value is o = B = 8 bit.

At the end the *example*: The capacity of the hard disk is 70 gibibytes, expressed by *binary* unit gibibyte (GiB) pursuant to IEC (1999) [1]. This capacity can be expressed by *decimal* unit gigabyte (GB). With the use of Table 5 the following can be calculated:

70 GiB = 70 · 1,073 74 GB = 75,1618 GB.

The letter B is the symbol for the unit byte defined as eight bits.

The International Electrotechnical Commission with its solution relieves the decimal units of ambiguity. At the same time the users of the binary information units are required to make the effort needed to get used, in the period of adaptation, to the new name **mebibyte** and the new symbol **MiB** and to break the habit of using the current name **megabyte** and symbol **MB**. Therefore, when using the **binary** units (see Tab. 3, 4, 5)

**Table 6** Entries related to information unit byte (Croatian: bajt, osmak; French: octet; German: Byte), its binary multiples and their symbols or abbreviations in language books. The data are presented as published. The symbols, abbreviations and interpretations as stated within the entries are shown in the round brackets.

| | |
|---|---|
| Dictionaries of foreign words: | |
| *Croatian:* | Anić-Goldstein, [1]1999 [3]: B, bajt (–), bit (*izg.* bajt), byte (*v.* bajt), gigabajt (GB), kilobajt (1000 bitova), kilobyte (*v.* kilobajt), megabajt (M, MB), terabit (*izg.* terabajt) |
| *German:* | Duden, [6]1997 [28]: Byte (–), Gigabyte (GByte), Kilobyte (kByte), Megabyte (Mbyte) |
| Monolingual dictionaries: | |
| *Croatian:* | Anić, [3]1998 [2]: bajt (–), kilobajt (–) |
| *English:* | New Oxford, [1]1998 [32]: byte (–), gigabyte (GB), K, KB, Kb, kbyte, kilobyte (Kb, KB), M, MB, Mb, Mbyte, megabyte (Mb, MB), T, TB, Tb, terabyte (Tb, TB) |
| *German:* | Wahrig, [6]1997 [36]: B, Byte (B), Gbyte, Gigabyte (Gbyte), kb, KB, Kbyte, Kilobyte (kB, KB, Kbyte), MB, Mbyte, Megabyte (MB, Mbyte) |
| Orthographic books: | |
| *Croatian:* | Babić i dr., [4]1996 [5]: |
| *German:* | Duden, [21]1996 [27]: Byte (–), KB, Kilobyte (KB), MB, Mbyte, MByte, Megabyte (MB, MByte, Mbyte) |

| | |
|---|---|
| **write:** kibibyte (KiB) | **instead of:** kilobyte (kB) |
| **write:** mebibyte (MiB) | **instead of:** megabyte (MB) |
| **write:** gibibyte (GiB) | **instead of:** gigabyte (GB) |
| **write:** tebibyte (TiB) | **instead of:** terabyte (TB) |

## 4. Transition period

The mandatory use of new binary unit prefixes for the formation of multiples of numerical units in the area of data processing and transmission [1] in Croatia will probably be stipulated by the revised Law on Units [37] or by special state metrology regulation. It will have to determine the dead line after which only new names and symbols of binary prefixes (Tab. 3) will be legally valid. The transition period, in which both old and new names and symbols will be legally valid, could last up to five years. It will depend on the transition period determined in its Directive by the European Union.

As the Croatian Law on Units (1993) specifies nothing in view of information technology units, in the transition period most of the interested people will, under the circumstances, continue to use general large-edition language books. Table 6 shows the variety of actually used symbols in foreign languages and the poverty in the Croatian language on the example of the unit byte and its multiplies [2, 5]. Therefore, in the transition period, the new Croatian orthography and different Croatian dictionaries should introduce immediately new binary prefixes (see Tab. 3) and focus the attention to the withdrawal of the actual ones.

When revising these language books, the lexicographic faults should be corrected and the new ones should be avoided. One of such faults in the Croatian dictionary of foreign words [3] from 1999 is the wrong interpretation that the information unit **bit** is pronounced *bajt* (comp. Tab. 6), which makes the entries contradictory:

»**bajt** … the unit for the amount of memory equal to the set of 8 bits … *Engl.* bit ← **bi**(nary) (digi)**t**« (page 143)

»**bit** (*pronounce* bajt) … basic information unit that can acquire two binary values 0 or 1 … *Engl.* **bi**nary digi**t**« (page 181)

»**byte** *see* bajt« (page 211)

»**kilobajt** … *coll.* unit for the amount of computer information (1000 bits), *comp.* bit …« (page 674)

»**megabit**, *see* megabajt« (page 828)

»**terabit** (*pronounce* terabajt) …« (page 1281)

In *such* lexicographic presentation it is hard to understand this interpretation given by information technology expert and pedagogue: »This number selects one bit in this byte…« [33, page 92]. Some other faults are discussed in the third part of the note [15]. And the critique of information technology void in the Croatian orthography [5] compared with the entries in German orthography [27] speaks for itself (see Tab. 6).

Moreover the attention of the linguists should also be focused on standardization of short and long plural forms of units of measurement. Among Croatian metrologists the opinion prevails that the Croatian grammar supports the *short plural*, e.g.: »odgovaraju bajtima«, »pojedini bajti«, »32-bitne adrese«, etc. [33]. However, the Croatian dictionaries [2, 3], under the entry *bajt* specify the long plural: »bajtovi«. The Croatian orthography [5] does not deal with the units *bit* and *bajt*. Maybe this is why the dictionary [3] from 1999 does not observe its own standard on long plural. Under the entry *bajt* it gives the statements »8 bitova« and »milijun bajtova«, and under the entry *megabajt* »1024 kilobajtova«, although the singular form »megabajta« is required here and although the grammar description of the entry outlines the short plural: »megabajti«. The entry *kilobajt* also requires the short plural: »kilobajti« and in its description it has the form »1000 bitova«. The only adjective form of the information unit bit in the dictionary [3] is *bitovni* and there is no *bitni*. There is no adjective entry *bajtni* and *bajtovni*.

Failure to comply with our own standard – if it is not only lexicographer's superficiality – also affects other units of measurement. Thus the entry *vat*, meaning watt, specifies long plural: »vatovi« and the entry *volt* short plural: »volti«. And there are many other examples [3, 15, 17]. The transition period should be used for establishing the grammar and the orthography of units of measurement.

## 5. Conclusions

1. Equations and patterns (1) to (6) make the system of monosemic formation of values, names and symbols of decimal and binary units of measurement. This formation system also applies to widened international decimal and binary sets of prefixes. Moreover the system is the basis for the formation of solid compounds, unit names made by joining names of two or more units in one word (see the examples in Chapter 2).
2. Binary prefixes (Table 3, 4, 5), standardized in 1999 [1] by the International Electrotechnical Commission, should be properly introduced in the revised Law on Units of Measurement [37]. Furthermore the units bit and byte, as well as most other [15] information units of measurement should be regulated by law. It is quite inappropriate for this information technology age to use the unit law without any information unit.
3. As far as up-to-date units of measurements are concerned, the actual Croatian books dealing with orthography and dictionaries are full of voids and serious faults [11, 13, 15]. Therefore the authors of large-edition language books [2, 3, 5] should use the period aimed at introducing new binary units (see Chapter 4 and Table 6) for removing metrology and standardization faults made by previous editions and for including new contents conforming to the third millennium.

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## References and notes

Amendment 2(1999) to IEC Standard 60 027-2: *Letter symbols to be used in electrical technology,* Part 2: *Telecommunications and electronics.*

*Note:* The activity of the International Electrotechnical Commission (IEC) is described in the book written by Mr. M. Brezinšćak *Međunarodni normacijski priručnik*, Hrvatsko mjeriteljsko društvo, Zagreb 1993. (*International Standardization Manual*, Croatian Metrology Society). This book in Croatian made of 104 pages, A4 format, is divided in five chapters with the following titles: International ten-language standardization definition dictionary, International English-Croatian metrology dictionary, International standardization documents and standardization committees, Half century of Croatian standards, Seven decades of eradication of Croatian professional terminology.

V. Anić: *Rječnik hrvatskoga jezika*, Novi Liber, Zagreb [3]1998.

V. Anić, I. Goldstein: *Rječnik stranih riječi*, Novi Liber, Zagreb 1999.

S. Babić: *Tvorba riječi u hrvatskom književnom jeziku* (Nacrt za gramatiku), JAZU and Globus, Zagreb 1986.

*Notes:* The word made by joining two or more words into one is called *solid compound*. The examples of noun compounds are: *Banjaluka, blagdan, duhankesa* (page 31). The examples of adverbial compounds are: *naveliko, uistinu, zauvijek* (page 503–506). The author writes (page 31) that the compounds »are a difficult problem both theoretically and practically due to vague criteria«. In writing the names of complex units of measurement in the Croatian language three forms are used pretty unwisely: solid compounds, compounds with a hyphen and separated words, although the examples when it is reasonable (mostly algebraic reasons) [17] not to use compounds are quite few. More serious difficulties, but useful for metrology, arise in the formation of complex names of enterprises, companies and sport clubs; see the article by Branko Kuna *Višečlani nazivi – pravopisno i jezično pitanje*, Jezik **45**(1997/98)5, 183–190.

S. Babić, B. Finka, M. Moguš: *Hrvatski pravopis*, Školska knjiga, Zagreb [4]1996.

BIPM – Bureau international des poids et mesures (Organisation intergouvernementale de la Convention du Mètre): *Le Système international d'unités (SI)*, BIPM-Stedi, Paris [7]1998.

*Notes:* This is a bilingual brochure, A4 format; pages 1 to 79 contain the French original and pages 81 to 152 the English translation entitled *The International System of Units (SI)*. In case of doubt the French version shall prevail. The first four editions (1970, 1973, 1977, 1981) were only in French.

M. Brezinšćak: *Mjerenje i računanje u tehnici i znanosti*, Tehnička knjiga, Zagreb 1971. *Note:* The book (1310 + 42 pages) has been approved as the textbook of the University in Zagreb.

M. Brezinšćak: *Zakonska metrologija (Zakonsko mjeriteljstvo)*, Tehnička enciklopedija JLZ *M. Krleža*, 8. svezak, str. 496–525, Zagreb 1982. *Note:* »Approximately 100 experts of different professions took place in the formation of the Croatian terminology for quantities and units of measurement as authors or reviewers«, quoted on page 525. Sixteen of them, the authors of original (starting) proposals, are expressly mentioned.

M. Brezinšćak: *Zakonita mjerna jedinica*, Mjeriteljski vjesnik **12**(1994)3, 2199–2209.

M. Brezinšćak: *Dva stoljeća metričkoga sustava jedinica*, Mjeriteljski vjesnik **14**(1996)1, 2613–2621. *Note:* A large part of this article was previously published in the journal Mehanizacija šumarstva **20**(1995)4, 220–222, under the title *Dva stoljeća desetnoga sustava metričkih mjernih jedinica (1795–1995)*.

M. Brezinšćak: *Pomoć uporabnicima i piscima hrvatskih pravopisa*, Mehanizacija šumarstva **22**(1997)1, 35–60.

M. Brezinšćak: *Nova imena savjetodavnih odbora*, Mjeriteljski vjesnik **16**(1998)1, 3101–3103.

M. Brezinšćak: *Pravopis kao nacionalni projekt (7)*, Mjeriteljski vjesnik **16**(1998)1, 3108–3114.

M. Brezinšćak: *Je li naziv kilovatsat zakonit?*, Mjeriteljski vjesnik **16**(1998)3–4, 3237–3241.

M. Brezinšćak: *Leksikografska bijeda Anić-Goldsteinova rječnika*, Mjeriteljski vjesnik **17**(1999)1, 3359–3364 i **17**(1999)2–3, 3467–3475. *Note:* This *metrology critique* of Anić-Goldstein's *Rječnik stranih riječi* (Dictionary of foreign words) [3], published in 1999, will finally find its place in two volumes of Mjeriteljski vjesnik **18**(2000), journal of Croatian Metrology Society (HMD – Hrvatsko mjeriteljsko društvo).

M. Brezinšćak: *Stranputice u hrvatskoj tvorbi mjernih jedinica*, Mjeriteljski vjesnik 18(2000) [in print]. *Note:* This critique applies to the University Manual [18].

M. Brezinšćak at al.: *Slovnica i pravopis mjernih jedinica* [in print].

R. Buljan: *Abecedni indeks mjernih jedinica*, Graphis, Zagreb 1999. *Note:* The book (387 pages) was approved in 1999 as the textbook of the University in Zagreb. It was edited and elaborated by Ms. Ernestina Landau, Professor of English and German. She dedicated it to the memory of Mr. Rudolf Buljan (1925–1992), the member of Croatian Metrology Society from 1980.

G. D. Burdun at al.: *Meždunarodnaja sistema jedinic*, Vissaja škola, Moskva 1964.

CCU **12**(1996), BIPM, Sèvres 1998.

CCU **13**(1998), BIPM, Sèvres 1999. *The author's note* in the proofreading: A. J. Thor (Stockholm), the Head of the Technical Committee IEC TC 25: *Quantities, units, and their letter symbols*, informed competently the metrology public in his article *Prefixes for binary multiples* on page 81 of Metrologia **37**(2000) of the approval of the standard [1].

CEI / IEC: *Letter symbols*, including conventions and signs for electrical technology, Gèneve 1983.

CIPM **85**(1996), BIPM, Sèvres 1997.

Comité consultatif des unités (CCU), Rapport de la 11[e] session (February 21 and 22, 1995), BIPM, Sèvres 1995.

Comité international des poids et mesures (CIPM), Procès verbaux de la 84[e] session (October 5 and 6 and 12, 1995), BIPM, Sèvres 1996.

DIN 1301, Teil 1, Beiblatt 1(1982): *Einheiten. Einheitenähnliche Namen und Zeichen. Note:* The German unit das Bit (symbol: bit) is here in the company of other 12 names, among which: neper (Np), bel (B), decibel (dB), sugar degree (°S).

Duden: *Rechtschreibung der deutschen Sprache*, Dudenverlag, Mannheim [21]1996.

Duden: *Das Fremdwörterbuch*, Dudenverlag, Mannheim[6] 1997.

Larousse: *Le vérificateur d'orthographe*, Larousse-Bordas, Paris 1998.

Norme Internationale ISO 31–0([3]1992): *Grandeurs et unités – Partie 0: Principes généraux.*

Norme Internationale ISO 1000([3]1992): *Unités SI et recommandations pour l'emploi de leurs multiples et de certaines autres unités.*

J. Pearsall (Editor): *The New Oxford Dictionary of English*, Clarendon Press, Oxford 1998.

G. Smiljanić: *32-bitna mikroračunala*, Element, Zagreb 1993.

ST SEV 1052–78: *Metrologija. Jedinici fizičeskih veličin*, Izmjeriteljnaja tehnika (Moscou) 1979, No 1, p. 29–43.

*Note:* This was the standard legally approved by the Economic council SEV. The members of the Council were the following states: Bulgaria, Czechoslovakia, Cuba, Germany, Hungary, Mongolia, Poland and Soviet Union.

B. N. Taylor: *Guide for the Use of the International System of Units (SI)*, NIST Special Publication 811, 1995 Edition, NIST, Gaithersburg, MD 1995.

G. Wahrig, R. Wahrig-Burfeind and others: *Deutsches Wörterbuch*, Bertelsmann Lexikon Verlag, Gütersloh, [6]1997.

*Zakon o mjernim jedinicama* (Law on Units of Measurement), Narodne novine **155**(1993)58, 1469–1473. *Note:* Before this law, the inhabitants of Croatia, at the time of the former Yugoslavia, had to comply with the federal *Law on Units of Measurement and Measures* (1961, 1973, 1976, 1984).

## *Summary*

*In Chapter 1 the confusion is described arisen in the field of data processing and transmission, as the same name denotes both decimal and binary unit prefix, e.g. kilo denotes 1000 and 1024. The Croatian dictionaries increase this confusion by insufficiently precise interpretation of entries related to units of measurement; the examples are presented in the Chapter 4. Equations and patterns (1) to (6) establish the s y s t e m of monosemic formation of values, names and symbols of decimal and binary units. In Chapter 2 attention is focused on the formation of Croatian names for complex units of measurement. The author recommends the use of solid compounds whenever this is possible in view of transparency of unit name and flexibility of the sentence. Chapter 3 covers the Croatian binary prefixes accepted by the International Electrotechnical Commission in early 1999 in French and English. In his conclusion the author suggests that the legislative authorities should use the word formation system and data from this article when revising the Croatian Zakon o mjernim jedinicama (Law on Units of Measurement) from 1993. The linguists working on the development of the Croatian orthography and dictionaries are invited to correct the observed faults and to introduce new metrology and standardization contents conforming to the third millennium in their future editions.*

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