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FOREWORD

Dear Participants of the FORMEC Conference 2008 !

We are most happy to welcome you to the 41st FORMEC 2008 in Schmallenberg. The FORMEC-Conference has a long tradition and a very good reputation as European and international meeting for experts in forest work science and forest technology. Therefore we highly appreciate that nearly 100 experts have registered and will participate in this conference 2008.

The KWF has organised this FORMEC- meeting in combination with the 15th KWF-Tagung and we hope that you will use the opportunity to get information about the actual trends in the Middle European forest technology and to strengthen the contact to enterprises from more than 15 countries.

We invite you to start with the plenary session at the opening day of the KWF-Tagung and many working sessions within the following days..

The 15th KWF-Tagung is the forest technology highlight in 2008. More than 400 exhibitors will be at the fair of the KWF-Tagung, they will build more than 200 exhibitions tents and will show the wide range of innovations in forest technology. Furthermore the practical field demonstrations will allow a neutral discussion about the advantages of the shown technology, the benefits and the costs.

This 15th KWF-Tagung has two very specific topics:

In January 2007 the hurricane Kyrill had completely destroyed the selected area so that it was critical if the KWF-Tagung could take place in Schmallenberg. The KWF-board decided together with the producers of forest machines to remain in the area and to show in live-demonstrations wood harvesting in crops damaged by the hurricane.

Furthermore Schmallenberg is an area where private forests are the dominating form of forestry. We are happy having strong support from the private forest owners in Schmallenberg and therefore focus on their needs in terms of forest technology development.

We thank you all for coming and hope you enjoy your stay in Schmallenberg.
We wish you an interesting FORMEC-Conference with many fruitful discussions !

Your FORMEC-Team:

Ute Seeling
Aneliese Kläres
Katja Bleile

WRITTEN MESSAGE OF GREETING FROM THE NORTH RHINE-WESTPHALIA MINISTER OF INNOVATION, SCIENCE, RESEARCH AND TECHNOLOGY

Prof Dr Andreas Pinkwart

to the FORMEC Congress

Schmallenberg
2 - 5 June, 2008

I am greatly pleased that this year, international representatives from the research and business communities have gathered here at Schmallenberg to take part in Europe's major Congress on forest management and timber logistics and to compare notes.

There is no doubt that the timber industry is a very important branch of economic activity in Germany. With 3.4 billion cubic metres of wood Germany boasts the largest forest resources in the European Union. Altogether, the 16 German states accounted for some 20 per cent of the total amount of wood harvested in Europe last year. Germany thus ranks first in Europe in terms of wood harvest – even ahead of Sweden and Finland. Here in North Rhine-Westphalia, too, there are vast stretches of forest covering 27 per cent of the total area of this state. The forest industry provides jobs for some 5,500 people and achieves total sales exceeding 350 million Euros per annum.

Forestry is set to gain greatly in importance in the future, not least owing to the fact that it is likely to make innovative contributions to our future energy supply. Highly advanced lignocellulose-based biofuels are a case in point. On the other hand, the forest industry benefits from progress achieved in other sectors, for instance by taking advantage of the most innovative methods developed in the field of logistics.

The North Rhine-Westphalia government uses its best efforts to lend support to the drivers for progress. In recent years, we have made available funds for a project by RWTH Aachen university on a simulation model for recording and analysing North Rhine-Westphalia's forest resources down to every single tree and for calculating the optimum land use plan for the state's woodlands. Such projects not only help increase the economic outputs of forests but also make a major contribution towards nature conservation and soil protection and towards improving the recreational value of forests.

RWTH Aachen university will be presenting their "Virtual Forest" project during this congress. I cordially invite you to use this opportunity to take a look at the innovations in the field of forest work and forest technologies made in North Rhine-Westphalia.

I would like to express my heartfelt thanks to the 'Kuratorium für Waldarbeit und Forsttechnik' forestry association for organising this congress. To all those from the international forest research and industry community who have come to the Sauerland: welcome to North Rhine-Westphalia, the Innovation State! I wish the congress every success and that it may provide fresh impetus to all its guests.

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THE FOREST-BASED SECTOR TECHNOLOGY PLATFORM - NETWORK BUILDING FOR FOREST RESEARCH IN EUROPE

Wilhelm Vorher
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Keywords: Research Network, Strategic Research Agenda, Innovation

Abstract: After the launch of FTPs Vision Document in 2005, the European Forest-Based Sector started successfully with the implementation of its Strategic Research Agenda (SRA). The outcome from the first calls in FP7 of December 2006 looks promising. Also with the WoodWisdom-ERAnet FTP had a good start. Up to now we are also very content with the representation of our SRA-issues in the following calls. Meanwhile 24 National Support Groups (NSGs) have been founded and contribute actively to our European network. Twelve National Research Agendas (NRAs) are published and eight more are announced for 2008. This shows how positive the FTP initiative has been accepted by all stakeholders (forestry, wood products, pulp&paper, research community and supporting bodies) nationally and internationally.

Five FTP Conferences have attracted over thousand of people from across Europe, the last one between 19 and 21 May 2008 in Kranjska Gora, Slovenia, under the title “Growing Towards the Future – Joint innovation for successful forest-based business in Europe”. The final key note speaker was Commissioner Janez Potocnik, who gave an outlook on the future research policy of the EU. The European Technology Platform idea has started better than expected and will be developed further as an important tool for joint and cross sectoral research.

FTP invites all interested stakeholders to join its network for fruitful cooperation in R&D, different task forces, education and training, to make our forest-based sector fit for Lisbon.
Further Details: www.forestplatform.org

FOREST OPERATIONS ENGINEERING AND MANAGEMENT – CHALLENGES AHEAD FOR HIGHER EDUCATION

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Keywords: forest operations, forest engineering, future challenges, curricular building blocks.

Abstract: *The forest engineering and management community has been facing the problems of lacking scientific visibility, realigning the research efforts to the future challenges, redesigning curricular building blocks in higher education, and strengthening visibility and self-confidence. The contribution explores the requirements for a university program in "Forest Operations Engineering and Management" by addressing three issues: (1) what has been the conceptual worldview (paradigm) that has been shaping forest operations engineering and management? (2) what are the main challenges that we will probably been faced with? (3) what are the implications for qualification profiles and curricular building blocks for an inspiring, forward-looking higher educational program? Based on previous work of the author, the "network paradigm" will be used as a foundation model. We will then explore the challenges and requirements that we will probably been faced with in the fields of "supply systems engineering", "operations management", "ergonomics", and "operations ecology". The contribution intends to trigger a broad discussion on higher education in the field of forest operations engineering and management, and hopefully to start a dialogue on future-oriented qualification profile of a university graduate.*

THE VIRTUAL FOREST - SPACE- AND ROBOTICS TECHNOLOGY FOR THE EFFICIENT AND ENVIRONMENTALLY COMPATIBLE GROWTH-PLANNING AND MOBILIZATION OF WOOD RESOURCES

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Keywords: forest planning, mobilization of wood resources, aerial photography, robotics, virtual reality

Abstract: *In order to support competitiveness on the worldwide market - but also to overcome efficiency problems related to the forest owner structure in North Rhine-Westphalia (NRW), Germany - the "Virtual Forest" is being developed as an intelligent planning and decision support tool for forest growth as well as for wood mobilization. In practice, the heart of the Virtual Forest consists of a database of approx. 240 million single trees in NRW, its major wood resource. In order to identify the trees, latest aerial survey and satellite technology is used and combined with virtual reality and robotics know how in order to efficiently gather and visualize the data. Thus, the Virtual Forest will serve as a reliable and very up-to-date base and framework for new efficient forest planning, wood mobilization and machine logistics methods.*

1. Introduction

The Virtual Forest (Rossmann 2007) is a joint effort of various partners who combine their know-how in the fields of automation/robotics, machine development and forestry to realize a comprehensive framework in order to identify, visualize and optimize biological and technical processes in the forest.

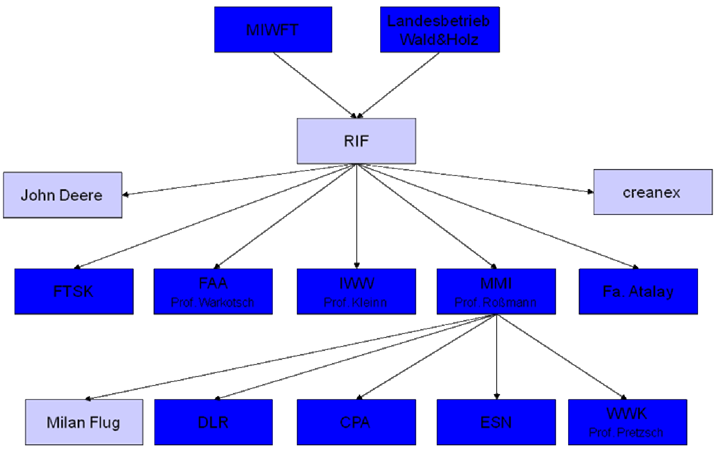

Fig. 1: Partners from science, industry and forest administration who contribute to the "Virtual Forest"

As shown in fig. 2, the developed methods draw from the fields of aerial survey technology, space- and terrestrial robotics, localization and navigation technology, sensor technology, virtual reality and – of course – latest silvicultural know how.

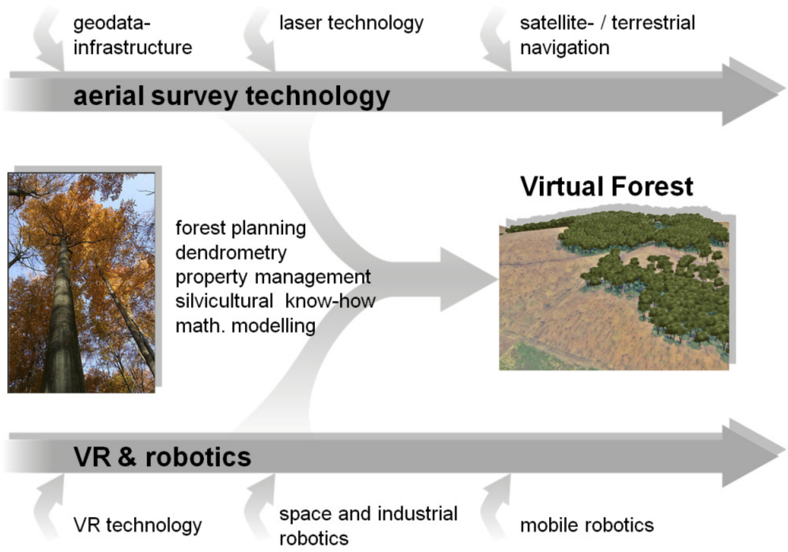

Fig.2: Combining the know-how of various scientific fields makes possible the “Virtual Forest”

The overall goal of the virtual forest is to develop a comprehensive database with a versatile structure which is able to hold all forest relevant data with a very high level of actuality. This database has to be filled in several steps to provide the necessary basic knowledge about the forest. The general idea is to use latest remote sensing technology, i.e. to fly an airplane or a drone to gather photogrammetric and laser based measurements about a forest. The sensed data then undergoes various image processing, object identification and classification procedures in order to derive tree-wise as well as stand-wise properties of the measured wood resources. The key to the success of this step is that a “multi-sensor-approach” is used which combines the data processing algorithms which have been and are being developed in cooperation with forest experts (see fig. 1) from all over Germany. These are currently being integrated into the Virtual Forest framework whose key design issue is to allow the algorithms to evolve. Whenever “ground truth” shows that the currently used algorithm does not provide satisfactory results, it may easily be changed or even replaced with an improved version. Thus the framework makes sure that it can always incorporate the most up-to-date state of science and technology.

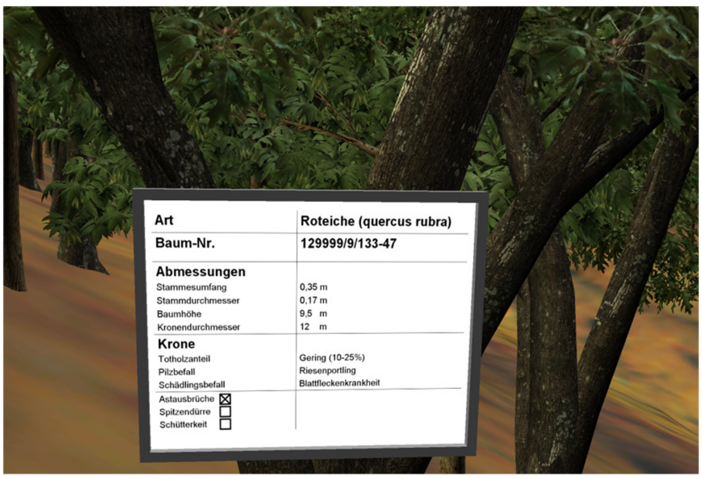

Fig.3: The results of the remote sensing step are “digital business cards” for each single tree

Fig. 3 show the results of this process for the tree-wise delineation: Every tree receives its “digital business card”, a collection of its properties that are relevant to its health, market value, treatment options etc.

Here, it is important to notice that by Virtual Forest ***not the virtual reality representation of the forest*** is meant, but ***the Virtual Forest is the resulting database of the single trees and the tree stands*** (where single tree data is not available or too expensive to gather).

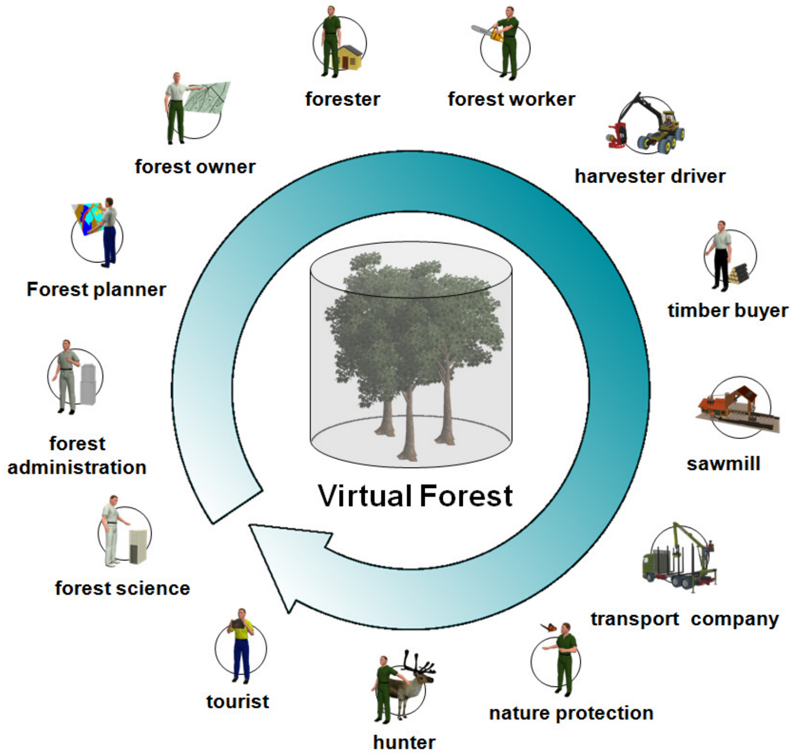

Fig.4: The Virtual Forest is being developed to be beneficial for various parties doing business in the forest

Of course, given the Virtual Forest database, it is rather straight forward to generate a corresponding virtual world of a forest as shown in many of the figures below. Although ***the virtual world is not the key result of the Virtual Forest***, it proved to be an ***exciting communication and crystallization point*** for the various partners (see fig.4) involved in forest related business models.

2. Application of the Virtual Forest Database in Practice

One of the design issues – and the reason why different automation experts (see fig. 1) are involved – is the practical applicability of the generated tools, methods and data in an foresters daily work. As doing business in the forest is complex and has a manifold of complex decisions to make and complex tasks to perform, the Virtual Forest project is devided into 21 sub-projects, of which the most important will shortly be summarized in this chapter.

2.1 Forest Planning

In order to support forest planning, a new 4D-GIS approach was realized, based on an innovative virtual reality and simulation software. In general, the 4D (i.e. the 4 dimensional) aspect was of utmost importance, because ***the fourth dimension - the time - is an important property*** of all information saved in the Virtual forest database. Thus, all objects are not only known with their geo-coordinates, but all related information is also time-stamped, so that a user immediately gets an impression, how current the presented information is. Furthermore, the Virtual Forest "never forgets" which means that no information entered will ever be deleted: It may be superseded by more current information, but it will always be kept in a revision history that can be questioned to provide a "look back into the past".

Being able to look back into the past is important in order to learn from the past, but combining this with capabilities to “look into the future” is the basis for economical success. Thus, the Virtual Forest integrates the tool SILVA (Pretzsch, 2002), a single tree based stand simulator, to provide a “look into the future” concerning the development of the stand.

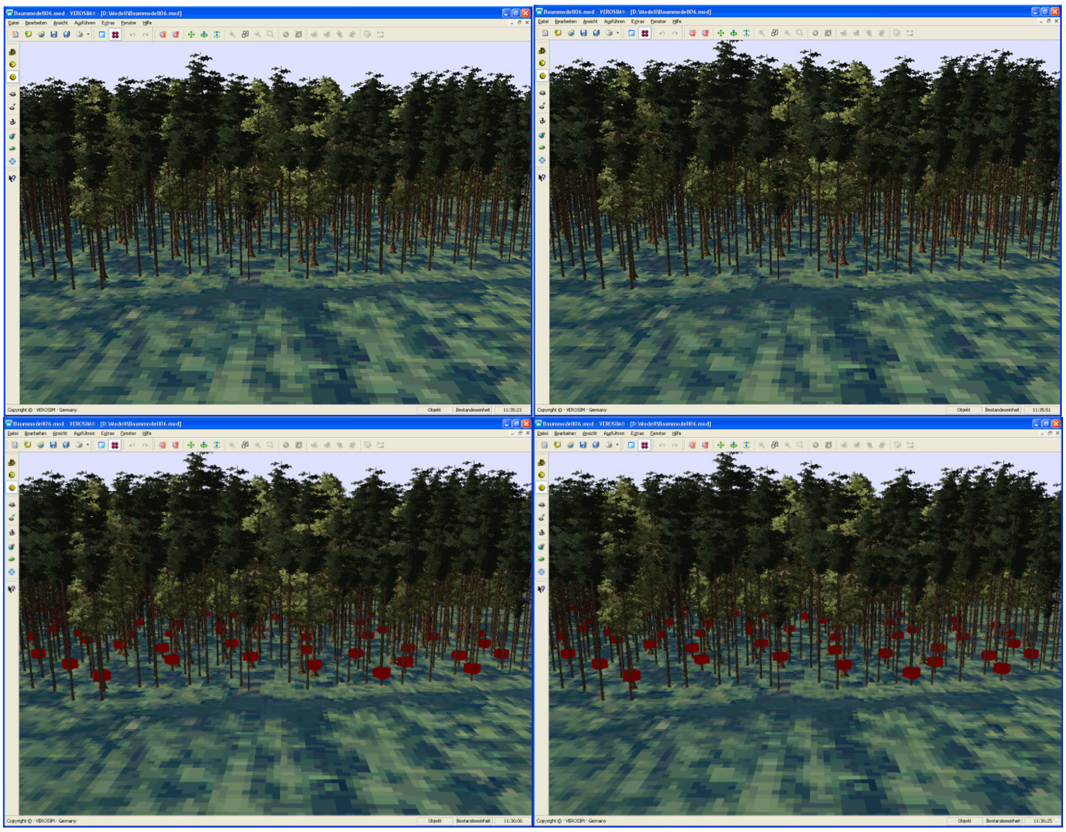

Fig. 5: From top left to bottom right – Results of the tree stand simulation with SILVA: The initial state of the stand, its state after 5 years of undisturbed growth, elite trees are chosen, support of elite trees through thinning

Fig. 5 shows a sequence of pictures which resulted from the stand simulation with SILVA predicting the development of a stand within the next 5 years – including the thinning recommended to support elite trees. The sequence of images in Fig. 5 is way more convincing if viewed directly in the virtual world of the Virtual Forest, because one can “see the trees grow” in time-lapse mode and feels like being inside a “time-machine”.

Whereas the single tree view is still a matter of science and research and is only just about to be introduced into a forester’s daily work, the stand-wise view is well known and accepted. Thus, the Virtual Forest also incorporates important aspects of today’s forest planning tools. By collaborating with Atalay Consult, Balve, Germany, renowned forest planning know how could also be integrated into the unifying framework of the Virtual Forest. As part of the cooperation, the existing forest planning software was made compatible to Virtual Forest data sources. On the one hand, this allows us to further use the proven prediction and forest planning tools of Atalay Consult based on the latest data sources. And on the other hand, the well understood forest planning methods serve as a reference to the new single-tree methods. An experienced forest planner can thus easily compare the results of the new approaches with the proven approach under one simple to operate user-interface.

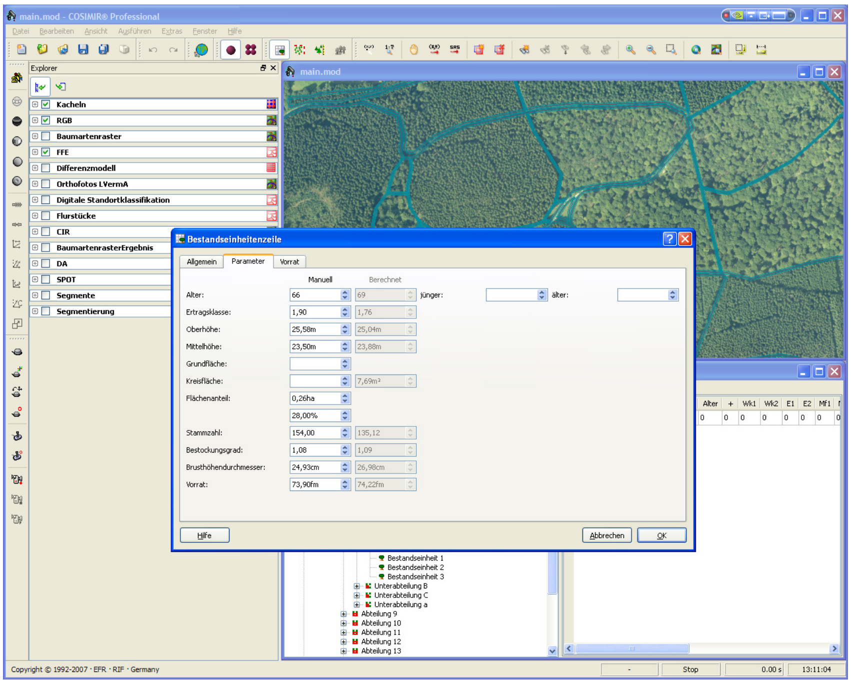

Fig. 6: State-of-the-art forest planning parameters and results may also be used in the Virtual Forest framework and are made available under a user-friendly user-interface

The 4D-Geo Information System (GIS) depicted in fig. 6 is a major, immediately usable outcome of the Virtual Forest for forest planning tasks. The user-interface has especially been designed for ease of operation and user-friendliness, and it is provided to support the daily work of the forester related to forest planning, environment protection, machine deployment and overall forest logistics and in-situ information collection.

It has to be stated here, that the knowledgeable forester is an important part of the Virtual Forest, because he/she has to verify the generated information against "ground truth" and has to add information that cannot be gathered by remote sensing technology, i.e. tree diseases, multi-level tree stands etc. On the other hand, the developed technologies relieve the forester from routine tasks like the measuring of tree heights and other tree properties that can well be derived from the gathered data.

2.2 Technical production

Another important aspect of the virtual forest is the support of the "technical production", i.e. the use of advanced mobile robotics technology in order to make the work of forest machines more efficient - e.g. by the introduction of a "automatic navigation to the next tree to fell"- feature - and also more environment friendly - e.g. by the support of automatic tire pressure control systems.

In order to be able to fully exploit the new capabilities of the Virtual Forest to support the technical production, i.e. the mobilization of wood resources, it is important that especially a harvester knows its exact location. If this is the case, the Virtual Forest's single-tree data, gained by the described remote sensing step, can be updated by incorporating the geo-referenced harvested trees: The harvester just has to "find out and remember" which tree was just cut and provide this information to back to the Virtual Forest. In the Virtual Forest database, those tree are then treated as "cut" and so the calculation of the available wood volume can incorporate the latest state without waiting for the next remote sensing flight.

Furthermore, this approach resolves a problem typical of the state of North Rhine-Westphalia (NRW) with its huge number of forest owners with only small parcels. About two thirds of the privately owned forest in NRW consists of parcels of a size between 0.5 and 1,5 ha per owner. Having this new single-tree based bookkeeping available, the felled trees can exactly be assigned to the parcel where they were felled – and thus to the owner.

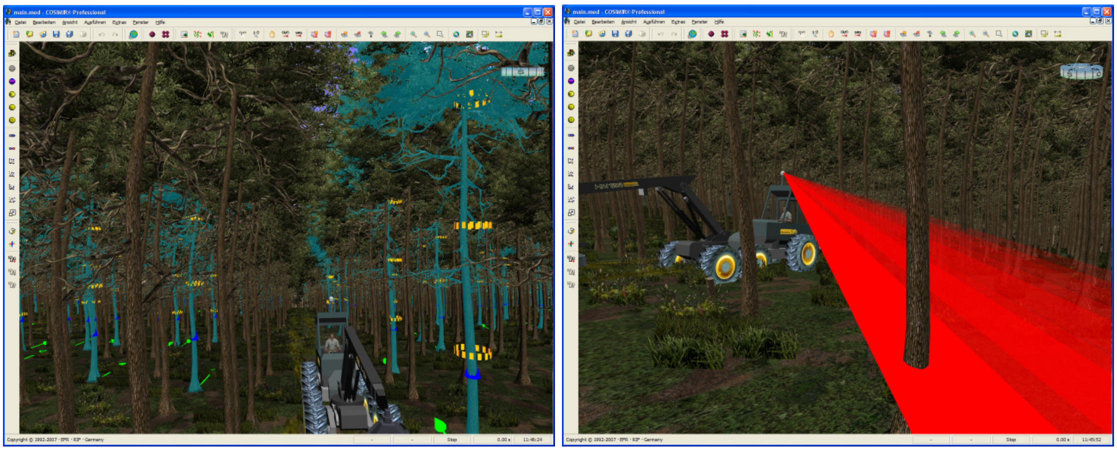

Fig. 7: Machine logistics, -deployment and –chaining in the Virtual Forest: The forest machines are equipped with new sensors to enhance effectiveness and

Various experiments showed that the GPS accuracy under the tree canopy is not sufficient to be able to identify and distinguish between single trees. Thus, the Virtual Forest supports the equipment of harvesters with “optical GPS”, a new technology that uses laser range finders (see fig. 7) in order to get a measurement of the trees close to its position. It then ***uses the single tree positions, previously generated for the Virtual Forest through remote sensing as a map to localize itself***. This is pretty much similar to human behavior: Look for landmarks, compare their configuration to a map, determine your position in the map.

First tests of this approach really provided amazingly good results. In a tree stand of spruce, age 80 to 100, the harvester was able to localize itself with an accuracy of approx. 30 cm, which is way sufficient for the bookkeeping as planned.

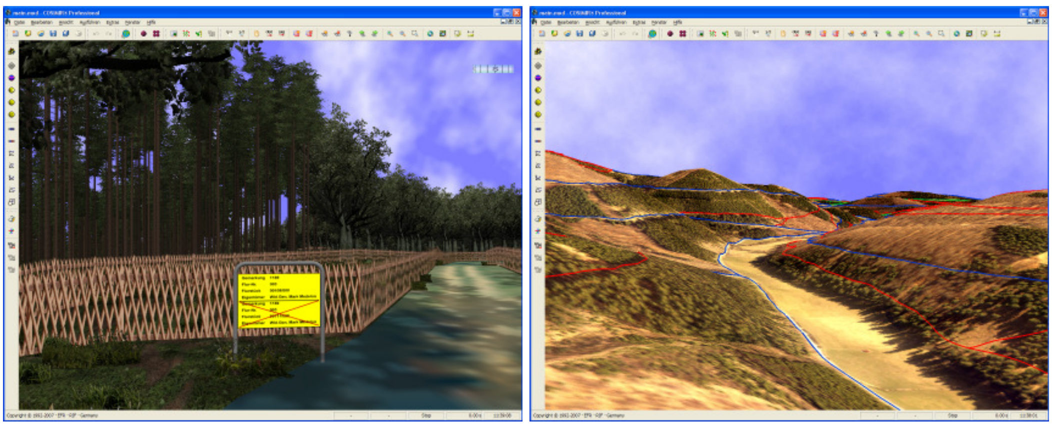

Fig. 8: “Virtual fences” are metaphors for parcel boundaries, working paths can be projected onto the terrain in order to evaluate potentially difficult working conditions

In order to facilitate the work for the harvester driver, metaphors are provided. Fig. 7 shows that the trees to fell are highlighted in light blue, so that the drivers can find the trees to cut easily. Fig. 8 shows “virtual fences” and virtual owner signs as metaphors of parcel boundaries, so that the driver can immediately see when he/she is crossing boundaries.

The right part of fig. 8 shows that in the Virtual Forest, the working paths of the forest machines can be projected onto the terrain. Terrain slopes can be viewed this way – or even better with the help of metaphors as shown in fig. 9. When preparing a forest machine operation, one can slide a "virtual spinning top" around in the terrain and watch its color. As soon as it changes from green to red, caution is advised, because the terrain might be too steep.

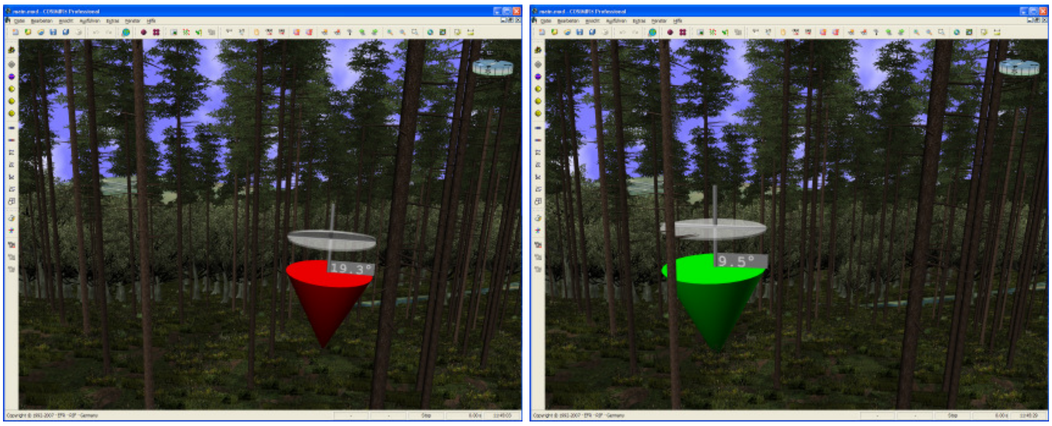

Fig. 9: Virtual "spinning tops" as metaphors provide information about the slope to expect and thus the difficulty of the terrain. A harvester probably would not want to enter a terrain where the color changed from green to red.

The next step is close: ***A navigation system for harvesters which guide the harvester to the next tree to fell.*** It is already possible today, to use computer software to automatically determine the trees to cut e.g. in a thinning operation. With the harvester navigation system, the chosen trees don't have to be marked with paint any more, their positions will just have to be downloaded into the navigation system.

Fig. 10: "Harvester navigation to the next tree": Is this the coming generation of harvester navigation systems which directly guide the driver to the next tree to cut. Look at the left onboard display!

Beyond the advantages described above, equipping a harvester with the laser sensors also provides important feedback for the remote sensing procedure: The remote sensing procedure derives e.g. the breast height diameter from the "visible, measurable or known" parameters of the tree like its height, crown diameter, age, water and nutrient supply etc.

This estimated breast height diameter can now be compared to the breast height diameters the laser sensor "sees" and thus serve as a basis to further improve the derivation model. Thus, ***"ground truth" for the Virtual Forest is provided for free***, as soon as the first thinning takes place.

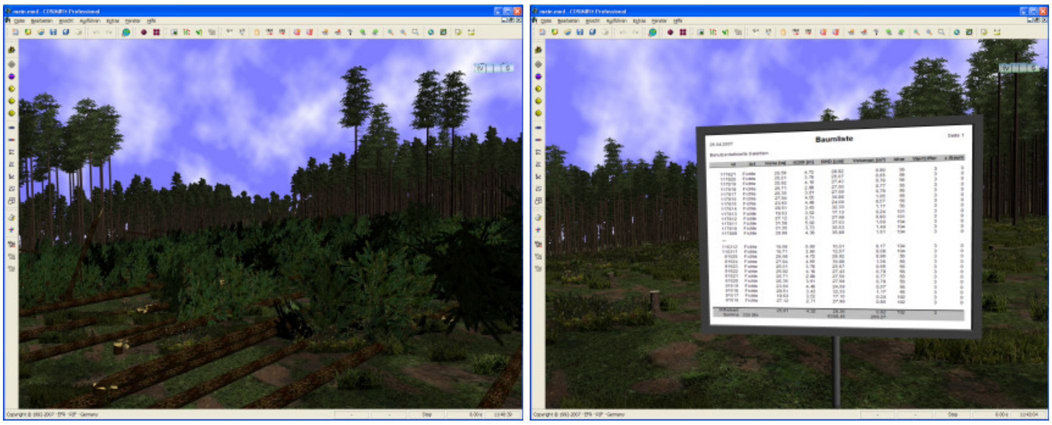

Fig. 11: The Virtual Forest does not only provide methods to quicker estimate the damages caused by windblow, it also provides the simulation methods to calculate the costs to cope with the damages

2.3 Advanced simulation technology

The Virtual Forest also drives forest machine simulation technologies to new heights – and to new application fields. A group of Virtual Forest partners around Prof. Warkotsch are currently developing a forest machine simulator that can not only be used for machine driver training, but also serves as the basis for the economical simulation of forest machine operation (Pausch 2005). The system allows to calculate the expected net profit by determining the logging cost with the help of an advanced simulation system. The determination of the logging cost can be performed very accurately today, because the approach carries out the logging ***in the virtual world as a simulation first*** and thus can calculate very precisely the logging cost to expect with respect to fuel, driving speeds, driver skills, machine capabilities etc.

Fig. 12: Advanced forest machine simulation technology is becoming more powerful but cheaper because the systems are now multi-use capable

As a side effect, this has opened a new application niche for the underlying simulator which originally was developed and marketed mainly for driver training. This new application opened new fields of application and lowered the introductory price for the driver training simulator to around 10.000€ which is almost an order of magnitude below current market prices and should further help to introduce latest virtual reality technology into the forest.

3. Conclusion

The Virtual Forest is about to become one of the most comprehensive and most current collections of knowledge about the forest and its wood resources available today. Thus, it has the potential to serve as the basis for economical success in the forest as well as for new scientific results related to the forest environment.The results gained so far are already promising and are currently being put to practical tests. It is important to the project not do develop another prototype, but to develop components that are readily available to foresters to alleviate their job.

Ranging from "biological production" to "technical production", the Virtual Forest is comparable to "Product Lifecycle Management" tools in e.g. the car industry. The complete lifecycle of the product "wood" is covered – but with a big emphasis on the biological production, i.e. tree growth. Thus, the implemented methods are equally well usable for nature protection purposes as for the evaluation of the efficiency of wood mobilization measures.

Integrating climate change effects together with new models to determine the effects and to evaluate countermeasures could be one of the next great challenges. The developed comprehensive database for such investigations related to the forest is available now through the Virtual Forest project.

Last but not least, the virtual worlds that can be generated from the Virtual Forest database will further help to understand the complex natural mechanisms. The generated virtual worlds – e.g. as shown below – can never substitute a real walk in the woods, but they can help to better understand how to sensibly use, preserve and protect it.

Fig.13: The Virtual Forest "at sunrise"

The authors would like to thank Dr. Franz-Lambert Eisele (Head of State Forestry Administration) and Dr. Rainer Joosten (Ministry of the Environment and Conservation, Agriculture and Consumer Protection of the German State of North Rhine-Westphalia) as well as Frank-Dietmar Richter (Chief Executive Officer "Landesbetrieb Wald und Holz NRW") for their various contributions to and support of the Virtual Forest project.

This work is supported by the State of North Rhine-Westphalia (NRW), Germany, the forest administration of Northrhine Westfalia and the European Union (Europäischer Fonds für regionale Entwicklung - EFRE)

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THE COMPATIBILITY BETWEEN THE FOREST OPENING-UP WORKS AND NATURAL ENVIRONMENT IN THE MOUNTAINOUS REGION OF METSOVO

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Keywords: compatibility, forest opening-up, G.I.S., natural environment

Abstract: *The need for the "Development and Protection of the Mountainous Regions" and at the same time the protection and preservation of its available natural assets has become a global concern. The purpose of this study is to examine the compatibility of the opening-up forest works with the natural environment of the mountainous region of the Municipality of Metsovo and afterwards to estimate the contribution of this method to the sustainable development of this area. Therefore, the intensity of the consequences that the opening-up forest works have caused to the natural environment of the area is examined by using countable criteria. The ability of absorption by the forest ecosystem has been also studied. The Geographic Information Systems gave the efficient and reliable rate extraction for these criteria. The results testify that the use of this method provides the estimation of the existing opening-up forest works and the selection of the compatible solution.*

1. Introduction

The development of an integrated forest opening-up method with forest works such as primary haul roads, haul passages and staking grade line harvesting methods (tractor roads, hauling road path) of wood, constitutes an interference to nature. This has to be studied with a very critical mind from the ecological aspect because of the consequences to the natural environment (Sedlak, 1993; Becker, 1995). Since the forest opening-up is inevitable, (Heinimann, 1994) in order to achieve their commercialization and at the same time their protection that corresponds to the viable development and the efficient forest fire confrontation, a golden section has to be found.

Contrary to the classical opening-up methods, which are mainly based on financial criteria, a method for the forest roads appreciation including financial,ecological and social criteria has to be developed (Doukas, 1994; Doukas and Akca, 1998). In this case, the straightforward forest opening-up as an independent variable in the model shouldn't be accepted, but as a part of the whole (Warner, 1973) because of the close connection to the development of the each time area that contributes to the protection of the natural attraction. It is very hard to estimate the forest opening-up consequences with financial extents by using familiar methods such as cost-benefit analysis. In order to estimate these consequences, the compatibility of the opening-up forest works with the natural environment could be used (Bürger et al., 1987; Doukas, 2004). That requires the use of countable criteria for the intensity of human impact to the forest ecosystem and the forest ecosystem absorption of the opening-up forest works. With the term "compatibility with the natural environment" we mean the definition, the description and the estimation of the impacts of an opening-up forest works to the natural environment as well as to take measures for its protection.
The study and the analysis of the compatibility criteria of the opening-up forest works with the natural environment, is accomplished with objective and financial manner with the use of the PC and the application of the software GIS (AutoCAD Civil 3D, 2008).

2. Materials and Methods

As a study area, we chose the sections 3 and 4 (Figure 3) of the municipal forest of Metsovo, in the Prefecture of Ioannina. These forest sections are in a road distance 23Km Northern from the Municipality of Metsovo. Specifically, the study area is situated at 21° 05′ 89′′ and 21° 10′ 56′′ Northern Latitude and between 39° 82′ 34′′ until 39° 85′ 49′′ Western Longitude from the bases of the National Observatory of Athens. The extension of the study area ascends 580ha. The study area (Figure 2) is represented at the orientation map (Figure 1).

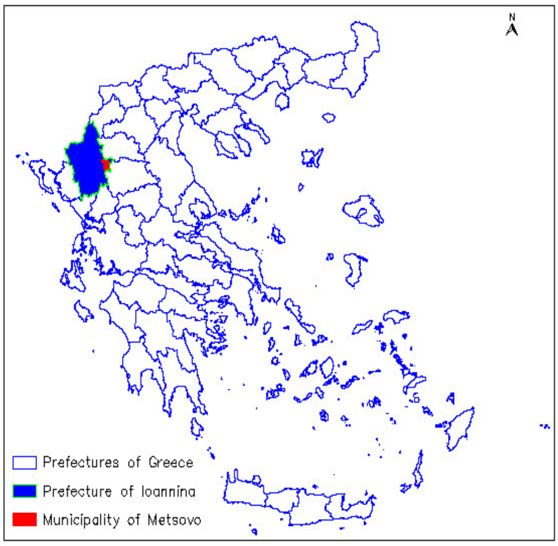


Figure 1. Orientation map of the study area

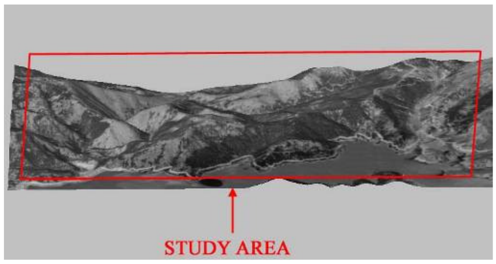


Figure 2. Study area

For the needs of the research we used: The digital orthophotomaps (248_413, 252_413) of the area and the respective digital terrain models DTM. Thus, the land use and the forest road net were digitized and finally, we extracted proof measurements that regard the extract of the land use area and the length of the forest road net (Doukas, 1995). We also used the forest management study for the municipal forest of Metsovo for the years 2005-2014 and we utilized factors such as harvesting, the management aspect, the already existing forest species, tree age etc. For the definition of the intensity of the human impact to the natural environment from the existing forest opening-up works and the exploit of the forest, we used respective criteria (Buwal, 1990; Mader, 1990; Heinimann, 1994; Doukas, 2004). At the same time were specified the importance (Gravity) factors that represent the intensity value of each criteria from scientists' opinions.

In detail, the intensity criteria that were used are:
1. Road Density. Logging means: Tractors. The excess percentage of Dec and Dmax is rated as the reduction of the optimum 100. The comparison of the existing road density Dex with the optimum theoretical Dth and the optimum economical road density Dec is based on their calculation applying the Kroth method (Kroth, 1973; Doukas, 1984; United Nations, 1988; Zundel, 1990; Trzesniowski, 1993). Importance (Gravity) factor: 3.

2. Use of tractors in skidding. The percentage of the use of tractors for skidding is rated as the reduction of the optimum 100. Importance (Gravity) factor: 2.

3. Opening-up percentage. The reduction percentage of the forest opening-up from forest roads and tractor roads which is <70%, is rated as the reduction of the optimum 100. Importance (Gravity) factor:

4. Skidding direction (horses, tractors, cable winches). The skidding direction percentage which is <45° comparing to the vertical to the road skidding, is rated as the reduction of the optimum 100. Importance (Gravity) factor: 1.

5. Traffic load and truck type. a) The excess percentage of the traffic load, in comparison to the one that is justified from harvesting, is rated as the reduction of the optimum 100. Importance (Gravity) factor: 2. b) The excess percentage due to truck overloading of the uniform truck loading according to the rules is rated as the reduction of the optimum 100. Importance (Gravity) factor: 2.

Afterwards, the ability of absorption of the forest ecosystem of the forest opening-up work impacts was studied. Specifically, the term absorption is defined by whether the impact effect will be absorbed from the forest ecosystem as time passes, as well as the number of impact receivers.

The estimation criteria of absorption that were studied and the respective importance (Gravity) factors are:

1. Forestry Criteria. Importance (Gravity) factor: 3.

a) Land uses: Woodlands: 100%, Forest area: 25-50%, no vegetation 15%.
b) Forest species: Coniferous: 65%, Broad-leaved: 75%, Mixed 100%.
c) Forest management aspect: High forest: 100%, Coppice forest 50%, Coppice with two ages of standards: 75-100%.
d) Forest age: Even aged: 50%, Under conversion to an uneven aged: 100%, Uneven aged: 75%.
e) Tree height: High >20m: 100%, Medium 10-20m: 75%, Low <10m: 25-50%.
f) Soil quality: I-II: 100%, III-IV: 50%, V-VI: 25%.
g) Forest productivity (Harvesting): High >3 m^3/year × ha: 100%, Medium 1-3 m^3/year × ha: 50%, Low <1 m^3/year × ha: 25%.

2. Topographical criteria. Importance (Gravity) factor: 2.

a) Slopes: High >20%: 5-25%, Medium 8-20%: 50%, Low <8%: 100%.
b) Directions: Northern: 70%, Eastern: 100%, Southern 70%, Western 100%.
c) Terrain relief: Mild: 100%, Various: 50%, Intense: 15%.

3. Social Criteria (number of receivers). Importance (Gravity) factor: 1. Depends on the number of people that accept the effect (receivers).

a) The tourist resort.
b) The national road net.
c) The railway net.
d) The archaeological area.
e) The neighbour city.
f) The neighbour village.
g) The European pathway.
h) The natural or artificial lake or river.

The rating of the criteria above, depends on the number of people that accept the effect and is rated 25% if the receivers are many, 50% if the receivers are a few and 100% if there aren't any.

The value (%) that estimates the impact intensity (I), which is not negative, is multiplied by the respective importance (Gravity) factor (B_I) and is divided by the sum of the importance (gravity) values so as to extract the barycentric average $\Sigma I=\Sigma(I \times B_I)/\Sigma B_I$. Likewise, the absorption (A) of the forest ecosystem, is multiplied by respective importance (Gravity) factor (B_A) and is divided by the sum of the importance (gravity) values so as to extract the barycentric average $\Sigma A=\Sigma(A \times B_A)/\Sigma B_A$.

The rates ΣI and ΣA represent the indexes that regard the degree of compatibility of the forest opening-up works with the natural environment.

3. Results

Rating of the intensity for each criteria of human impact (intensity) to the natural environment:

1. Road density: For the definition of the existing road density we applied the software AutoCAD Civil 3D 2008 (definition of topology, road length measurement, mensuration) from the digitized map of the study area that derived from the respective orthophotomap. For the determination of the mean vertical skidding distance, the mean inclined skidding distance and the curvature coefficient we applied the software GIS taking under consideration the logging means (tractors, two-sided skidding). The values that were rated are: Dex=28.31m/ha (Dex: existing road density) and Dec=Dthex:

$$Dthex = \frac{2500\ \ 100\ \ \sqrt{2}}{REm^{\kappa}\ \ E} = 24.14 \text{ m/ha} \qquad (1)$$

where Dec is the optimum economical road density equal to Dthex that is the theoretical existing road density, REm^{κ} is the mean inclined skidding distance for inclination ≤25%) = 217.73m and E is the opening-up percentage = 67.27%. The excess percentage of Dthex=24.14m/ha, and of Dex=28.31m/ha is 17.27%, therefore the value of the criteria is 82.73%.

2. Use of tractors in skidding: At the study area, are exclusively used tractors (Figure 5), therefore the tractor use percentage is 100% and the criteria value is 0%.

3. Opening-up percentage: The opening-up percentage was calculated by creating in the digitized map, a zone of width twice as the mean horizontal skidding distance (REm^{hor} = 217.73m) and both sides of the forest road in the study area (Figure 3). The skidding percentage is 67.27%, therefore the reduction percentage which is below 70% is 4.06% and the criteria value is 95.94%.

4. Skidding direction: The skidding direction is always >45º if tractors are used as skidding mean. Therefore, the criteria value is 100% (Figure 4).

5. Traffic load and truck type. a) The excess percentage of the traffic load: At the study area we observed excess of the traffic load (30 tractors) comparing to the admissible from harvesting, number of tractors (26). Therefore, the excess percentage is 13.33% and the criteria value is 86.66%. b) The excess percentage due to truck overloading: We observed excess of the truck loading, 35tn rather than 32tn. Therefore, the excess percentage is 8.57% and the criteria value is 91.43%.
Rating of the absorption ability of the skidding consequences from the forest ecosystem:

1. Forestry criteria.

a) From the digitized map of land uses is clear that the 47.5% of the study area is covered by woodlands, the 23.1% from forest area and the 29.3% has no vegetation. Therefore, the absorption is 63.445%.
b) Likewise, the study area is covered by coniferous trees with absorption 96.72% and by broad-leaved trees with absorption 3.28%.
c) The forest management aspect is high forest with maximum absorption 100%.
d) The forest age is under conversion to an uneven aged forest with maximum absorption 100%.
e) The mean tree height, arises for the 60% from 10-20m, 35% >20m and 5% <10m, therefore the absorption for this criteria is 82.5%.
f) The soil quality is I-II: 30.34%, III-IV: 61.89% and V-VI: 7.76%, therefore the absorption is 63.225%.
g) The forest productivity (Harvesting) is 1.86 m^3/year×ha, according to the last forest management study which is 1-3 m^3/ year×ha. Therefore, the absorption is 50%.

2. Topographical criteria. For the extraction of the absorption values we created slope and direction maps, applying the software AutoCAD Civil 3D 2008 and the digital terrain models DTM of the area.

a) At the slope categories 0-8%, 8-20% and 20-100%, correspond to the percentages 2.46%, 9.27% and 88.27% (Figure 6).Therefore, the criteria value is 29.165%.

b) Likewise, the directions are: Northern: 31.93%, Eastern: 18.52%, Southern: 28.35%, Western: 21.20% (Figure 7). Therefore, the criteria value is 81.92%.

c) The Terrain relief is described as intense with absorption value 15%.

3. Social criteria.

a) The study area is a tourist resort, since in a road distance of 23 km there is the town of Metsovo, in a road distance of 17 km there is the ski centre and in a road distance of 3 km there is the artificial lake and the Aoos river sources. The absorption is 30%.

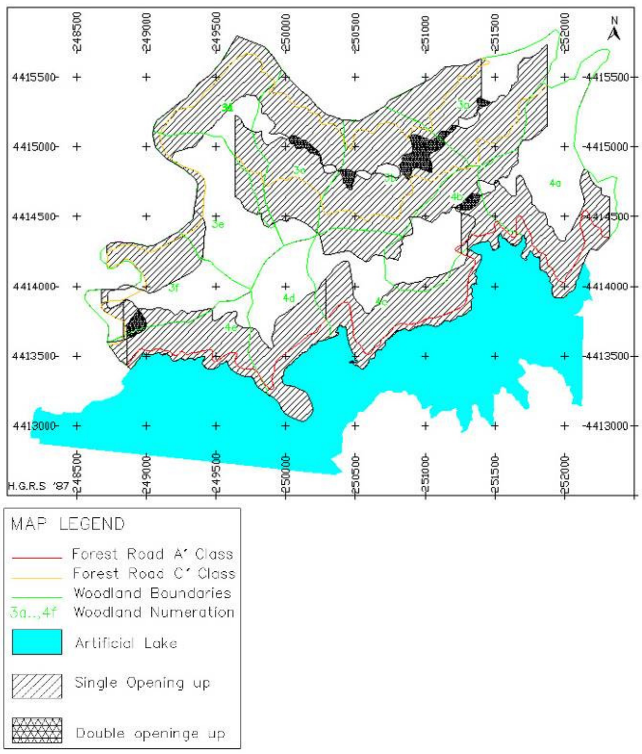
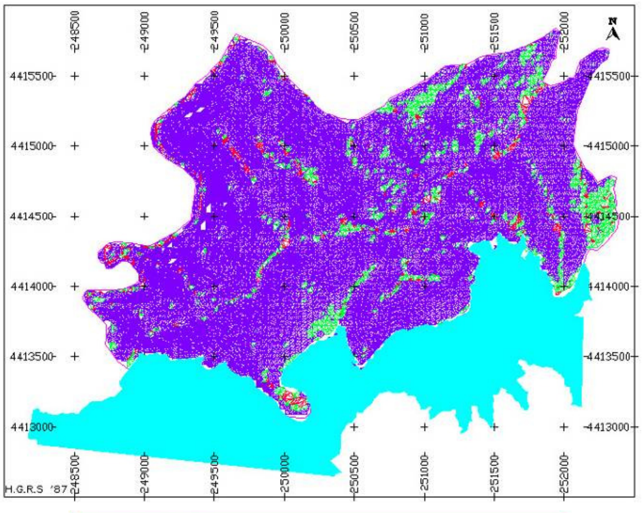


Figure 3. Percentage of opening-up

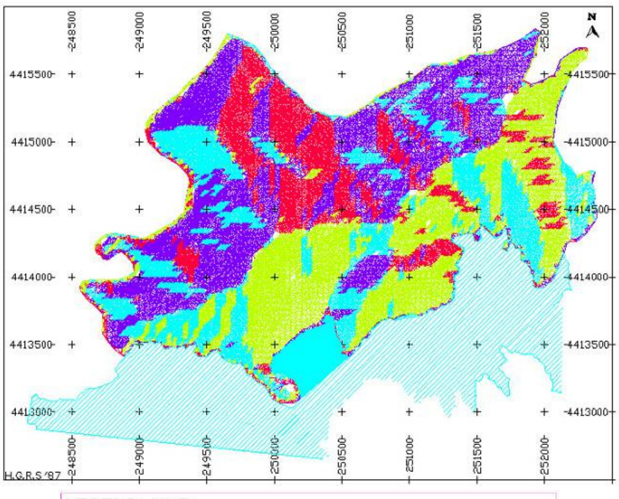
Figure 4. Skidding direction
Figure 5. Tractor



Slopes Table				
Number	Minimum Slope	Maximum Slope	Color	2d Area
1	0.00%	8.00%		137781.84
2	8.10%	20.00%		519233.54
3	20.10%	100.00%		4940952.74

Artificial Lake

Figure 6. Slopes map



Directions Table				
Number	Minimum Direction	Maximum Direction	Color	2d Area
1	0.00	100.00		1074271.91
2	100.10	200.00		1645187.13
3	200.10	300.00		1227819.29
4	300.10	399.92		1852143.71

Artificial Lake

Figure 7. Directions map

b) The national road net of the study area connects Metsovo with the villages of Eastern Zagori. Only a small number of vehicles pass through the national road net of the area only during summer, thus the criteria value is 95%.
c) There is no railway net passing through the study area, thus the criteria is not valued.
d) There is not an archaeological area in the study area, thus the criteria is not taken under consideration.
e) There is no a neighbour city, since the closest town is Grevena in a road distance of 60 Km and Ioannina in a road distance of 70 km. The criteria are not valued.
f) There is no a neighbour village in the study area. Metsovo is in a road distance of 23 km and the villages of Eastern Zagori are at least 15 km far from the study area and only there only a few habitants only in the summer. The criteria value is 90%.
g) There is no a European pathway in the study area thus the criteria isn't valued.
h) In the study area there is the artificial lake of the Aoos river sources and the Aoos River, therefore, the absorption is 30%.
In the tables below are presented in brief the percentages of the intensity and the absorption criteria as well as the respective rates ΣI and ΣA:

TABLE 1. Criteria of intensity

INTENSITY				
acn	**Criteria**	**Rate (%)**	**Importance**	**SUM**
1	Road density	82.73	3	248.19
2	Percentage of use tractors during skidding.	0.00	2	0.00
3	Opening-up percentage.	95.94	3	287.82
4	Skidding direction	100.00	1	100.00
5	Traffic load and truck type			
a	Excess percentage of the traffic load	86.66	2	173.32
b	The excess percentage due to truck overloading	91.43	2	182.86
	SUM		13	992.19
	Average $\Sigma I=\Sigma(I\times B_I)/\Sigma BI$	**992.19/13=76.32%**		

TABLE 2. Criteria of absorption

ABSORPTION				
acn	**Criteria**	**Rate (%)**	**Importance**	**SUM**
1	**Forestry Criteria**			
a	Land uses	63.445	3	190.335
b	Forest species	65.330	3	195.990
c	Forest management aspect	100.000	3	300.000
d	Forest age	100.000	3	300.000
e	Tree height	82.500	3	247.500
f	Soil quality	63.225	3	189.675
g	Forest productivity (Harvesting)	50.000	3	150.000
2	**Topographical Criteria**			0.000
a	Slopes	29.165	2	58.330
b	Directions	81.920	2	163.840
c	Terrain Relief	15.000	2	30.000
3	**Social Criteria**			0.000
a	Tourist resort	30.000	1	30.000
b	National road net	95.000	1	95.000
c	Railway net	-	-	-
d	Archaeological area	-	-	-
e	Neighbour city	-	-	-
f	Neighbour village	90.000	1	90.000
g	European pathway	-	-	-
h	Natural or artificial lake or river	30.000	1	30.000
	SUM		31.000	2070.670
	Average $\Sigma A=\Sigma(A\times B_A)/\Sigma B_A$		**2070.670/31=66.80%**	

4. Conclusions

The maximum road density (Dmax) can be:

$$Dmax = \frac{\sqrt{18123.2\ N\ E\mu}}{Su} = 36.10 \text{ m/ha} \qquad (2)$$

where Dmax is the maximum road density, N is the annual harvesting, = 1.86 m^3/year×ha, Eμ are the variable skidding costs = 0.0162 euro/m^3 (A.R.R.B.W., 2006) and Su are the annual maintenance costs of forest roads = 0.42 euro/current meter.

Therefore, in the study area, 580(36.10-28.31) = 4518.2 m of new tractor roads have to be added and from the existing forest roads, 580(28.31-24.14) = 2418.6 m should be converted to tractor roads. Thus, the skidding percentage will be increased and will arise at 70%. The new roads (there were added 4540 m and converted 2425 m) are presented in figure 8.

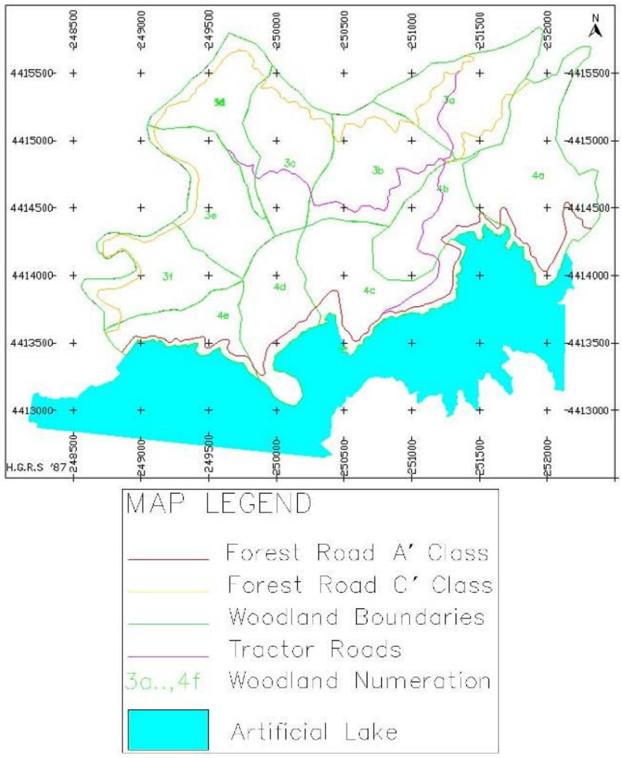


Figure 8. New tractor roads

The average of the positive intensity of the impact that arises from the study area (ΣI=76.32%), represents that the existing forest opening-up works were constructed in a compatible for the environment way. It is confirmed from the absorption average which was calculated (ΣA=66.79%), that the specific forest ecosystem has absorbed the negative consequences that came from the forest opening-up works. The above conclusions are based on countable values, which constitute indexes of environmental consequences from the forest opening-up works to the natural environment. The application of this method is considered to be reliable not only for the estimation of the existing forest opening-up works but also for the study of their impact to the environment before the construction of new ones. The usage of the PC and the GIS technology, contributes to the application of the method for the calculation of most of the intensity and absorption criteria values. A suitable database is required for the application of the method. Thus, the data processing is achieved quickly and the creation of digitized maps and diagrams for various suggested road nets is evitable.

The application of an integrated development of the area, must be based on the viable development which depends on the preservation of the natural environment, the activation of the human and social resources, the utilization of the special social, cultural and financial characteristics that the Municipality of Metsovo offers. For the achievement of the above development model, major role would play the study of the intensity consequences that the forest opening-up works have caused to the natural environment as well as the estimation of their absorption. The study results will be straightly exploited, as improvement standards for the construction of forest roads and greater forest works will arise, under the prism of the compatibility with the natural environment.

5. Acknowledgements

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USING NETWORK ANALYSIS TO OPTIMIZE FOREST ROAD NETWORK FOR CABLE LOGGING

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Keywords: Cable logging, Road density, Road network, Optimization, Network analysis

Abstract: *Cable logging systems are common in mountainous forests of Austria where 19% of the woods are harvested by cable cranes. There has been a classical method to optimize the road spacing or road density based on the minimization of yarding and roading costs in the past years but this method does not give the possible road locations to the planners.*

In this paper, the developed time predicting models of yarding and installation costs of Syncrofalke tower yarder are used to calculate the yarding cost per cubic meter for the planned cable corridors in a mountainous forest area of 196 ha. Different roads were planned to open the area. The roading costs of the segments are computed using the slope map of the logging block. The data were imported to NETWORK 2000. The shortest path algorithm, simulated annealing and great deluge algorithms were run to find the best solution where the planners could decide what possible road segments can be eliminated from the planned road variants to optimize the total cost of logging.

1. Introduction

Austria is a mountainous country in central Europe. About 60% of the forests has slope greater than 30% and 22% of the forestlands are located in the steep ground with slope more than 60%. Hilly terrains and mountainous forest regions led to use cable yarding systems in this country. About 19% of harvesting operations are done by cable crane. The common types of cable logging systems are sledge winch, tower yarder and self propelled carriage. Tower yarders are more common cable cranes used in cut to length or whole tree yarding systems. Road planning is an important step in planning the forest operation. Optimization of the road network can help minimize the total cost of harvesting. The average road density in Austrian forests is 45 m/ha (www.bfw.ac.at). The optimal road density of one-way forwarding operations of 19.9 m/ha has been reported by Ghaffarian et al (2007). For one-way cable logging in Southern Austria where the roading cost per meter does not have high changes, Ghaffarian et al (2007) reported an optimal road density of 55.6 m/ha.

It is necessary to determine optimal road density to minimize the combined logging and road cost. Many researchers have studied optimum road spacing. Matthews (1942) was first and developed a model to define optimum road spacing based on minimizing the total cost of skidding and roading from the viewpoint of a landowner. Using the minimization of total cost method can only give the planner a guide for road network planning. The roads can not be placed anywhere and it is necessary to locate the roads in the place which help minimizing the road construction and yarding costs. Usually cable logging systems are applied in hilly terrains where the roading cost is different depending to the ground slope. The Matthews' formula assumes roads can be placed almost anywhere, the unit cost of road construction is constant anywhere in the landscape, and road gradient is not limiting. These assumptions can not be verified in mountainous, roughly and steep terrains. Therefore the other approach should be used in road network optimization in slope areas.

In the past years, mixed integer mathematical programming and heuristic algorithms such as TIMBRI (Sullivan, 1974), TRANSHIP (Kirbey et al. 1981), MINCOST (Wong, 1981), NETCOST (Weintraub, 1990), NETWORK (Sessions, 1978) and NETWORK 2000 (Sessions and Chung, 2003) have been used to find the appropriate solution for certain fixed and variable cost problems. Sessions (1992) introduced the method of using network analysis for road and harvesting planning which is applied in this study. Tan (1999) developed a spatial and heuristic procedure to locate forest roads. He reported that the improved procedure proved to be beneficial in helping forest road planning managers evaluate alternatives and hence select the optimal location for a road network. Stueckelberger et al (2006) considered roading cost, ecological effects and suitability for cable yarding landings in their automatic road-network planning using multi-objective optimization in Switzerland. The network analysis was used to optimize an existing forest road network of skidding operations in Northern Iran (Ghaffarian and Sobhani, 2007).

Unlike the case study of optimal road spacing in Southern Austria, roading cost in Northern case study is different. In Steyr and Gmunden, Limbeck-Lilienau (2002) studied the production of cable logging using the Syncrofalke tower yarder. Using her time study data base, a time predicting model is developed using multiple regression and ORS for one and two-way yarding. Optimal road network is studied in a sample forest area using network analysis to find the best possible road network.

2. Method of study

2.1. Site of study

The site study located in Steyr and Gmunden in Northern Austria was harvested using the Syncrofalke tower yarder (Table 1). The Synkrofalke tower yarder was used to yard the whole trees to road side in this study. This yarder was combined with a Wolf 50 B processor (Figure 1). The working team consisted of two persons; a yarder operator and the chainsaw operator who did felling, topping and choker setting. The yarder operator was free to start delimbing and bucking the tree using the processor when the carriage was at the landing and during out-haul. The yarding was done uphill and downhill (Limbeck-Lilienau, 2002).

Table 1. Site study description

Yarding distance (m)	0 to 300
DBH (cm)	28 to 32
Tree volume (m^3)	0.67 to 1.06
Slope of cable way (%)	32 to 60
Stand composition	Fir-Larch and Beech
Stand density (n/ha)	551-745

To study the optimal road network using the network method, a digital map of a forest area of 196 ha in the northeast of Austria was used. Most part of this sample area was steeper than 35%.

Figure 1. Syncrofalke tower yarder combined with a Wolf 50 B processor (Photo by B. Limbeck-Lilienau)

2.2. Yarding time predicting model

The variables such as yarding distance, lateral yarding distance, load volume, tree volume, harvest intensity, stand density, yarding direction, harvesting time (summer or winter) and slope of cableway were used in modeling. The multiple regression and stepwise method was applied to develop a model to predict the time of yarding per cycle. In this method, if the desired variables have significant effect on residual mean squares of model, they enter the model.

2.3. Road spacing

The roading costs in Steyr and Gmunden vary from 14 to 100 Euro/m. The forest road specifications are presented in table 2. The logging volume ranges from 100 to 230 m^3/ha. The hourly cost of the tower yarder is about 205 Euro/h.

Table 2. Specifications of forest road in Austria

Specification	Main road	Secondary road
Use	Truck and trailer	Truck
Passage time	Permanent	Saisonal
Roadbed width	5-5.5	4.5-5
Road way width	3.5-4	3-3.5
Max. longitudinal gradient	10(12)	12 (15)

Stampfer et al (2006) developed the estimated time to set up and take down the cable yarding systems in Austria for different systems. Their models were used to calculate the installation cost per cubic meter

Installation time (hrs) = Set-up (hrs) + Take-down (hrs) (1)

Set-up time (hrs) = EXP (1.42 + 0.00229 x corridor length (m) + 0.03 x int. support height (m) + 0.256 x corridor type - 0.65 x extraction direction + 0.11 x yarder size + 0.491 x extraction direction x yarder size).

$R^2 = 0.78$ (2)

Take-down = EXP (0.96 + 0.00233 x corridor length (m) - 0.31 x extraction direction - 0.31 x int support + 0.33 x yarder size).

$R^2 = 0.64$ (3)

The proposed roads were planned in the sample logging area. The total number of potential roads was 16,624 m as a density of 84.8 m/ha (Figure 2). A maximum longitudinal gradient of 12% was used to plan the roads. The slope was classified to four categories of 0 to 35 %, 35 to 60%, 60 to 90 % and 90 to 132%. The skyline corridors were planned for the whole area based on the topography and road locations. The spacing of corridors was assumed as 30 meters. Since uphill yarding is more productive than downhill yarding, uphill yarding was used where possible. The area and logging volume per each corridor were computed. The corridors with similar yarding distance or direction were grouped (Figure 3 and 4) as a node or segment. The roading cost per each segment was calculated base on the table 3 and length of the road. For the planned area, four mills and one final mill or destination were considered.

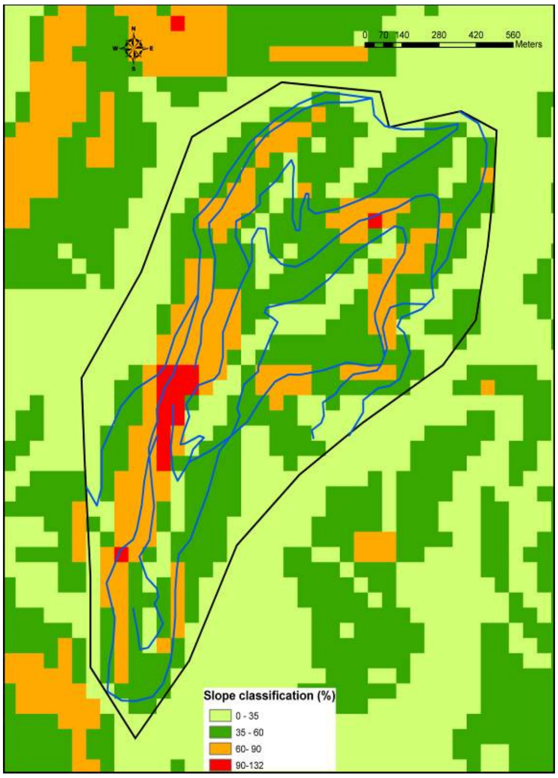

Figure 2. Planned roads in the sample area

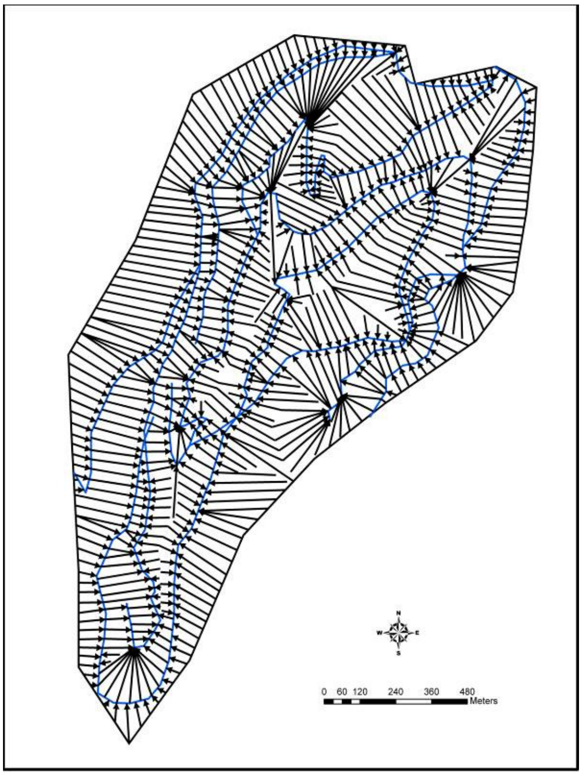

Figure 3. Planned cable ways and yarding direction

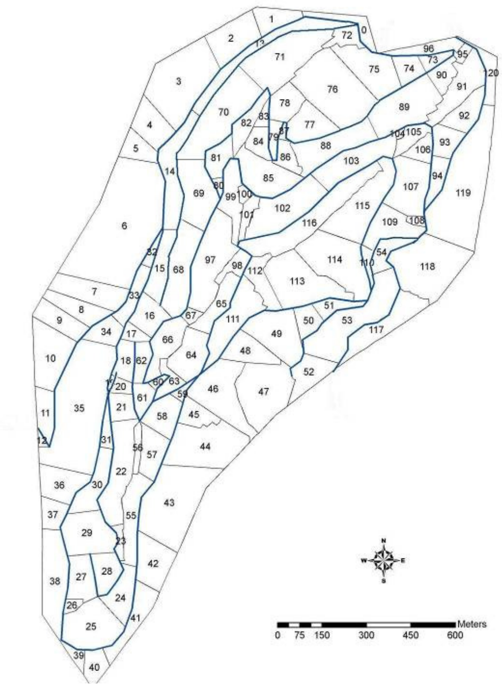

Figure 4. Grouped corridors (Segments) of sample area

Table 3. Assumed road construction cost as a function of ground slope

Ground slope (%)	Road construction cost (Euro/m)
0-35	14
35-60	28
60-90	50
90-132	100

To solve the shortest path subproblem within the shortest path heuristic, a variant of the Dijkstra algorithm is used. The basic premise of this algorithm is to find the length of the shortest path between the starting vertex and first vertex; then the length of shortest path between the starting vertex and second vertex; continuing until the length of the shortest path between the starting vertex and ending vertex is found.

Simulated annealing (SA) is a search technique which exploits an analogy between the ways in which a metal cools to a minimum energy crystalline structure (the annealing process). It forms the basis of an optimization technique for combinatorial and other problems. The algorithm employs a neighborhood random search which not only accepts changes that decrease the objective function (assuming a minimization problem), but also some changes that increase it as a way for avoiding being trapped in local minima.

The great deluge algorithm (GDA) is a recently developed variant on simulated annealing. It is similar to SA in that only a single change is considered to a "current" solution, the resulting temporary solution is evaluated, and a decision is made whether or not convert the temporary solution to the current solution (Bettinger et al, 2002).

The GDA was introduced by Dueck (1993) and proved superior to similar Monte-Carlo based algorithms in solving a 442-city and 532-city Traveling Salesman Problem. The form of the GDA as presented by Dueck (1993) consisted of using a single parameter in the determining of whether or not to convert the temporary solution to the current solution (and perhaps change to an inferior solution). The use of one parameter rather than two, as in a simulated annealing algorithm, is believed to de-sensitize the algorithm thus leading to equally good results even when parameter estimation and formulation is poor.

The objective of the network problem is to minimize logging and road cost. The network model for the 196 hectare problem is expressed mathematically as:

$$\text{Minimize } z = \sum_{i=0}^{i=120} Yc_i V_i + \sum_{i=0}^{i=120} Rc_i V_i \qquad (4)$$

Subject to: $V_i \geq 0$, $Yc_i \geq 0$, $Rc_i \geq 0$

Where: Yc_i= logging cost per node per m^3

Rc_i= Roading cost per segment

V_i= Logging volume per node

3. Results

3.1. Yarding model

Time (min./cycle)= 0.005× Yarding distance (m)+ 0.054× Lateral yarding distance (m)+ 1.019×Load volume (m^3)+ 0.023× Harvest intensity (%)+ 0.002× Stand density (n/ha)+ 0.028× Slope (%)+ 0.376× Extraction direction

Rsq= 0.894, Adjusted Rsq=0.893 and number of observation= 752 (5)

The resulted Rsq of the model shows that 89.4% of the variations can be explained by the model. The values for uphill and downhill yarding are 0 and 1 respectively as a dummy variable. Based on the significance value of analysis of variance table, the developed model is significant at the probability level of 5%.

Table 5. Analysis of variance of the model

	Sum of Squares	df	Mean Square	F	Sig.
Regression	22411.578	7	3201.654	895.352	.000
Residual	2664.017	745	3.576		
Total	25075.595	752			

The production rate and yarding cost per cubic meter are 10.4 m^3/PSH_0 and 19.71 Euro/m^3 respectively. The descriptive statistics of the parameters used in the yarding model are presented in table 6.

Table6. Summary statistics of the dependent and independent variables

Variable	PSH_0 (min.)	Yarding distance (m)	LYD (m)	Load volume (m^3)	Tree volume (m^3)	Harvest intensity (%)	Stand density (n/ha)	Slope (%)
Maximum	13.89	300	22	3.457	3.457	95.26	1045.11	67
Mean	5.44	114.1	6.35	0.877	0.679	34.88	969.47	45.72
Minimum	1.55	0	0	0.076	0.076	1	369.68	6

3.2. Optimization of road network

The data including variable costs (sum of yarding and installation costs per cubic meter), fixed cost (roading cost) and logging volume per nodes were input to the Link and Sale files of the Network 2000 program. The shortest path algorithm was run and found the best solution with the minimal total cost of 78.87 Euro/m^3 including variable cost of 56.81 Euro/m^3 and fixed cost of 22.05 Euro/m^3. The best routes found by the program were marked on the map to see what road segment can be used and what segments can be eliminated from the proposed road segments.

Great deluge and simulated annealing algorithms were also run to the same data base but they could not found better solution.

In order to test the best solution found by the SP algorithm, the road segments of nodes 13, 14 and 15 were eliminated and the algorithm was rerun to see if a lower total cost can be found. The solution had a total cost of 96.24 Euro/m^3 (logging cost of 75.37 and road cost of 20.87 Euro/m^3) which is obviously higher that the first solution.

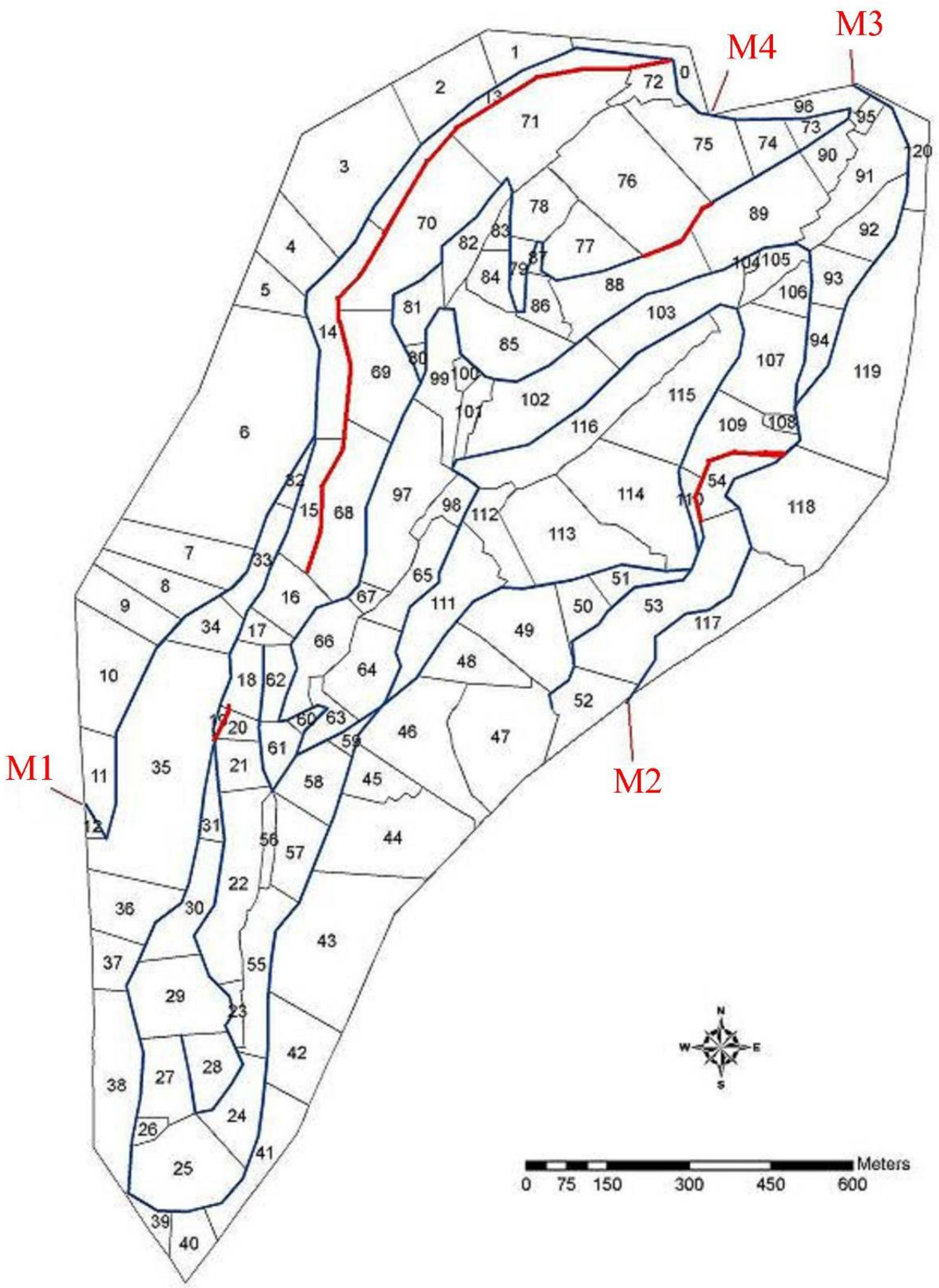

Figure 5. Best solution found by SP algorithm (the red road segments should be eliminated)

The optimal solution results a road density of 75.5 m/ha (Fig.5). Figure 5 suggests eliminating the red road segment to reach the minimum total cost per cubic meter.

4. Conclusion

In hilly and mountainous terrains, optimal road spacing computed by Matthew's formula or minimization of total cost by graphing total cost for different road spacing is only a guide which can not be applied to a real optimization of forest road network in steep terrain. The network procedure applied in this study, started with planning the possible road segments in the logging block considering the ground slope and longitudinal gradient of the road. Based on the solution found by shortest path algorithm, some road segments from the planned roads were eliminated to achieve the lowest cost of yarding and roading cost (Figure 5).

The relation between ground slope and roading cost was assumed as table 3, however because of the importance of ground slope, it is necessary to study its relation with roading cost. The next studies can also use the hydrologic and soil stability maps to plan the possible road variants more carefully.

Acknowledgment

We would like to thank Mr. Martin Kuehmaier from Institute of Forest Engineering at BOKU for his help.

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CONCEIVING AND MECHANICAL DESIGNING OF A WALKING HARVESTER FOR TEMPORARY TRAILS

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Abstract: In these days it´s common to harvest trees fully mechanized from skid roads, which are planned in a distance of 20 metres to each other. These trails should be permanently used. If they have an average width of four metres, they will take over about 20 percent of the area that is precedencely used technical by the harvesting machines. If the soil is ecologically valueable or tends towards compaction, it will be useful to raise the distance between the trails up to 40 metres.
Out of the reach of the harvester cranes, one has to harvest motormanually for example with a chainsaw. But if it could be possible to limit the impact on the soil so it has the chance to regenerate by itself, it will be permissible to operate this area by a special harvesting machine. This machine will be moving on authentic „temporary trails“, because the soil is precedencely used biological – not technical.
Also such kind of machine has to be light and requires a novel chassis, that makes it possible to touch the soil just in a punctiform way. The marginal impact and the huge interfaces for regeneration of the soil are a grand advantage to protect it against extensive consolidation.
This presentation wants to introduce such a machine, which could be used on „temporary trails“. Established chassis were analysed in regard to their compatibility of soil. So, chassis with wheel-based- or crawler-type-undercarriage shows linear and continuous impacted tracks. Because of their weight, there are huge vertical affecting forces and because of the acting slip, there are tangential affecting forces, so called shear forces. These forces act together and disturb or destroy the driven soil.
A stepping movement offers a punctiform, non-continuous consolidation. But the existing solutions got a too small step size, so that moving uphill shows, as well as wheel based machines, continuous tracks. Walking excavators are harmful, too, because the machine acts as a wheel-based one or the „walking“ boom slids the mass of the machine behind.

What is demanded?

- the impairment of soil should be minimised
- the deadweight of the machines should be reduced
- renouncement of relative motions (in terms of the soil)
- avoidance of continuous and/or extensive consolidations of soil.

The examinations show a novel kind of stepping movement that is non-bionical. It is patented now. So it is possible to put the feet of the machine only vertically on to and off to the soil. The mechanism enables the harvesting machine to reach a stepping distance of eight metres. With every step, only three touch-downs contact the soil. There is no need of brakes, steering, driving gear and so on anymore, so there is a reduction of weight possible. The walking or stepping mechanism is very simple conceived, also simple to control by the operator. It is possible to rotate the machine in an angle of 360° on the spot, without any added technical efforts. Also after every step, it is allowed to choose an absolut new direction of moving. With the stepping mechanism, it is possible, that a forestry crane with an outreach of 10 metres could act dynamically in up to large 480 squaremetres in workspace, without any relative motion in terms of the soil.
The feet of the walking machine builds a large platform in the forest, so it is possible to lift a big bulk with a light deadweight of the machine itself. A movement uphill, downhill (36% gradient) and aslant is possible without any problems.
The harvesting machine was conveived and designed in a degree dissertation of the TU Dresden with the skills that was teached as a special kind of mechanical engineering. This kind, so called, „Industrial Design Engineering“ includes the integrated development of products in mechanical engineering and in

design (as shaping or creating the exterior). The conceiving includes static calculations to the point of examine several mechanical parts of the machine in stress simulations; also many, for a former realisation absolutely necessary single solutions. Last but not least, the workplace of the operator was ergonomically designed.
The weight of the walking harvester is just about 7.5 tons. The absolutely„Worst Case“ (uphill with 36° gradient in an disadvantageous position, working with the maximal outreach of ten metres) offers an netto lifting power about 60 kNm. Just a light modification of this worst-case-position allows a lifting power up to 100 kNm! Comparable Harvesters got either a deadweight of 11 up to 16 tons or a maximal outreach of seven metres. If the harvester gots an accumulating felling head and works on a temporary trail between two permanent trails, it will be useful, that the „temporary-trail-machine“ fells trees into the area of ordinary harvesters, working on the permanent trails. The ordinary ones could finish the process. The walking mechanism allows to move on rocky parts and to cross barriers with a dimension up to 4 m (for example watertrenches). A low-cost-transportation is possible with two plug-on-wheels and a special hitch on a simple semi-truck.

PULPWOOD VERSUS ENERGY WOOD: SORTING STRATEGIES FOR DIFFERENT STANDS AND MARKET CONDITIONS

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Keywords: bioenergy, industrial wood, energy recovery, top end diameter

Abstract: *In this study the influence of the top end diameter on assortments industrial and energy wood is analysed. Therefore 37 existing stands have been measured and assortments have been calculated under certain conditions with the help of the computer program Holzernte 7.1. In result the changing amount depending in top end diameter could be predicted for tree species class coniferous wood, non-coniferous wood and pine for different dbh-classes. In result it can be seen that small dimensioned trees owns the greatest possibility of variation between industrial and energy wood. But big dimensioned trees offer a higher total amount of both assortments.*

1. Introduction

Due to increasing demand for energy wood and at the same time increasing demand for wood-based products as well for pulp and paper products, there is a competition between wood for energy recovery and wood material meant for other wood products. The prices of wood raw material are on the rise, which is especially important for industries, where costs for raw material are one of the most important factors. This development perhaps will lead to economical problems for an industry sector that used to finance especially thinnings in younger stands indirectly.

On the other hand, rising prices of round wood and a new woody biomass using industry, like the energy sector will likely improve the economic situation of forest owners. But this situation could change, if pulp and paper companies as well as panel companies stop operating, because of a lack of low-cost raw material. That is why the question for an efficient use of woody biomass has to be raised, to satisfy the demand of both sectors.

Different approaches to assessing the cost-benefit of using wood material for energy and other industrial use have been discussed. One way could be the more efficient use of woody biomass in conventional harvesting systems. In this case, for forest owners and / or forest entrepreneurs it is important to know, how the volume of the various assortments of industrial and energy wood will change by varying the top end diameter. To answer this question is aim of a project, which is taken place at the University of Applied Forest Science Rottenburg and the University of Freiburg (Germany). The results of calculation of wood volume will be combined with harvesting productivities and costs, so as to optimise wood supply chains after various price scenarios.

2. Materials and methods

A total of 30,265 trees have been sampled from 37 stands with a total area of 55.8ha. For each tree, diameter at breast height (dbh) and total height (up to the tip) were measured.
Based on these data records for trees to be felled and the criteria of assortment, which are presented in Table 1, the volume of different assortments was calculated with the help of the computer program Holzernte 7.1, which was developed by FVA Baden-Württemberg (Freiburg, Germany). It is expected to calculate the volume for stem wood, industrial wood and energy wood. In order to analyse the influence of dbh on these assortments, different dbh-classes in steps of 10 cm, starting with 0 cm, were generated. To achieve a bigger data pool and to improve the usability of the models, tree species have been classified into three groups of tree species:

- none coniferous wood
- coniferous wood
- pine

The reason for excluding pine as a separate class and not sorted into the class of coniferous wood, is to be found in the modelling process of the calculation program Holzernte 7.1, but the criteria of assortment were the same as in the case of coniferous wood.

Table 1: criteria of assortment as it is used for the calculation of the amount of different assortments depending on the top end diameter for industrial wood

tree species classes	assortment	min length	max length	minimum top end diameter
non-coniferous wood	stem wood	2.7 m	2.7 m	18 cm
non-coniferous wood	stem wood	5.0 m	5.0 m	18 cm
non-coniferous wood	industrial wood (long)	2.0 m	3.0 m	7 cm; 8 cm; 10 cm; 12 cm; 14 cm
none coniferous wood	energy wood	--	--	--
non-coniferous wood	stem wood	2.4 m	2.4 m	13 cm
coniferous wood	stem wood	5.0 m	5.0 m	15 cm
coniferous wood	industrial wood (long)	3.0 m	3.0 m	7 cm; 8 cm; 10 cm; 12 cm; 14 cm
coniferous wood	industrial wood (short)	2.0 m	2.0 m	7 cm; 8 cm; 10 cm; 12 cm; 14 cm
coniferous wood	energy wood	--	--	--

To calculate volume the program Holzernte 7.1 uses different terms of stem wood and terms of merchantable wood according to other calculating models (BDAT, BWI 2). Of special interest for this study is the calculation of volume of energy wood that can be harvested, which is defined as the difference between the whole tree volume and the volume of wood used for other utilisations (d > 7 cm) in addition with a percentage deduction. This means, while changing the top end diameter of industrial wood, the volume of energy wood will change, too. The percentage deduction for the use of energy wood is 5 % for crown material with a diameter greater than 7 cm (merchantable wood, use of 95 %) and 40 % for crown material with a diameter smaller than 7 cm (brushwood, use of 60 %). Figure 1 shows the basic model of assortments, as it was calculated here.

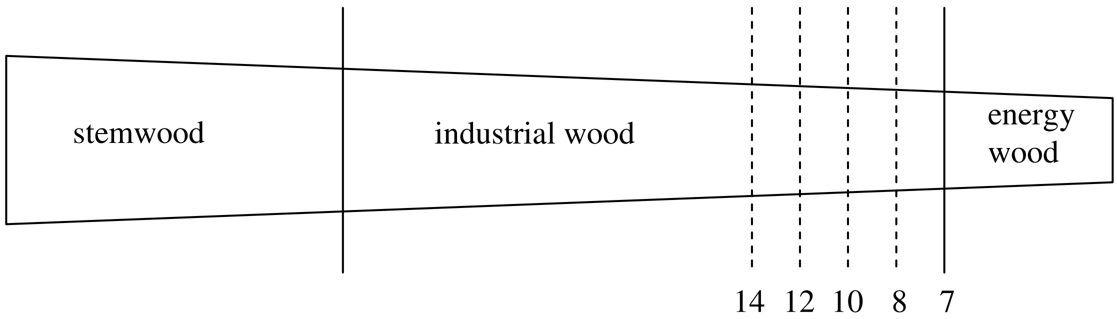
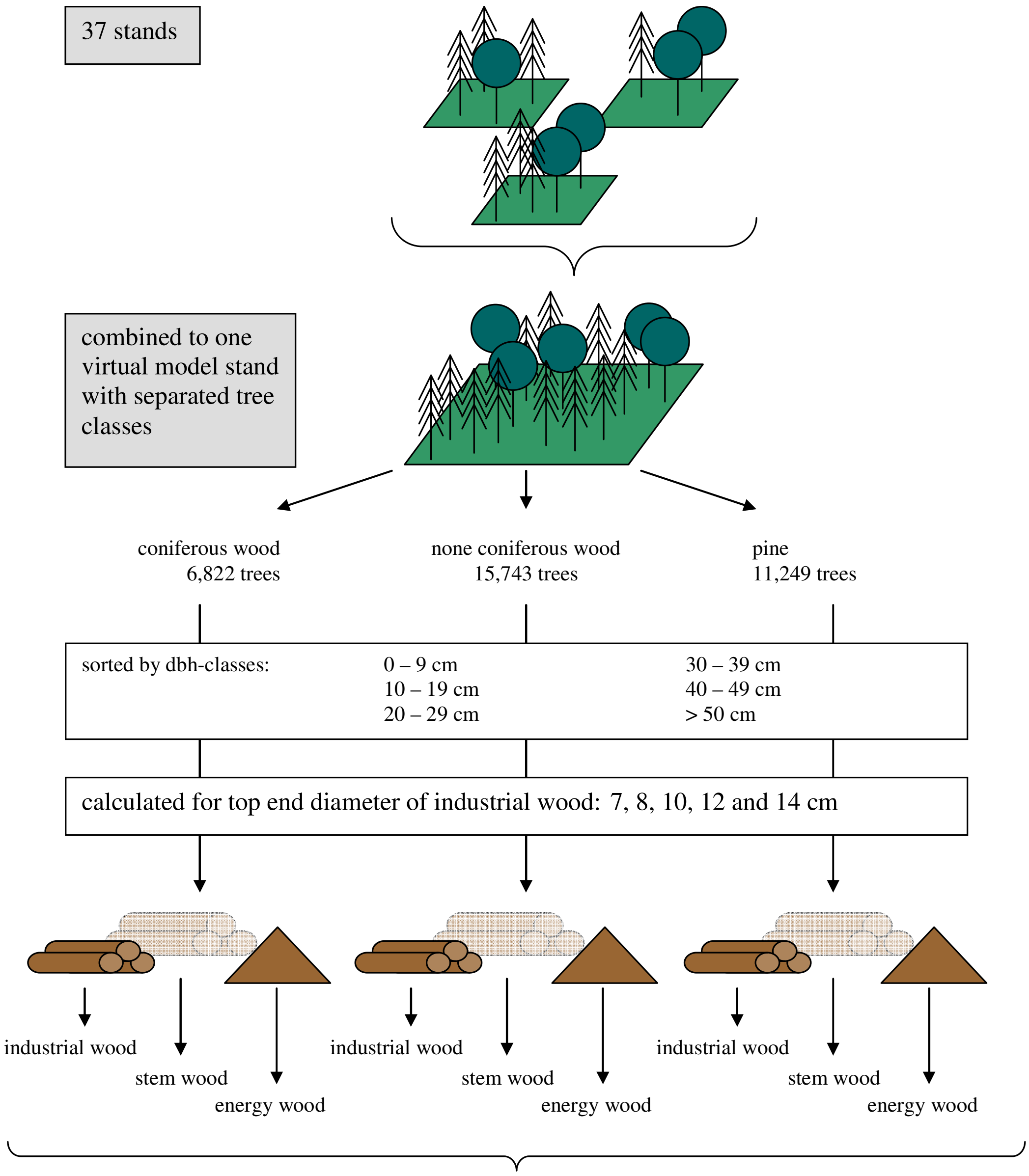


Figure 1: Basic model of assortment

By combining the sample area, as mentioned previously, and later picking out different diameter classes for the three tree classes, the information of the used area got lost. The reference figure of the volume data changed from area oriented to tree oriented.
To solve this problem the data have been transformed later. On the one side the new reference figure is the total harvested volume per ha, which is assumed as 20 m³/ha. On the other side it is a certain number of trees. These steps allow a comparison between the diameter classes and tree classes. Figure 2 gives an overview of this approach.



top end diameter of industrial wood	dbh-class	coniferous wood			none coniferous wood			pine		
		stem wood	industrial wood	energy wood	stem wood	industrial wood	energy wood	stem wood	industrial wood	energy wood
7	0 – 9 cm									
	10 – 19 cm									
	…									
	> 50 cm									
8	0 – 9 cm									
	10 – 19 cm									
…	…									

Figure 2: Overview of approach, with result volume in m³

3. Results

Based on a given volume to be harvested, in this case 20 m³, there exists a wide range of development of volume above top end diameter among the different diameter classes. For example, in the case of coniferous wood the assortment energy wood showed that the volume of thinned trees (dbh < 29 cm) increased rapidly to 72 % (14.3 m³ of 20.0 m³), while the volume of larger dimensioned trees did not increase when the top end diameters were increased (compare Figure 3). Further it can be seen, that the volume of energy wood of dbh-class 0-9 cm increased by 3.5 m³ (33 %) while increasing the top end diameter by 1 cm from 7 cm to 8 cm. In comparison to that the scope of changes of dbh-class 30-39 cm amounts just 0.8 m³ but 43 %, while changing top end diameter from 7 cm to 14 cm.
Similar results can be seen for energy wood from coniferous wood and pine. The development for industrial wood shows same changes, but in the opposite trend.

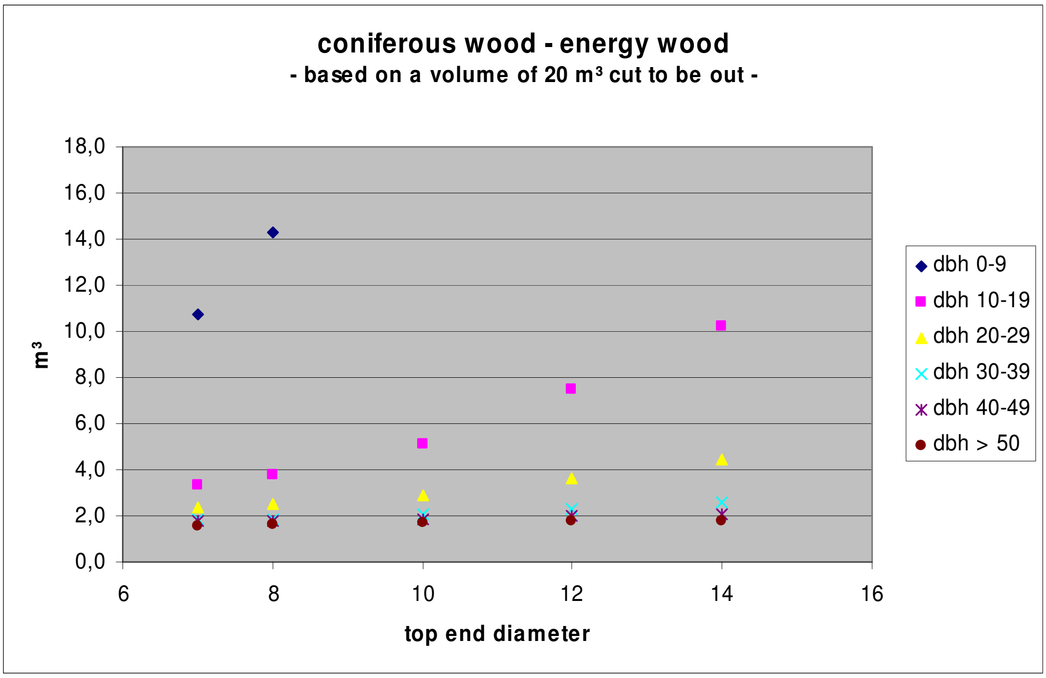


Figure 3: Calculated volume of energy wood for conifers depending on top end diameter, based on a total harvested volume of 20 m³, separated for various dbh-classes

It can be stated that the volume is changing differently between dbh-classes in absolute numbers, but similar in percentage. There are two facts which can mainly be taken as reasons for this development.

1. The basis of a harvested volume of 20 m³ provides a different number of trees behind that and of course there are a lot more trees needed to accumulate the amount of 20 m³ out of small dimension classes, than out of larger dimension classes. Because of that the effect of changing volume above top end diameter occurs more often, due to the higher number of trees.
2. Small dimensioned trees have only two assortments: industrial wood and energy wood. The volume changes in this case is possibly much higher than for larger dimensioned trees, where the biggest part of the total volume is related to the assortment stem wood. This is getting clearer, if the design of the diagram will change to an allocation of assortment also based on a harvested volume of 20 m³, as it is exemplified for pine in Figure 4 to Figure 7. But every researched group of tree species shows the same trend; also the group of non-coniferous wood does not match that strong.

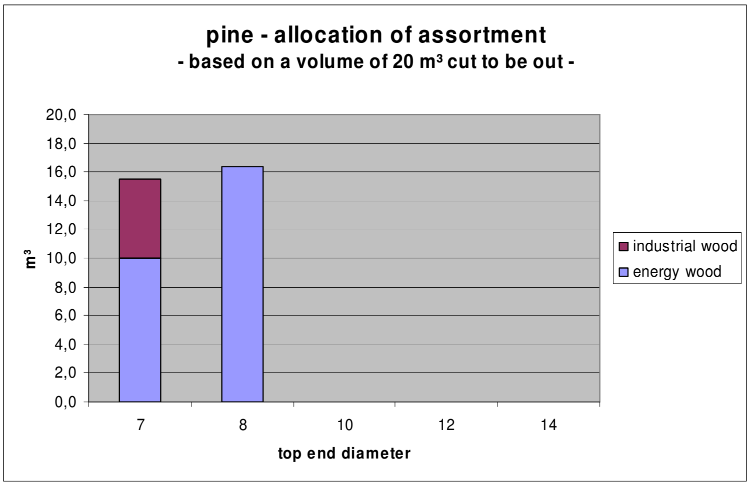


Figure 4: Allocation of assortments for pine depending on top end diameter, based on a total volume to be cut of 20 m³, for dbh-class 0-9 cm

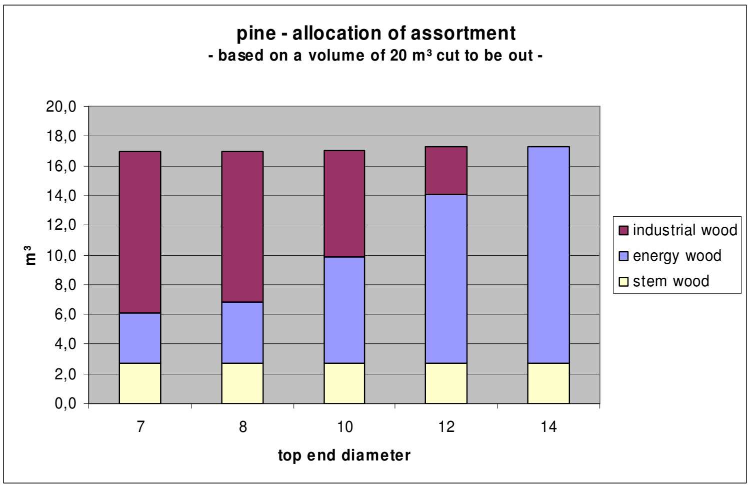


Figure 5: Allocation of assortments for pine depending on top end diameter, based on a total volume to be cut of 20 m³, for dbh-class 10-19 cm

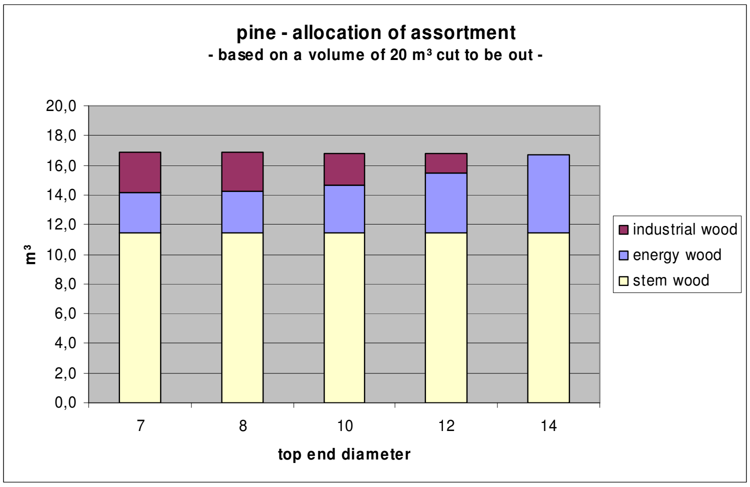


Figure 6: Allocation of assortments for pine depending on top end diameter, based on a total volume to be cut of 20 m³, for dbh-class 20-29 cm

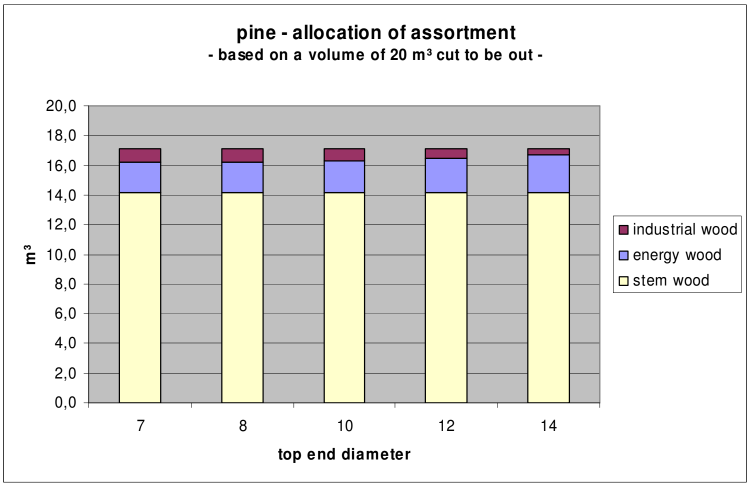


Figure 7: Allocation of assortments for pine depending on top end diameter, based on a total volume to be cut of 20 m³ for dbh-class 30-39 cm

This trend just turns around, if the base changes for a certain number of trees instead of a volume to be cut. In this case the biggest change above the top end diameter takes place for dbh class > 50 cm, which is related to the high volume of one tree. As an example for non-coniferous wood, Table 2 shows the calculated volume of energy and industrial wood depending on top end diameter.

One effect that still had been described before can be seen very clearly: for the dbh-class 10-19 cm are just two assortments available (due to sorting criteria), with the result of a large change of volume. The next higher dbh-class (20-19 cm) provided three assortments and due to that the possible amount of change decreased. In result this dbh-class contained the lowest change of volume.

Table 2: Volume of energy – and industrial wood for none coniferous wood, depending on top end diameter, separated by dbh-classes

assort-ment	dbh-class	absolute volume in m³								
		top end diameter								
		7	8		10		12		14	
		m³	m³	Δ_7[1]	m³	Δ_7	m³	Δ_7	m³	Δ_7
energy wood	0-9 cm	0.17	0.21	0.04						
	10-19 cm	0.52	0.55	0.03	0.73	0.21	1.01	0.49	1.38	0.86
	20-29 cm	1.82	1.82	0.00	1.90	0.08	1.98	0.16	2.14	0.32
	30-39 cm	3.79	3.79	0.00	3.93	0.14	4.04	0.25	4.17	0.42
	40-49 cm	6.84	6.84	0.00	7.11	0.27	7.30	0.46	7.51	0.67
	> 50 cm	9.19	9.19	0.00	9.65	0.46	9.93	0.74	10.21	1.02
industrial wood	0-9 cm	0.07	0.03	0.04						
	10-19 cm	1.37	1.35	0.02	1.17	0.20	0.89	0.48	0.53	0.84
	20-29 cm	1.59	1.59	0.00	1.51	0.08	1.42	0.17	1.26	0.33
	30-39 cm	2.62	2.62	0.00	2.48	0.14	2.36	0.26	2.23	0.39
	40-49 cm	6.19	6.19	0.00	5.90	0.29	5.70	0.49	5.49	0.70
	> 50 cm	8.19	8.19	0.00	7.70	0.49	7.41	0.78	7.12	1.07

Conclusions

1. Already a top end diameter of 7 cm provides a great volume of energy wood, which can be additionally used. Depending on dbh-classes, the possible additional volume by changing top end diameter varies very much.
2. Stands with small dimensioned trees (base on a certain area) exhibit the biggest potential to verify between industrial and energy wood. Here the highest volume for industrial and energy wood can be expected.
3. Large dimensioned trees already provide the greatest volume of industrial and energy wood and they have a great potential for an additional volume, due to shifting assortments. But based on a certain area, there is only a small contribution to be expected.

In a next step these calculated results will be combined with harvesting productivities and timber prices, to gain models of assortment for various price scenarios. These will be included in a decision support system for forest owner and forest operator to optimise an area related net revenue.

[1] Δ_7 means the difference between the volume of the current top end diameter in comparison to the volume of a top end diameter of 7 cm

WOOD ENERGY FROM PLANTATIONS: HARVESTING AND SUPPLY OF WOOD CHIPS

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Keywords: Short Rotation Plantations, Harvesting, Supply

Abstract: *Short rotation plantations (SRP) with poplar or willow trees are able to deliver fuelwood in short harvest cycles, from three years upward. Because the production line "fuelwood from farmland" has to achieve competitiveness in relation to traditional agricultural products, there is a remarkable cost pressure to create efficient technologies up to the fuel-wood-supply. Therefore it is important to analyse the existing techniques and to define the best for different circumstances. In the context of the research project AGROWOOD, one of the tasks has been to analyse the different alternatives for the fuelwood supply in the relation to the energy efficiency. Field studies shoed that concerning wood harvesting, best results have been achieved by using the un-interrupted chip technology. For drying the wood chips, an air ventilation process based on the self-heating of freshly harvested wood chips is an alternative to achieve high energy efficiency for drying the chips without external energy input. This technology enables the reduction of the water content of the chips to 30 % within three months, thus bringing a higher energy content of the chips and so a better price on the fuelwood market.*

1. Introduction

At present, 6.7% of the total primary energy supply in Germany comes from renewable sources such as biomass, wind, solar, hydropower, and geothermal sources (BMU, 2008). Among those forms of renewable energy, wood covers the highest percentage with approximately 70% or ca. 4.7% of the total energy supply (FNR, 2007). The necessary wood supply is provided from forestry, timber industry, recycling, and landscape management measures. In addition to the above-mentioned options, there is also the possibility to produce wood in the agricultural land by fast growing trees in short rotation cycles. The development and deployment of woody biomass resources in the agricultural land has several advantages over agricultural sources, but because of the limited land, wood production on farmland by short rotation plantations (SRP) should be cost-effective and has to compete against traditional farmland products directly. Hence, the possibility to establish this one against traditional farming will depend on the net revenues and profits per unit of land (hectare). The economic calculations should include opportunity costs for lost agricultural production and the costs of plantation establishment, management, biomass harvest and delivery. Therefore, field studies about best practices of harvesting and storage of fuelwood from SRP are being performed to find out practices that bear comparatively low costs and a high energetic efficiency. The case studies described here are part of the research project AGROWOOD (www.agrowood.de) at the TU Dresden. The project (2005 – 2009) is financially supported by the Federal Ministry of Education and Research / Project management Juelich.

2. Techniques for SRP harvesting

There is a wide range of possible techniques to SRP harvesting up to the supply of wood chips (see Fig. 1). Alternatives of harvesting in plantations were analysed and described by a numbers of authors (e.g. BURGER, 2007; HARTMANN/THUNEKE, 1997; LANDGRAF et al., 2007; OLDENBURG, 2007; SCHOLZ, 2007; SCHOLZ/LUECKE, 2007; GAIO/DA VAL, 2007). The first processing step can be split at three different lines of technique – the log-, the bundler- and the chip-technique. If the log- or the bundler-technology (see Fig. 1, level 1 and 2) is to be used in chips production, normally it will be realised by the so-called interrupted techniques.

After being felled by chain saw or harvesters, the trees will be deposited before the next processing step starts (see Fig. 1). Because the cutting and the chopping of the trees will be carried out by separate machines, also the first two versions of the chip technology (see Fig.1, level 3.1 and 3.2) will be realised by interrupted chain of process. Only the use of a reaper-chipper-machine permits an un-interrupted harvesting (see Fig.1, level 3.3 and 3.4 and Fig. 2).

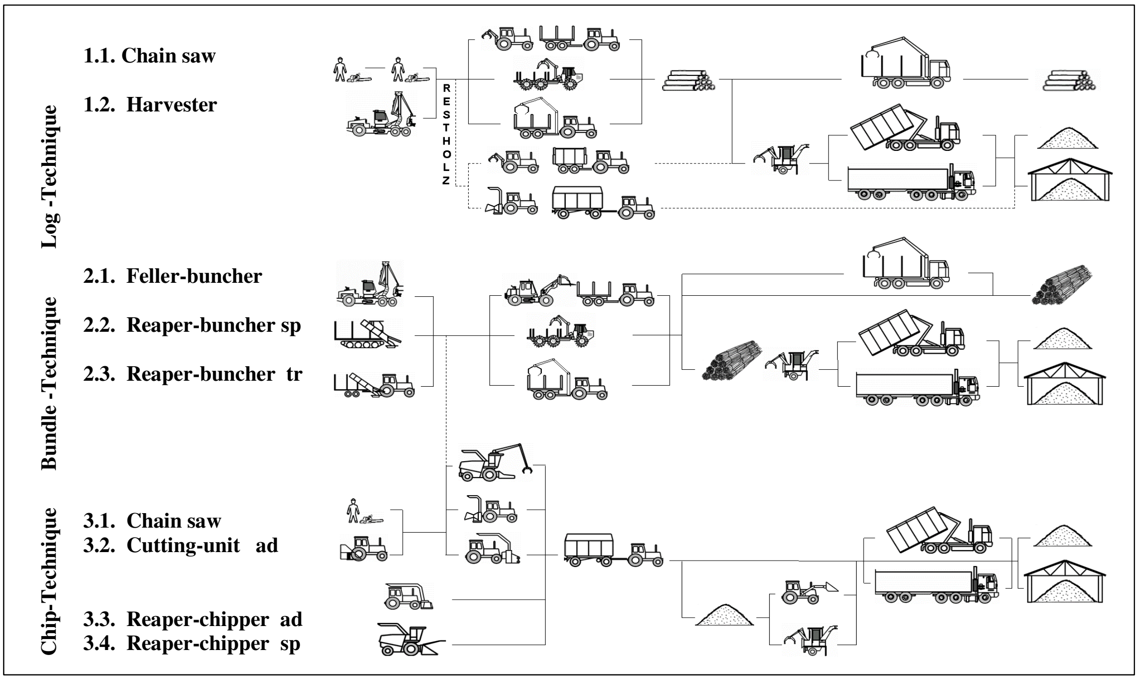

Figure 1: Fuelwood harvesting techniques in short rotation plantations (sp - self propelled; tr - trailed; ad – adapted) (with modification from: SCHOLZ, 2007).

Both techniques, interrupted or un-interrupted process chain, have their advantages and disadvantages. Generally, one should reduce iterative handling in the chain of process. This argument will to be stronger if the harvesting good has a low value or a low compactness of the packing. Costs are increased every time if the product is touched or handled. Because of the complexity of the factors involved, yet it is often not so easy to find out the best technique. But one of the advantages of these techniques is that un-interrupted techniques avoid the pollution of the harvested material.

Otherwise, interrupted process chain has advantages in from the viewpoint of machinery chain with a wide difference in capability and availability of the single chain links. Often the cost-efficiency of a powerful key-machine dominates the total result of the full production chain. Therefore, sometimes it could to be positive to interrupt the chain of process and so to guarantee optimal terms for the most expensive machines.

Figure 2: **Example of un-interrupted harvesting of willow trees by Reaper-Chipper KRONE BIG X with the adapter-unit Woodcut 750 (Prototype)**

Another advantage of using the time of interruption of the harvesting process could be reduction of water content of the wood by air drying directly. Wood logs in a swath have a much higher drying capacity than chips in a pile. SCHOLZ and IDLER (2005) in field studies in Brandenburg (Germany) showed than in a storage-drying-test of free deposited poplars (full trees) the water content was reduced after 35 days (from the end of February up to the start of April) from 50% to 35 % by natural air drying only. Thereby, the energy content of the wood increased. This effect leads to a higher market prices based on the higher energy content per volume unit. According to the described study, the heat value of the poplar trees increased from 7.6 MJ/kg to 11.0 MJ/kg (see Fig. 4). Theoretically, this will lead to a price-increase per volume of nearly 50 %.

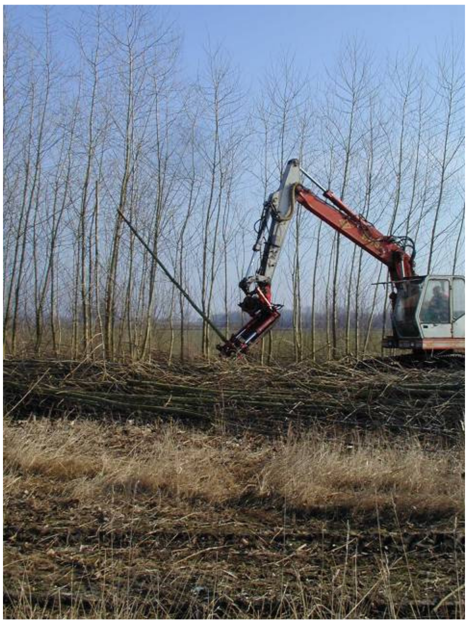

Figure 3: Example of interrupted harvesting by feller-buncher (excavator with processing unit) and agricultural chipper (CLAAS-JAGUAR) (Harvesting of poplar/ age 8; Schoenberg, 2004)

When deciding about criteria for designing the wood harvesting techniques in SRP aimed to fuelwood chips, one should consider the following:

- From the viewpoint of high capability and efficiency of the harvesting, at present, the uninterrupted technique with self-propelled agricultural reaper-chipper like CLAAS or KRONE seems the eligible version to achieve the best results.
- Two are the preconditions for application of such technique: (1) the double row planting structure, and (2) the trunk diameter in the cutting level should be 7-12 cm but not exceed 12 cm. This diameter is the largest to handle by the cutting units at present.
- The plane should be well driveable to carry out the parallel-technique to deliver the chips into a transport unit directly also in winter by frozen soil or snow. A gradient of the plane of more than 10 % constrains the manoeuvrability and limits the application of this technique.

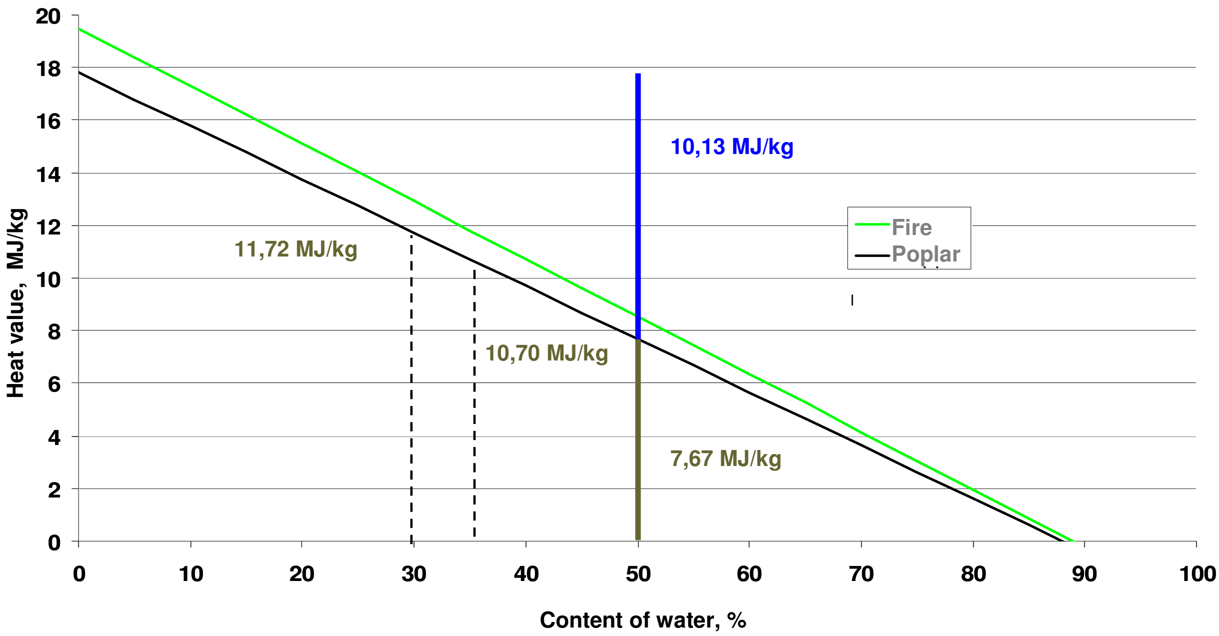

Figure 4: Correlation between water content and heat value of wood

- These machines achieve a capacity of nearly 20 tonne dry mass per hour. To make fully use of this capability, for a working speed of the reaper-chipper of 6 km/h, the yield of the plantation should be nearly 30 t/ha fresh mass.
- Concerning harvesting of trees with cutting diameter of 12 cm or more – from the age of 5 years, depending on the quality of the site and the tree species – crane processors or harvesters could be used. Thereby the technique could be used as full-tree-technique with in a swath deposit (see Fig. 3) or as short-wood-technique (see Fig. 5). The latter will make sense if the buyer would like to get short-wood e.g. for pulpwood. Meanwhile, the wood from branches and crowns will be chipped at the field margins and deliver to the fuelwood-market. The interruption of the process can be used for reducing the water content of the wood.

Figure 5: Harvesting of poplar (age 10) by harvester VALMET 901 and chipping

Apart from the capacity, the main criteria for choosing a technique, are the specific costs per volume unit. Results of field studies in the Lands of Saxony and Brandenburg (Germany) show that the costs of the chopping technique vary from 24 €/t_{atro} to 46 €/t_{atro} (t_{atro} -means absolute dry) (see Table 1). On the contrary, only the cost of short-wood preparation by harvester without chopping is 46 €/t_{atro}. The technique could be recommended only if the supply of short-wood will provide an added effect and so a better price in relation to chips. The technique could be recommended only if there is a significant difference in price between short wood for the processing industry and fuelwood for energy production.

Table 1: **Cost of SRP harvesting techniques for producing chips or logs including chip-transportation to the store by means of agricultural tractor and trailer**
(according to: HEINRICH, 2007; KIENZ, 2007; SCHOLZ et al., 2007)

Harvesting machine	capacity[1] t_{atro} /h	Costs of machine €/hour	Costs of the chip technique[2] €/ t_{atro}	Remarks
CLAAS Jaguar 850/880 + Adapter-unit HS 2	8,8 - 23,0	215 / 230	24 - 44	Chip technique + 5 km transport to chip store by agricultural tractor and trailer
KRONE Big X + adapter-unit Woodcut 750	7,5 - 21,1	220		
Harvester Valmet 901	2,9	63[3]	46	Log technique, transport by forwarder to the field margin

[1] capacity related to the absolute working time
[2] costs of technique reduced of 30 % capacity (flat rate factor of reducing for unproductive time, in reference to KOFMANN/SPINELLI, 1997)
[3] minimal cost rate because a very high annual utilization (in reference to entrepreneur data: 2000 h/a)

3. Storage of wood chips

The energy stored in woody biomass can be transformed into 'usable' energy. Usable energy is energy in a form that is sold (electricity, heat, etc.). Before transformation can take place (prior of use in bioenergy-based power plants), the wood from SRP has to be dried to improve the conversion efficiency. The water content of fresh harvested chips is approximately 50%. Because of that, as can be depicted also from the Fig. 4, the heat value per volume unit is less than half when compared to absolutely dry chips. For burning purposes, the water content should be nearly 30% while for gasification ca. 20%.

Different drying procedures are used in practice. Because the chips in the pile have a relatively high storage density, it is almost impossible to use the free air circulation for drying. Rather, an air circulation is to be generated which will take the water (water vapor) and transport it outwards of the pile.

In the cold-air-drying option, the fresh air will be supplied to the pile through channels by blowers. Depending on the air humidity and the temperature, the content of water could be reduced. In contrary, the hot-air-drying supplies the pile through channels with preheated air by blowers also. Therefore the drying process depends on the external conditions but it needs a remarkable input of technical energy.

Because of the micro-biological destruction, fresh harvested chips will be self-warmed. Shortly after beginning of the storage, the temperature can go up to 70°C. This process will exist only if fresh harvested biomass will be stored. In reality, after storing for some time, the process of self-warming will decrease significantly. Whereas the temperature of increasing e.g. for the storage of moist straw could come up to start of burning, the self-warming-process in a wood chip pile is quite safely. This is a natural process without technical energy and could be used in the sense of efficiency. Based on the process of biomass self-warming, a new technique for drying wood chips was established at the TU Dresden (see Fig. 6) and a patent application has been filed (registration number: PCT/EP2005/009241). The wood chips will be stored directly after the harvesting in piles with a high between 3 and 5 meters. Because of technical appliances like fence-channels, the air circulation initiated through the self-warming-process will be managed in the pile, thus, the warm-air absorbs the water-vapor and transports it through the exhaust air dome outwards. After 1 to 3 months the content of water is reduced to 30% or less. The technique could be used in backwater-free and driveable sites.

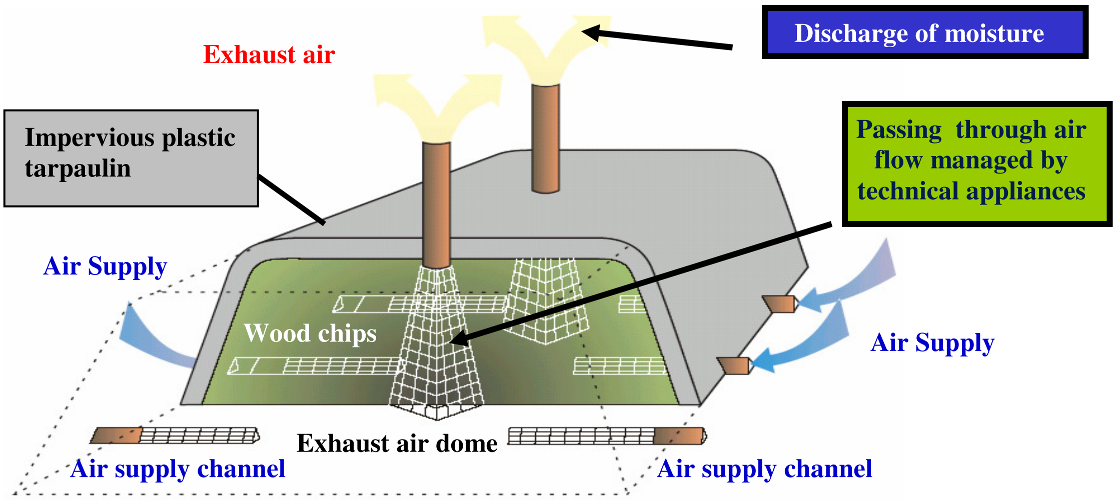

Figure 6: The Dome-Aeration-Technology (Dombelüftungsverfahren)
Source: BRUMMACK/ BARTHA (2005); TROIS/POLSTER (2007), (modified)

Figure 7: Implementation of the Dome-Aeration-Technology, (Raschuetz, 2007)

This technique allows a combination of both, drying and storage and can be realised also at the field margins. The technical appliances consist of simple steel, thus the acquisition or self-manufacturing is of low cost. In addition, by the termination of the process would be easily and simple to recycle the appliances. The area needed for this technology is defined between 0.4 and 0.5 m^2/m^3 wood chips (GROSSE et al. 2008). The costs of the Dome-Aeration-Technology is calculated to be 4.50 to 5.00 €/ t_{atro} (BRUMMACK / POLSTER, 2008). By using this technology, while the water content in the wood chips during one to three months can be reduced more than 20 %, (from 50% to 30%) in the same time the heat value of the chips increases about 40 % (see Fig. 4). Provided that the contracted price of delivery with the buyer is based on the heat value per volume, the increased heat value will proportionally increase the market price of the chips per cubic metre. The price-arrangement in relation to the energy content of fuelwood is described by KANZIAN et al. (2006). The price per tonne of absolutely dry chips increases ca. 2 € per percent of water reduction. Approximately the cost investment for drying the chips from 50% to 30 % water content are nearly 5 €/ t_{atro}, but the price of the chips increases nearly 40 €/ t_{atro}.

4. Conclusion

- The economic attractiveness of bioenergy plantations is a result of interactions between biological factors (e.g. growth rates, site conditions), and prices such as costs to establish and manage plantations, and importantly, the price of wood chips in fuelwood market. Based on the relationship of output to input of energy, wood chips from SRP, offer an excellent energetically efficiency, as the output exceeds almost 20 times the input (WISSENSCHAFTLICHER BEITRAT, 2007). Therefore, it is possible to manage land simultaneously as a carbon sink and for the production of solid wood products and for biomass for energy. So, the added production of fuelwood chips on farmland by SRP is a good possibility for fulfilling the increasing demands.

- The techniques of short-rotation plantation harvesting principally can be separated into: (1) un-interrupted, and (2) interrupted harvesting chain. Both techniques, offer their advantages and disadvantages. Considering the small diameter of the trees, generally un-interrupted techniques are less cost-intensive. It is worth to emphasize that the techniques should be applied especially if harvesting need to be realized during a short-period of time and by powerful machines. The techniques with agricultural reaper-chipper are able to harvest trees up to 12 cm cutting diameter. If the cutting diameter is larger, one could use the typical interrupted techniques used in forest harvesting and logging (harvester, feller-buncher), or also un-interrupted techniques by chipper-harvesters.

- Drying of fresh harvested chips combined with storage is an important extension of the chain of supply.

- In the framework of the research project AGROWOOD, a new technology named Dome-Aeration-Technology has been developed. The technology is based on the natural warming process of fresh biomass and manages the air flow passing through by special technical appliances. This technology allows drying of the wood chip to a water content of less than 30% in a time-period of only 1 to 3 months. The reduction of the water content of the wood chips to the above-mentioned level leads to a high energy efficiency since this process happens without technical energy. In this way, drying of fresh harvested chips guarantees significantly a higher price on the fuelwood-market.

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THE QUANTITATIVE ESTIMATION OF THE FOREST RESIDUALS AS BIOMASS FOR BIOENERGY FOR LOCAL INDUSTRY AND VILLAGES IN FOREST REGIONS OF RUSSIA

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Keywords: Biomass resources, bioenergy, statistical method for quantity estimation of the forest residuals, small enterprises, local industry.

Abstract: *Statistical method of the quantitative estimation of forest residuals was developed, based on the line intersect method. New method based not on separate wood particle assessment but on the piles assessment of the forest residuals, which crossed the intersect line. This greatly increases the possibility of the method for estimation of forest residuals after harvesting logging operations, as for reducing of labor content and increasing of accuracy of the estimation.*
A statistical method was developed for estimating the volume of forest residuals, based on the well-known Buffon's problem. The resulting formulas permit estimation of the volume of forest residuals after harvesting operations

The most increase of using biofuel in developed countries with considerable timber resources (Sweden, Finland) is expected from forest. These are forest residuals, thin trees and stumps. Rising price on fossil fuel and improvement technology have done the fuel from forest is competitive.
Russia has all necessary conditions for development bioenergy, particularly on base of wood residuals from forest. The Development of bioenergy in Russia is held up by low internal prices on fossilized power systems and absence state political stimulations.
In Russia the most perspective raw material for bioenergy is wood raw material.
Russia, having quarter of all world wood resources, bioenergy wood share in energy is while small. This is explained by several reasons:

1. Comparatively low prices on fossil fuel and not enough state support.
2. There is no enough infrastructures, connected with bioenergy, including technologies and equipment for forest operations to produce wood fuel chips and equipment for power production.

At present time, bioenergy in Russia is developing, mainly, on three directions:

1. Using of wood waste after sawmilling, woodworking and others wood processes to produce energy for own purposes.
2. Production of the bioenergy fuel (pellets, briquettes etc.) on export.
3. Development of local energy on the base of local wood resource.

In our work, we consider the problems of local energy in Russia. Local energy directed to satisfy the needs in heating and power supply villages and objects of local industry.
The problem of local wood fuel, particularly, urgent for distant forest villages. The inhabitants of these villages are traditionally oriented for logging operations in forest to produce round timbers. However, in new economic conditions, because of high transport tariffs, round timber trade become unprofitable for distant forest regions. The solution is in development local industry, oriented on deep conversion of round timber, for example, into sawmills products. For these purpose, the development of the local energy sector is key problem. Local energy can develop on the base of local energy resources - wood fuel.
The energy for these goals can be produced by small, and even by mini power stations with generating capacity 0.5 - 1 megawatt for the villages with population up to 1000 persons. Today such power stations rather usual, as overseas, so and beside us in country.
There are some successful examples of such projects in Russia.
As a local wood fuel for power systems can be used:

1. The forest residuals, processed into wood fuel chips.
2. The waste of sawmilling and wood processing enterprises of local industry, convert to wood fuel chips.

The advantages of local energy are:

1. Stability of the deliveries of the fuel for the power systems.
2. Stability of the prices for supplied energy.
3. Creation of new work places.
4. Increasing of the local budget because of the up growth of the local industry.
5. Solution of the ecological problems of the contamination of surrounding ambience and reduction surge of carbon dioxide.

The imperfections of the local bioenergy from forest in Russia are:

1. The high prices for work operations in forest to obtain wood fuel chips.
2. Comparatively low prices on fossil fuels.

So, we see, that using the wood fuel chips for power production, promotes economic and social development in distant forest regions. However, low prices on fossil fuels, does not stimulate the economic interest of timber industry to produce fuel from forest in Russia. The prices per round timber higher, than the price per wood fuel chips. For the logging enterprise the production of the wood fuel chips means the drawing away of the technology and workers from the main production - timber felling. Solution is in specialized small businesses with its own technology and equipment, oriented on production and supply of the wood fuel chips from the cutting areas after logging operations into the local power stations.

In this article we consider some questions concerned with work of such specialized small enterprises.

The level of profitability of the specialized small enterprises will depend on volume of the forest residuals, from technology of production the wood fuel chips, as well as will be defined by expenses on logistics chains, including transport-storage operations with chips.

Thereby, profitable work of the specialized small enterprise is connected with decision of the following problems:

1. Estimation of the real volume of forest residuals, remained on cutting area after logging operations and suitable to conversion on wood fuel chips.
2. Rational technological process.
3. Amount of equipment.
4. Cost-performance of the technology.

In this article, we pay attention only to one of the problems.
We present the statistical method of the estimation of forest residuals after harvester logging operations, including mathematical tools, allowing quantitative and qualitative estimation of the forest residuals on the base of the direct account on the cutting area.

Methods of the quantitative estimation of forest residuals we can divide into two groups:

- The forecasting methods of the estimation.
- Direct methods of the estimation on cutting area after logging operation.

The forecasting methods assign the volume of the forest residuals as a certain percent from the general volume of the forest stand depending on several factors.
Unfortunately, the forecasting methods do not show, how many forest residuals, from available on cutting area for conversion on wood fuel chips, are dirty with soil. This can do only methods of the direct estimation, applied on cutting area directly.
The most simple and efficient methods of the direct estimation in field condition are statistical methods. Amongst such methods, for instance, method test square and the line intersection method. The line intersection method differs the simplicity.

The essence of this method in that that on cutting area is split line or several lines and are taken into account all waste, crossed by lines. For the first time this method was offered foreign researcher Warren and Olsen for estimation of the volume of forest residuals. Most full development this method has been got in works of Russian scientists Karpachev S.P., Lukjanov A. A., Scherbakov E.N. Slinchenkov A.A. [1].

These and others studies have shown that forest residuals powerfully different both the forms and the volumes. So, the method has a high labor-intensiveness content.

In our work, we offer the new method of estimation of the forest residuals, based on the line intersection method. The essence of the method is in estimating forest residuals not by the pieces of wood, but by piles - by heaps of forest residuals.

In basic researches the piles of forest residuals were presented in the form of circles.

On a rectangular flat area of size *HxL* (Figure 1) *n* numbers of the piles of forest residuals are randomly inhere. Let us consider that all piles have, in plan, the form of circles by radius *R* and pile's centers have coordinates *X*, *Y*, and the law of the distribution of piles are random within the intervals [0; *H*], [0; *L*]. Through the area, a line by length l has been drawn. Let an angle of orientation of this line is φ and the law of the distribution of the angle is random within the interval $\left[-\frac{\pi}{2};+\frac{\pi}{2}\right]$.

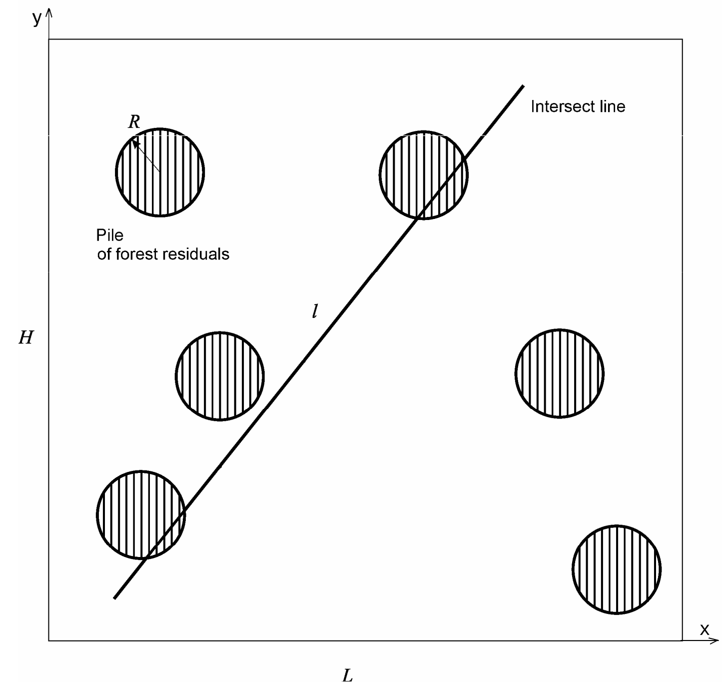

Figure 1: Piles of forest residuals on the flat cutting area (model)

The number of the piles on cutting area by size of *LxH* possible to define by formula

$$N = \frac{M[m]}{p}, \tag{1}$$

where $M[m]$ - average of the number of intersects the piles with the line;
p - probability of the intersects the piles with the line.

In practice the value $M[m]$ can be estimated by the sample mean of the number of intersects the piles with the n lines, as

$$m = \frac{\sum_{i=1}^{n} m_i}{n}. \qquad (2)$$

Estimation of the number of the piles can be calculated from formula

$$N \approx \tilde{N} = \frac{m}{p}. \qquad (3)$$

The formula for the required number of the lines may be expressed as

$$n = [\frac{Var \cdot t}{P}]^2; \qquad (4)$$

where t - confidence index;
P - probability level, %;
Var - coefficient of variation, %.

Formula (3) allows estimate special characteristics of the piles, for instance, volume of forest residuals

$$\tilde{V} = \frac{1}{p}(\frac{\sum_{j=1}^{k} v_j}{n}), \qquad (5)$$

where v_j - volume of the j pile, which was intersected by the line

Basing on the main positions of the theories of geometric probability, we carried out basic researches of the probabilistic features of the method of the line intersects for estimation of the idealizing models of the concourses of the forest residuals. Probability that the arbitrarily chosen intersect line will cross concourse of the radius R, is

$$p(+|R) = \frac{A_+}{A}, \qquad (6)$$

where A_+ – the area of the favorable events (crossing the pile with the line);

A – the full system of all events (the all positions of the pile on the cutting area).

Probability that line of the length $l > 2R$ on cutting area by size LxH will cross pile of forest residuals by radius R, is

$$p = \frac{\pi^2 \cdot R^2 + 4\pi\{\frac{R^2}{2}[\frac{l}{2R} - arctg\frac{l}{2R}]}{\pi \cdot L \cdot H} + \frac{\frac{l^2}{8}\arcsin\frac{1}{\sqrt{1+(\frac{l}{2R})^2}}\} + 4\pi\int_{R^*}^{R_c} dr \cdot r \cdot \frac{\sqrt{R^2 - \frac{[R^2 - (\frac{l}{2})^2 + r^2]^2}{4 \cdot r^2}}}{\frac{l}{2}}}{\pi \cdot L \cdot H}. \qquad (7)$$

The formula (7) inconvenient for practical use since it is difficult to calculate the integral. If intensify condition $l >> 2R$ that indeed exists in practice, then formula (7) is converted to simple form

$$p = \frac{2 \cdot R \cdot l}{L \cdot H}. \qquad (8)$$

Formula (8) may be generalized for the cutting area of the any form.

$$p = \frac{2 \cdot R \cdot l}{F}, \qquad (9)$$

where F - area of cutting area, m^3.

Using results of the basic researches, were received graphs and made analysis of functional dependences of the required number of the lines *n* from radius of the piles of forest residuals *R*, numbers of the pile *N*, lengths of cutting area *L*, factors to accuracy *P*, coefficient of variation *Var* and the other factors (Figure 2 as an example).
Studies of the piles of forest residuals in forest have shown that radiuses of the piles satisfactory comply with the normal law of the distribution, but as for the coordinates - random law. Testing was conducted on χ^2 Pearson criterion on 5% significance level.
The purpose of investigations in forest was study the form of the concourses, as well as studying the laws of the distribution radius of the piles R.
The distances were measured between the piles on axis X and Y, as well as diameters of the piles R. The examples of the distribution are brought on Figure 3, 4 (as examples).
Studies of the estimation of forest residuals with the line intersect method in the forest have shown that the estimation of the volume with the analytical formula satisfactorily comply with experimental result at a significance level 5%.

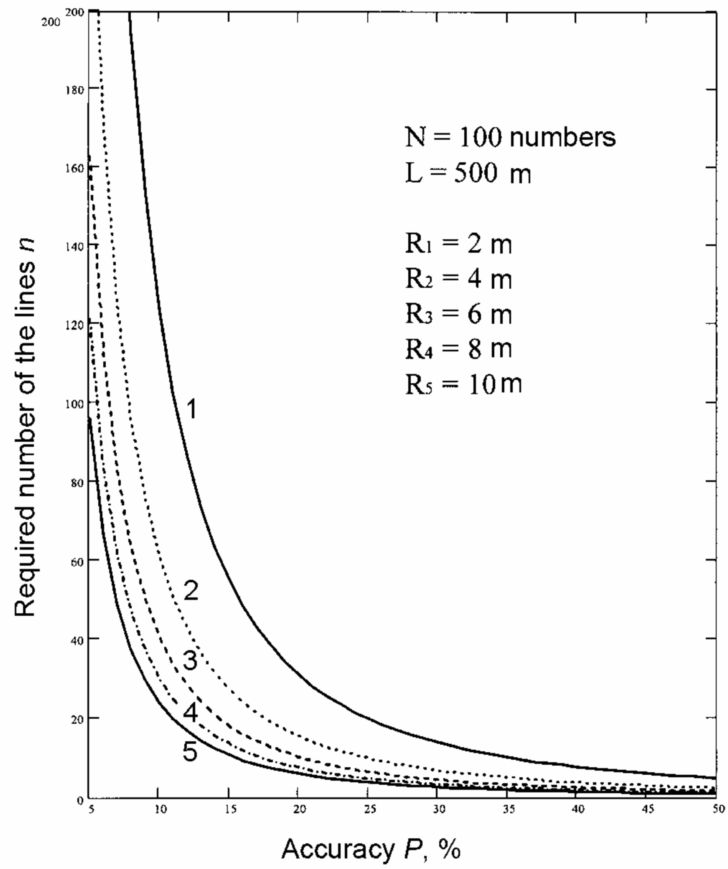

Figure 2: Required number of the lines *n* dependence of accuracy *P*, %

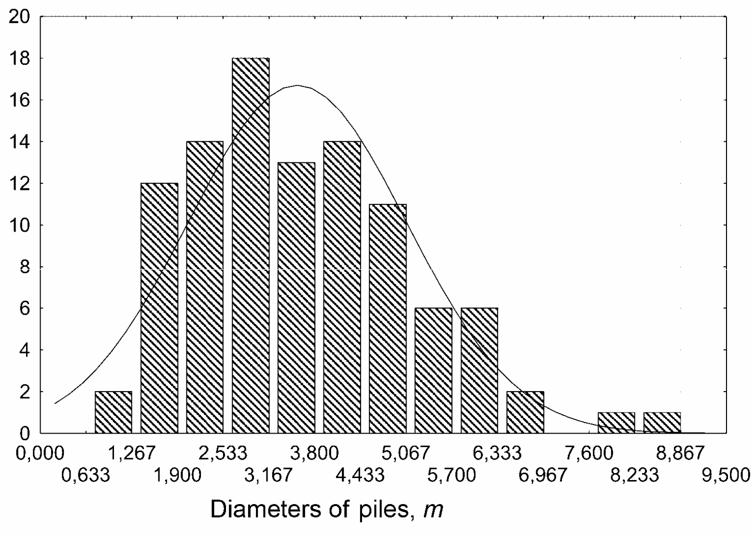

Figure 3: Normal law of distribution of the diameters of piles on the cutting area

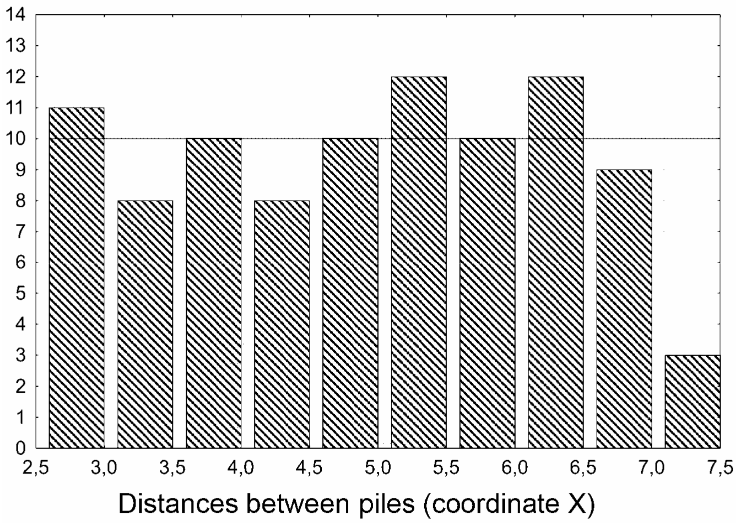

Figure 4: Random law of distribution of the distances between piles of the forest residuals on the cutting area (coordinate X)

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GPS ACCURACY IN HARVESTER TECHNOLOGIES AND POSSIBILITIES OF ITS USE IN THE CONTEXT OF THE CR

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Abstract: *The paper focuses on the accuracy evaluation of the geographic position determination by means of GPS receivers integrated in modern logging machines – harvesters. In order to be able to assess the achieved accuracy, a comparative measurement by a Post-Processing Trimble Pathfinder ProXH device was conducted. The technological preparation of the workplace was performed by means of a portable GPS, digital map and TimberNavi software in the monitored stands. The result of the paper is the evaluation of accuracy attained by integrated GPS antennas in the logging and hauling machinery during determination of the machine's position. It further provides the assessment of the influence of the crown canopy as a factor affecting the quality of the received signal. The conclusion gives an evaluation of the possibility of a technological preparation of the workplace by means of a portable GPS and a digital map and utilizing the data from GPS devices integrated in the logging and hauling machinery on a larger scale in forestry operations with respect to the achieved accuracy of the existing GPS receivers and wood logistic systems currently in use.*

1. Introduction

The history of GPS dates back to the 1960s when the U.S. Navy started developing the Transit project. Later on, the U.S. Air force also became interested in satellite navigation. Nowadays, the system is widespread in the civil sphere as well and the number of users keeps growing; it nevertheless continues to remain under the the U.S. Department of Defense supervision. GPS is not the only satellite navigation system but it is certainly the one used most at present. GPS can secure the coverage of the whole earth surface by navigation signals and thus enable the determination of position anywhere on Earth.

The application of GPS was introduced to forestry towards the end of the 1980s. First, GPS devices were used to localize survey plots in the process of elaborating the forest working plan and during road network planning (Martin, 2000). Present GPS devices have a wide range of application. Practical use of GPS receivers in modern logging and hauling machinery – harvesters, forwarders and timber-transport units – is a logical result of this versatility and it enables the monitoring of wood mass as it moves along the wood-processing logistic chain.

Quality of the recorded data in logging and hauling machinery and their factual applicability is now subject to frequent discussions. The accuracy of the GPS receivers in logging and hauling machinery is chiefly affected by the their type and by the specific properties of the forest environment. As any other measuring system, the GPS is liable to systematic and random errors. Errors originating as the signal travels through the ionosphere and troposphere (atmosphere in general) are of systematic nature. Since there is no vacuum in these atmospheric layers, the signal is subject to delays. Corrections calculated on the basis of tropospheric and ionospheric models are employed to minimize this phenomenon. The so-called “multipath” represents a random type of error. It is a multiple diffusion of the GPS signal caused by ground echo or by a reflection from building roofs or other structures. The accuracy of positioning is also affected by geometric configuration of the satellites during the seance.
This influence is described by the DOP (Dilution Of Precision) parameters. GDOP (Geometric DOP) characterizes the impact on all of the determined variables. PDOP (Position DOP) influences spatial positioning. HDOP (Horizontal DOP) and VDOP (Vertical DOP) affect the horizontal or the altitudinal components of the position. TDOP (Time DOP) defines the influence on the correction determination of the receiver's clock.

The better the configuration becomes, the lower DOP numerical values and higher accuracy are obtained. The positioning accuracy is also predicated on the angle of projection of the satellite with respect to the plane of the antenna (horizon). The signal of satellites with a low angle of projection are more affected by the error of signal diffusion than the signal of satellites with a higher angle of projection. The angle of projection is mostly opted for within the range of 10° to 15°. In the case of relative and differential methods, the accuracy is also affected by the length of the base line, which means the distance between the reference station and the mobile receiver.
Apart from correct placement of the antenna and longer time of recording, measurement accuracy can be enhanced by applying corrections in situations when the positioning is made more precise by means of the data of a known location supplied from the ground station. The positions of the portable receivers are subsequently corrected according to the known positioning deviation. Two basic types of corrections are used - “real-time DGPS” and post-processing. Data acquired from several sources (commercial and non-commercial), mostly available on the internet, can be utilized for post-processing corrections. To be able to make use of the post-processing system, a necessary software must be installed in the GPS whereby the data for post-processing can be registered. Additionally, software for separate post-processing is also required. The provided accuracy is of submeter quality. The advantage is that it can be used in all kinds of terrains; the positioning refinement however takes place only after the return from site.

2. Objectives

The scope of this paper is to determine the present achieved accuracy levels of positioning at logging and hauling machinery fitted with GPS. The comparison will be based on the planimetric data registered by the GPS device in a harvester and the post-processed data from the manual GPS whereby the node centres of the extracted lanes were charted. The impact of the crown canopy on the harvester positioning accuracy in two different stand types will be tested as well:

- Spruce stand No. 1 of high density
- Larch stand No. 2 with the admixture of broadleaves in the winter period

Another question to be answered by the paper are the possibilities of a technological preparation of the workplace by way of a portable GPS and a digital map and by using the data from GPS devices integrated in the logging and hauling machinery in forest operation on a broader scale with regards to the attained precision of the existing GPS receivers.

3. Materials and Methods

3.1 Methods

The selected stands were logged over by a John Deere 770 D thinning harvester with a common GPS antenna supplied together with the machine. The antenna was placed on the roof of the operator's cabin and connected to the navigation system via a USB interface. The extracted lanes were charted by the integrated GPS Trimble Pathfinder ProXH receiver for the purpose of determining the accuracy of the harvester positioning. The device in question disposes of an integrated H-Star technology whereby measurements of up to 30 cm tolerance precision can be achieved. The control software moreover demonstrates a highly reliable and real time accuracy that can be expected after processing in an office. This device is also equipped with the EVEREST technology for more precise measuring in a forest environment as well as in a built-up area. Placement of the unit on a 3 m-high range pole significantly improved the satellite signal reception.
GPS Trimble Pathfinder ProXH – basic technical information:

- Integrated GPS SBAS – EGNOS (WAAS) receiver and antenna
- H-Star technology for up to 30 cm accuracy during post-processing
- Real time submeter accuracy
- EVEREST technology for forest environments and built-up areas
- RTCM input support by DGPS correction
- NMEA support and TSIP data transmission

The nodes of the extracted lanes were pinpointed by means of the Trimble Pathfinder ProXH device. The acquired data were subsequently made more accurate by post-processing utilizing the correction data from the nearest three reference stations of the CZEPOS (Czech positioning) service operated by the Czech Office for Surveying, Mapping and Cadastre (COSMC).

These data, combined with the planimetric readings of the harvester during its work on the lane, were processed in the environment of two Open Source GIS programmes – specifically GIS GRASS 6.2.3 and Quantum GIS, version 0.9 "GANYMEDE" – for the evaluation of achievable accuracy of the GPS receiver integrated in the harvester. First, the measured nodes (ProXH) were connected to form lines representing the individual extracted lanes. Next, the shortest distances of the nodes measured by the harvester from these lines were determined by means of the *v.distance* module in the GRASS application. These deviations were then statistically evaluated.

3.2 Study Area

First thinnings were chosen as suitable stands in which the extraction lanes and the trees for selection were indicated by marking paint. The selection of young stands was intentional so as to prevent unrestrained movement of the harvester in the stand.

Table 1. Characteristics of the monitored stands

Stand	No. 1		
Locality	Hranice		
Age	25 years		
Slope gradient	3° - 5°		
Elevation (m a.s.l.)	385 - 405		
Stocking	100%		
Tree species	Representation	av.High	av. DBH
Spruce	95 %	14	15
Larch	4 %	16	15
Beech	1 %	8	12

Stand	No. 2		
Locality	Znojmo		
Age	30 years		
Slope gradient	0° - 1°		
Elevation (m a.s.l.)	390		
Stocking	100%		
Tree species	Representation	av.High	av. DBH
Larch	40 %	14	15
Oak	40 %	16	15
Hornbeam	20 %	8	12

4. Results and Discussion

Harvester position data can be registered in various ways. For the purposes of this measurement, the registration time interval in the TimberNavi programme (part of the TimberOffice software package in the harvester) was set at 5 minutes. This interval proved to be the most appropriate during previous measurements chiefly with respect to the travelling speed of the machine at work.

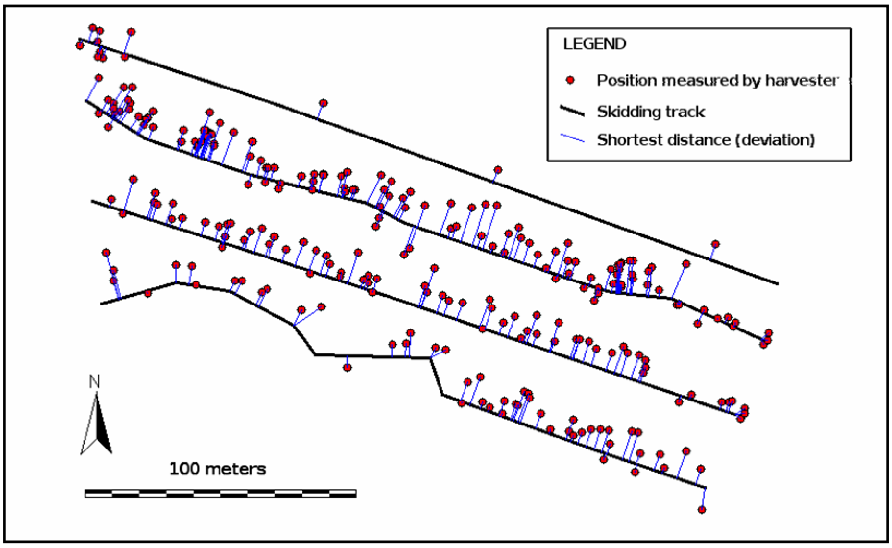
4.1 Spruce stand No.1

In stand No. 1, the skidding track in the length of 1,001 m was evaluated in order to assess the GPS accuracy. The harvester recorded 267 points which correspond to over 22 hours of monitoring. The harvester-measured points were compared to the connecting line between the nodes passing through the centre of the extracted lane. The deviation value was defined as the shortest distance between the lane centre and the position determined by the harvester. For the results and their comparison see the following graphs and table.

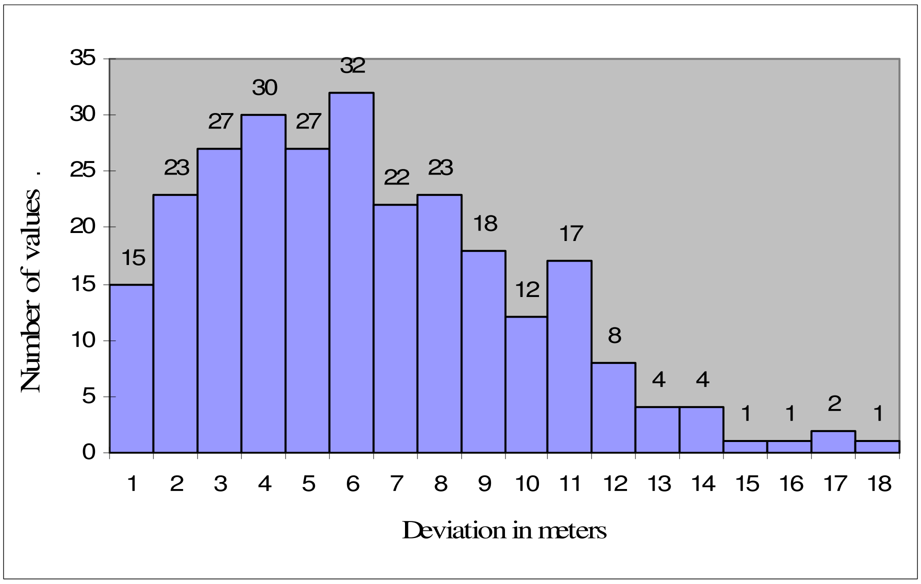
Mean value of deviation in stand No. 1 was 5.81 m with a standard deviation of 3.5 m. Minimum value of deviation was 0.01 m and maximum value from the monitored sample of 267 readings was 17.38 m. The determined deviations of measurement in the case of stand No. 1 are caused mainly by two factors. The first factor is crown canopy which was significantly denser in stand No. 1 (young spruce fully closed stand). The second factor causing the deviation is topography. The topography in stand No. 1 was broken with a slope gradient of roughly 3° - 5°.

Since the tracks were logged crosswise to the lane perpendicular to the contour of the slope with a gradient of 3° - 5° under a dense canopy, a unilateral satellite shadow was formed which was reflected in the strongly biased nature of the deviations.

Graph 1. Deviation values for stand No. 1 between the positions measured by the integrated harvester GPS positions and the straightened lines from Trimble Pathfinder ProXH after post-processing



Graph 2. Number of values within the one meter tolerance



Histogram No. 2 shows the distribution of deviations of harvester measurements from the centre of the straightened line. Total evaluation of the deviations reveals that in stand No. 1 14 % of values were within the measurement accuracy tolerance of 2 m from the line, 46 % of values within the 5 m tolerance and 92 % within 10 m.

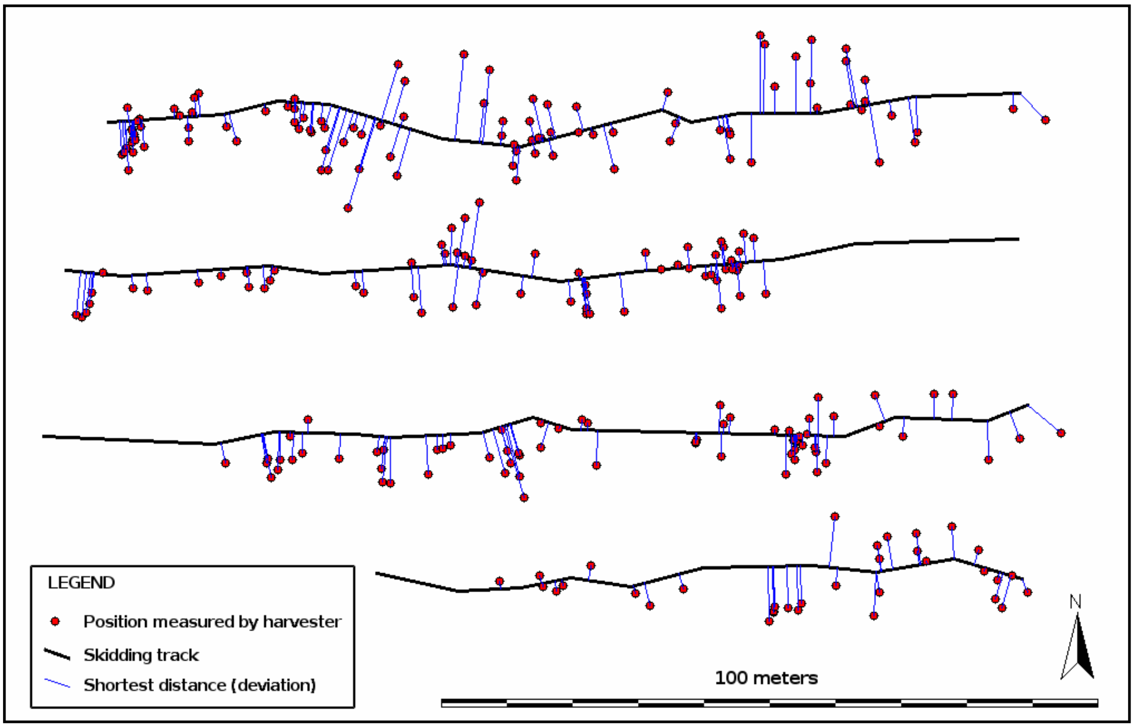
Table 2. Relative interpretation of the determined deviations in stand No. 1

Deviation value in metres	0 -1	1.1 -2	2.1-3	3.1-4	4.1-5	5.1-6	6.1-7	7.1-8	8.1-9	9.1-10	10.1-11	11.1-12	12.1-13	13.1 +
Relative deviation in %	5.6	8.6	10.1	11.2	10.1	12.0	8.2	8.6	6.7	4.5	6.4	3.0	1.5	3.4
Relative accumulated deviation in %	5.6	14.2	24.3	35.6	45.7	57.7	65.9	74.5	81.3	85.8	92.1	95.1	96.6	100

4.2 Larch stand No. 2

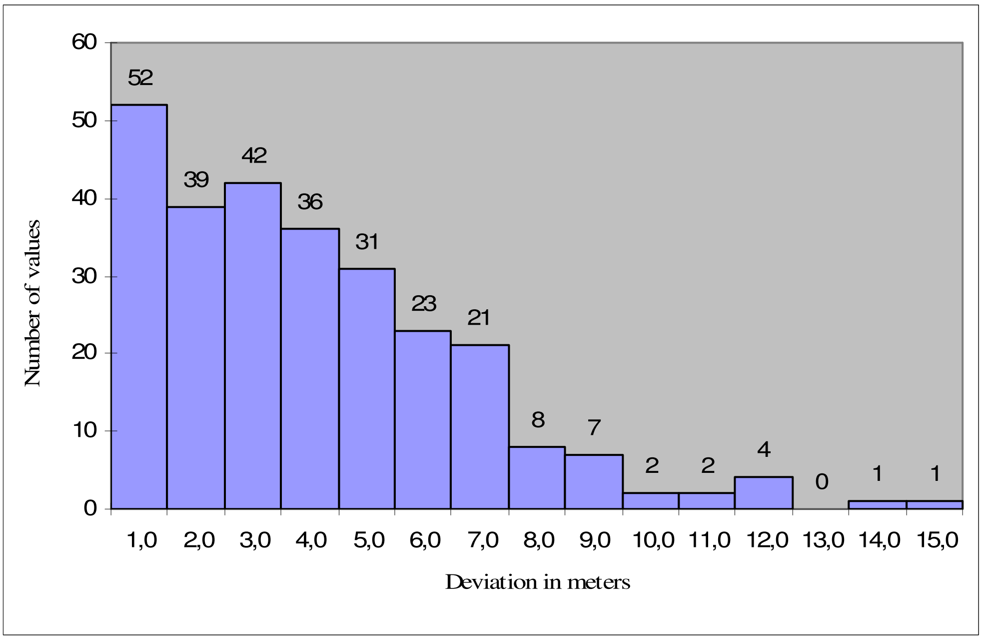
In stand No. 2, the skidding track in the length of 533 m was evaluated for the assessment of GPS accuracy. Harvester recorded 269 points which correspond to over 22 hours of monitoring. The points measured by the harvester were compared to the connecting line between the nodes passing through the centre of the extracted lane. The deviation values were defined as the shortest distance between the centre of the lane and the position determined by the harvester. For the achieved results and their comparison see the following graphs.

Graph 3. Deviation values for stand No. 2 between the positions measured by the integrated harvester GPS and the straightened lines from Trimble Pathfinder ProXH after post-processing



In stand No. 2, mean deviation value of 3.53 m and standard deviation of 2.68 m were established. Minimum value of deviation stood at 0.02 m and the maximum determined value of deviation in the monitored sample of 269 measured values was 14.25 m. Stand No. 2 was characterized by a flat terrain ideal for GPS measuring. The stand species composition (larch and broadleaves) and the date of measurement (January) additionally excluded any significant interference of the crown coverage with the quality of the received signal. The established results considerably reflect the better conditions. It needs be nonetheless noted that harvester logging technology is primarily designed for use in conifer stands and that spruce is the main commercial species in the CR.

Graph 4. Number of values within the one meter tolerance



The preceding histogram shows the deviation distribution of harvester position measurements from the centre of the straightened line. When compared with stand No. 1, a higher bias of deviation distribution is apparent – the overall data are hence more accurate. Total evaluation of the deviations reveals that in stand No. 2 34 % of values fell within the measurement accuracy tolerance of 2 m from the line, 74 % within the 5 m tolerance distance and 97 % within the 10 m tolerance which is a remarkably better accuracy than in stand No. 1.

Table 3. Relative interpretation of the determined deviations in stand No. 2

Deviation value in metres	0 -1	1.1 -2	2.1-3	3.1-4	4.1-5	5.1-6	6.1-7	7.1-8	8.1-9	9.1-10	10.1-11	11.1-12	12+
Relative deviation in %	19.3	14.5	15.6	13.4	11.5	8.6	7.8	3.0	2.6	0.7	0.7	1.5	0.8
Relative accumulated deviation %	19.3	33.8	49.4	62.8	74.3	82.9	90.7	93.7	96.3	97.0	97.8	99.3	100

4.3 Possibilities of technological preparation of the workplace

The measurement also involved the examination of prospects for using digital technological preparation of the workplace. At present, this would be a map with the indication of the planned felling operations, planned skidding tracks, roadside landings, protected zones, dangerous localities etc. which would be produced by forestry employees with good knowledge of the local conditions by means of a small PDA device with an integrated GPS. The processed data would be charted on the digital map to be copied in the harvester or forwarder. Thus the time required for the handover of the workplace would become significantly reduced, potential inconsistencies during the controlling process would become eliminated and in future, physical marking of these operations on site would no longer be necessary. So far, the submitted solution is not yet applicable in the conditions of the CR especially due to relative capital intensity of purchasing the PDA devices equipped with the GPS function and also because of insufficient accuracy achieved by the harvester GPS receivers.

5. Conclusion

It needs be stated that this paper is a pilot part of a project focusing on the assessment of applicability of planimetric data acquired from GPS receivers in modern logging and hauling machinery. The objective of the whole project is to integrate the logging cycle – felling operation planning on a digital map of the stand, monitoring of the logging process and timber haulage, transmission of information about the actual amount of stock according to the specific localities and the integration of these information in a system of timber transport logistics – into one information network. High variability of the obtained results confirmed that the existing GPS receivers in logging and hauling machinery rather play the role of accessory information for the machine operators with respect to their approximate position or the location of the logged timber. Utilization for tasks requiring deviation variability falling within the order range of 1 – 2 m, e.g. logging of the extraction lane according to a digital map or navigation to a concrete tree designed for felling, is still out of the question. Yet recently, the satellite systems of navigation have witnessed great boom and significant progress and so it can be expected that it will not take long for the accuracy and performance of the navigation systems to grow better. In general, the precision of navigation systems in specific forest conditions will be always inferior to open spaces (fields, roads) due to diverse interferences.

It needs also be noted that the use of navigation systems in logging and hauling machinery, particularly when digital base maps are available, has a positive impact on the operators despite its drawbacks. It improves their orientation in forest stands and reduces the risk of forgetting wood mass in incidental felling which are factors contributing to better communication between the operators and thus to higher efficiency of the logging junction. We firmly believe that in future, the use of navigation systems in logging and hauling machinery will become more widespread and for this reason it is necessary to search for ways of an effective utilization of the amount of recorded data.

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PRODUCTIVITY OF A 6 WHEEL LONG BOOM GRAPPLE SKIDDER IN VERTICALLY STRUCTURED HARDWOOD STANDS – A CASE STUDY IN THE COMMUNAL FORESTS OF AALEN

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Technische Universität München, et al., 2008
Joint Project ANW, Section Forest Operations DFFVA, TU Dresden, TU München, TU Göttingen, KWF, FVA Baden Württemberg, Forstverwaltung Aalen)

Abstract: *The "Arbeitsgemeinschaft für Naturgemäße Waldwirtschaft Deutschland" (ANW)" invited a joint working group to think about solutions for economical low impact harvesting operations in intensively structured nature orientated stands. The harvesting method should be flexible, appropriate to large hardwood as well as to conifer trees. It should be feasible for selective cuts, a skid-trail spacing up to 40m and cause only little damages even in stands with understorey and dense natural regeneration.*
Finally, a combined and at the same time detached tree-length method with extraction by the HSM 904 6WD 6 wheel long boom grapple skidder (net lifting torque 220 kNm) was tested in a 850 m³ and 14 ha selective cut near Aalen (December 2007). The main tree species were beech (fagus silvatica) and spruce (picea abies), natural regeneration was from 1m up to 10m height. The spacing of forest roads was about 300m – 400m. After clearing skid trails and extraction of 80 – 90 % of the cut volume, remaining difficult stems were yarded lateraly over the skid trail and separately crosscut by chainsaw in order to use the crane reach (7,2m) as much as possible. The mean piece volume of extracted logs and stems was about 1m³ s.u.b. before final crosscuts at the landing were applied. On average, 3 m³ solid under bark per load were extracted. The preliminary results are an average productivity of 15 m³ s.u.b. per pmh 15 (productive machine hour including 20 % non productive times up to 15 min duration = in German "MAS").
After the operation the FVA Freiburg (SAUTER, SIEMES, 2008) attested relatively low damages. Only 6 % of the residual rtees were hurt by extraction processes (definition of damage: at least one debarked spot >= 10 cm² per tree). The final statistical analysis e.g. regarding felling direction, distances to the skid trail and log lengths is still in progress. The goal is to set up a comprehensive model of the process observed.

1. Objectives

The discussion and steps of further evolution of harvesting systems base on a variety of local experiences, field tests and research work. New combinations and modifications of existing elements play an important role.

A screening of existing methods in ANW Enterprises was undertaken (ERLER 2008). The given task was to define a harvesting method which should fulfil the following demands:

- It should be suitable for selective cuts,
- hardwoods and conifers in mixed stands,
- applicable for tree lengths or multiple lengths, various assortments,
- able to harvest very large trees as well as medium sized stems,
- feasible for various terrain situations and a skid trail spacing up to 40m or more,
- cause relatively low damages even in stands with structured natural regeneration,
- productive and economically acceptable.

2. Process description

The discussion passed several stages including preliminary field tests. Ideas and critics of foresters, work safety specialists, workers, machine operators, manufacturers staff, and operators were considered.

Finally the Process was defined as follows, in order to keep extracted piece volumes as high as possible while preserving the remaining stand:

A Preparation

1. Predefinition and marking of skid trails with a recommended spacing between 30m and 45m. Marking of trees to be removed.

2. Definition of landing space e.g. along forest roads with a recommended width of at least 5 m – 7 m.

B Primary Operation

3. Felling and delimbing by chainsaw. First priority: low damages to natural regeneration. Second priority: Chose suitable felling direction to facilitate skidding.

4. Measurement of length, marking of crosscut points for assortments by chainsaw. Forked stems and crowns are cut off. Further crosscuts only if necessary for clearing skid trails.

5. Optional (if no measurement at plant is accepted): write down length, diameter and grade on ready stems, workers proposal: if measured write down measures on debarked spots close to future crosscuts so as to ease work at landing.

6. Extraction of tree lengths or multiple lengths by long boom grapple skidder. Herewith use of the crane lifting power to manipulate stems above regeneration and between remaining trees in order to avoid damages. Winch yarding only in case of bigger distances.

8. Crosscuts by chainsaw operators at landing starting as soon as necessary (e.g. because of limited space at landing).

9. After extraction of most of the stems and clearing the skidtrail: lateral yarding of difficult stems into and over the skid trail. This improves options for crane actions and accelerates necessary crosscuts in secondary operation.

10. Start with the next skid trail.

C Secondary operation (detached from primary skidding operations)

11. Crosscuts at remaining inserted stems along skid trails by chainsaw operator or in rare cases by skidder operator.

12. Final Extraction. Herewith using crane only.

13. Finish work at landing (crosscuts, final piling, write down measures).

3. Short sketch of field study

The task of the TU Munich (PAUSCH, WEBER) was to analyse productivity, to discuss and formulate the final work assignment for the working staff, to write a guide for the experimental design, incorporating feedback of the working group and after all to coordinate the field trial in cooperation with the Forest Administration of Aalen. The Forest Administration and the loggers supported our joint project perfectly. This enabled us to conduct the whole experiment including stand preparation within the last four weeks of 2007.

In the experiment, felling directions, lengths and diameters of all assortments per tree were measured and numbered in advance. To ensure productivity results even under hard conditions (snow, rain, darkness, dense regeneration), the volume of every load was measured at the landing.

The detailed time study itself lasted seven days, included about 240 loads, 430 trees with in total 746 m³ s.u.B.

The total area of 14 ha consisted of two separated stands and the average distance from the forest to the road was 100m. The skid trails existed already. 3 of 12 skid trails had been locked for study purposes in order to gain a higher portion of trees yarded by winch. About 757 logs (mainly tree-lengths and multiple lengths) were extracted to the landing.

The skidder operator had long term experiences with a less powerful, older HSM model. He was instructed by an operator of HSM. Because of the tight schedule, he trained only one week on the new Model HSM 904 6WD. For this purpose the machine operator and the professional chainsaw operators trained on a separated area before the time study started.

During the study, the machine operator worked very concentrated and proved a good spatial feeling when manipulating stems between remaining trees. Final piling operations were to a remarkable extent executed in darkness after extraction at day light. These times and fuel consumption were daily registered by the operator himself.

4. Selected preliminary results

Table 1 contains the productivity values in m³ s.u.B. per pmh15 (= MAS). For calculation purposes 20% of non productive times are assumed. “Distance” does not incorporate driving on the forest road e.g. for piling work. The productivity values of table 1 incorporate all machine activities, including secondary operation as well as final piling and driving.

Table 1: HSM 904 6WD – Study Aalen. Productivity [m³ s.u.B. per pmh15] depending on mean piece volume and distance from forest to forest road.

	Mean piece Volume of load [m³ s.u.b]			
Distance [m]	***0,5***	***1***	***1,5***	***2***
5	12	21	29	37
50	8	15	21	26
100	7	13	19	24
200	7	12	17	22

A remarkable percentage was extracted directly from the forest road (= distance 0m) which is not included here. The formula of the following productivity function only refers to productive times without including separate final piling. It so far includes only two influencing variables:

$$\ln(\text{productivity}) = \text{constant} + b1 * \ln(\text{distance [m]}) + b2 * \ln(\text{mean piece volume [m}^3\text{ s.u.B.]})$$

Corrected R^2 = 0,45, standard error of estimation = 0,54.

Table 2 : Preliminary productivity function. Statistical results.

	coefficients		standardised coefficients			95%-confidence- interval of B	
	B	standard error	beta	T	significance	lower limit	upper limit
constant	3,725	,178		20,916	,000	3,374	4,076
ln (distance [m])	-,146	,039	-,195	-3,691	,000	-,224	-,068
ln (piece volume [m³ s.u.b.])	,841	,065	,678	12,861	,000	,712	,970

FURTHER DEVELOPMENTS OF SYNTHETIC ROPES FOR LOGGING APPLICATIONS IN FORESTRY

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Keywords: synthetic ropes, wear mechanisms, rope life, end connectors.

Abstract: *Based on long-time experience in the industrial use of both synthetic ropes and steel wire ropes, Teufelberger started research and development in synthetic ropes for logging applications in 2005. Practical tests were done in tight cooperation with the "Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)".*

For some years the benefits of synthetic ropes in logging have been reported (see also Garland J.J., 2004a, Oregon State University): pronounced improvement of working conditions in manual harvesting, consequentially increased productivity due to the weight reduction of the rope by about 80 % as compared to steel as well as reduction of accidents.

This paper presents results of lab and practice tests for fibre ropes made of Dyneema© combined with other synthetic fibres. Newly developed technical solutions for the rough conditions of logging help maintain the excellent technical properties of Dyneema© for a longer time while improving abrasion resistance and providing an indication of rope wear / rope life. Work also focused on the design of end terminations/connectors with little compressional force. With Stratos logging ropes the use of synthetic ropes in logging has become practicable and leads to cost savings that make them pay off.

1. Introduction

The introduction of the second generation of synthetic polymer fibres, i.e. of high-modulus, high-tenacity fibres in the last quarter of the 20th century opened a new material source for fibre ropes. With the development of high-modulus polyethylene (HMPE, Dyneema©) fibres a material has become available that is stronger than steel on an area basis and about 10 times stronger on a weight basis (see table 1; data for polyester fibre (PET) as a well-known commodity fibre are included for comparison). It stands to reason that there is a high advantage of HMPE over steel wire rope in applications where weight is a critical factor – an advantage that may well justify a higher material price.

Table 1: Tensile properties of steel wire, high-modulus polyethylene and polyester fibres
(McKenna, Hearle, O'Hear, 2004)

quantity	unit	steel wire	HM-PE	PET
density	[g/cm³]	7.85	0.97	1.38
strength per unit area	[MPa]~[N/mm²]	2600	3400	1130
strength per weight[2] (tenacity)	[cN/tex]	33	350	82

[2] Correctly, the quantity considered is strength per weight per length as equal lengths of fibres are compared. For the sake of understanding, we have called this quantity "strength per weight" instead of "strength per weight per length" or "strength per linear density".

One application in which weight plays the major role is logging and especially mountain logging. The use of HMPE fibre ropes as a substitute for steel wire ropes

- leads to a significant reduction of work loads (ergonomic aspect),
- reduces the potential for accidents as it eliminates wire break that may lead to punctures and as it reduces fatigue which is often the cause of accidents,
- pays (economic aspect) as task times are significantly reduced, therefore shortening preparation time and increasing productive harvesting time.

As regards the ergonomic aspect, extensive studies have been performed by the Forest Engineering Department of Oregon State University (Garland et al., 2002; Garland et al., 2004a). These studies compare the use of steel wire rope to synthetic fibre rope and show that upon use of HMPE ropes heart rates are reduced, recovery after exertion is improved and that workers subjectively assess work loads as reduced.

Depending on the logging application, task times are reduced. Dragging a synthetic rope uphill takes only approx. 25% of the time used for a wire rope. In skidding, again out hauling of the rope takes only 50% time with a synthetic rope whereas further tasks like hooking and unhooking or winching in are only shortened by a minor amount (Garland et al., 2004a). Similar magnitudes are given by a study performed by HAWK Fachhochschule Göttingen, Germany in 2004, where workers estimate that work power doubled during the use of Dyneema© rope in winch applications (Schultze et al., 2004).

In order to assess the ergonomic benefit of *Stratos* Logging Ropes a project on "Efficiency and Ergonomic Improvements for Cable Yarding Operations in Steep Terrain" headed by the Austrian "Universität für Bodenkultur – Department für Wald- und Bodenwissenschaften" in cooperation with Teufelberger amongst others is to start shortly and ought to be completed by the end of May 2009.

Our field test showed that in the use of synthetic ropes as a guyline for a yarder, overall preparation time is reduced by 50%. Based on data provided by a major logging company in Austria, installation time for guylines may be assumed as one hour, meaning a reduction of 30 minutes or rather a respective increase of harvesting time. Assuming 72 installations per year this gain of harvesting time sums up to 36 hours per year or 300 cubic metres of solid timber more to be harvested. Additionally, installation may be done by two workers instead of four. We have developed a calculation tool to show the benefit of the synthetic rope. Contrasting the benefit with the higher cost of a synthetic rope indicates amortization within 6 to 12 months.

Change from a steel wire rope to a synthetic rope in winching is reported to pay off within a month of skidding. (Garland et al., 2003)

The critical points in the use of synthetic fibres in logging applications are high sensitivity of HMPE to lateral forces (compression) and difficulties in assessing remaining rope life. As steel wire rope end connectors often work due to compressional forces these devices cannot easily be used on synthetic fibre ropes. Besides, lateral forces are exerted to the winch line when it is wound on the drum. It has been our major concern to find means of assessing remaining rope life and to develop end connectors that are suitable both for the synthetic rope and the application in question.
Focus has been on guylines for yarders and for intermediate supports, synthetic extension lines for wire skylines, winch lines for skidders and chokers. Wear mechanisms for these applications were considered and lab tests as well as field tests carried out accordingly.

2. Applications and Wear Mechanisms

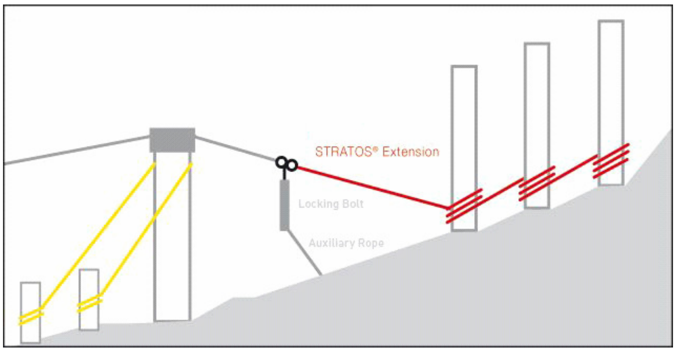
2.1 Static Applications

Static applications in this report include guylines for yarders and intermediate support trees (figures 1 and 2) as well as synthetic extensions for steel wire skylines. A schematic picture shows the use of these synthetic extensions (figures 3 and 4).

Figure 1: Synthetic guylines *Stratos Anchor* Figure 2: Synthetic guyline *Stratos Support* for yarder for intermediate support tree

Figure 3: Synthetic extension line *Stratos Extension*

Figure 4: Scheme of the use of *Stratos Extension*



The properties required by the static applications described are visible in figures 1 to 3.:

- high abrasion resistance: The rope end is usually wrapped around a tree stump where it is exposed to the rough surface of the tree bark and at the same time "cuts" into the tree stump under high tensile load.
- good tension fatigue: The rope is not exposed to a constant load but may see load cycles, e.g. for a 22mm steel wire rope 3.5 to 5.5 kN were measured.
- good bending fatigue: At the top of the yarder the rope is subject to cycling over sheaves. Due to changes in load (see tension fatigue) minor rope movement on the sheaves must be considered.
- exclusion of torsion: Torsion in the rope leads to uneven distribution of load among the rope
- strands and therefore to a reduction in overall rope strength.

Besides, HMPE requires low lateral stress, which must be considered in the design of the end connector.

2.2 Winch Lines

In winch lines as shown in figure 5 abrasion resistance is an even more important issue than with static line applications. Winch lines are often dragged along the forest soil and therefore subject to severe abrading conditions. Bending and tension wear are also reported for winch lines (Schultze et al., 2004).

Figure 5: Synthetic winch line *Stratos Winch*

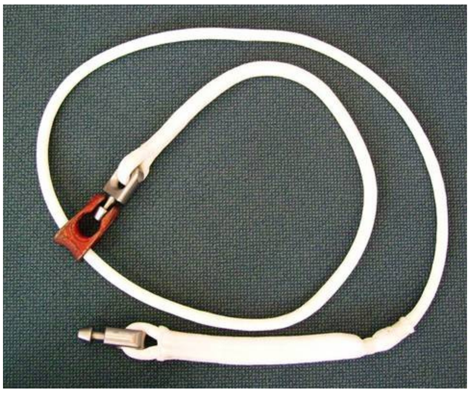
High lateral forces are exerted to the winch line when it is wound on the drum. After 7 months of use the part of *Stratos Winch* wound on the drum was heavily distorted and had a nearly triangular crosssectional shape. The tensile strength of this part had, however, only decreased by a few percent.

It is a common procedure to re-do a wire rope end because of damage. As the same occurs to synthetic winch lines, a rope connector that can easily be repaired is a must. Schultze et al. even recommend to re-use the rest of the rope by re-connecting it with a long-splice and to turn the rope leading to more even wear (Schultze et al., 2004).

2.3 Chokers

Due to the shorter length of chokers the weight reduction stays in the background as compared to the other applications described and the absence of jaggers and reduced risk of injuries becomes of higher significance. The synthetic rope's flexibility makes it easy to work with.

Figure 6: Synthetic choker line *Stratos Choker*



As with winch lines, abrasion is the most critical wear mechanism: Choker lines are not only dragged along the forest soil but also rub against the tree bark. Figure 6 shows a synthetic choker with the sewn end protected by a cover sleeve.

2.4 Measurement of Fatigue Resistance

The most important wear mechanisms in the quoted logging applications may be summarized as bending fatigue, tension fatigue, torsion and abrasion. Abrasion resistance is dealt with separately (see chapter 3.) as external abrasion "is not considered fatigue" (McKenna, Hearle, O'Hear, 2004) and as extensive studies of the BFW focused on the topic of abrasion and abrasion resistance and deserve a separate chapter.

Bending fatigue (also: flex fatigue) means the effect of bending of the rope structure, e.g. when guylines run over sheaves like at the top of the yarder. The rope is subject to compressional forces on the inside radius of a bend and to tension on the outside radius. Flex fatigue depends on many variables like fibre material, sheave surface material, rope construction, load levels and frequency, the probably strongest influence being D/d ratio (D being the diameter of the sheave, d the diameter of the rope; large D/d ratios increase rope life) (McKenna, Hearle, O'Hear, 2004).

We tried to calculate how many bending-cycles one particular piece of rope may see and made the following assumptions: During one go of the carriage along the skyline, the guyline is assumed to be exposed to 10 load increases that lead to minor movements on the sheave. With six goes per hour and 10 hours per day, the same piece of rope would be subject to 600 bending cycles per day. With 15 days of harvesting in one place, that part of the rope would be exerted to 9,000 bending cycles. After the next installation the rope piece is most likely to be in a different place and not at the top sheave again.

Therefore the following test was performed: A *Stratos Anchor* 26 mm was subject to a bending fatigue test of 10,000 cycles with bending in one direction under a constant load of 80 kN. The diameter of the pulley (pulley groove: 20 mm) was 280 mm leading to a D/d ratio of 9.7 to 12 (as the rope is slightly oval). The rope was inspected after every 1,000 cycles and in all cases no wear was detectable visually apart from the rope running flat in the bending area. After 10,000 cycles the tensile strength of this "used" rope was measured and no strength loss was found.

Tension fatigue refers to rope wear due to cyclic loading and unloading, which primarily leads to internal fibre abrasion followed by filament breakage and therefore loss of strength. Tension fatigue is again dependent on fibre material as well as load difference (between minimum and maximum load), load level (mean load) and frequency. Internal abrasion being the key to tension fatigue, the performance of the fibres is strongly influenced by fibre finishes.

Data show that "the tension fatigue life of polyester ropes is greater than that of […] wire ropes. Indications are that a similar situation exists for […] HMPE ropes" (McKenna, Hearle, O'Hear, 2004).

These findings were further supported by tension fatigue tests on Stratos Anchor 26mm. Minimum and load maximum load were set at 30 and 100 kN respectively. Frequency was set at 1 Hz and the rope was subject to 600,000 cycles. It must be considered that for a 22mm steel wire rope measured loads were a lot lower (see 2.1). Assuming that the rope may have 6 goes per hour and 10 goes per day the rope will see 60 goes/day. Further assuming 200 work days / year this would amount to 12,000 goes/year. Taking the maximum life time of a comparable steel wire rope, which is 7 to 8 years, about 90,000 goes in a rope life time are the maximum expectation. During one go several load changes may occur – always keeping in mind that it is highly improbable that these load changes are as high as 30 to 100 kN. We therefore set 600,000 cycles as maximum. The rope was tested for its remaining tensile strength after this severe treatment and a negligible strength loss of 1.5% was found. These findings support our view that HMPE ropes can replace steel wire ropes without having to expect problems as far as tension fatigue is concerned.

Tension fatigue must not be confused with overloading, which does not refer to a slow deterioration of rope strength but means excessive tension or shock loading. This type of damage is reported to be difficult to detect by visual or tactile inspection (McKenna, Hearle, O'Hear, 2004). *Stratos* Logging Ropes try to overcome this problem with the help of a special rope pattern: It is made of lines at regular and relatively short intervals. Differences in inter-line distance of more than 3.0% -as may occur as the result of overloading – are easily visible and a clear indication of some overload event (see figure 7).

A remaining elongation of less than 3.0% is regarded as the result of normal use of the rope. In order to proof this assumption a further bending fatigue test of 10,000 cycles was carried out using *Stratos Anchor* 22mm with bending in one direction under a constant load of 40 kN, diameter of the pulley being 280 mm (pulley groove 20 mm) leading to a D/d ratio of 11.4 to 14,4 (oval rope). After the test the rope again showed no strength loss and a remaining elongation of 2.5 %, which is in strong support of the above mentioned recommendation.

Torsion is supposed to reduce rope strength as it leads to unbalanced loads on rope strands. Tests showing the influence of torsion on rope strength were carried out by Tension Technology International (funded by the Marine Accident Investigation Board). A 22mm *Stratos Anchor* was used and led to the results shown in table 2.

Table 2: Test results of influence of rotation on rope strength of a 22mm *Stratos Anchor*
(O'Hear, Nichols, 2006)

twist [turns/m]	residual strength [%]
1	96
3,5	85
5,5	56

The data show that a high twist that seems unlikely in use is necessary to substantially reduce rope strength. Nevertheless, *Stratos* Logging Ropes are equipped with a special rope pattern to make the user aware of rope twist immediately (see figure 7).

Figure 7: rope pattern of *Stratos* Logging Ropes : straight lines indicate torsion, cross lines indicate overloading

In conclusion, the data indicate that bending fatigue, tension fatigue and torsion are relevant wear mechanisms in logging, but tension fatigue is reportedly better of HMPE ropes than of steel wire ropes, the amount of bending on a guyline does not affect the rope and torsion is not likely to be so high as to lead to a deterioration of rope strength. Moreover, the *Stratos* Logging Rope pattern indicates torsion and overloading or other incidences that may lead to local rope elongation.

3. Abrasion Resistance

Ropes in logging are confronted with rough abrading conditions: forest soil, tree barks, branches etc. most likely under high loads. This holds true for steel wire and synthetic fibre ropes. While abrasion and wear of steel wire ropes can be assessed on the basis of a specified number of broken wires, synthetic ropes become fuzzy and eventually this fuzziness may become so prominent as to hide the initial braid structure. It has proven difficult to assess remaining rope life and strength loss from the appearance of a fibre rope (Takumi, 1997).

Pilkerton et al. gave some indication on rope life in 2003 and reported that "synthetic rope initially fuzzes up from broken filaments that produce a protective cushion but when braided rope is worn 25% from abrasion it should be replaced" (Pilkerton, Garland et al., 2003). Nevertheless, they still reported in 2004 that wear and replacement criteria were needed (Garland et al., 2004a).

With *Stratos* Logging Ropes a new way has been found to resolve this issue. The ropes are constructed as cover-core ropes with a synthetic abrasion resistant cover protecting the load bearing HMPE core.

The cover does not contribute to the rope strength. Any damage of the cover by abrasion will therefore not reduce the strength of the core, which has been confirmed by tests (see below).

In order to simulate rope wear acceleratedly under conditions to be expected in logging a test unit was built with the support of the Federal Research and Training Centre for Forests in Gmunden. These dynamic wear tests (together with further lab tests) gave us a sound basis for developing an optimized rope cover and are the basis for rope life assessment and the definition of replacement criteria for synthetic ropes as compared to steel wire ropes.

For planning the test track the following criteria had to be kept in mind:

- The test track has to be suitable for both chokers and winch lines made of either synthetic fibre or steel wire simulating dragging,
- the test track has to be the closest possible approximation of most severe use in logging,
- the conditions for the ropes have to be virtually constant throughout the test series,
- the results of the test units have to be comparable,
- the conditions of a test series have to be reproducible,
- changes of the samples and change of direction have to be automated to the greatest possible extent and have to be simple.

Bearing these requirements in mind, a test track of about 40m length and 3m width was equipped with a rough surface closely simulating extreme conditions in logging so as to accordingly expect fast wear of the rope samples. About 20 cm of rough limestone gravel (grain size 0/32) mixed with about 25% humus were put on a coarse gravel bed. The track was compressed and rolled.

In order to simulate fixed obstacles in out hauling and to prevent the track from gradual depression seven concrete sleepers in cross direction were dug into the track at a distance of 3.5m. The sleepers protruded the track surface by about 3 cm. At one end of the test track a buffer stop was set down for testing maximum potential load. The load that had to be dragged was about 1500 kg in weight and consisted of two joined beech logs and additional concrete weights. This test load was dragged to and fro with the help of diverter pulleys and a double drum winch.

Straps were attached to each log end. Yokes were fixed between the chokers and the winch line to even out load differences and to ensure similar loads on each of the four chokers. This test design made it possible to make four tests on chokers and one test on a winch line in one go (see figures 8 and 9). Chokers are tested for abrasion resistance, the winch line may be judged by its winding properties.

Figure 8: test track design

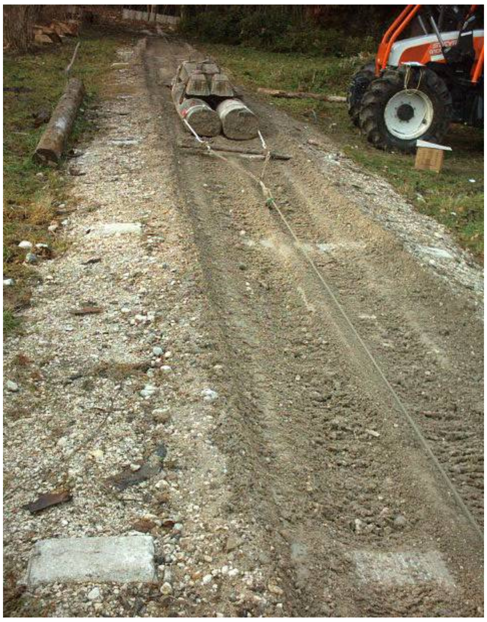


Figure 9: beech logs with concrete weights
numbers refer to test positions 1 to 4

On an average 50 cycles (1 go in one direction = 1 cycle) were carried out until wear of the chokers became visible. One test set consisted of 5 rope sample sets. Each test set was started and ended with steel wire ropes. On the one hand, these steel wire rope samples were tested for reference, on the other hand, the conditions of the test track were checked for possible changes during the test set. The second, third and fourth rope sample sets were different synthetic fibre ropes with one of these rope sample sets being the best in the preceding test set and the other two being new developments. This procedure ensures good test reproducibility.

The change of rope wear was evaluated and documented with the help of photos. Pictures were taken at regular intervals. The rope quality was assessed after measurement of remaining tensile strength of the worn rope samples in the lab. All ropes in table 3 are without coating. Tensile strength results refer to the rope including sewn ends (3 sewing patterns).

The results of one test set (see table 3) indicate that there are differences in position with positions 2 and 3 being consistently more abrading than positions 1 and 4. Steel wire rope wear is reproducible (1^{st} and 2^{nd} runs), but the test track loses some abrasiveness in the course of the test set (3^{rd} run). Therefore, the results were normalized based on the assumption that the steel wire rope of the 1^{st} and the 3^{rd} run must show the same strength loss after the same treatment. A linear degradation of abrasion conditions was assumed (see diagram). The diagram also includes the strength loss of a Dyneema rope without cover (as used until the development of *Stratos* Logging Ropes) and shows a dramatic strength loss of nearly 60% by abrasion as the load-carrying HMPE fibres are damaged.

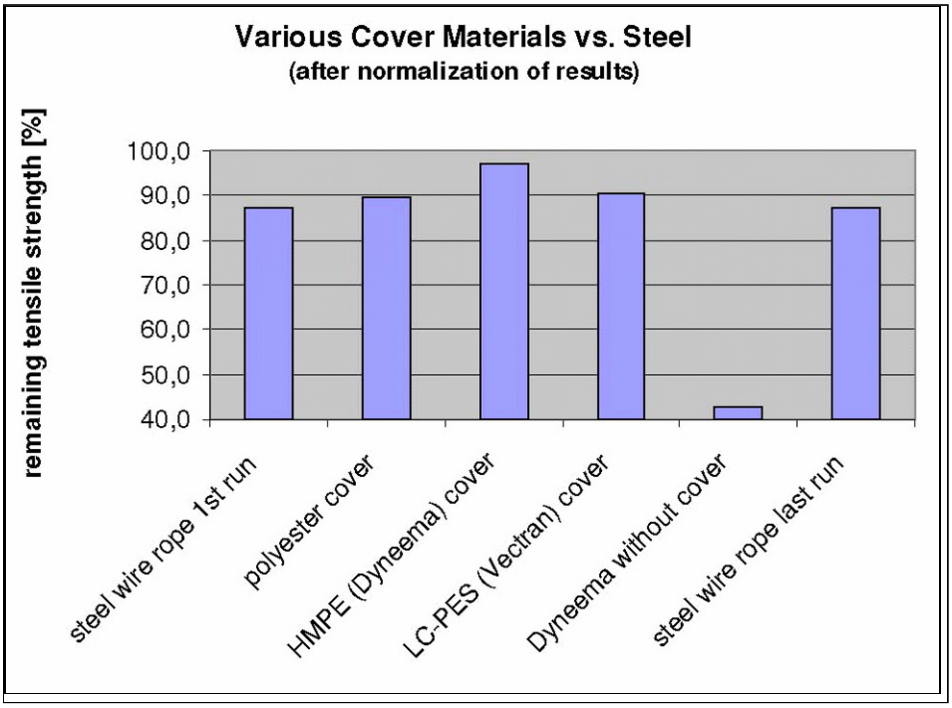
The steel wire chokers were clearly past their rope life after the test and showed only little more tensile strength than the synthetic fibre chokers. In all synthetic fibre chokers the cover was still intact with the exception of PET cover in positions 2 and 3. The cover of position 2 was severely damaged, the cover of position 3 was damaged to a minor extent. In those cases where the cover was damaged (this was also confirmed by further test sets) the core was exposed to abrasion and dirt and lost strength immediately and to a high extent. HMPE ropes showed higher tensile strength after use than before, which may be attributed to bedding-in and in-situ stretching of the rope.

HMPE shows promising properties as the cover material. Polyester can do under less abrasive conditions and is used in *Stratos Anchor*.

Table 3: Results of abrasion tests

				tensile strength [kN]					
	rope make	**diameter [mm]**	**linear density [g/m]**	**new rope**	**used rope position 1**	**used rope position 2**	**used rope position 3**	**used rope position 4**	**average of positions 1-4**
steel wire rope 1st run	216 WS+SC	11.0	479.0	83.1	79.9	73.6	61.7	74.5	72.4
steel wire rope					80.0	65.8	68.0	81.7	73.9
polyester	HMPE core - PET cover	13.3	117.4	63.3	70.7	38.2	58.4	72.7	60.0
HMPE (Dyneema)	HMPE core - HMPE cover	13.0	94.7	63.5	78.6	77.8	77.6	78.0	78.0
LC-PES (Vectran)	HMPE core - Vectran cover	13.5	116.8	66.3	67.2	69.1	63.9	65.6	66.5
steel wire rope 3rd run	216 WS+SC	11.0	479.0	83.1	84.0	81.4	80.1	83.1	82.2

Figure 10: Diagram visualizing results of abrasion test



These findings lead us to the conclusion that a damaged cover is a clear indication that the Dyneema© rope must be disposed of, whereas Dyneema© ropes with an intact cover that still protects the core have sufficient remaining tensile strength.

4. End Connectors

The use of wire rope end connectors on synthetic fibre rope is not immediately possible. Most wire rope end connectors work by means of external pressure (lateral force; clamping). High local lateral force, however, is most disadvantageous to HMPE and other high modulus synthetic fibres and reduces their tensile strength considerably. Most obviously, a rope – and also a synthetic fibre rope – "is only as strong as its weakest link, and this is often the termination" (McKenna, Hearle, O'Hear, 2004).

Depending on the use of the rope and its termination application specific criteria for the end connectors were found:

- end connectors for static applications must be able to bear high loads,
- connectors of synthetic extensions to wire ropes must be designed in a way to prevent potential rotation of the (laid) wire rope from propagating to the synthetic fibre rope,
- stoppers on a winch line must bear high loads, protect the rope termination against abrasion and be easy to repair,
- connectors of the winch line to the winch must deliberately break at a certain load for safety reasons,
- choker ends should be able to be used with standard steel wire configurations on the winch line as these are more easily available than special solutions. It has, however, been found that standard steel wire choker configurations are not ideal and ought to be replaced by solutions designed for fibre ropes.

An enormous number of tests had to be carried out in order to find the best kinds of rope terminations. In several rather complicated constructions using basically steel bolts as a stopper for a winch line, we found that the steel construction would be distorted and badly damaged while the synthetic fibre rope would still be fine.

End connectors that ought to bear high loads, i.e. end connectors for static applications, are best designed by splicing. Buried eye splices show smallest strength loss as compared to the rope's free length (Garland et al., 2004b). The eyes can be further connected with shackles and the like. Whenever one rope end is fixed to and wrapped around a tree trunk the rope and rope end must be protected against abrasive wear. The best result was gained with a leather cover around the core/cover-rope. Furthermore, abrasion resistance can be adjusted to the necessary level by choosing a suitable cover material (HMPE for most severe conditions like in rope extensions, PET in less rough circumstances like in guylines; see chapter 3.).

In guylines for support trees a special sling attached to the rope was developed to further secure the rope against slippage due to movements of the support trees. These slings are sewn unto the rope at regular intervals and are further protected by an abrasion resistant cloth (patent granted). This protecting cover can easily be removed from the sling needed for installation of the guyline (see figure 11).

Figure 11: Rope slings (red) on guyline for support tree

Figure 12: Stratos Extension connection with locking bolt

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Connections between synthetic ropes Stratos Extension and (laid) wire ropes must be fixed with a locking bolt to avoid propagating rotation as described above (see figure 12).

Two types of stopper on our winch rope *Stratos Winch* have proven to be practical: One of them is based on an eye splice and can therefore be repaired on the spot; the other one is a resin socketed termination whose repair takes a workshop. In both cases, the fibres of the rope end are protected against compressional forces by a steel casing. Figure 15 shows Stratos Winch after 240 uses.

Figure 13: Splice based end

Figure 14: socketed termination

Figure 15: Stratos Winch after 240 uses

As for *Stratos Choker*, sewn ends have stood the test. They can be produced with highly reproducible strengths. We have, admittedly, had the experience that the bends on standard end configuration for steel wire chokers are rather narrow and induce rope break at the bend. Choker lifetime seems sufficient for a start but can be further improved by using special end connectors for synthetic chokers. Some users might, however, prefer to use standard wire rope hardware, which is possible even now. The sewing ought to be protected against abrasion by a cover.

5. Conclusion

In the course of two years, Teufelberger have developed new synthetic fibre ropes of cover/coreconstruction for various logging applications: guylines for yarders (*Stratos Anchor*) as well as for support trees (*Stratos Support*), synthetic rope extensions for wire rope skylines (*Stratos Extension*), winch lines (*Stratos Winch*) and chokers (*Stratos Choker*). The ropes had to stand trials in the lab (to test the influence and relevance of wear mechanisms), on a test track simulating application (most of all to test abrasion resistance) and in the field. The cover/core construction makes it possible to use a special rope pattern as an indicator for torsion and overloading. An intact cover protects the core and indicates good tensile strength characteristics. End connections and terminations based on splicing and sewing have stood the test especially in static applications. More work is done to optimize choker ends, though.

These findings make the use of synthetic fibre ropes in logging practicable. 80% weight reduction leading to positive ergonomic effects and a reduced number of accidents are good reasons for synthetic logging ropes, higher productivity most probably being the best.

6. Acknowledgements

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Nick O'Hear of Tension Technology International (TTI) has been a great partner in discussions and allowed us to use his data on rope rotation, gratefully funded by the Marine Accident Investigation Board.

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THE INFLUENCE OF THE SKIDDING DISTANCE ON THE VALUE OF DAMAGE DONE TO THE SURFACE SOIL LAYER IN THE COURSE OF TIMBER HARVESTING IN PINE THINNINGS

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Keywords: timber harvesting, horse skidding and skidding with cable winch, level of soil damage.

Abstract: The requirement to apply those timber harvesting technologies which are the least damaging to the environment ought to be put into the management practice of the State Forests as a priority. In recent years, a number of research and implementation tasks have been undertaken in this respect. Studies conducted for several years in the Department of Forest and Wood Utilization, Agricultural University of Cracow and concerning the timber harvesting technology which uses the winch powered by the chain saw engine (Sowa and Stańczykiewicz, 2003, 2005) have shown that, with respect to its environmental impact, this technology is competitive as compared to the one based on horse skidding. The present study consisted in determination and comparison of the size of damage done to the surface soil layer in the course of horse skidding and skidding by means of the Multi FKS winch, and determination of the relation between the skidding distance and the amount of soil damage in the two technologies. The scope of the work was limited to late thinning in a pine stand. The results show that the horse skidding technology caused greater soil damage: on average U_g = 2,10; max U_g = 14.8. The technology using the winch resulted in a lower value of damage (on average U_g = 1,28; max U_g = 10,0). Statistical analysis shows that there is no significant correlation between the U_g index and the distance in horse skidding (r = -0,24, p = 0,177) whereas skidding by means of the winch revealed a high, statistically significant correlation (r= -0,7, p=0,000). The values of the U_g soil damage indexes in the technology using the winch showed significant differentiation depending on the distance from the skidding trail: the highest values were obtained close to the skidding trail while the lowest ones were in the area most distant from it.

1. Introduction

The requirement to apply those timber harvesting technologies which are the least damaging to the environment ought to be perceived as a priority in the management practice of the State Forests. *The Report on the Condition of Forests* (*Raport o stanie lasów*, 2003) notes that improper management may result in damage to the whole forest ecosystem, permanent limitation of site productivity and of extra-production forest functions. Forwarding, which requires the purchase of expensive machines, is commonly disregarded and it is considered that skidding by means of horses causes little damage to forest ecosystems (Giefing et al., 1995; Krag et al., 1986; Laurow, 1990; Messingerova, 1997). Studies conducted for several years in the Department of Forest and Wood Utilization, Agricultural University of Cracow and concerning the timber harvesting technology which uses the winch powered by the chain saw engine (Sowa and Stańczykiewicz, 2003, 2005) have shown that, with respect to its environmental impact, this technology is competitive as compared to the one based on horse skidding.

The present study consisted in determination and comparison of the size of damage done to the surface soil layer in the course of horse skidding and skidding by means of the Multi FKS winch, and determination of the relation between the skidding distance and the amount of soil damage in the two technologies.

The scope of the work was limited to late thinning in a pine stand.

2. Methods

The present research was conducted in the Forest District of Dąbrowa Tarnowska, in a stand where late thinning was being performed. The basic characteristics of the object of the research are presented in Table 1.

Table 1. The basic characteristics of the stand where the present research was conducted

Total surface [ha]	13,34
Forest site type	Fresh mixed coniferous forest
Economic type of stand	Larch-oak-pine
Share of species [%]	Pine - 100
Age [years]	68
Stand density index	0,9
Density	Moderate
Average breast-height diameter [cm] / height [m]	27/25
Stand quality class	Ia
Merchantable bole [m^3/ha]	396
Other features	Flat area, covered with turf, undergrowth: 60% of alder buckthorn

In a selected stand, before harvesting, on each of 4 measurement plots with a grid of squares of 12.5 x 12.5 m, 32 circular sample plots with the radius of 3.99 m were set up. The circular plots were situated along 5 strips of land. Strip no. 1 was the closest to the operation route and strip no. 5 was the farthest from it. On plots no. 1 and 2 harvesting was done by the chain saw operator; horse skidding was carried out from the stand to the operation route. On plots no. 3 and 4 cutting and debranching was done by the saw operator, who always preserved the direction of felling which was opposite to the operation route, where the Multi FKS winch was installed in order to pull logs to the operation route. In both technologies under analysis, skidding was carried out at the angle of about 45^o to the operation route. Thus the distance of skidding between particular strips was approximately a multiple of 17 m. The skidding technology with the cable winch powered by the chain saw engine had been described in detail by Sowa (Sowa, 2000). Felling was performed in summer months (June-July) in periods without rainfall.

Assessment of damage done to the surface layer of soil was performed on the circular sample plots after harvesting, by means of measurements of the damage using the measuring tape, exact to 1 cm.

Comparison of damage done to the surface layer of soil as a result of the technological processes under analysis was conducted by means of the U_g index elaborated by Suwała (1999) (1).

$$U_g = G_{ko} + G_{bp} + 2\,G_{bg} + G_{kp} \tag{1}$$

where:
U_g – synthetic index of damage to the surface layer of soil,
G_{ko} – percentage of the volume of ruts in 10-cm-thick soil,
G_{bp} – percentage of the volume of shallow ruts, up to 5 cm deep, in 10-cm-thick soil,
G_{bg} – percentage of the volume of deep ruts, over 5 cm deep, in 10-cm-thick soil,
G_{kp} – percentage of the volume of the traces of horse hooves in 10-cm-thick soil, calculated on the basis of an empirical formula.

Since the measurements were made on small, circular plots with the surface of 0.5 are, where very precise measurement of all damage done to the surface layer of soil is possible, the calculations disregarded G_{kp}, including hoof traces in the categories of either shallow or deep ruts, depending on their depth. Moreover, wheel ruts were not noted because the skidding was not performed using wheel vehicles. Thus the synthetic index of soil damage was calculated according to the following formula:

$$U_g = G_{bp} + 2\, G_{bg} \qquad (2)$$

where:
the symbols are as in formula (1).

The values of the U_g indexes underwent statistical calculations by means of the Statistica 6.0 PL programme (StatSoft, Inc., 2004).

3. Results and discussion

The empirical distribution of the U_g indexes from particular plots were subjected to the Shapiro-Wilk test in order to determine their accordance with the normal distribution. The normal distributions were obtained only after the logarithmic transformation of the U_g indexes. The results of the tests are presented in Table 2.

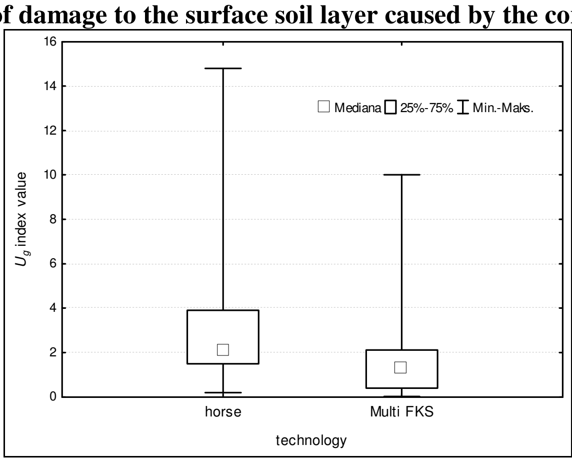
Table 2. Results of the Shapiro-Wilk tests: accordance of the U_g indexes with the normal distribution

	Before transformation				After logarithmic transformation			
Skidding	Horse		FKS winch		Horse		FKS winch	
plot	1	2	3	4	1	2	3	4
W	0.629	0.809	0.813	0.667	0.629	0.918	0.954	0.943
p	0.000	0.002	0.001	0.000	0.959	0.121	0.241	0.279

The uniformity of the research sample was determined by means of the t-Student test, determining the significance of the differences of the mean value of the U_g index between plots 1 and 2 (horse skidding) and plots 3 and 4 (skidding by means of the FKS winch). A lack of significant differences was noted both between the plots where horse skidding was used (t = 0.496; p = 0.623) and between the plots where skidding was done by means of the winch (t = -1,291; p = 0,205).

By means of the t-Student test, the significance of differences of the mean value of the U_g index was determined between the technologies applied. The results obtained (t=2,744; p=0,008) indicate significant differences. The basic descriptive statistics of the values of the U_g index are presented in Figure 1.

Figure 1. The level of damage to the surface soil layer caused by the compared technologies

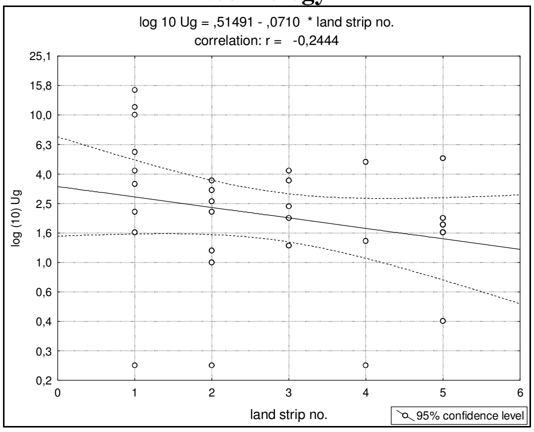


The skidding technology using the horse was characterized by higher values of the damage index (U_g = 2.10); the maximum values were also higher (the maximum U_g = 14.8). The skidding technology using the winch was characterized by lower values of the damage index (U_g = 1.28); and smaller variability (max U_g = 10.0). The present results are very close to those presented by other authors. For example, Suwała [1999] notes that in similar conditions in thinned pine stands, the U_g index for horse skidding was 2.4.

As in the research by Sowa and Stańczykiewicz (2005) concerning tree damage, similar categorization of the compared technologies according to their harmful impact on forest soil was obtained. These authors also showed a larger harmfulness of horse skidding than of skidding performed by means of the Multi FKS winch.

The power and character of the dependencies between the size of damage to the surface soil layer as described by the values of the U_g index and the number of a strip of land, indicating the skidding distance, were analysed on the basis of the analysis of regression. The results obtained for the technology with the use of horses are presented in Figure 2.

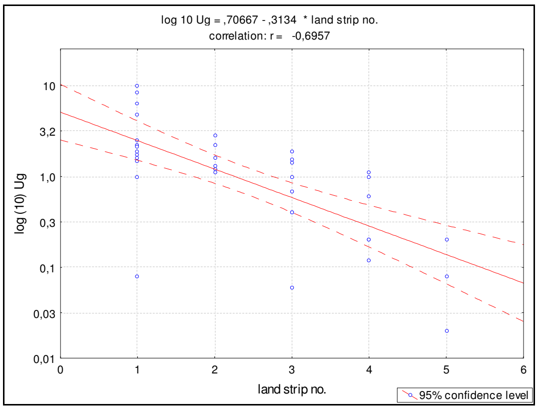
Figure 2. Dependence of the size of soil damage on skidding distance in the horse skidding technology



The coefficient of correlation between the values of the U_g index and the skidding distance in the technology under analysis indicates a weak relation between these variables. The coefficient of correlation obtained also turned out to be statistically insignificant (t = -1.380, p = 0.177).

The results of analysis of regression for the technology of skidding with the Multi FKS winch are presented in Figure 3.

Figure 3. Dependence of the size of soil damage on skidding distance in the technology of skidding with the Multi FKS winch

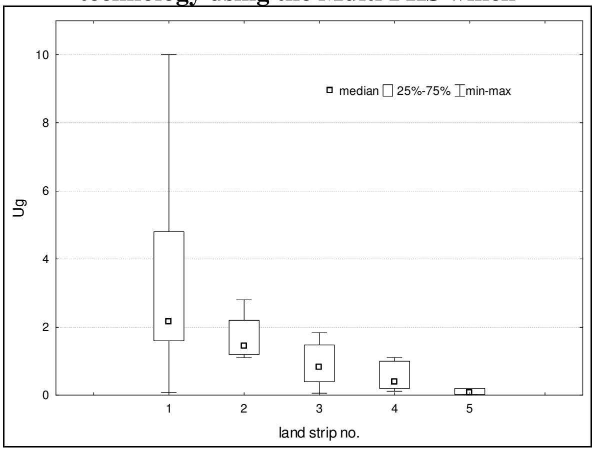


For this skidding technology, a high correlation, close to r = -0.7, was obtained. The coefficient of correlation is statistically significant (t= -2.579, p=0.000). Such results must probably be connected with the specificity of carrying out skidding in the technologies compared. The use of the winch makes it necessary to perform skidding along a straight line, from the place of felling along the rope towards the winch. Skidding with the use of the horse is often carried out in curvilinear motion, with curves, going round obstacles and frequent maneuvers in the stand.

Research by Sowa and Szewczyk (2005) confirmes this hypothesis, showing that, in the same stand, the length of horse skidding is by over 25% larger than the length of skidding with the winch.

The significance of the differentiation of values of the U_g indexes on given land strips, which is visible on the diagrams, was verified by means of a single-factor analysis of variance, after previous verification of the uniformity of variance in groups by means of the Levene test. For horse skidding, it was not shown that damage on subsequent land strips differs significantly (F=1.257, p=0.306). This result is confirmed e.g. in research by Suwała [1999], who notes that, for horse skidding, the distance between operation routes does not affect the differentiation of the size of the soil damage index. Different results were obtained for skidding with the winch. The variances of the indexes turned out to be uniform (F=1.257, p=0.306) and analysis of variance showed statistically significant differentiation of the mean values of the U_g indexes on particular land strips (F=8,676, p = 0,000). The position statistics of the U_g indexes on subsequent land strips are presented in Figure 4.

Figure 4. Descriptive statistics of of the size of soil damage on particular land strips – the technology using the Multi FKS winch



Precise differences between the means of particular groups were determined by means of the NIR test. Its results are presented in Table 3.

Table 3. The results of the NIR test concerning the differences of the mean value of the U_g indexes on subsequent land strips in skidding with the Multi FKS winch

Land strip no.	1	2	3	4	5
1		-	+	+	+
2	0.570		-	+	+
3	0.013	0.108		-	+
4	0.002	0.023	0.374		+
5	0.000	0.000	0.003	0.025	

Explanations: - a statistically insignificant difference; + a statistically significant difference

Analysis of the Table indicates that damage which occurred on land strip no.1 does not differ from damage on strip 2. The mean values of the U_g indexes concerning strips 2 and 3 do not differ statistically from the previous and following strips. Damage on strip 5 is the smallest and significantly different from that on all other strips.

Damage done to the surface soil layer due to skidding with the cable winch, carried out in accordance with the technology analysed in the present research, increases in proportion to the skidding distance; and a significant reduction of the level of damage is noted for the distance of over 30 m. From this point of view, it is therefore inadvisable to exceed this skidding distance.

4. Conclusions

1. A significantly higher level of damage from harvesting done to the surface soil layer was noted for horse skidding than for skidding with the Multi FKS winch.
2. For the horse skidding technology, no relation was noted between the skidding distance and the size of damage.
3. In the skidding technology with the Multi FKS winch, the size of damage done to the surface soil layer was strongly correlated (r=-0.7) with the skidding distance.
4. In the skidding technology with the Multi FKS winch, the values of the U_g indexes at subsequent distances from the operation route showed significant differentiation, with the highest value near the operation route and the lowest one on the most distant land strip.

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RISK OF THE SOIL DAMAGE WHILE THE HANDLING OF CLAIMS BY LOGGING AND HAULING TECHNOLOGIES

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Key words: wind throw disaster, harvestor technology, soil compression

Abstract: *The hurricane Kyrill didn't damage only stands in the Czech Republic, but in all of Europe within the days from 18th to 19th January 2007. There are new fears of possible impacts, which can occur there now. It is especially soil damage caused by forest mechanizations and water erosion. For the logging and hauling operations wheel-harvester Timberjack 1270B, the tracked-harvester Timberjack 2628, the forwarders Timberjack 1110 and Timberjack 1410 were used in the in the Military Forests and Estates of the Czech Republic. The soil compression was maximal in beaten tracks of the machines, which is depending on the depth of a measurement from 0.06 to 2.71 MPa. The highest relative increase of the unit draft was on the top bed of the soil basis from 4 to 8 cm. The unit draft increased about 43 - 63 % in the beaten tracks.*

1. Introduction

Hurricane Kyrill stoke not only the Czech Republic but the whole Europe at the turn of January 18th and 19th 2007. The wind velocity was over 40 m/s and in the alpine areas exceeded 53 – 60 m/s. The hurricane caused area or scattered windfalls and windbreaks in a lot of state or private forests. Damage of the wood with its economical consequences is not the only impact. After taking the damages out there are fears of other sequels, particularly soil disturbance, logging and consequently water erosions that could appear after inconsistent employment of the logging and hauling technologies.

The soil structures are defined by primary physical factors, in particular a soil type, volume soil water, plasticity and share of soil skeleton. The soil damage is also influenced by a soil cover (weed infestation, brushwood underlay) and technical parameters of a machine including track.

The main problem concerns a soil compression that is the cause of other problems for species and microorganisms. Except natural and unavoidable subsoil compaction there is a big influence of artificial subsoil compaction by logging and hauling mechanization, transport stems or another productive instruments, which grows with the rising weight. For example in the last 40 years the weight of a tractor rose 126% (Šařec, 1997).

2. Material and methods

The research of the soil damages is analyzed with Military Forests and Estates of the Czech Republic in Horni Plana. There was processed 1840 % of the allowable cut after the hurricane Kyrill. The harvester Timberjack 1270B and the forwarders Timberjack 1110 and Timberjack 1410 were used for logging and hauling work stages in spruce stands. The standard technology couldn't apply because of the windbreaks and windfalls. Operators couldn't adhere to line spacing (c. 20 – 25 m) for minimal soil damages. Machinery had to go to damaged trees and they couldn't run on the same (any) lines because there was the peaty soil.

For the fast liquidation of logging residues a slash bundler Timberjack was used and for the soil sanitation the dredger MenziMuck was used.

Tab. 1: Engineering characteristic of the machines

Choice characteristic	*Timberjack 1270B*	*Timberjack 1110*	*Timberjack 1410*
Weight (kg)	15 900	14 300 – 15 700 *(dep. on equipment)*	16 500 – 17 500 *(dep. on equipment)*
Load capacity (kg)	---	11 000	14 000
Length (mm)	7 070	8 910	9 295
Width (mm)	2 860	2 860	2 950
High (mm)	3 650	3 700	3 700
Chassis clearance (mm)	624	605	605
Engine power (kW)	152 at 1800 r.p.m.	113 at 2200 r.p.m.	136 at 1900 r.p.m.
Označení přední pneu	600 x 26,5	700 – 26,5	700 – 26,5
Označení zadní pneu	600 x 34	700 – 26,5	700 – 26,5
Pojezdová rychlost (km/h)	0 – 25	0 – 25	0 – 25

Many factors influence the soil compression. These are machine parameters (e.g. machine weight, machine dimensions – table 1), technological factors and working conditions. A responsible position the soil type has and his characteristics which are define for the analyzed stands in forest types. The stand description, technological and working conditions are registered in the appendix 1.

The gale-disaster of the analyzed stand 100A1 is c. 20 hectares (i.e. 55 % of the total area). This forest stand is on two forest type sets (SLT) – 7V (the major part of the stand) and 7S (the northwest part of the stand).

SLT 7V is specific with a medium-soft soil where variable quantities of a soil skeleton are. There is a sandy loam or loamy sand. The soil type is “cryptopodzolic soil”. The humus layer is “peat moder”. SLT 7S is typical for a medium-soft soil or a soft soil. It is gravelly soil mostly and fresh humid. The soil type is “cryptopodzolic soil” or “humic podzol” here. The humus layer is “moder” (Průša, 2001).

2.1 Mechanical damage of the soil surface

The check measurements of the mechanical soil damages were taken in a sample forest. There were demarked two sample plots on the different soil conditions. One sample plot was 900 m^2 large. The mechanical damages (i.e. track depth) were measured 5 meters from each other in both tracks and the measurements were averaged.

2.2 Soil compression and measuring technology

The measurement of the unit draft (UD) is carried out with the penetrometer. This is one of the possible applied technologies for the compression detection, his intensity and a depth. Penetrometrie is a fast method for a unit draft comparison between a pressure travels and an undamaged soil surface. This method is also used for the soil regeneration control. The measurement is divided into a few phases:

1. The measurement is 20 by 20 meters on the skidding lanes. The first measurement is carried out in the right track, the second measurement is between beaten tracks and the third puncture is two meters from the right track in a stand.
2. The measurements are carried out on tracks. We register a number of the puncture and the material on the lane (moss, forest weed, brushwood).

The unit draft is measured depending on the volume soil water which is measured with the electronical hydrometer “ThetaProbe ML2x”. The soil water is taken with the probe on the soil to six centimeters. The volume soil water is assigned as $\theta_v = \frac{V_W}{V_C} \cdot 100$, where θ_V (%) is the volume soil water, V_W (m^3) is a body of water and V_C (m^3) is a total soil volume.

3. Results and discussion

There were analyzed a mechanical soil damage and a unit draft in the stand 100A1.

3.1 Mechanical soil damage on skidding lanes

The first measurements of mechanical soil damage were carried out in south-east part of the stand. There was the zero slope and the maximal volume soil water was nearly 100 % in a humus layer. The water was stagnated in tracks and we could think the soil was saturated.

If we will separate the soil damages to classes (Ulrich, 2002), we can say there was the biggest ratio of beaten tracks deep over 26 cm (to 58 %). There were high soil banks and water stagnated in tracks (fig. 1a). There isn’t any erosion risk for the zero slope and for rapid soil maintenances which were done with the dredger MenziMuck.

The second sample plot has a small ratio of the mechanical soil damages in northern part of the stand, where the slope is more than 10 % (Fig. 1b). The first reason is stony soil surface on the steep land and the second reason is an observance of distances of skidding lanes (ca 15 – 20 m) which are marked downgrade. On the flat the skidding lanes were marked randomly with more roading because harvester or forwarder drives can not repeat for soil water on the same lanes. The results show the predominant depth of travels to 7 cm on the steep land (88 %).

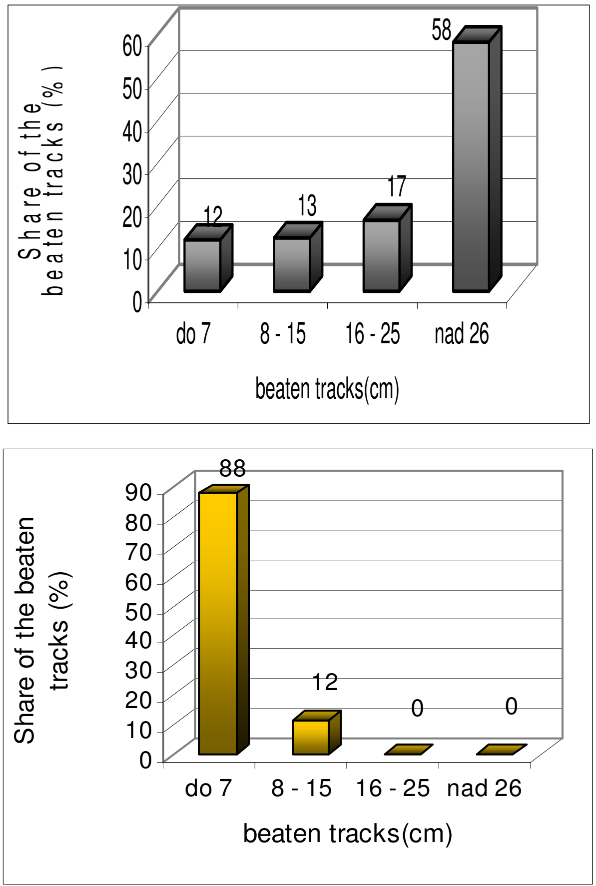


Fig. 1: Mechanical soil damages. a) Plain field with a peaty soil, b) Sloping ground (11- 20 %) with a skeletal soil.

3.2 Soil compression

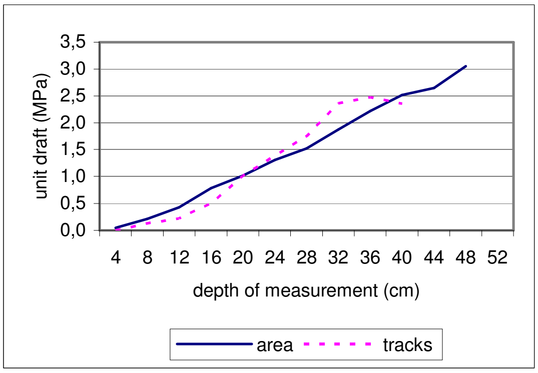
Results acknowledge conception of the unit draft for a constant number of trips depending on soil surface and his pad. Its brushwood, forest weed and moss in the analyzed stands.

The highest unit draft was while driving on the "clean" skidding lane and its true of to both forest types. The unit draft is lower if there is a grass. The lowest unit draft was affirmed on the lanes with brushwood.

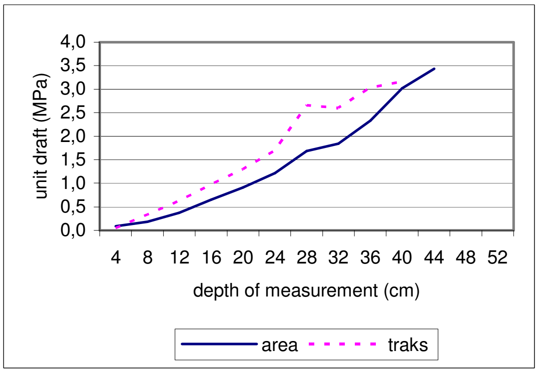
The first and second analyzed skidding lanes, which were 340 meters long, were in the southern part of the gale-disaster area. The average volume soil water was 93,4 % in beaten tracks. The reason was standing water in tracks – 65 % of measured points. Between the tracks the volume soil water was 69,1 % and the volume soil water was 74,3 % on the forest area which wasn't damaged with forest mechanization. The main reason of the high soil water, which has an influence on the unit draft, was the long forest-free slope after the disaster on the south-east part of the stand. The slope of the analyzed stand was in the three classes from 0 to 33 %. The accumulation of the surface moisture was caused by lengthwise harvester lanes. It was only right technology to the wood processing and skidding and to an assurance of an optimal work safety. The third and fourth sample lanes were marked in the same stand as the foregoing lanes. They had the same length (340 m) and the slope was to 33 %.

The big influence on the unit draft fluctuation has the soil water distribution. The volume soil water can be 50 – 80 % in wet mineral soil (Miller and Gaskin, 1998). 48 % of sample measurements, those were on undamaged soil surface, have presented wet soil with the volume soil water more than 76 % there out 81 % of measurements were on the flat in the southern part of the stand. Here the supersaturated soil couldn't absorb more water, which has gravitated down the high localities.

Fig. 2a shows minimal influences of forest mechanization on the soil compression, if the soil is saturated with water. The unit draft has linearish trend on the undamaged soil – from 0,1 MPa to 3,1 MPa at a depth from 4 cm to 48 cm. The slightly soil compression is measurable at an equal soil water on beaten tracks. This unit draft copy the unit draft of the undamaged soil with a small difference from - 0,1 to + 0,5 MPa and this difference isn't statistically significant. On that occasion we can see only mechanical soil damages (see capitol "*Mechanical soil damage on skidding lanes*").



a)



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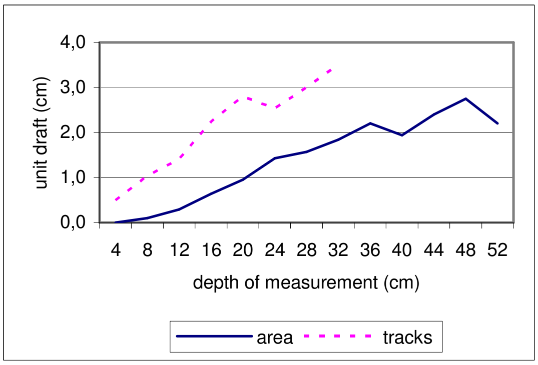

c)

Fig. 2: Unit draft.

a) Volume soil water more than 76 %

b) Volume soil water from 51 to 75 %

c) Volume soil water from 25 to 50 %

The difference of the unit draft growth between an undamaged area and beaten tracks markedly, if the volume soil water is at interval from 51 to 75 % (Fig. 2b). This absolute difference is from 0 to 1,0 MPa and the relative difference growth from 0 to 79 %. The maximal percentage increase is registered over again in layers to 12 cm (from 68 to 79 %). The maximal absolute increase of the unit draft is measured in the depth of 32 cm. After that there follows decrease of the unit draft and we register same unit draft in the depth of 40 cm in the entire stand.

The least volume soil water (25 – 50 %) show the top disparity of the unit draft between compacted parts of a soil surface (tracts) and undamaged forest areas. The difference of the unit draft is in interval 0,5 - 1,9 MPa at a soil depth of 4 - 20 cm (Fig. 2c). This absolute value of the unit draft sinks at the soil depth of 20 cm and more deeply. The maximum increase of the relative unit draft is top in an upper level of a track, where is more than 933 % in comparison with undamaged forest area. At the soil depth of 32 cm the difference of unit draft is 91 %.

We can not miss out other technological conditions at work of the harvester technology. It is the application of a brushwood underlay for an optimal harvester pressure distribution on the soil surface. Fig. 3 shows lower soil compression if the brush is on the skidding lanes. The difference of the unit draft is lower by 0,1 – 0,3 MPa. The relative difference is from 0 to 33 %, nevertheless we can't confirm a statistically significant difference in dependence on monitored soil cover.

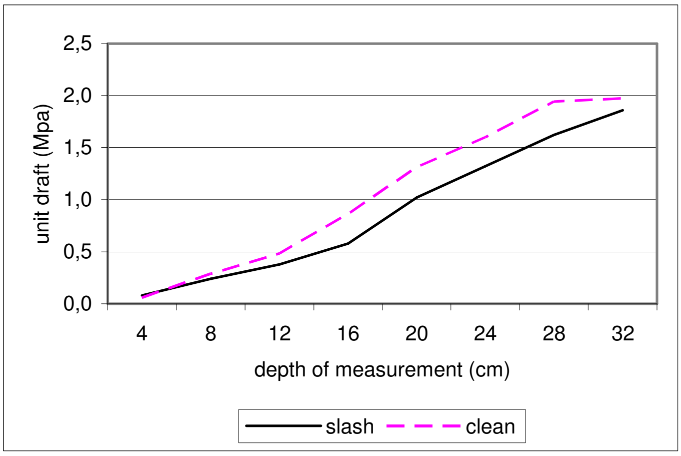

Fig. 3: Comparison of the unit draft between tracts with brush and free from brush tracts.

The table 2 compares the unit draft between two set of forest type versus measuring points. There is the evident difference in favour of the forest type 7V, where the maximal different is 0,4 MPa between the track and the undamaged area. The soil of the forest type 7S have major differences for the skeletal soil, slope and less humus layer. We can see the difference 0,9 MPa at the depth of 32 cm between beaten tracks and undamaged forest area.

The unit draft between tracks is constant or lower because there is soil loosening of tire sidewalls.

Tab. 2: Unit draft in dependence on forest type sets

Forest type set	7V			7S		
Depth of measurement	Track	Intertrack	Undamaged forest area	Track	Intertrack	Undamaged forest area
(cm)	(Mpa)			(Mpa)		
4	0,0	0,0	0,0	0,1	0,0	0,0
8	0,1	0,0	0,1	0,4	0,1	0,2
12	0,2	0,1	0,3	0,7	0,5	0,5
16	0,5	0,3	0,5	1,2	0,7	0,9
20	1,0	0,5	0,8	1,5	1,0	1,2
24	1,3	0,8	1,1	1,9	1,3	1,6
28	1,7	0,8	1,5	2,8	1,7	1,8
32	2,2	1,1	1,8	2,9	2,0	2,0
36	2,3	1,3	2,3	3,2	2,3	2,4

3.2 Statistical analysis

This statistical analysis of the unit draft was carried out on the skidding lane, where harvesters, forwarders and the slash bundler have moved. The length of 680 meters was chosen from four skidding lanes on the gale-disaster area, which was c. 20 hectares large. The measurement of the unit draft was realized on 101 points.

We have used the statistical t-test for the analysis of the statistical significance of the measured unit draft between beaten tracks and undamaged areas. 637 measurements are available for this analysis. These measurements were carried out at ten differential depths from 4 to 40 cm. The t-test confirms the statistically significant differences between tracts and undamaged forest area only at the depth of 28 and 32 centimeters. Statistically significant relationship is not confirmed between beaten tracks and undamaged area at other depths. Since the p-value is less than 0,05, there is a statistically significant difference between the two distributions at the 95,0% confidence level (tab. 3).

Tab. 3: : t-test to evaluate the differences in means of soil unit draft between beaten tracks and undamaged areas

Depth of measurement	Average unit draft of track	Average unit draft of undamaged forest area	t-value	Degree of freedom	p-value
(cm)	(MPa)		(-)	(-)	(-)
4	0,1	0,04	0,35	65	0,72
8	0,3	0,2	1,15	65	0,25
12	0,5	0,4	0,73	65	0,47
16	0,8	0,7	0,60	65	0,55
20	1,3	1,0	1,41	65	0,16
24	1,6	1,3	1,25	62	0,21
28	2,2	1,57	2,43	56	0,02
32	2,6	1,9	2,51	53	0,02
36	2,7	2,2	1,46	46	0,15
40	2,6	2,6	0,13	36	0,90

4. Conclusion

- The influence of a machine used in any technological process more or less reflects on a soil surface. The soil must be able to resist, retain the force and react. The reaction increases from chassis, the tires, and subsequently ceases in dependence on the ground bearing capacity.
- In the researched area we can classify the natural erosion of the soil as middle and in selected micro-relieves as high. The soil is mild up to middle permanent wet or alternately dry. On these soils we mainly recommend using multi-axle harvesters and forwarders with low-pressure tires, 700 mm wide, where the pressure on the soil is spread out commensurable to weight of the machine. Mechanization travels do not exert on the gley soil (Vavříček et al., 2008).
- Although the producer of the forwarders confirms maximum pressure of unloaded machine on the soil in dependence on width of tires, number of wheels and front and back axles from 32 to 71 kPa, and in load of 11 tons up to 100 kPa, we can not slacken other technological conditions in using of harvester technology, i.e. using of a brushwood underlay for a decompression of a machine and transported wood in maximum. A Slash should be always put down in front of the machine on skidding lanes. During salvage cuttings the situation is complicated by impossibility of equable setout of the skidding lanes on the area and necessity of individual machine travel to particular trees so that we could use a maximal power of the hydraulic crane without harm of machines and with maximum assurance of machine stability during a processing of the windbreaks and windfalls. The optimal brushwood underlay is 30 cm layer of slash (Ulrich, 2002). During mentioned check measurements in the spacing of 20 meters, slash was put down on skidding lanes in 83% of all monitor points.
- The tracks in researched fields are not smooth and continual and there are dregs of the slash in them. Based on these reasons we can assume that there is no risk of large area or local water erosions. Depth soil damages (beaten tracks) were reconstructed in threatened part of the forest area.

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Appendix 1: Definition of the analyzed stand

A. Work stand identification		
Stand		100A1
Forest type set		*7V / 7S*
Forest area	(ha)	36,44
Cutting area	(ha)	c. 20
Age		107
Species / share	(%)	SM / 100
Breast-height diameter of species	(cm)	36
Mean height of species	(m)	28
Average tree volume	(m^3)	1,20
Timber reserve	(m^3/ha)	9 052
B. Natural conditions		
Altitude	(m)	1130 – 1225
Exposition		JV
Terrain slope	(%)	0 – 17
Erosion risk		worse eroding
Ground bearing capacity		bearing ground
Capacity of terrain		snag free
Soil surface		mean weed infestation
C. Characteristic of timber harvesting		
Timber harvesting		Incidental felling
Species		SM
Average assortment value	(m^3)	1,20
Logging area	(ha)	36,44
Total timber volume	(m^3)	9 052
D. Characteristic of workplace and technology		
Skid way		at edge of stand
Marking of skidding lanes in stands		free movement
Average length of skidding lanes	(m/ha)	780
Logging method		assortment method
Mechanization for felling		harvester – tab. 1
Mechanization for off-road haulage		forwarder - tab. 1
Lane with	(m)	3 – 3,5
Workspace with	(m)	13 – 20
Brushwood layer on skidding lanes	(cm)	0 - 30

NEW REDUCED IMPACT HARVESTING TECHNIQUES IN TURKISH FORESTRY

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Key Words: Environmental damage, Chute systems, Monorail, Harvesting operations, Turkish forestry

Abstract: *Forest harvesting activities are generally more expensive and difficult than any other forestry activities. Also, these activities can bring about important damages to environmentally restriction conditions such as saplings, forest soil, and river. Because public concern to the visual and ecological effects of forest operation has increased in recent years, improving of environmental friendly harvesting techniques has considered important. Objective of this paper is to introduce three alternatives reduced impact harvesting techniques in Turkey known as chute system, monorail and controlled sliding. All of these systems which are portative and basic mechanism can be installed in short time. While the chute system and monorail are used to transporting of thin wood material, controlled sliding technique in polyethylene chutes is used to transporting of thick wood material such as logs and pole. Damages of harvesting activities to residual stand can be minimized by these methods.*

1. Introduction

Turkey has a total land area of 775 945 200 ha, of which 26.6 percent is covered by forests. Because active timber harvesting area is 80.19 percent of total forest area, forests play a major role in Turkey. About 7 379 000 people live in forest village, and depend on the forest for their livelihoods. Forestry operations contribute approximately 2 percent to the total national revenue (**SPO, 2001; Konukçu, 2001**).

Harvesting activities is the most important intervention factor among forest operations. These activities consist of felling, bucking and extracting stages. Marked trees pre-harvest are felled and bucked by chainsaw. Afterwards trees cut into short logs about 3 m or 4 m and extracted from the stand to the landing. The extraction activities are the most damage to residual stand and transported log.

Ground-based skidding by manpower is used the most commonly in Turkey. Ground based skidding activities has realize about %72 by man power, %15 by animal and %8 by tractor. The other extraction technique is cable crane (%5) (**Erdaş and Acar, 1993**). The ground-based skidding is often considered to result in large-scale environmental degradation. It would become compacted causing accelerated runoff and erosion, which made regeneration very difficult. Remaining trees often were damaged by the rolling logs, which frequently resulted in decay and disease (**FAO, 1999**). Also, the damages to residual stands can be listed decreasing of timber quality and forest productivity (**Johnson and Cabarle, 1993**).

Damage to the residual stand by uncontrolled logging caused reduction of forest value for the future timber production. Several experiments have demonstrated that reduced impact logging techniques can reduce damage by at least 30–50% compared with normal operation (**Pinard and Putz, 1996; Bertault and Sist, 1997**). It has been estimated that in area were removal of approximately 30-50 m^3 ha^{-1} of timber by conventional logging method resulted in 10-25 % total area compacted by skid trails, roads and landing sites (**Winkler, 1997**). Reduce impact harvesting activities embrace extraction techniques known to increase the post-harvest forest value and the long-term potential for sustainable forest management (**Johns et al., 1996; Putz et al., 2001; Holmes et al., 2002; Krueger, 2004**).
One of the most significant trends over the past decade has been the increased mechanization of harvesting activities (**Heitzman and Grell, 2002**). Forest management practices have moved towards more environmentally sound harvesting methods to supply sustainable forest management. Extracting methods of timber with less damage to residual trees and forest soil are needed.

Environmentally friendly harvesting activities should be developed to minimize negative impacts of harvesting activities to residual stand.

Objective of this paper is to introduce two alternatives reduced impact harvesting techniques in Turkey known as chute system, monorail and controlled sliding. It is hoped that these systems will help to improve forest-harvesting practices and decrease impact of harvesting to residual stand.

2. Newly Reduced Impact Harvesting Techniques

2.1. Monorail System

Development of monorail system embarked by monorail in 1999 is one of the most environmentally friendly timber harvesting methods in Turkey (**Acar et al., 2002**).

Monorail system consists of locomotive and railway car moving on a rail. Railway route consisting of a rail eliminates the negative features of the land. Before railway route is installed, it is necessary to clean the trees, sapling and every kinds of material on the transportation route. A narrow corridor can be suitable for monorail route in intensive regeneration areas. The monorail can work any height from earth surface by means of carrier and supportive foot.

The monorails railway width is decided by hall width which is 30 cm height from the ground depending on the locomotive and the railway car width. The monorail system, thus, can be established various elevation from earth surface. Carrier and supportive foot have 16 mm diameter and 75, 100, 125, 150 cm length (**Acar and Unver, 2004**). Thus, it is an environmentally friendly transportation vehicle.

Monorail system is available to transportation of thin wood material, fuel wood, saplings, non-wood yield, hand tools and forest labor safety. Also, it is very functional vehicle for recreational survey within forest. Natural parks can be used for tourism. It has reduced work difficulties and energy loss, thus it increases work efficiency. The Figure 1 shows the main part of monorail.

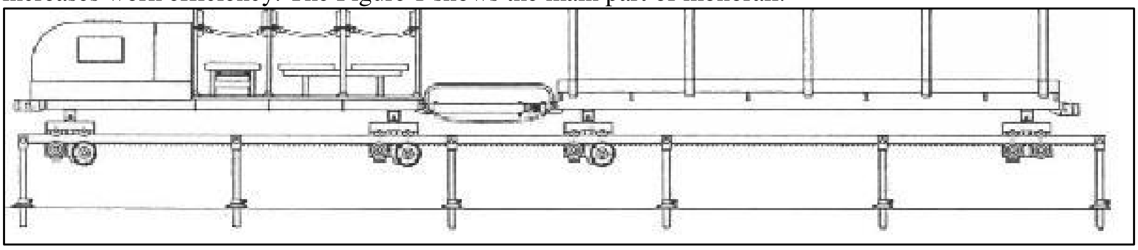

Figure 1. A Monorail System Plan

The monorail system is a modern forest transportation vehicle. It provide that saving of time and human force consumption, increasing of work productivity, decreasing of new forest road building, decreasing of quantity and quality losses. As well, it is an ergonomic tool.

2.2. Controlled Sliding In Chutes

Subsequently, controlled sliding in the polyethylene chutes method was improved in 2007. The system consists of an artificial route made in polyethylene chutes, 10 BG motor, brake drum, one carrying the mainline, and one carrying the haul-back line, at least two holds, direction mechanism, break device, harness, control handle, and a redactor (**Acar et al., 2008**).

Motor performing controlled sliding or pulling can be hydraulically or electrically operated. Generally, it is preferred electrical motors because of ergonomically. Motor has to have 120 volt power and the dimensions must be at least 40 X 40. A redactor has been installed to the motor to improve electric and gravitational power. The mechanism is approximately 80 kg and it can be separated into two parts and carried by two labors to reinstall it in the forest. The redactor which decreases the cycling of the motor from 1200 to 30 in a minute was installed to the system. Fixing the motor mechanism is very important because the product to be carried with this system is weight log. The mechanism brought to the area must be replaced on a quite flat ground with its feet strongly standing on the floor. Then, to prevent the movement of the mechanism during transportation, it must be strongly tied to the near by trees with security ropes.

It is not necessary to open any corridor while establishing an artificial route consisting of polyethylene chutes. The chute route can be easily established vertically in the slopes between 10 % and 70 %, whereas the route can be established in the way that the route is angled to the contour lines in more than 70 % slopes.

Fixing the mechanism in the area must be planned and done carefully. The mechanism brought to the area must be replaced on a quite flat floor with its feet strongly standing on the floor. Then, to prevent the movement of the mechanism during transportation it must be strongly tied to the trees near it with security ropes. That the route is flat is important and bobbins or direction post should be used if necessary.

While downward transportation of logs in polyethylene or fiberglass chutes is defined by controlled brake system without using motor, upward transportation of logs is defined by a portative drummed motor mechanism or a forest tractor with drum. Polyethylene chutes are installed to each other from their tips called female and male with screws. In the downward sliding, the upper tips of chute must be installed in the inner part of the previous one, so the coupling of slide logs in the chutes are prevented. On the other hand, pulling from down to up the route is established by constructing chutes one on the other previous one.

After the fixing process, sliding the log tied to a steel cable is done with the help of the control handle without starting the motor. Establishing the route, carrying and installing the system are generally done by two laborers and starting it is done by an operator with one or two laborers. Ideal sliding distance is 300m to transport the product, but it can be more in the flat areas. Sliding the logs downward can only be done after discharging the retrograde cable in a controlled way when the motor is off. After this, the motor is started and empty retrograde cable is drawn and rolled on the drum (Figure 2).

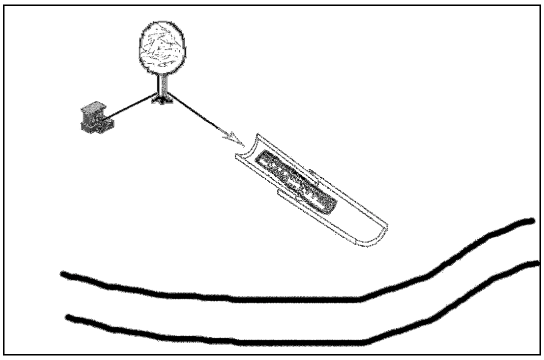

Figure 2. Controlled sliding of logs to downward in polyethylene chute rout

If there is a forest road near the harvesting area, the system is installed to MB- Track forest tractor during pulling logs upward. However, if there is no forest road, it is installed to a drummed mechanism having motor. The logs are pulled upward with the power of the motor in the flat or slopped route (Figure 3).

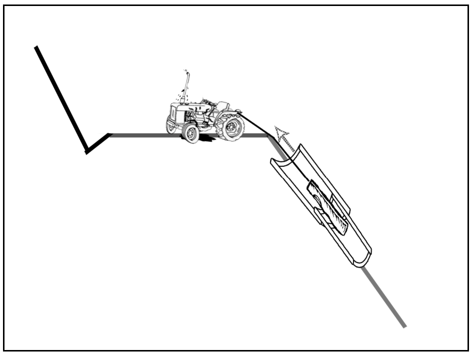

Figure 3. Pulling of logs to upward in polyethylene chute rout

3. Conclusion and Recommendation

Research results demonstrate, furthermore, that reduced impact timber harvesting is not necessarily more expensive than conventional timber harvesting, moreover economically profitable, because timber lose of value caused by conventional timber harvesting is twice than lose of value caused by reduced impact timber harvesting and the latter will consequently enhance future forest productivity and reduce the cost associated with potentially adverse off-site consequences of timber harvesting. When using these systems, it is important that operations are well supervised and that the quality, as well as the quantity, of work is controlled.

These methods have proven to have less impact especially to residual trees, saplings and forest soil. Trees wounded by logging activities are especially susceptible to infection and subsequent decay by fungi, thereby reducing the future value of the wood product. It is hoped that these systems will become the system for harvesting in the near future.

Ground-based skidding is often unproductive and results in undesirable environmental impacts. The Black Sea Region in Turkey is very steep slopes therefore using of ground-based skidding should be severely limited. These systems are uniquely suited to mountainous areas, such as steep slopes and unstable soils. The use of new systems, such as controlling sliding in chutes and monorail system, will reduce the negative impacts associated with harvesting, permit better use of forest resources, and help maintain sustainable forest ecosystems.

The wood material can be transported easily without touching of forest floor by both of the systems that are not cause land and money looses. In addition, monorail transports easily and safety the material workers and supplies to the working areas in forest. Both of the systems eliminate the negative features of the land and have the surface become artificially useful.

Soil disturbance and damage to logs are minimized since logs are transported on artificial route made in polyethylene chutes or a railway without touch on the soil or the other materials. With this system, regeneration is left largely undisturbed, since logs are lifted out of the forest, even in a single tree selection system.

Forests in the Black Sea Region in Turkey compose of spruce (*Picea orientalis*) largely. Sometimes, thin wood materials, few formless logs or piece of logs such as tops or debris can be left in the forest because of difficulties of transportation or products of nominal value. This provides a breeding ground for the spruce bark beetle (*Ips* spp. or *Dendroctanus* spp.), the major forest pest in the conifer zone (**Akıncı et al., 2005**; **FAO, 1999**). Both logs and the other wood debris can be transported easily by both of the newly techniques.
The new methods should be tested and proven to be less damaging to residual stand compared to the current ground skidding system. It is needed additional skills and more qualified forest labor to both of the systems, especially installation stages.

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THE LEVEL OF ENVIRONMENTAL DAMAGE FROM TIMBER HARVESTING DEPENDING ON SKIDDING METHODS

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Keywords: timber ground skidding, forwarding, forest environment damage, probabilistic model

Abstract: *The need to create the methodology of assessing the level of ecological damage caused by timber harvesting seems to be unquestionable. Analysis of relevant research done both in Poland and abroad shows that it is considerably difficult to asses harvesting damage to forest in an objective and complex way. Most research includes only some fragmentary problems of the damaging role of the timber harvesting process on the forest environment. A large number of variable factors affecting this environment as well as a large number of those of its elements which can be damaged effectively hinder the creation of one uniform method of damage assessment that would be simple to use, based on objective data and, at the same time, include the influence of various elements on the level of damage. The aim of the present research was to determine multicriterial synthetic indexes of the lack of harvesting damage to the forest environment WW_{bu} for harvesting technologies which are basic in Polish conditions and include various methods and technological means of skidding. The present research was performed in three regions of southern Poland, representing a lowland, an upland and a mountain area. The WW_{bu} multicriterial index of environmental damage amounted to 0.9548 for horse skidding, 0.9377 for farm tractor skidding and 0.9215 for skidding by means of the LKT skidder. When two skidding methods were combined (e.g. the horse + the LKT), the WW_{bu} index ranged from 0.9378 do 0.9624.*

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1. Introduction

The need to elaborate a methodology of assessing the level of ecological damage from timber harvesting seems to be unquestionable. Analysis of the literature on the subject in Poland (Maciaszek and Zwydak, 1992; Porter, 1994; Giefing, 1995; Paschalis and Porter, 1994; Laurow, 1995; Cybulko, 1995; Muszyński, 1995; Stajniak, 1995; Suwała, 1995, 1997; Sowa, 1997 and others) indicates that there are considerable problems with objective and complex assessment of damage due to harvesting in the forest.

Out of necessity, most research includes only fragmentary issues related to the damaging effect of the timber harvesting process on the forest environment. A multiplicity of variable factors affecting the forest environment in the course of harvesting (various stressors affecting the forest, the use of various technological systems, different techniques and methods of harvesting work arrangement, various kinds of harvesting machines and devices, etc.) as well as a large number of elements of the forest environment which can be damaged (e.g. soil, forest floor vegetation, seedlings, saplings, the shrub layer, the main stand, etc.) make it very difficult to elaborate a uniform method of damage assessment that would be simple to use, based on objective data and, at the same time, include the influence of various elements on the level of damage.
The need for a complex approach to this problem, both in research and in practice, was the reason for an attempt to apply the probabilistic description of the phenomena of damage to the forest environment, which would allow for holistic understanding, including very numerous factors related to environmental damage due to timber harvesting. Due to the fact that damage done to the forest environment, occurring in the course of the harvesting process, has a random character in a given stand, the new method of

assessment of the damage from harvesting in the forest environment was empirically verified by means of a model solution based on the methods of the calculus of probability.

In 1997, Sowa elaborated a theoretical model of analysis of damage to the forest environment caused by timber harvesting. The model was presented at the Congress of Polish Foresters. The basis of the model approach to assessment of harvesting damage in a stand is as follows:

By determining the form of single-factor empirical functions of the density of the distribution of damage from timber harvesting to the environment and, next, by applying functions known in the theory of mathematics, one can describe mathematically – for each component of the forest environment - which part of the ecosystem will or will not undergo damage or destruction;

On the basis of functions of a lack of damage to the environment, approximated on the distribution rows, one can estimate the coefficients of a lack of damage which characterize numerically the size of the lack of damage from timber harvesting in single elements of the forest environment (e.g. soil, undergrowth, the regeneration level, the main stand);

Next, one can approximate the multi-dimensional function, which would consist of single-factor functions of the lack of damage, thus determining – after the calculation of the parameters of this function – the value of the coefficient of the lack of damage to the forest environment as a whole.

2. Research aim and scope

The aim of the present research was to determine multi-criterion coefficients of the lack of damage from harvesting to the environment WW_{bu} for the harvesting technologies using various methods and various technical means of timber skidding which are basic in Polish conditions. The research was performed in some stands in the state forests in three regions of southern Poland, representing: a lowland – the forest district of Krzeszowice, an upland – the forest district of Gromnik and a mountain area – the forest district of Jeleśnia (which has the highest situated economic stands in Poland) as well as the Forest Experimental Station in Krynica.

The general rule adopted in the present research was that the research team should not interfere in the process of timber harvesting. In all categories of terrain, measurements included the determination of damage caused by harvesting in thinned stands (early and late thinnings) and in mature stands, where timber was harvested in the long-wood system and in the short-wood system with the common method of individual felling. In the course of the present research, the transactors who were performing timber harvesting used the most common skidding means in Poland (horses, farm tractors and LKT skidders) as well as typical skidding methods (hauled, half-suspended and suspended skidding). The research concerned all layers of the forest where harvesting was performed. The size of damage was determined in surface soil layers, forest floor vegetation, seedlings, the regeneration layer and the stand remaining on stem. Damage to all forest layers was considered in the elaboration of the mathematical model.

The researchers adopted the rule of permanent establishment of the circular sample plots according to the grid. On each plot, the condition of the forest was registered before harvesting, measurements of damage caused by harvesting and skidding were taken after harvesting, after which the measurement results were juxtaposed, elaborated and introduced in the mathematical model, and the results of the calculations were assessed. The final stage consisted in elaborating multi-criterion indexes of the lack of damage caused by harvesting to the forest environment.

3. Research methods

3.1. Field work methods

Measurements and assessment were performed on the sample plots twice: before and after harvesting. One of the measures taken when the plots were being set up was their permanent marking in the forest so as to be able to return to them after harvesting. It was assumed that the whole regeneration layer in the stand in which damage was to be measured had the growing usefulness.

A grid of squares with the side of 25 m was established in field. At its crossing points, one-are circular plots with the radius of 5.64 m were set up. The following measurements and assessments were performed on each circular plot before harvesting:
- measurement of all trees growing on a circular plot and determination of the height of trees to be removed;
- stock-taking of the scope of the regeneration layer (small trees with the breast-height diameter under 7 cm, older than 2 years) in the assumed height classes from 0.5 m to over 4.0 m, measured at every 0.5 m;
- assessment of the percentage of the area of the bottom forest storey covered with plants, considering the species of shrubs, seedlings (up to 0.5 m high) and the forest floor vegetation (dwarf shrubs, pteridophytes, bryophytes, monocotyledonous and dicotyledonous plants);
- registration, on the outline of the circular plots, of any changes in surface soil layers existing before harvesting.

The tasks performed on each circular plot after harvesting were:
- stock-taking of the number of trees removed and the number of trees damaged in the course of harvesting;
- determination of the number of damaged small trees in the regeneration layer according to the classification based on 9 damage classes (Sowa and Stańczykiewicz, 2007): destroyed tree; damaged trees with no chances of survival; broken top sprout above the last whorl; broken stem below the last whorl; broken side branches (up to 20% of total number, 21 - 40% of total number, above 40% of total number); a tree tilted from its vertical position; bark removed off a tree;
- determination of the zones where the forest floor vegetation was destroyed or damaged in the course of harvesting. The zones were measured with the measuring tape and, next, their area was calculated by comparison with geometrical figures;
- measurement of the linear parameters (length, width, depth) of soil damage caused by skidding means or by transported logs. The kind of damage was assessed in the following aspects: compacting the soil, tearing off the surface soil layer down to its mineral level and visible "sweeping" of the forest litter.

3.2. Calculation methods

It was assumed that the empirical distributions of environmental damage "u", obtained from the measurements, are the discrete representative of continuous distributions. Considering the occurrence of skewness empirical distribution of random variables, and referring to previous research (Sowa, 1997). An assumption was made that the beta function of the density of distribution of probability best approximates the empirical distributions of environmental damage due to timber harvesting. Statistical analyses were performed using the standard form of the beta function of the density of distribution, whose domain is the <0. 1> interval. Thus for all empirical distribution rows, relative values of environmental damage u were adopted. They were determined on the basis of field measurements of damage on sample plots.

3.2.1. The model of one-dimensional function of threat

On the basis of earlier research by Sowa (1997), it was noted that:
1. The function of the density of distribution of probability B(u) is a probabilistic projection of damage done to the forest environment due to timber harvesting, determined by means of the random variables of damage to particular elements of the environment.
2. The distribuant F(u) of this distribution determines the cumulated probability of the occurrence of environmental damage due to harvesting.

Analysis of the course of the distribuant of the beta distribution as well as analysis of the above statement 2 allow for noting that the higher the probability of occurrence of a smaller value of environmental damage ($u \to 0$), the higher the value of the distribuant for this u and the larger the area under the whole distribuant of the distribution. It may therefore be assumed that the value of the area under the distribuant constitutes the measure of environmental damage caused by timber harvesting. Considering the fact that the distribuant of the beta distribution is described in the interval of <0. 1> and the statement that the area under the distribuant is the measure of environmental damage caused by timber harvesting, the area above the distribuant (i.e. the complement to the unit) will be the measure of a lack of damage.

The one-dimension function of a lack of environmental damage may be defined as follows:

$$F_{bu}(u) = 1 - F(u). \tag{1}$$

Considering the formula of the function of the density of the beta distribution (1), the result is:

$$F_{bu}(u) = 1 - \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} \int_0^t x^{p-1}(1-u)^{q-1}\,du, \ldots u \in <0,1>. \tag{2}$$

The measure of a lack of damage, described as the coefficient of a lack of damage W_{bu} will be:

$$W_{bu} = \int_0^1 F_{bu}(u)\,du. \tag{3}$$

The W_{bu} coefficient so defined describes, at the same time, the area above the F distribuant of the beta distribution:

$$W_{bu} = \int_0^1 F_{bu}(u)\,du = \int_0^1 (1 - F(u))\,du = \int_0^1 1du - \int_0^1 F(u)\,du = 1 - \int_0^1 F(u)\,du.$$

When the definition of the function of the density of the beta distribution is used, the W_{bu} coefficient is as follows:

$$W_{bu} = 1 - \frac{\Gamma(p+q)}{\Gamma(p)\Gamma(q)} \int_0^1 \int_0^u u^{p-1}(1-u)^{q-1}\,du. \tag{4}$$

Formula 4 is used to calculate the values of the coefficients of a lack of damage to the elements of the forest environment.

Fig. 1. The model of approximation of the function of a lack of environmental damage $F_{bu}(u)$ and the coefficient of a lack of damage $W_{bu}(u)$

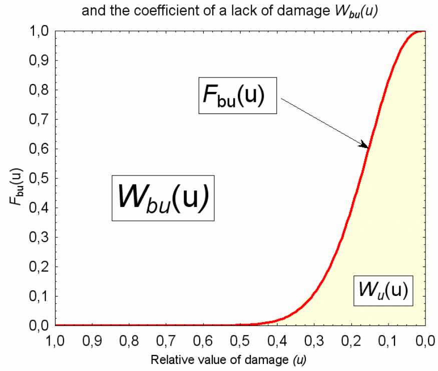


Fig. 2. The graphic model of estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$

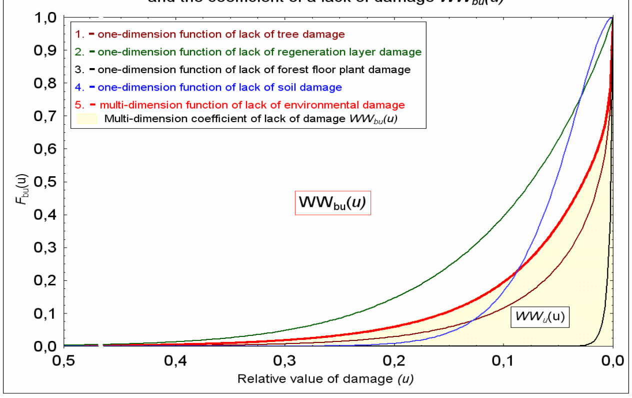


Figure 1 is a graphic presentation of the model of approximation of the function of a lack of environmental damage and the coefficient of a lack of damage due to harvesting. The dark area is the measure of environmental damage due to timber harvesting. The light area above the curve is the measure of a lack of this damage.

3.2.2. The multi-dimension model of the function of threat in the process of timber harvesting

The equation, elaborated here, for the model of the one-dimension function of a lack of damage, concerns the level of damage determined for one of many damaged elements of the forest environment analysed. It is therefore true for this one element (e.g. for damage to trees which remain at the felling site or damage to forest floor vegetation). If there was a possibility of such work at the felling site that only one element of the environment became damaged in the course of harvesting, then the one-factor function of a lack of damage could be applied without reservation.

However, in practice there will always exist an influence of many different elements of the technological process (e.g. various methods of work arrangement, various machines and devices, various technological systems, various sizes of the harvested timber, etc.) on many elements of the forest environment (e.g. on the remaining stand, saplings, the shrub layer, seedlings, soil, forest floor vegetation, etc.).

Therefore there is a need to determine the coefficient of a lack of damage for many variables simultaneously and thus to create a new, multi-dimension (multi-factor, multi-criterion) function of density of the distribution of probability.

For practical purposes, the researchers adopted a method of combining one-dimension functions of the density of probability and in this way created a single (combined) function of density, for which a new distribuant, and then a new coefficient of a lack of environmental damage, can be determined.

Assuming that the random variables $u_1, \ldots, u_k$, whose functions of density are respectively equal $f_1, \ldots, f_k$, are combined, so that u_i occurs with probability p_i, and $\Sigma p_i=1$, then the function of the density of probability is:

$$\tilde{f}(u) = \sum_{i=1}^{k} p_i f_i(u) . \qquad (5)$$

and its distribuant is:

$$\tilde{F}(u) = \sum_{i=1}^{k} p_i F_i(u) . \qquad (6)$$

where F_i are the distribuants of the combined variables.
The function of a lack of environmental damage will then be:

$$\tilde{F}_{bu}(u) = 1 - \tilde{F}(u) = 1 - \sum_{i=1}^{k} p_i \tilde{F}_i(u) = \sum_{i=1}^{k} p_i - \sum_{i=1}^{k} p_i \tilde{F}_i(u) = \sum_{i=1}^{k} p_i (1 - \tilde{F}_i(u)) .$$

Using formula (6) and introducing the symbol $F_{bu(i)}$ for the function of a lack of damage for the variable u_i, results in the following formula:

$$WF_{bu}(u) = \sum_{i=1}^{k} p_i F_{bu(i)}(u) . \qquad (7)$$

The coefficient of a lack damage for the combined variables can be calculated on the basis of formula (7):

$$WW_{bu} = \int_0^1 WF_{bu}(u)du = \int_0^1 \sum_{i=1}^{k} p_i F_{bu(i)}(u)du = \sum_{i=1}^{k} p_i \int_0^u F_{bu(i)}(u)du .$$

Its final form will be:

$$WW_{bu} = \sum_{i=1}^{k} p_i W_{bu(i)} . \qquad (8)$$

where $W_{bu(i)}$ are the coefficients of a lack of damage for variables u_i.

As results from equation (8), the new value of the coefficient of a lack of damage is constituted by the sum of the products of empirical probabilities p_i of a lack of damage for a given environmental factor (expressed e.g. in percentage) and the values of the coefficient of damage $W_{bu(i)}$ for a one-dimension function. In other words, for multi-factor models of the function of a lack of damage, the combined lack of damage is the sum of the lack of damage of particular elements of the environment weighted by the probability of their real occurrence in the process of timber harvesting.

Therefore, on the basis of observation of the plots where harvesting has been performed, it is sufficient to know the percentage of damage caused by harvesting to particular elements of the forest environment in the total sum of all damage as well as the values of the coefficients of a lack of damage for one-factor functions $W_{bu(i)}$ (determined on the basis of the present model) in order to be able to determine the combined lack of damage to the forest environment in which harvesting has been performed (cf. Figure 2). Figure 2 illustrates – for four damaged elements of the environment – the assumptions of the model of assessment of the multi-criterion coefficient of a lack of environmental damage caused by timber harvesting $WW_{bu}(u)$.

4. Research results and discussion

On the basis of the methodological assumptions adopted in the present research, for three categories of stands: a lowland (the forest district of Krzeszowice), an upland (the forest district of Gromnik) and a mountain area (the forest district of Jeleśnia as well as the Forest Experimental Station in Krynica) and for three categories of management: early thinnings, late thinnings and mature stands, in 27 compartments, on the grid of squares with the side of 25 m, the researchers set up sample plots on which harvesting was performed.

In each compartment, 32 circular sample plots of 1 are each were set up. They represented altogether 16% of each hectare under analysis. Due to the configuration of the terrain, the existing area compartment, slopes, the shape and size of the manipulation area, in some cases the number of sample plots differed from the assumed one. Altogether 293 sample plots were set up in mountain stands, 387 in upland stands and 258 in lowland ones. The total number of circular sample plots was 938; and their joint area was 9.38 ha of the stand.

Stock-taking of the condition of the forest was not performed on all sample plots. The different number of plots where stock-taking was done after harvesting resulted from the fact that forest district authorities decided not to perform harvesting on certain circular plots, which had already been set up. Moreover, considering the fact that not all kinds of damage occurred on each circular sample plot, which is a normal way of the environment being affected by harvesting, the eventual number of plots whose measurements entered the calculation base after harvesting was 787. Consequently, there were 2352 variables used to assess damage to soil, 5488 variables to determine damage to the forest floor vegetation, 70,560 variables to calculate damage to the regeneration layer, and 2352 variables to assess damage to the trees of the main stand. The total number of random variables in the database was 80,752.

4.1. The results of the calculation of the multi-criterion coefficient WW_{bu}

In the analyses concerning the approximations of the functions of a lack of damage, it was not possible to approximate the beta functions from the empirical distribution rows only in 3.9% of the cases of random variables. This fact confirms the hypothesis that the distribution of environmental damage caused by timber harvesting can be described by the beta distribution with the estimated parameters p and q on the assumed level of significance α=0.05.

In accordance with the assumed calculation methods, the value of multi-criterion coefficients of a lack of environmental damage was calculated for the analysed independent variables and damaged elements of the environment by applying the algorithms described in the research model and the approximated one-factor functions of a lack of damage. Tables 1-3 present the values of the coefficients of a lack of damage to particular elements of the forest W_{bu} and the multi-criterion coefficient WW_{bu}.

Table 1. The values of the multi-criterion coefficient of a lack of damage to particular elements of the forest in relation to stand categories

Stand category	Skidding method	W_{bu} of soil	W_{bu} of forest floor vegetation	W_{bu} of regeneration layer	W_{bu} of trees	WW_{bu} of environment	p
1	2	3	4	5	6	7	8
Mountain stands	altogether	0.9425	0.9960	0.9792	0.9132	0.9598	0.2996
	horse	0.9430	0.9980	0.9795	0.9211	0.9605	0.1916
	horse+farm tractor	0.9028	0.9952	0.9886	0.9714	0.9635	0.0358
	horse+skidder	0.9623	0.9912	0.9834	0.8648	0.9559	0.0721
Upland stands	altogether	0.8628	0.9608	0.9896	0.9413	0.9340	0.4879
	horse	0.8817	0.9566	0.9820	0.9441	0.9416	0.0820
	skidder	0.8339	0.9528	0.9828	0.9206	0.9259	0.2153
	horse+farm tractor	0.9203	0.9799	0.9836	0.9743	0.9611	0.0694
	horse+farm tractor+skidder	0.8590	0.9656	0.9868	0.9569	0.9420	0.1211
Lowland stands	altogether	0.9029	0.9334	0.9849	0.9517	0.9462	0.2126
	farm tractor	0.8956	0.9229	0.9923	0.9448	0.9362	0.1663
	horse+farm tractor	0.9481	0.9711	0.9792	0.9714	0.9740	0.0463

Table 2. The values of the multi-criterion coefficient of a lack of damage to particular elements of the forest in relation to utilization categories

Utilization category	Skidding method	W_{bu} of soil	W_{bu} of forest floor vegetation	W_{bu} of regeneration layer	W_{bu} of trees	WW_{bu} of environment	p
1	2	3	4	5	6	7	8
Mature stands	horse	0.9077	0.9730	0.9865	0.9139	0.9453	0.1311
	skidder	0.8354	0.9526	0.9811	0.9300	0.9237	0.0953
	horse+skidder	0.9623	0.9912	0.9886	0.8648	0.9559	0.0721
Late thinnings	horse	0.9163	0.9992	0.9555	0.8542	0.9308	0.0363
	farm tractor	0.9162	0.9124	0.9855	0.9613	0.9418	0.1019
	skidder	0.8324	0.9529	0.9826	0.9145	0.9276	0.1200
	horse+farm tractor+skidder	0.8590	0.9656	0.9836	0.9569	0.9420	0.1211
Early thinnings	horse	0.9594	0.9945	0.9810	0.9640	0.9748	0.1063
	farm tractor	0.8655	0.9425	0.9839	0.9235	0.9274	0.0644
	horse+farm tractor	0.9211	0.9807	0.9855	0.9727	0.9656	0.1514

Table 3. The values of the multi-criterion coefficient of a lack of damage to the forest in relation to timber skidding methods

Skididng method	W_{bu} of soil	W_{bu} of forest floor vegetation	W_{bu} of regeneration layer	W_{bu} of trees	WW_{bu} of environment	p
1	2	3	4	5	6	7
horse	0.9261	0.9844	0.9815	0.9291	0.9548	0.2737
farm tractor	0.8956	0.9229	0.9849	0.9448	0.9377	0.1663
skidder	0.8339	0.9528	0.9820	0.9206	0.9215	0.2153
horse+farm tractor	0.9211	0.9807	0.9855	0.9727	0.9624	0.1514
horse+skidder	0.9623	0.9912	0.9886	0.8648	0.9559	0.0721
horse+farm tractor+skidder	0.8590	0.9656	0.9836	0.9569	0.9378	0.1211

4.2. The graphic illustration of the results of estimation of the multi-dimension function WF_{bu} and the value of the multi-criterion coefficient of a lack of damage to the forest environment WW_{bu}.

Fig. 3. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for horse skidding

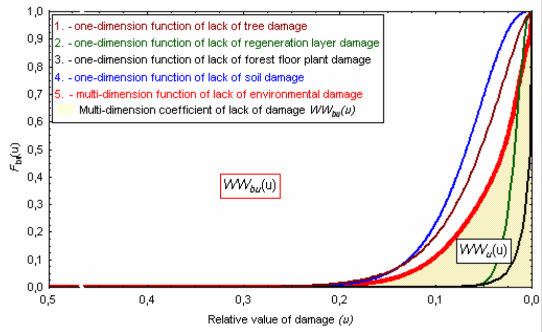
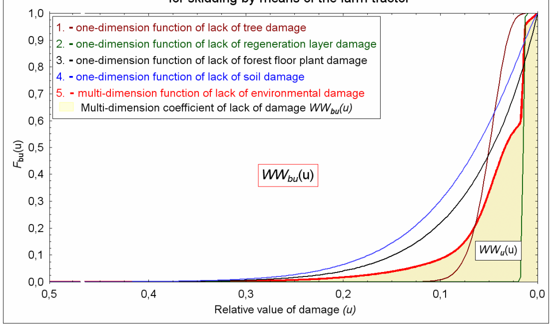


Fig. 4. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for skidding by means of the farm tractor



Among the timber skidding methods under present analysis, skidding by means of horses (Figure 3) caused the smallest damage to the forest (WW_{bu}=0.9548). Its influence on the different forest layers varies, however. The largest damage occurred in soil (W_{bu}=0.9261) and on trees (W_{bu}=0.9291). Damage caused in the regeneration layer (W_{bu}=0.9815) and in the forest floor vegetation (W_{bu}=0.9844) was much smaller and had similar values. Analysis of damage caused to the environment by skidding with the use of the farm tractor (Figure 4) allows for the statement that the use of this skidding method caused a higher level of damage than the use of horses (WW_{bu}=0.9377). Skidding by means of the farm tractor brings various kinds of damage to each forest layer. Analysis of the values of the coefficients of a lack of damage shows that the smallest damage occurs in the regeneration layer (W_{bu}=0.9849), on trees remaining in the stand (W_{bu}=0.9448) and in forest floor vegetation (W_{bu}=0.9229). A considerably higher level of damage was noted in soil (W_{bu}=0.8956).

Fig. 5. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for skidding by means of the LKT skidder

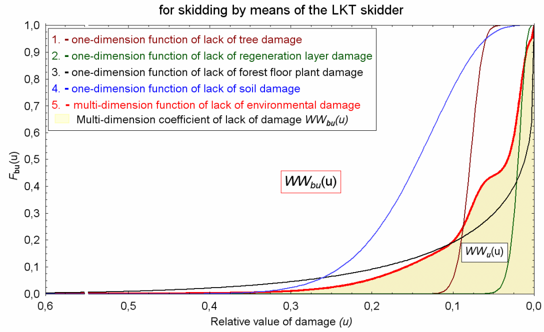
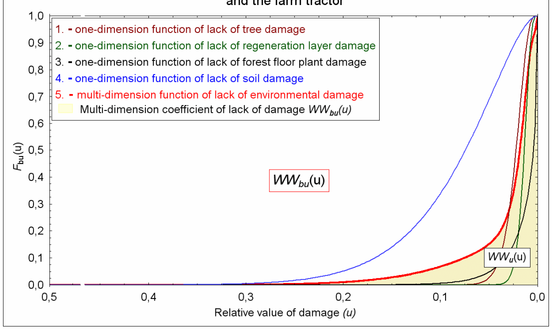


Fig. 6. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for skidding by means of horses and the farm tractor



Skidding with the LKT skidder is one of the methods which cause the largest damage to the environment. For the skidding with the LKT, the multi-criterion coefficient of a lack of damage was WW_{bu}=0.9215 (Figure 5). It may therefore be assumed that skidding with the LKT caused an almost twice higher level of environmental damage than e.g. skidding with the use of horses. The largest damage occurred in the soil (W_{bu}=0.8339) and on trees remaining in the stand (W_{bu}=0.9820). A combination of skidding means is a common way of skidding in practice. Figure 6 presents the level of the lack of damage to the forest, noted for skidding with the use of horses and the farm tractor. The value of the coefficient of a lack of damage is WW_{bu}=0.9624. Therefore, it is the combined skidding that caused relatively smaller environmental damage. It must be emphasized that in three forest layers (trees, the regeneration layer and the forest floor vegetation), similar, small degree of damage occurs. Soil damage is much larger: the coefficient of a lack of damage amounts to W_{bu}=0.9211 here.

The combination of skidding with the use of the LKT and horses had a positive effect. Figure 7 presents the level of the lack of environment damage for this combination. Generally, the value of the multi-criterion coefficient of a lack of damage WW_{bu} is 0.9559. It may be concluded that the combination of skidding with the use of the LKT and horses causes twice smaller damage to the forest than skidding of skidding only with the use of the LKT. In the latter method, very considerable damage is done to trees of the main stand (W_{bu}=0.8648) but almost no damage to the forest floor vegetation (W_{bu}=0.9912).

Fig. 7. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for skidding by means of horses and the LKT skidder

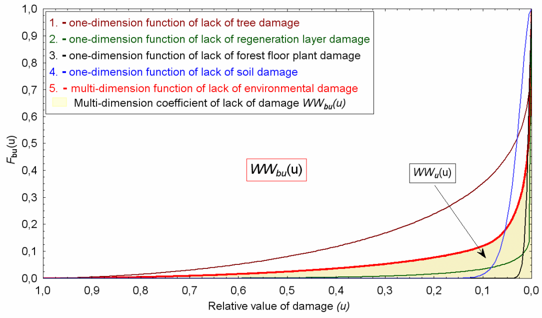
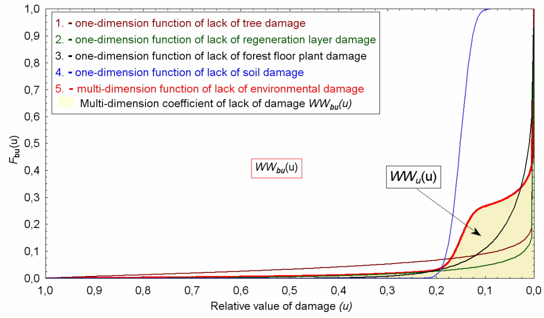


Fig. 8. The graphic model of the estimation of the multi-dimension function $WF_{bu}(u)$ and the coefficient of a lack of damage $WW_{bu}(u)$ for skidding by means of horses, the farm tractor and the LKT skidder



The use of three skidding means brought an ecologically unfavourable result. Figure 8 presents the functions of a lack of damage for this combination of skidding technologies. The general level of the lack of environmental damage in this case was WW_{bu}=0.9378, which should be regarded as high. Very serious damage was done to the soil (W_{bu}=0.8590). The level of damage to the remaining trees amounted to W_{bu}=0.9569 while in the case of the forest floor vegetation it was W_{bu}=0.9656. The smallest damage occurred in the regeneration level, where (W_{bu}=0.9836). Among all of the examined methods, only skidding with the use of the LKT caused more environmental damage than the above combination.

It is not possible to determine, by means of the model discussed here, what influence is exerted on the condition of the forest by a particular kind of damage, e.g. what is more important from the ecological point of view: soil damage or regeneration layer damage, or which class of regeneration layer damage will consequently bring more serious changes in the condition of the forest. Analysis of the literature in the aspect of the state of research on environmental damage due to timber harvesting, conducted in the present study, shows that no answer has been found to these questions yet.

It may be concluded that the model of assessment of damage caused by harvesting solves the problem of its quantitative measurement in the forest environment. Qualitative assessment of damage caused to the forest environment by timber harvesting may be investigated in the future, after conducting extensive long-term and thorough research in many aspects of forest science.

5. Conclusions

The results of the present research allow for the following conclusions:

1. The present research shows that the distribution of environmental damage caused by timber harvesting is the beta distribution on the significance level α=0,05.
2. The beta functions of a lack of damage to a stand, presented in this research, describe the negative influence of timber harvesting processes on the forest environment. Particular coefficients of a lack of damage are used for the assessment of the size of damage caused by harvesting.
3. According to the present research, particular forest layers become damaged by timber harvesting processes to different extents. Generally, the largest damage (nearly 10%) occurred in soil, trees were damaged to a smaller extent (6.4%), the forest floor vegetation to a still smaller extent (3.7%) while the smallest damage was observed in the regeneration layer (1.6%). The overall level of damage to the forest environment amounted to 5.4%.
4. Among the terrain categories under analysis, the largest damage occurred in the upland stands and the smallest in the mountain stands. In the comparison of the forest utilization categories under analysis, the largest damage caused by harvesting was noted in late thinnings while the smallest was occurred early thinnings.
5. Analysis of the level of environmental damage due to skidding showed that, generally, the largest damage was caused by the LKT skidder, smaller by the farm tractor and the smallest by horses.

However, considering the damage caused by skidding means in different forest layers, what must be emphasized is a high level of damage to the regeneration level and soil caused by the farm tractor.

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EQUIPMENT AND TECHNOLOGIES OF COMBINED PROCUREMENT OF MERCHANTABLE WOOD WITH CUTTING WASTES UTILIZATION FOR ENERGY PRODUCTION IN BELARUS

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Keywords: wood fuel, technological processes, machine systems

Abstract: *Current conditions and prospects of using wood fuel in Belarus are analyzed. The data on the annual economically available potential of wood fuel in Belarus and forecasts of its increasing are given. The projects of construction of small wood-fuel combined heat and power plants are considered. The technological processes of chip fuel production are presented. The domestically produced machines and mechanisms, used for wood raw materials procurement and comminution, for chip fuel transportation and storage, are analyzed. The recommendations for development of wood fuel productions in Belarus are given.*

1. Introduction

The energy consumption in the Republic of Belarus is about 33 million tons of standard fuel[3] annually, and only 15 per cent of this amount is covered by the own resources. The costs of purchasing the required energy resources and electric energy are about 2 billion € annually, that is equal to more than 30 per cent of the total amount of import of the Republic of Belarus, resulting in dependence of its economy on external factors. For 2006–2010, the challenge is issued to decrease the GDP energy intensity by at least 31 per cent, with GDP growth rates about 156 per cent (against 2005 level); in 2015, GDP energy intensity shall be decreased by at least 50 per cent, and in 2020, by 60 per cent. Meanwhile, along with measures for energy saving and introduction of energy-efficient technologies and equipment, a set of measures is implemented for maximization of utilizing local and renewable energy sources.

The total volume of forest stands in Belarus is about 1414 million m^3, that is about 243 m^3 per hectare. The average annual increment is slightly less than 30 million m^3, and the total volume of cuttings of all types is about 14 million m^3 only. In this respect, the matters of both logging volume increase and wood waste utilization for energy production, including utilization of logging, sawmilling, wood processing wastes and low-quality fuel timber, become especially important.

[3] 1 ton of standard fuel is equivalent to 29300 MJ

2. Wood fuel potential

To determine the potential of wood fuel resources in Belarus, the procedure was developed by the authors of this paper. On the basis of this procedure, the ***potential, technically available and economically available*** volumes of wood fuel were determined for the period up to 2015.

The possible *annual potential volume* (tons of standard fuel) *of wood fuel* (V(pot)), produced as a result of principal and intermediate harvesting, was determined using the formula:

$$V(pot) = \left(\sum_{(i)=1}^{(n)} V(i) \cdot K(i) + \sum_{(j)=1}^{(m)} V(j) \cdot K(j) + \sum_{(y)=1}^{(k)} V(y) \cdot K(y) \right) \cdot T(1) + \sum_{(e)=1}^{(n)+(m)+(k)} V(e) \cdot T(2), \quad (1)$$

where (i), (j), (y), (e) are the indices characterizing, respectively, the volumes of wood procured in principal harvesting, intermediate harvesting, forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality in exploitable forests, volumes of firewood used for heating; (n), (m), (k) are the numbers of cutting areas; V(i) is the volume of principal harvesting (m^3/year); K(i) is the wood waste generation coefficient for principal harvesting (0.16…0.29); V(j) is the volume of young stands tending cutting, thinning, selective sanitary cutting and other types of cutting (m^3/year); K(j) is the wood waste generation coefficient for young stands tending cutting (0.16…0.29), thinning (0.18…0.31), selective sanitary cutting (0.17…0.26) and other types of cutting (0.18…0.27); V(y) is the volume of cutting in forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality (m^3/year); K(y) is the wood waste generation coefficient for forest burnt-out places (0.01…0.1), windfalls and fallen wood areas (0.2…0.4), utilization of natural mortality in exploitable forests (0.16…0.28); V(e) is the volume of firewood for heating, procured in principal harvesting, young stands tending cutting, thinning, selective sanitary cutting, other types of cutting, in forest burnt-out places, windfalls, fallen wood areas, utilization of natural mortality; T(1) and T(2) are the factors for conversion from m^3 to the standard fuel tons with respect to wood waste and firewood.

The annual technically available volume (tons of standard fuel) *of wood fuel* (V(tech)), produced as a result of cuttings of all types, was determined using the formula (1), by multiplying the appropriate components by the wood waste extraction coefficients (0.45…0.6 for principal harvesting, 0.35…0.6 for intermediate harvesting, 0.65…0.8 for forest burnt-out places, 0.6…0.8 for windfalls and fallen wood areas, 0.2…0.3 for natural mortality).

In turn, *the annual technically available volume* (tons of standard fuel) *of wood fuel* (V(econ)), produced as a result of cuttings of all types, was determined by multiplying the *technically available volume* (V(tech)) of wood fuel by the coefficient, characterizing the economic reasonability of its using for the heat energy generation. This coefficient was determined, taking into consideration the wood fuel cost on the cutting area, hauling distance, transportation costs, wood fuel limit prices; according to the calculations and actual data from the enterprises, this coefficient is about 0.35…0.7.

The possible *annual available volume* (tons of standard fuel) *of wood fuel* (V(wood)), produced as a result of sawmilling and wood processing, can be determined using the formula (2), proposed by the authors of this paper:

$$V(wood) = \left(\sum_{(u)=1}^{(r)} (V(u) \cdot K(u) - P(u)) \right) \cdot T(3), \quad (2)$$

where (u) is the index characterizing the direction of merchantable wood consumption; (r) is the number of directions of merchantable wood consumption; V(u) is the volume of consumption of merchantable wood for (u)th production (m^3/year); K(u) is the wood waste generation coefficient for (u)th production (0.18…0.39 for sawmilling, 0.2…0.6 for wood processing); P(u) is the volume of consumption of wastes from (u)th production for technological purposes (m^3/year); T(3) is the factor for conversion from m^3 to the standard fuel tons with respect to wood waste in sawmilling and wood processing.

The investigations, carried out on the basis of the procedure proposed, indicate that the annual economically available wood fuel potential for the enterprises of forestry complex is about 6.8 million m^3, and in 2015 it will increase by 55 per cent.

In this connection, the plans are developed, stipulating both increase of consumption of wood fuel on small power engineering plants, and construction of 16 small combined heat and power plants (CHP plants) with about 1.2 million m^3 annual consumption of wood fuel. The enterprises of the Ministry of Forestry and “Bellesbumprom” Concern will be the principal suppliers of wood fuel for these power plants.

3. Promising systems of machines and equipment

In cooperation with “Minsk Tractor Plant” Republican Unitary Enterprise, a series of wheeled logging machines for principal and intermediate harvesting was developed, including harvesters, forwarders, trailing trucks with handlers, various logging tractors. Production of similar machines was implemented also by “Amkodor” Open Joint-stock Company (see Figure 1). The specific feature of these machines is a wide application of imported components and equipment, including hydraulic handlers, shear-and-grapple felling units, components of hydraulic actuators and automated control systems.

a *b*

Figure 1 – Wheeled logging machines: a) harvester (“Amkodor” Open Joint-stock Company); b) forwarder (“Minsk Tractor Plant” Republican Unitary Enterprise)

For implementation of technologies of combined procurement of merchantable wood with utilization of cutting wastes for energy production, the before-mentioned enterprises have also launched production of mobile chippers with barrel-type units (“Jenz GmbH“, Germany; “Kesla OYJ“, Finland), having the capacity about 40...100 m^3 loose per hour (see Figure 2).

a *b*

Figure 2 – Mobile barrel-type chippers with hydraulic handlers: a) driven by the stand-alone motor MR-40 (“Minsk Tractor Plant” Republican Unitary Enterprise); b) driven by the forwarder motor, with the collecting bin “Amkodor-2902” (“Amkodor” Open Joint-stock Company)

In cooperation with “Minsk Automobile Plant” Republican Unitary Enterprise, a road train for chips transportation was developed, with 80 m^3 loose turn volume (see Figure 3a). Also, the development of a chip truck with removable containers, having the turn volume about 35…40 m^3 loose, is at the final stage now (see Figure 3b). Wheeled front loaders are also produced in Belarus, having 400…6000 kg capacity, with removable process equipment, able to handle both round timber and chip fuel, with the load height up to 5.93 m.

a *b*

Figure 3 – Trucks for chips transportation (“Minsk Automobile Plant” Republican Unitary Enterprise): a) road train MAZ-5516+MAZ-8561; b) chip truck with “multilift” container handling mechanism MAZ-6501

4. Technological processes and economic effectiveness of chip fuel production

The availability of domestically produced logging equipment, in combination with foreign machines widely used in Belarus (“Farmi Forest Corporation”, Finland; “Heizomat GmbH”, Germany; “Vermeer Corporation”, the USA), gave an opportunity to implement several technological processes of logging with chip fuel production at the cutting area and at intermediate or interseasonal storages. For the flowchart of the most typical existing technological process of chip fuel production, see Figure 4.

Figure 4 – The flowchart of technological process of chip fuel production

For provision of small CHP plants, both existing (Belarusian State District Power Plant, 22 200 m^3; Osipovichi small CHP plant, 34 000 m^3; Vileika small CHP plant, 60 000 m^3; Pinsk small CHP plant, 88 000 m^3) and planned for putting into operation in 2008 (Petrikov small CHP plant, 26 300 m^3; boiler plant in Rossony, 30 000 m^3; small CHP plant of "Mostodrev" Open Joint-stock Company, 38 000 m^3; Pruzhany small CHP plant, 60 000 m^3) with wood fuel, it was necessary to choose the most rational technological process and machine system.

As a result of solving this problem by several departments and organizations, and with no practical experience, the actual cost of chip fuel production for CHP plants in Belarus varies greatly. For example, for Vileika small CHP plant (where the fuel supply system was developed by the authors of this paper), the cost of chip fuel is about 15 €/m^3 solid; for the Belarusian State District Power Plant, this cost is about 22 €/m^3 solid, and for Osipovichi small CHP, about 28 €/m^3 solid.

5. Conclusion

The multiple technical and economical investigations, carried out by the authors with regard to the conditions existing in Belarus, give an opportunity to make the following conclusions.

1. At present, various technologies of combined procurement of wood and chip fuel production, both of them based on fully mechanized systems and involving mechanized work, can be implemented in Belarus. However, principal technical and economic indicators of these technologies are lower than those in countries with highly-developed forestry.

2. The technological processes, providing procurement and hauling of wood on cuttings of principal and intermediate harvesting as assortments, will become predominant, because of their better economic effectiveness indicators and maximum compliance with the requirements of forest certification.

3. Within the combined process of wood raw materials procurement, it is most reasonable to use mobile machine systems for chip fuel production. This machine system shall include: load-haul-dump machines; mobile barrel-type chippers, driven by a stand-alone motor, having the capacity at least 40 m^3 loose per hour; chip trucks, having turn volume more than 35 m^3 loose, or road trains, having turn volume about 70…80 m^3 loose; a bucket front loader, with bucket volume at least 5 m^3 loose.

4. As a rule, for fuel timber, comminution at interseasonal storages is most reasonable. For logging wastes, comminution at intermediate storages, located near all-weather roads, with the delivery distance not exceeding 5 km, and for sawmilling and wood processing wastes, communition at the source is most reasonable. Meanwhile, the required conditions of effectiveness of these processes are as follows:

- concentration of cutting areas;
- large volumes of cutting wastes and low-quality timber at intermediate storages, located near all-weather roads;
- scheduling of chip fuel hauling for the final consumer;
- finished products transportation distance should not exceed 50 km.

5. As a whole, for production and delivery of wood fuel in Belarus, about 228 logging tractors, 762 load-haul-dump machines, 167 chippers and tractors for their transportation, 620 chip trucks, 74 chip loaders are required.

6. The further improvement of the system of providing the power engineering plants in Belarus with wood fuel shall include:

- investment support of the enterprises for purchasing the equipment (subventions, credits on easy terms) and tax benefits;
- formation of wood fuel market, and stabilization of prices for the long-term period;
- development of domestic engineering industry, with regard to the machines and equipment for production and delivery of chip fuel;
- development of repair facilities and establishing of service facilities for special equipment;
- construction of new forest transport roads and proper maintenance of the existing ones.

7. At present, some experience of wood raw materials combined procurement and chip fuel production has been accumulated in Belarus. Positive results are obtained, confirming reasonability of involving the renewable wood resources in power engineering. There is hope that the prime cost of wood fuel procurement in Belarus can decrease as a result of implementation of international; experience, improvement of logging machines system and increasing their reliability, and implementation of advanced European technologies, matching the natural, industrial, social and economic conditions in Belarus.

FOREST WOOD CHIPS SUPPLY CHAIN IN SOUTHERN ITALY

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Keywords: forest biomass, wood chips, supply chain, South Italy, transporting

Abstract: *In Calabria, Southern Italy, in the last five years some wood biomass power plants larger than 10 MWe have been installed. Organizing wood fuel supply is a main question: wood chips fuel is supplied through both terrestrial and marine routes. This research focuses on the forest supply chain of three wood biomass plants (for a total of 70 MWe). The yearly wood chips consumption is close to 1 million of green tons. The primary goal of this study is to analyze the local forest wood supply chain.*
On first, general figures about supplied wood chips or wood were collected for each wood biomass power plant. Above all the amount of wood chips from local area was analyzed. Therefore forest wood chips supply chains were approximately identified. Thus time studies were sorted for chipping operations in order to evaluate chipping systems with stationary chippers and mobile chippers. Different productivities and costs were analyzed.

1. Introduction

Calabria is located in South Italy. It is a region particularly rich in productive forests: forests present an average increment of 6-8 m^3/ha per year. Calabria forests cover 480 067 ha: beech, Corsican pine and silver fir are the most spread tree species. The correct use of woodland resources of Calabria may account for an important solution for the problems of this Region whose levels of mechanization in this field are still very poor (Zimbalatti, 2005).
Calabria supplies numerous sectors of southern Italian wood industries. The annual amount of harvested timber in 2006 was 732 700 m^3 (ISTAT, 2008), about the 9% of the national amount and the 34% of the total amount of timber harvested in southern Italy. In the last thirteen years an increase of the harvested timber has been recorded: from the analysis of the national statistical database (ISTAT, 2008) (Figure 1), firewood harvesting increased more than roundwood harvesting. In ISTAT database firewood is an aggregate category including all the wood suitable for energy destination (Zimbalatti et al., 2005).

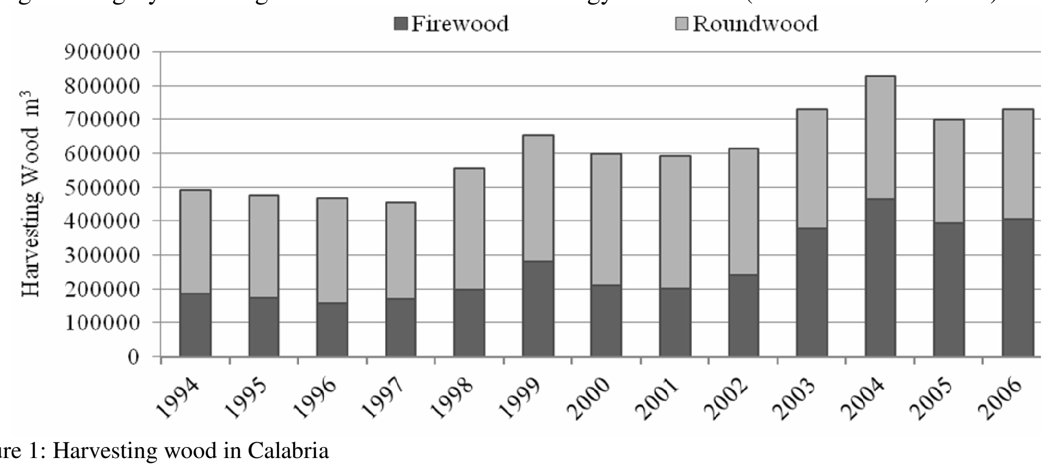

Figure 1: Harvesting wood in Calabria

In the last few years in Italy several bio-energy companies, attracted by Government subsidies, planned and build wood biomass power plants (Neri and Piegai, 2007).
Therefore, also in Calabria in the last years some wood chips biomass power plants have been installed. As a consequent wood harvesting for energy wood has been stimulated. Figure 1 highlights in fact an increment of wood energy harvesting from 2002 to 2006.

1.1 Wood chips "theoretical" quantification and supply chain

A wood chips production system is a sequence of various steps, including processing, transportation and decision making, with the goal of converting forestry woody biomass into fuel and providing transport of this resource from the forest to the plant (Stampfer and Kanzian, 2006). The possibility to use forest biomass for energy production can be realistic only where its supply is economically feasible. Cost-efficient wood chips supply in mountainous area depends on chipping and transport interface, transport cost and, where forest biomass for chips production is not considered a by-product, on harvesting and extraction operations (Stampfer and Kanzian, 2006). As the efficiency of forest operations largely depends on forest road network characteristics, therefore chipping and transport interface and biomass transportation also are influenced by forest road network characteristics (Spinelli et al., 2007).
GIS-based analysis results useful also in order to determine the forest biomass wood chips production. Different approaches have been presented by means of inventory forest data or simply land-use cover data. According to Smeets and Faaij (2007) and Kanzian and Kindermann (2007), five types of potential forest biomass quantification can be used: "theoretical", "technical", "economical", "ecological-economical" and "ecological". "Theoretical" quantification represents the maximum availability and it gives just an idea about the potential of an area.

1.2 Aims

This research focuses on the forest supply chain of three wood biomass plants that cover a total power of 70 MWe. The yearly biomass consumption is estimated in 1 million of green tons. The primary goal of this study is to investigate the local forest "energy wood" (Stampfer and Kanzian, 2006) supply chain in order to describe the realistic use of forest wood biomass for energy production in Calabria.
Working systems and wood supply management are thus analyzed in order to highlight the current local forest wood biomass supply chains. Three wood biomass power plants were investigated in relation to their supply chains.

2. Materials and Methods

2.1 Wood biomass power plants in Calabria

Overall, Calabria presents four wood chips energy plants. In this study three of them were considered and their supply chain analyzed. Two of the three wood chips energy plants are located in province of Crotone, properly in Cutro and Strongoli, along the oriental part of Calabria on the coast of the Ionian sea. The other wood chips energy plant is located in Rende in the western part of the region (Figure 2).
The wood energy plants present different size and annual wood chips demands. Table 1 reports the main data of the wood energy plants. The annual wood chips demand of these three plants reaches 750 000 t (moisture content, w = 50%). The total hourly demand of wood chips is approximately 93 t (w= 50%). Forest wood chips represents the 35-40% of the entire wood chips demand. The remaining amount of wood chips is supply from local wood industries and agriculture residues or by oversea energy wood or agriculture residues importation.
Therefore the import of energy wood in Calabria has increased. Mainly energy wood is imported from Latin America because highly competitive. Every year 300 000 tons are imported from these areas to supply wood energy plants.
These wood energy plants use also residues from local agricultural practices and these residues cover about the 5% of the demand.

Table 1: The main properties of plants case studies

Plant	Location	Power	wood chips demand	
-	-	MWe	t/h (w = 50%)	t/y (w = 50%)
A	Cutro	16.5	20	160 000
B	Strongoli	46.0	57	460 000
C	Rende	14.0	16	130 000

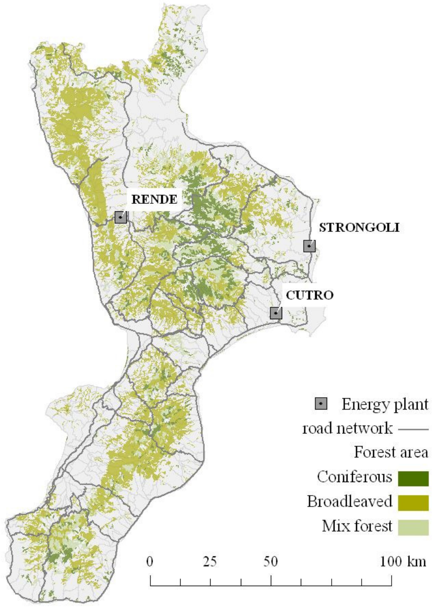

Figure 2: Wood chips power plants localizations in Calabria in respect of forest resources

2.2 Wood chips supply analysis

In the energy wood supply, forest supply represents often the most expensive solution (Ranta, 2005; Stampfer and Kanzian, 2006; Spinelli et al, 2007). Therefore it is necessary to manage the wood chips production with a cost-efficient supply in order to increase productivity and to reduce costs.
In order to figure the situation in Calabria, the first step is to investigate the current wood chips supply chain. On first, wood chips supply chains were approximately identified. Two different wood chips supply chain were thus highlighted (Figure 3; Figure 4). Forest wood chips production can be based on chipping operation location: at yarding close to forest area or at energy plant. Generally energy plants are used to buy energy wood in form of roundwood and rarely in form of slash. Anyway some forest enterprises are used to chip forest biomass at yarding and thus supply energy plant with wood chips.
Thus general figures about supplied wood chips or energy wood were collected for each considered wood biomass power plants: one forest chipping working site at yarding was investigated and the three chipping working sites at each energy plants were analyzed in according to companies data.
Above all the “theoretical” amount of forest wood (Smeets and Faaij, 2007) from local area was estimated within a supply distance of 150 km. In fact the “theoretical” forest biomass quantification was consequently used for estimating energy wood (roundwood or wood chips) availability supply curves. One of the most common approach used for supply analysis is to evaluate the annual offer in relation to the supply distance. Costs of transportation highly depend on travel time, which is a function of distance and road properties.
Supply investigations are commonly supported by GIS-based analysis: the cumulative “theoretical” mass for wood chips production in relation to the distance of the plant from forest resource area can be used thus for this purpose. Therefore in this study after the estimation on the availability of forest biomass, the supply analysis considered a transport distance up to 150 km. The analysis was based on network GIS based analysis and land use cover data. For each productive forest hectare an average availability of 2.7 t (w = 50%) was considered.

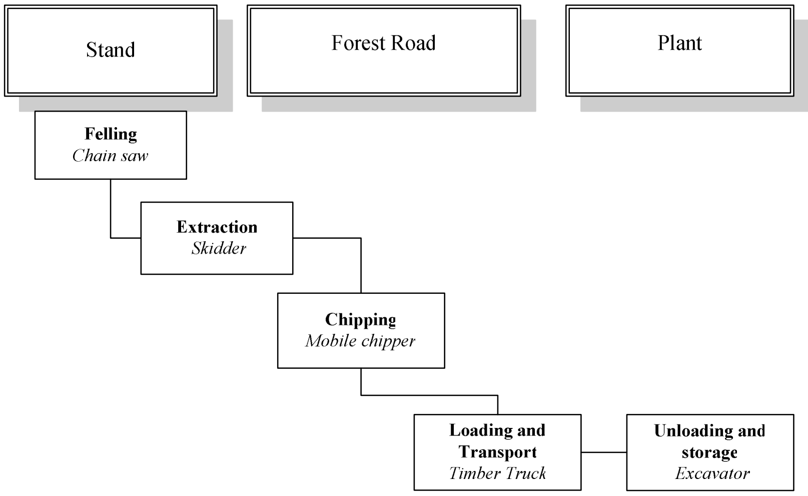

Figure 3: Forest wood chips production at yarding close to forest area or at energy plant

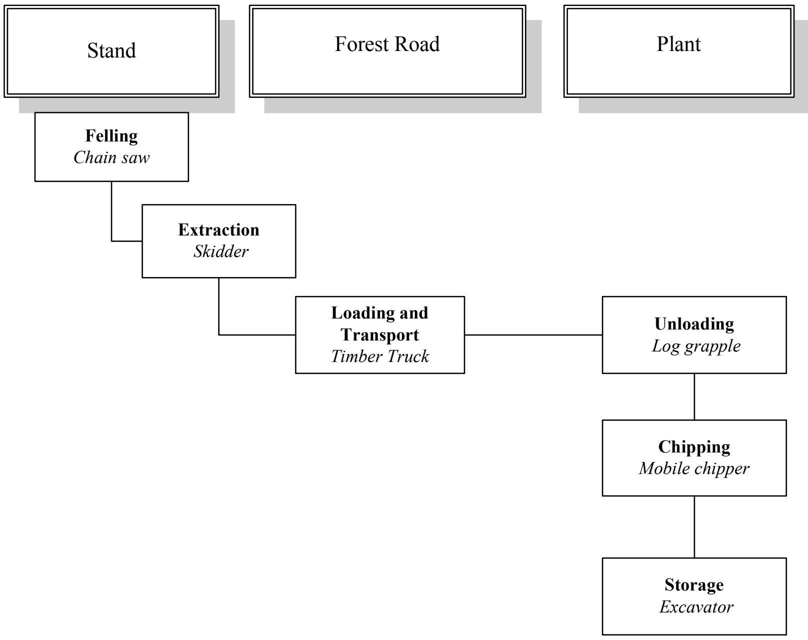

Figure 4: Forest wood chips production at energy plant

<u>Wood chips process</u>

Wood chips operations have been analyzed both at yarding and at wood biomass energy plant. Working system productivities are related to machine types and power, feeding systems, energy wood material type (roundwood, slash, logging residues).

For the chipping site at yarding, working time was analyzed by time studied surveys. The method study was based on stop-watch study in according to Berti et al. (1989).

In order to calculate the hourly cost of chipping operations at yarding as for the chipping at plant, Miyata (1980) approach was applied. According to the data and information collected, Table 3 reports the hourly costs for two mobile chippers working at energy plant (Rende and Cutro) and for one mobile chipper at yarding. In one energy plant (Strongoli), chipping operation is based on a stationary chipper (Bruks Klockner, 1200 kW). For this machine the hourly cost is determined by the company at 150 €/h while productivity is estimated at 93 t/h (w = 50%). It is supposed from the company that the stationary chipper works 2100 h/y.

Table 2**:** Calculation of mobile chippers hourly costs

				Jenz 560D	Brucks 803CT	Jenz 561D
mounted on				trailer	truck	trailer
working at				energy plant	energy plant	yarding
Description and data	Symbol	Unit	Formula	At plant	At plant	At forest
Purchase price	P	€		230 000	400 000	280 000
Salvage value	S	€	20% P	46 000	80 000	56 000
Estimated life	n	Year	-	8	8	8
Power	Pt	kW	-	205	320	340
Daily utilization	DSH	hr	-	16	8	8
Yearly utilization	DY	Days		240	238	200
Scheduled operating time	SH	hr	DSH*DY	3840	1904	1600
Average fixed investment	AI	€/year	(P-S)*(n+1)/2n+S	149 500	260 000	182 000
Machine maintenance rate	RMr	%	%Depr	13.8	24.0	16.8
Knives maintenance rate	RMc	€/hr	/hr	5.3	6.5	6.0
Interest rate	R	%	-	5	5	5
Taxes and insurance rate	ITGr	%	-	8	8	8
Fuel consumption rate	Fc	l/hr	-	32	40	45
Oil consumption rate	Lc	l/hr	-	0.7	0.9	1
Hydraulic oil consumption rate	Lci	l/hr	-	0.3	0.4	0.5
Fuel cost	Fp	€/l	-	1.3	1.3	1.3
Oil cost	Lpm	€/l	-	2.40	2.4	2.4
Hydraulic oil cost	Lpi	€/l	-	2.40	2.4	2.4
Operators cost	WB	€/hr	-	45.0	45.0	45.0
Fixed Costs						
Annual depreciation	Depr	€/year	(P-S)/n	23 000	40 000	28 000
Interest cost	In	€/year	AI*R	7 475	13 000	9 100
Taxes and insurance	ITG	€/year	AI*ITGr	11 960	20 800	14 560
Total	OC	€/hr	Depr+In+ITG/SH	11.05	38.8	32.0
Operating Costs						
Maintenance and repair cost	RM	€/hr	RMr+RMc	19.1	30.1	22.8
Fuel consumption cost	FC	€/hr	Fc*Fp	41.6	52.0	58.5
Oil and lubricants cost	LC	€/hr	Lc*Lp	2.4	3.1	3.6
Operators cost	Pc	€/hr	= WB	45.0	45.0	45.0
Total	OpC	€/hr	RM + FC+LC+Pc	108.1	130.6	129.9
	TOTAL	**€/hr**	**OC + OpC**	**119.1**	**169.4**	**161.9**

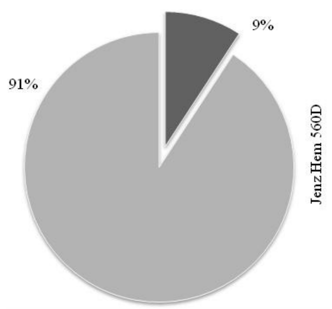

Figure 5: Jenz 560D at plant

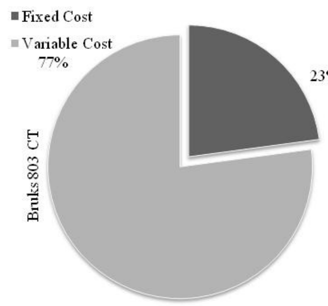

Figure 6: Bruks 803 CT at plant

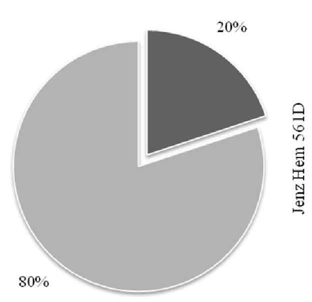

Figure 7: Jenz 561D at yarding

Results

<u>Wood chips production cost</u>

The investigated mobile chipper in forest yarding is a Jenz 561D (340 kW). Time studies concerned the chipping of forest residues and roundwood. The energy wood material was distributed in pile along the forest yarding. Piles had an average dimension: length of 35 meters, width from 3 to 4 meters and height up to 2.5 meters.

The chipper proceeded along the piles and loaded wood chips directly into wood chips trucks and trailer (in average with a capacity of 78 m^3). From work time study analysis, the chipping operations presented a productivity of 15 t/h.
For what it concerns productivities of chippers working at plants, they were estimated on the data collected by interviews to the companies.

Table 3: Productivities of chippers

	power	location						
	kW	-	t/y	t/h	h/y	d/y	€/h	€/t
Jenz 561 D	340	mobile chipper at yarding	24 000	15	1600	200	162.2	10.8
Jenz 560 D	250	mobile chipper working at plant	50 000	14	3571	238	119.1	8.51
Bruks 803 TC	320	mobile chipper working at plant	50 000	30	1667	238	169.4	5.65
Bruks Klockner	1200	stationary chipper	200 000	93	2151	269	150	1.61

Supply analysis

Supply cost was estimated in according to companies indications on transport type and costs. Transport cost by truck and trailer was fixed in 88 €/h. The transport cost (one way) was thus fixed at 0.12 €/km per ton (w = 50%) for energy wood and in the case of wood chips transport at 0.17 €/km per ton (w = 50%).
Supply cost was related to supply distances and energy plant chipping characteristics (Figure 6). Energy wood biomass price was defined at 25 €/t (w = 50%) at forest yarding. At the yarding energy wood can be chipped or load to truck and trailer (cost was estimated in 0.57 €/t) and transported to energy plant. In this case chipping operations is performed at plant.

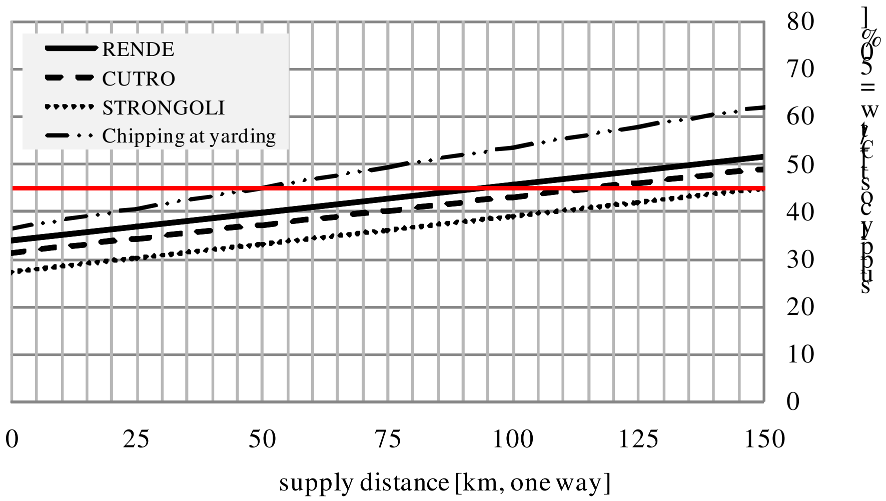

Figure 8: Supply cost for wood chipping process at plant (Rende, Cutro, Strongoli) and at yarding (included a energy wood cost at yarding = 25 €/t)

Supply distance and forest biomass distribution

In Figure 8 forest biomass supply curve for the three power plants is presented. The supply-curves are calculated according to the distribution of forest area and the location of the power plants in relation to road network (Figure 9). The forest potential amount is supposed in 2.7 t/ha per year (moisture content, w=50%)

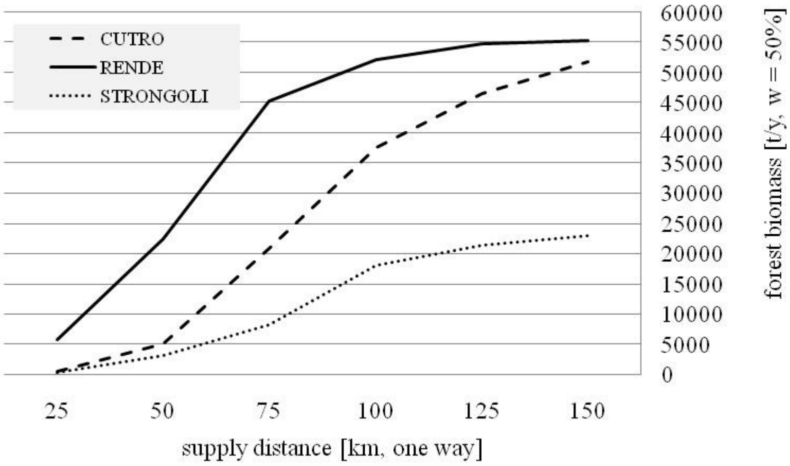

Figure 9: Potential forest biomass amount in relation to supply distance

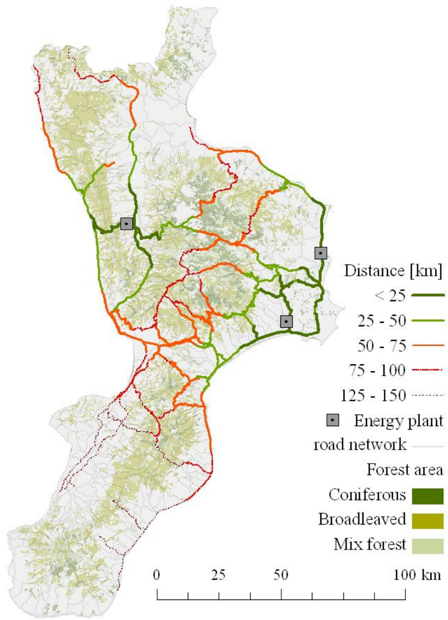

Figure 10: Forest biomass distribution and supply distance

Conclusion

In Calabria, the wood chips demand for energy use is high and it is met partially by local forest enterprises.

The current supply chains are nearly to be cost-efficient relating to the oversea importation of wood chips (at harbor 40 €/t, w = 50 %). Increasing local biomass productivity allows for an increasing scale of the entire system. The highest price for local wood chips is justified to promote local economies and social development.

In this study, by using geographical resource mapping and cost distance analysis, the costs of wood chips supply from forests to energy plants were analyzed for three selected sites in Calabria. In fact, large amounts of biomass are transported for long distances in the area.

The supply analysis highlighted that within a distance of 150 km, the offer of forest energy wood is not enough. In fact a part of the residual energy wood come from other part of the region, wood industry or oversea import.

For what it concerns the supply cost, the supply chain with chipping operation at yarding result less cost-efficient in respect of the supply with chipping at energy plant. The maximum cost-efficient supply distance, in fact, results 50 km.

When chipping is performed at energy plant and the supply considers roundwood, the cost-efficient supply distance increase also up to 160 km. That depends on chipping cost: stationary chipping operation at energy plant presents generally a lower hourly cost and higher productivities. In the same time the supply chain shows an advantage when the transport concerns energy wood in form of roundwood in respect of wood chips.

The presented model could be improved by adding precision to geographical data on forest production and by investigating the productivity and transport cost. By collecting all the information and integrating them by time studies, the analysis could be complete with an optimization study.

Anyway, the improvement of forest resource in Calabria cannot be attained only through a general increment in terms of wood chips supply but should be rather based on a re-arrangement of the management of the same productive forest area likely to result in a steady productive supply of timber that responds to the needs of the wood chips market.

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The authors participated equally in all the phases of the present work

SKID TRAILS AT WOOD HARVESTING

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Key words: skid trails, wood harvesting, skid patterns

Abstract: *Skid trails provide to maintain activity and service of forestry. They are very important for renewing of forests with intensive. Skid trails go into forest and enable to remove logged timber out forest. They are generally two patterns: Branching pattern and parallel pattern.*
This study was conducted to investigate skid trails' importance, aim and patterns at wood harvesting. In addition, it was evaluated that how skid trail is minimum effect on wood products, soil and environment emphasize at planning of skid trails.
Consequently, parallel pattern damages lesser than branching pattern environment that was found. Wood products should be skidded uphill on water supplies regions. Besides, they could skid downhill on the other regions. Operational Planning Map of the study area was created for minimum reduced wood products, soil and environment before harvesting.
Before harvesting, planning of skid trails could provide quick production and minimum negative impact on environment.

1. Introduction

An unsurfaced trail, usually single line and occurring on a gradient steeper than a truck road. A skid trail is generally temporary in nature and is used to transport the log or tree by either dragging or carrying, thus creating ground disturbance. Purpose of it; a trail used to transport logs and trees from the stump to the landing or concentration area (Anonym, 2002a). Skid trails provide to maintain activity and service of forestry. They are very important for renewing of forests with intensive. Skid trails go into forest and enable to transport logged timber out forest.

Skid trail patterns: On moderately flat ground in small timber, research found the following skid trail spacing yielded the skid trail areas shown in the table 1 below. The skid trail pattern is generally parallel trails of various spacings. On steeper or broken terrain, you can expect these percentages to increase (Figure 1) (Garland, 1997). Systematical located skid trails yield certain patterns that cover the area within acceptable limits.

Table 1. Skid trail areas.

Spacing	Percent of area in skid trails
Logger's choice	20
350 m.	11
520 m.	7
870 m.	4

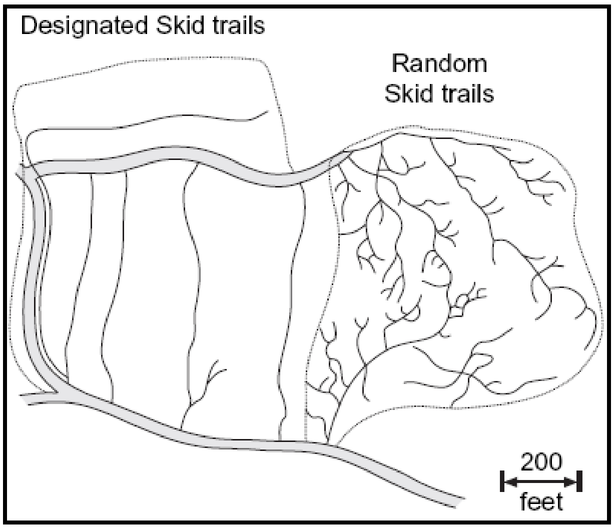

Figure 1. Ground disturbance comparison between designated skid tails and random skid tails.

In this example, random skid trails result in about 25 % more ground disturbance then designated skid trails. Two common patterns are the branching and the parallel skid trail. On gentle slopes, the branching pattern in Figure 2 has one or more main trails from which other trails branch off to provide access to the area. On steeper slopes, the parallel skid trail pattern reflects the attempt to parallel the contours (see Figure 3) (Garland, 1997).

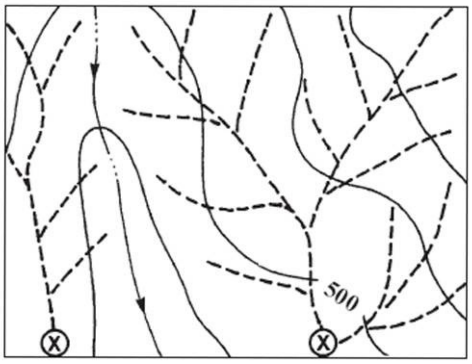

Figure 2. Branching pattern (not to scale);
X = landing location

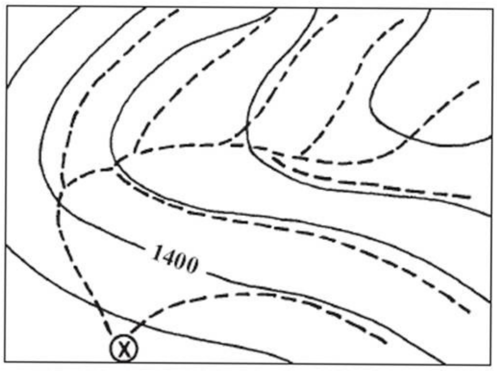

Figure 3. Parallel pattern (not to scale)
X = landing location

Generally, landings should be available so that the longest skid distance is less than 350 to 450 m. Average skid distances of 250 m. or less reduce logging cost. If closer landings are environmentally acceptable, they will improve greatly the efficiency of the operation (Garland, 1997).

2. Planning Criterions of Skid Trails

2.1. Skid Trails for Timber Harvesting

When laying out and building skid trails for ground skid, it should be taken into consideration of bellow:
• Minimizing the area of land used for trails and landings.
• Planning skid trails by marking or flagging prior to felling. This helps the fellers know where to fell the trees for easiest skid. Planning minimizes the total amount of land taken up by skid trails.
• Using the smoothest, firmest ground available.
• Making the trails as straight as possible.
• Avoiding obstacles such as hummocks, trees, rocks, and stumps.

• Avoiding causing “rub trees” whenever possible. If it is needed create a rub tree, harvest it near the end of the logging operation. If left in the stand, these trees often have “catfaces”, which result in rot and breakage at later time.
• Cutting the stumps in the skid trails as low as possible.
• Filling the low areas with cull trees and slash.
• Avoiding blocking of streams – particularly intermittent streams – when constructing trails (Anonym, 1999).

2.2. Criterions of Skid Trails for Water Quality Protection

• Bladed skid trail grades should not exceed 25 %. However, steeper segments may be required to avoid boundary lines, sensitive areas or other areas not accessible using skid trails of lesser grades. Allowances for skid trail grades of up to 35% for short segments can be acceptable. If steeper grades are necessary, practices must be used to prevent concentrated water flow that causes gullying. Skid trails should not be constructed on sidesteps exceeding 60%. If it is impossible to limit exposure of mineral soil, alternate systems should be considered such as extra cable length, cable yarding, or others.
• Overland and dispersed skid on steep slopes should not exceed 35% or when bare soil areas provide potential for channeled flow.
• Avoid skidding in a streambed.
• Skid trails should be located outside the SMZ (Streamside Management Zone).
• Any skid trail that must cross a perennial or intermittent stream or drainage ditch should use a bridge or culvert of acceptable design. Logs shall not be dragged through a stream of any type.
• Skid trail crossings of any stream channel should be as close to a right angle as possible.
• Turn water out of skid trail at least 7.5 m. prior to stream crossing.
• Break grade frequently to avoid long, continuous stretches of the same grade. Rutting should be avoided whenever possible and especially where it causes channelized erosion. If rutting is unavoidable, concentrated skidding may be used to reduce the amount of disturbance. Site preparation should be used to ameliorate excessively compacted or rutted sites.
• Upon completion of skidding, areas subject to erosion should have water bars installed immediately.
• A permanent vegetative cover should be established upon exposed soils that are greater than or equal to 5% slope, or less if soil type is highly erodible.
• Temporary closeout of skid trails should occur if the skid trail will be inactive for periods longer than seven days or if a severe storm event is anticipated (Anonym, 2002a).
• Follow the contour to the greatest extent possible. Timber should be skidded uphill either to a contour skid trail or more level ground.
• On slopes of 20 percent or greater, skid uphill.
• Skid trails on slopes should have occasional breaks in grade or logging slash that disperse water.
• Where stream crossings are planned, use portable crossing structures, culverts, poles or natural fords with firm bottoms, stable banks and gentle slopes. Do not use soil as a temporary fill material when water is in the stream.
• If a ford or crossing will cause excessive rutting or turbidity, then bridges, culverts, concrete slabs or other constructed fords should be used.
Minimize the number of stream crossings. Skid across a stream only at stable locations identified during harvest planning.
• Upon completion of skidding, remove all temporary fill material from streambeds. If the banks are crushed or if soil is eroding, stabilize the stream banks.
• Should not use stream channels as skid trails.
• avoid logging in excessively wet areas or during excessively wet weather. If skidding in wet weather, take the following precautions to protect water quality.
• It should be stabilize bare areas during any temporary shut-downs in logging operation if needed to protect water quality.
• Minimize skid trail construction at grades greater than 30 percent. With grades greater than 30 percent, install frequent rolling dips and follow contours. Stabilize these skid trails.
• If off-site soil movement occurs, control it with rolling dips, temporary water bars, and prompt revegetation.
• Minimize straight runs of 1040 m. or more at grades greater than 20 percent (Anonym, 2002b).

2.3. Controlling Erosion and Runoff from Active Skid Trails

The following guidelines will aid in proper skid trail construction.
• Grades: Keeping skid trail grades as low as topography will permit. Should not go straight up the slope but proceed on a slant or zig-zag path and avoid long, steep slopes.
• Ephemeral channels: Where possible, culverts should be use, temporary bridges, or other structures at ephemeral channels.
• Drainage: All trails should have drainage using turnouts and natural dips. Allowing water to accumulate on trail surfaces may lead to unwanted flows into streams or channels.
• Bank seeps need drainage control structures (which can be skidded across) immediately below them.
• Extra steep skid trails need drainage control structures (which can be skidded across) immediately above them.
• Skidding over wet soils may cause excessive rutting and should be avoided, if possible. Excessive rutting can be practically defined as a depth exceeding the ability of the available equipment to resurface the trail.
• Maintenance includes preventing water from accumulating on trails. Berms of dirt pushed up along the edge of trails often prevent water from draining and should be periodically removed. Temporarily unused trails need to have drainage control structures constructed to prevent rill and gully erosion (Anonym, 1990).

2.4. Designated Skid Trails Minimize Soil Compact

• Skidding downhill is preferred for all ground-based systems. Downhill skidding to the landing is termed favorable; an uphill trail to the landing is called an unfavorable or adverse grade. The feasibility of unfavorable skid trail grades depends on how long they are, how much of the trail system is unfavorable, and the type of skidding equipment. You usually can expect some amount of uphill skidding.
• It should not excavate skid trails on less than 20-percent sideslopes (slope of the hillside) to achive a flat running surface. Side slopes beyond 20 percent may require excavating 30 or 60 cm. of earthwork at the trail center to achieve narrow (machine-width) skid trails. This is necessary because the loaded vehicle tend s to slide down slope. Keep excavated skid trails narrow and adequately treated to minimize erosion.
• Skid trails should be designated with clearcuts or partial cuts (thinnings, overstory removals, etc.). the size of the turn (group of logs to be skidded) partially determines the size of winch line you should use and thus the spacing of skid trails.
• Large timber or large turns of smaller trees (such as form clearcuts) will require winch lines that are heaver and harder to pull than those used for smaller timber or smaller turns collected from within a stand of residual trees (Garland, 1997).

3. The Study Area

The study area average slope is % 17 is about 32 ha. It comprises 131st Compartment. It takes shape shrub age of *Pinus brutia* stands. There are total 786 m. length existing forest roads and about 600 m. length stream in the study area. Climate of the study area is hot and drought.

Skid trails planned for interim harvest. Total 6328 m. length skid trails were planned on the study area. So this area was exactly managed. Planned skid trails are generally parallel pattern. This pattern prevents better branching pattern, thus average height of *Pinus brutia* is 25 m., distance of among skid trails were planned 25 m. Planned skid trails contain 1.7 ha (5 %) of 32 ha study area. Average lengths of skid trails are 260 m. It reduces logging cost. The stream which was buffered 30 m. was in the area. Skid trail wasn’t planned this buffer. So stream was protected. That skid trails were planned, timber was skidded uphill either to a contour skid trail or more level ground. In addition, skid trails were designed straight for operator achieves higher speeds and spend less time. Therefore stumps obstruct skidded wood products; sharply turning skid trail weren’t designed. Map of planned skid trails is created (Figure 4).

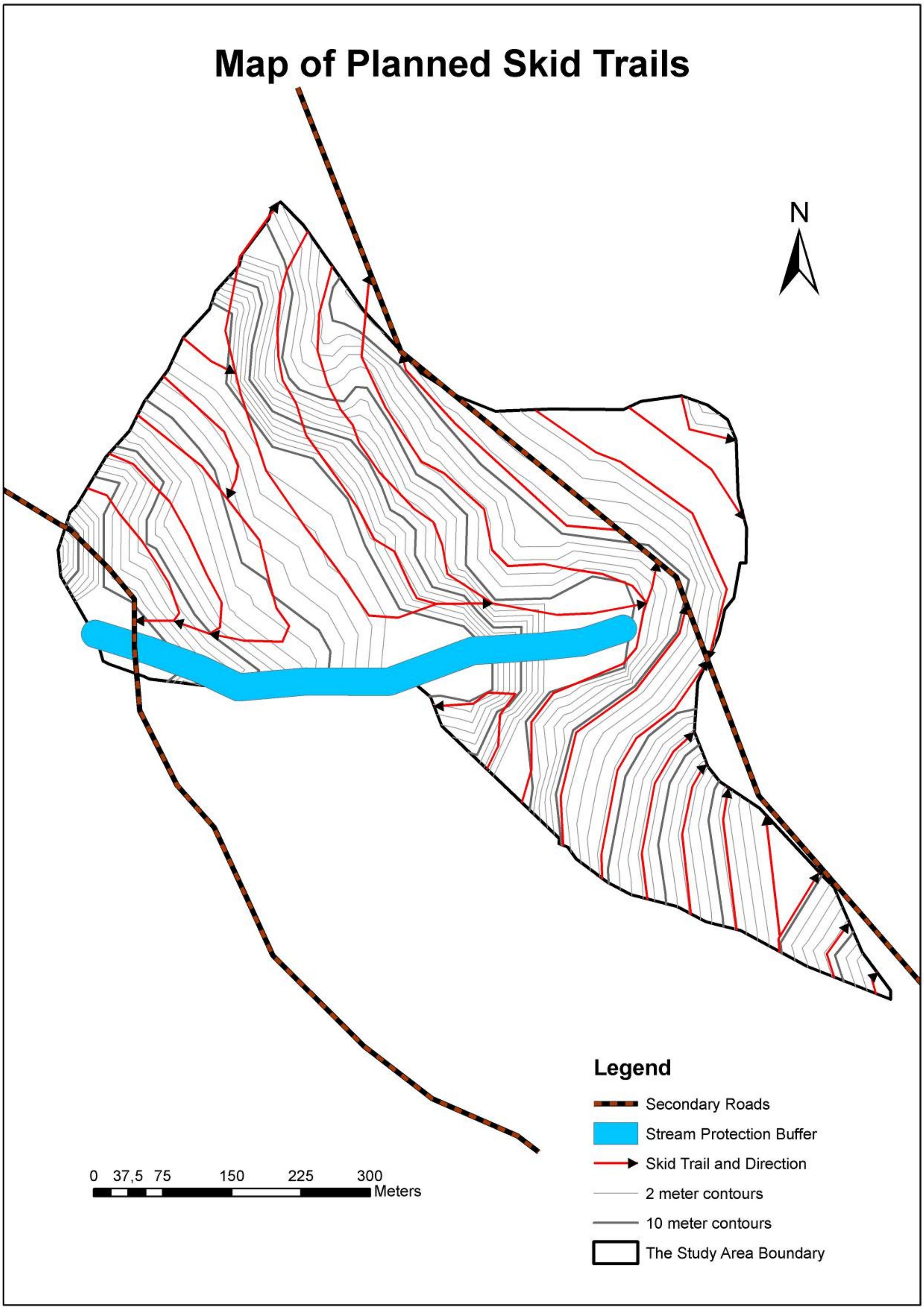

Figure 4. Map of planned skid trails

4. Results

This study consequence: The study area was exactly managed, thus skid vehicles easily transport wood products. Average skidding distance was found 12.5 m. Because of reduction of skidding distance, cost was decreased. Time of skidding was decreased. Skid trails were located outside stream buffer, thus water supply was protected. Skidding trails were designed straight, so operators achieve higher speeds and spend less time.

Before harvesting, planning of skid trails could provide quick production and minimum reduced environment.

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ENVIRONMENTAL IMPACT OF TIMBER HARVESTING IN TURKISH FORESTRY

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Key Words: Timber harvesting, Environmental impact, Turkish forestry

ABSTRACT: *In the World, forest lands getting reduce day by day and drawback to mountainous regions. This condition was made forest enterprise and especially forest transportation more important. Wood extraction operations which are done on forest ground surface are more difficult and expensive than track transportation on the forest roads during forest transportation and it is important point of view impacts of environment*

Transportation operations which are done in forest inside, especially on difficult terrain are more hazardous for environment. Transportations on ground surface in forest lands cause erosion on forest soil, damage on planting stock, trees in the stand and losses of quality and quantity on transported logs. This condition is rising up against of us when taking account of losses of forest value. This is more important on mountainously regions. The transportation systems which are established by using partially environmental conditions and used local can be reduced to minimum level.

Increasing environmental concerns have demanded more environmentally sound as well as economically efficient timber harvesting systems. This study aimed to identify timber harvesting systems implemented throughout the generally and to assess (Tractor and Skyline Systems) environmental impact.

1. INTRODUCTION

According to last forest inventories, Turkey has 20.7 million hectare total forest areas which make up % 27 of its total. Approximately % 46 of the total forest area is on steep land with slopes greater than % 40. Due to this fact that, harvesting in mountainous regions has always played a significant role in Turkey (NDP, 2005).

In the past last decades, the World public has become increasingly concerned about the protection and conservation of our natural environment. There is a growing need for environmental protection measures in all facets of forest operations. The ever increasing focus on ecosystem management and resource protection on public and private forestland in the world creates challenges for timber harvesting operations. The primary challenge is the implementation of environmentally sound timber harvesting methods, equipment, and management plans. These harvesting methods and equipment must also prove to be economically sound or cost effective.

In spite of these many positive contributions of timber production, there are also negative effects, particularly with respect to decreasing soil quality and water quality resulting from mechanized harvesting methods and equipment.

Rationalization efforts have resulted in an increasing mechanization of timber harvesting systems. The development and deployment of harvesting systems aims to provide physically feasible, economically viable, and environmentally sound solutions. Environmental soundness consists of several impacts, such as damages to the residual stand, to the soil, or adverse effects on human health and safety (Dykstra, 2001).

Increasing environmental concerns have demanded more environmentally sound as well as economically efficient timber harvesting systems. This study aimed to identify timber harvesting systems implemented throughout the generally and to assess (Tractor ve Skyline System) environmental impact.

2. ENVIRONMENTAL IMPACT OF TIMBER HARVESTING

2.1. Timber Harvesting

Harvesting includes felling trees and transporting logs on skid trails to a landing where products are sorted and loaded onto trucks for transport to a mill or harvesting system (felling, delimbing, bucking, logging, Tablo1). Skid trails are temporary travel-ways for logging equipment to transport felled trees or logs to a landing.

Table 1.Timber harvesting systems

	STAND	ROADSIDE
FELLING		
DELIMBING		
BUCKING		
LOGGING		

2.2. Environmental Impact

These improved harvesting practices are more ecologically sound than traditional selective logging. They are known by several names, such as Environmental impact of timber harvesting (EIT) Low Impact Harvesting(LIH), Reduced Impact Logging(RIL), or Natural Forest Management (NFM) (Bawa and Seidler 1998; Dykstra, 1992). In principle, the objective is the harvest of trees in a way that allows the forest to regenerate naturally before the next round of logging. The system relies on careful planning of road, skid trails, and tree locations.

In order to carry out the activities of forestry at the point of ecological view for the regions where road construction is difficult and harmful, alternative transportation methods may be taken into consideration. Before opening up forest areas, ecological features of the area have to be researched for finding out appropriate methods. In order to achieve this aim, the system which will be used before the interference to the forest Environmental Impact has to be done.

2.3. Environmental Impact of Timber Harvesting

Tractor Systems: The skidding operations are usually done with skidders and crawler tractors that transport logs by dragging them with a grapple or chokers. The capacity of the skidder is highly dependent on its drawbar is horsepower, weight and traction obtainable under the ground conditions during operation. Skid distance is generally the most important variable since it affects cycle time more than any other variables. If the skid distance increases, travel time will increase accordingly. In some cases where skid trail is quite straight, the longer the distance, the faster the travel speed without load.

Forest vehicles, skidders and tractors, cause soil disturbance due to forest operations. Forest soil disturbance can be broken down into three categories: compaction, rutting and soil displacement.

Soil compaction represents a volume soil deformation (Gameda *et al.*, 1987) and increase of bulk density, as a result of compaction of soil particles under the effect of an external force (Arnup 1998).

Formation of ruts is the effect of soil compaction.

The formation of ruts is defined as damage to soil structure caused by deformation of its surface, and it occurs when the soil load reaches the limit value of its strength (bearing capacity). Then the soil volume is reduced not only due to its compaction but also due to the so-called soil breakage. Due to soil breakage, a certain volume of soil is squeezed along the rut, i.e. displacement of soil occurs. Displacement of soil is a mechanical movement of soil or its superficial layer under the impact of the vehicle or extracted timber (Sexias 2003).
The damaging effects of ruts and soil displacement are mixing of soil layers, creation of unfavourable conditions for seed germination, decrease of porosity, decrease of nourishing material in the soil, damage to trees roots, increase of soil freezing depth and increase of erosion risk.
Forest products are hauled by skidding directly over the ground using forestry and agricultural tractors and special forest tractors. (Figure 1).

Figure 1. Damage to soil after harvesting

Skyline Systems: Skyline Systems are used to transport the forest products between 300 and 2000 meters distances. According to skyline distances, these are classified as the following:

- short distance (less than 300 m)
- middle distance (between 300-800 m)
- long distance (more than 800 m)

Extraction from compartment after increasing the forest road network would not give good results as economical and technical because of high and steep slopes in mountainously areas. Skyline Systems with mobile winches are more useful for extraction from compartment on the high and steep slopes.
Today, Koller K 300 as short distanced Skyline Systems, Urus M III as middle distanced Skyline Systems and Gantner as long distanced sledge Skyline Systems are used on the forest areas of Turkey. Koller K 300 and Urus M III Skyline Systems transport mostly uphill raw wood material. Gantner Skyline Systems had been transported downhill logging and realized hanger logging with gravity system (Çalışkan, 2005).
The forest product can be transported by suspending completely or partly (one side of the material rubs) by using skyline system. Generally skyline system where downhill transportation is done, it is seen that one side of the material rubs. Also, one side material rub is seen where the skyline transportation cable is low from ground. On the other hand, uphill transportation is accomplished by suspending the material completely.
Stand Damage; Scarring was the most common type of damage for all harvesting systems. More crown damage was found in skyline units and some root damage was observed in ground-based thinning units.
Damage was highly concentrated near skid trails and skyline corridors. Stand damage could be effectively reduced by well-prepared thinning plans and careful logging. Careful logging to minimize residual stand damage resulted in increased thinning costs, but reduced future value losses to crop trees could justify the increased costs. Every skyline system causes some damage to residual trees. Allowing operators to leave an undamaged, marked tree and cut a damaged, unmarked tree instead could promote long-term stand health.
Soil Impact; It is imperative to assess - consider existing soil compaction & historical disturbances when monitoring soil impacts for harvesting operations in second-growth stands (Hoogervorst, 1994).

Spatial variability of compaction -disturbance is significant. This variability presents challenges for sampling-interpretation of resource effects-management needs. Skyline thinning caused relatively minor soil disturbance - little or no soil compaction.
Forest vehicles, skidders and tractors, cause soil disturbance due to forest operations. Forest soil disturbance can be broken down into three categories: compaction, rutting and soil displacement.

Figure 2. The skyline system corridor and damage of soil after harvest

Figure 3. Skyline corridor and damaged tree


Figure 4.Damaged Stand and Tree

3.CONCLUSIONS

Due to the technological developments, extracting short diameter products from compartment is getting easier. Skyline system is used when the logs are extracting from compartment. While transporting these heavy yields, some damages may be come in to being on the transportation way and on the surrounding area. The probability of recovering transportation way is low.

For that reason the opening up way of skyline system should not be large. Skyline system way has to be taken in to consideration while carrying out the process of cutting and felling the trees. So, side rub distance can be minimized in order to increase the efficiency of skyline system and reduced the damage to the soil.

Forest soil compaction and rut formation are considered as criteria in assessing environmental acceptability of forest vehicles.

The research of tractors performance examine on soft soil showed a considerable effect of tractors on soft soil (rut formation and penetration characteristics). It was also soft soil suffered serious damage after the very first pass of the vehicle.

Damages to soil caused by skidding/tractors cannot be completely eliminated. They can , however, be minimized to an environmentally acceptable and economically tolerable level by applying the most favourable technical and technological solutions, and by choosing the right time for performing specific operations with respect to the soil bearing strength. The development trends are focused on finding work technologies that would lower the intensity of the vehicle’s impact on the soil, and on developing machine technical characteristics.

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SYSTEMS ANALYSIS AND SUSTAINABILITY IMPACT ASSESSMENT – AN EXAMPLE FROM THE EUROPEAN FORESTRY-WOOD CHAIN

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Keywords: Sustainability Impact Assessment (SIA); Forestry Wood Chain (FWC); systems analysis, (business process) modelling; economic, environmental and social indicators; ARIS

Abstract:

Today's present situation of the European FWC with its corresponding processes is determined, by means of modelling and calculating its individual process steps and abilities by using a professional modelling software, which is in this case ARIS Architect.
Consequently, the individual processes from tree harvesting and wood transport to the provision of pre-processed materials fed into industrial processes are described, involving also loops, decision points and variants. For a later point in time, modelling of scenarios is planned.

Within these models it is possible to link individual activities with economic, environmental and social indicators. Those indicators represent a selected and balanced set from IPCC and MCPFE indicators. Values for these individual indicators are either calculated within this model itself, or by already existing partial models for allocation, wood quality, transport and harvesting.
In the consequence, all processes and activities are linked with numeric values for each indicator, which assess the process's sustainability. Those can be summed up per chain alternative, thus comparing the sustainability of different alternatives on basis of hard figures for all three levels of sustainability.

1. Statement of the Problem

Ever since the Brundtland report (1987) was presented by the Norwegian minister president at the World Commission on Environment and Development (WCED), the most acknowledged global description of sustainable developments clearly defines those as such that "meet the needs of the present without compromising the ability of future generations to meet their own needs" (UN, General Assembly, A/RES/38/161, 1983). The European Union pledged themselves to transfer this principle of sustainability to all economic sectors. This has been lately discussed at the Conference in Bali, 2007 and will be among the major points of discussion during the upcoming conference in Copenhagen, 2009.

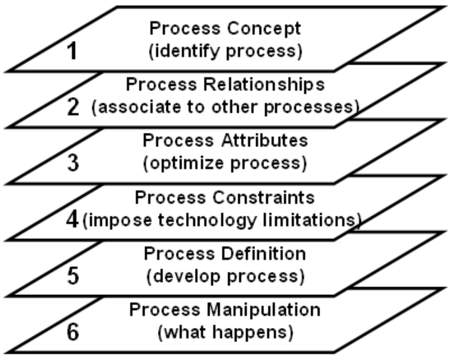
Europe's forestry's and wood industry's growth chances and competitiveness are particularly linked to the aspect of sustainability: only if forests, which are a natural and renewable resource, are managed sustainable at all levels (economic, environmental and social), they yield great future chances in a regional perspective as well as in a global context. The pre-condition is that also the downstream parts of the FWC, i.e. wood industry including consumption and recycling, are managed according to the principles of sustainability. Assessing those is the task of the integrated EU-project of the 6th framework programme EFORWOOD, whereas in particular it is task of the Institute of Forest Utilization and Work Science, University of Freiburg to coordinate and accomplish this for the part of harvesting, forwarding and transport to millgate entrance together with five more institutes within EFORWOOD's module M3. For further reference and information see `www.eforwood.com`.

Purpose of the study and scientific approach: Definition of terms and methods

Now, how can those sustainability issues be dealt with along the processes of harvesting and transport operations as well as in terms of wood quality and raw-material allocation?

The method chosen in this study is the one of "business process modelling". Hereby the current and future processes of an enterprise are presented, so that the current process may be analysed and improved. The definition of processes – as it is also given in the scientific literature (see for instance the following books: Niestrasz: "Object-Oriented Software Composition"; Forbrig: "Objektorientierte Softwareentwicklung mit UML"; Bernroider et al.: "Grundzüge der Modellierung") – signifies that a "process (lat. processus - movement) is a naturally occurring or designed sequence of `operations` or `events`, possibly taking up time, space, expertise or other resources, which produces some outcome. A process may be identified by the changes it creates in the `properties` of one or more `objects` under its influence" (wikipedia, 10/05/2006). "Immaterial processes" like planning or material allocation are also to be implemented, especially if they take up time, money and other resources. A process has also a time dimension. In terms of "business process modelling", for example, this is defined as "a collection of related structural activities that produce something of value to the organisation", being marked by "inputs, method and outputs", whereas it "can be part of a larger, encompassing process and can include other business processes that have to be included in its method" (wikipedia, 09/03/2006).

Generally, the used processes are structured following this philosophy, and have a starting point and an end point and contain classes with e.g. objects, attributes and methods. Furthermore, processes are modelled in a formal structure, so that they can be computerized. Hereby the methodological theory of UML (Unified Modelling Language, an object oriented programming approach) is used, which can be applied for all future calculations, quantitative modelling, etc, as well as Zachmann's approach for process orientation (compare Tab 1). Zachmann distinguished six steps on the way from process depiction, analysis and optimisation which are:



Tab 1: ZACHMANN'S approach to process modelling

1. *Process Concept*: identification of involved processes at different levels of detail, such as Level I: Harvesting – forwarding – transport, as main processes of the depicted part of the FWC. On Level II: for eg transport processes some possible alternatives are Alt 1: transport by truck to millgate, and Alt 2: transport by truck to terminal, followed by transport by train to millgate. In high resolution of detail one of those transport alternatives could be described at Level III as: Search of to-be-transported timber off main roads – loading of timber pile – securing of load – transport to millgate – registration at mill entrance – deloading of timber.
2. *Process Relationships*: Association to other processes: borders and products of all processes in perspective are defined as well as their linkage. Special interest is on involved persons, machines, resources, information and data systems. Hereby it is essential that a strict logic in depicting the status quo of subsequent processes, as it is here that system breaks, dead-ends and redundancies on process level become obvious.
3. *Process attributes*: A prerequisite of process optimisation in terms of performance is to link values to individual processes. Those values are reflected by the selected set of indicators and are the basis of further calculations. It gives an overview over employed process steps and resources even at a very small scale. Inefficient processes can easily be spotted in this format.

4. *Process constraints*: After all possible systems have been gathered, limitations for the system in use have to be selected. Those may fro instance be legal restrictions (eg 40t trucks), technical restrictions (eg compatibility of used information systems, steep/narrow routes), planning restrictions (eg availability of transport vehicles and drivers).
5. *Process definition*: This is the definition of processes not only at a conceptional level, but as they are, using for instance a professional modelling software, as in this study, ARIS Architect. Hereby processes are modelled at all needed levels of detail, and linked to each other as well as to employed resources.
6. *Process manipulation*: What happens if, for instance, the course of processes is altered/harmonised, resources employed are distributed differently, new processes are implied, new information systems are used? The analysis of those question is the final step in this approach.

In step 3 "Process attributes" a set of indicators, which's values are to be linked to the individual processes is mentioned. Indicators are "any of a group of statistical values (as level of employment) that taken together give an indication of the health of the economy, environment and/or society" (MERRIAM-WEBSTER, 2008, adapted). They are among the key tools for a sound system analysis as they are the basis for quantifying the FWC's sustainability. As such a set has been selected which is based on IPCC and MCPFE requirements, as well as well balanced in terms of representing economic, environmental and social indicators.

2. The main findings

Main target of this study is to develop a method which makes it possible to assess the sustainability of the present European FWC, as well as of possible future variations. Furthermore, a higher level of detail and information should thereby become inherent in terms of the determination, calculation, modelling, and subsequent optimisation of

- Timber and fibre characteristics
- Interaction between wood quality, processing and product quality (sawlogs, pulpwood, bio-energy)
- Quality characteristics of raw timber
- Methods of planning and production (harvesting methods)
- Transport methods and systems

To put it into a nutshell, the overall target of this study is the analysis of effects and consequences of changing framework conditions by using a business process modelling method.

3. Outlook

Modelling and optimising these processes of the FWC with respect to economical, environmental and social sustainability has a huge benefit potential for regional, national and global forestry and wood industry.

In the course of the next two years the above mentioned processes are being and will be modelled, integrating existing models and completing given gaps to form a partial chain or stand alone model which can be integrated into the EU-project EFORWOOD's model. This partial chain model will have all its processes and optimisation scenarios connected with indicators for economical, environmental and social sustainability in order to find the most suitable action alternative at a given real-world situation within the forest-wood-chain.

Against that background, more information about product as well as process characteristics will strive towards a better – and more sustainable – choice of methods applied. This will have an economic, as well as an environmental and social output.

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ANALYZING AND ESTIMATING DELAYS IN HARVESTER OPERATIONS

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Keywords: time studies, logging, harvester, machine delays, forestry

Abstract: *Delays are recognized as being one of the major factors that limit productivity in most forestry operations and are therefore an integral part of most time studies. However, delay events are erratic in both occurrence and magnitude and are therefore difficult to precisely quantify within the relatively short observation period of a typical time and motion study. This paper analyzes the delay component of thirty-four harvester time study data sets that were recorded between 1998 and 2006. All the studies were designed and carried out with the same principal investigator. The data sets were all based on harvesters either harvesting and or processing. Three delays categories were used: mechanical, operator and other. Delays averaged 28.9% of the total scheduled time for all 34 studies, comprising of 7.1% mechanical, 4.7% operator and 17.1% other delays. Delay averages were compared within category description assigned to each data set for statistical significance. Example results include: total delays were higher for operations working on hot decks versus cold decks, and operations working in mixed stands had more than twice the overall delays compared to operations in plantations. Looking at just mechanical delays, machines that both felled and processed, compared to just processing, had higher mechanical delays. Interestingly, dedicated harvesting machines, versus harvesting heads mounted on an excavator base, had on average higher operator delays.*

1. Introduction

Time and motion studies have been, and are still frequently used to describe, understand and improve forest operations. Research on the productivity of forest operations is obtained by measuring the time consumed and the quantity produced and then carrying out a statistical evaluation to relate the two quantities (Steinlin 1955). Performance studies can be comparative or correlation studies (Samset 1990). The aim of correlation studies is to find the relationship between the performance of the machine and the various influencing factors, such as tree size, extraction distance, terrain slope, etc. (e.g., Appelroth 1985; LeDoux and Huyler 2000).

For most forest operations productivity studies the data collection procedure consists of a set of detailed time and motion studies conducted at the cycle level. In general, detailed time studies are more discriminating than shift-level studies and can detect smaller differences between treatments (Olsen et al. 1998). In general, cycle times are defined and split into time elements considered to be typical of the functional process analyzed. This is done with the intent of isolating those parts of a routine that are dependent on one or more external factors (e.g., tree size, percent of leaning trees, slope, travel distance) in order to enhance the accuracy of the productivity models. The criteria followed for such subdivisions should aim at: 1) isolating significant cycle elements; 2) reflecting as much as possible on other similar existing protocols (Berti et al. 1989; Landau 1998) and, 3) avoiding unnecessary detail.

There have been various attempts to standardize time study procedures, including those by the Nordic Council of Forestry, IUFRO (Bjorheden et al. 1995) and the European Union (CTBA 1997). For example;

differentiating between ‘scheduled machine hours’ (SMH) from the work only ‘productive machine hours’ (PMH), and defining mechanical availability (MA%) are all common concepts. A comprehensive set of definitions for forest operations terms, including common time study terminology, was published by the US Forest Service (Stokes at al. 1989). Most of their time study definitions were in turn taken from two American Pulpwood Association technical publications (APA 1972; APA 1981). These time-study terminology definitions help in defining each term and in many cases suggest appropriate categorization of time elements

Differing definitions still occur to reflect local work condition, or simply reflecting methodologies used by previous studies with which one intends to compare results. Although most proposed protocols agree in principle and are relatively clear and simple, problems exist in their application in the field.

Conway (1982) noted the importance of delays in all phases of production. A major problem exists in the reliable recording and evaluation of machine delays. Even basic definitions have not been interpreted consistently. Early definitions focused on two types of delays: ‘productive’ and ‘non-productive’ (McGraw and Hallett 1970). Many recently published productivity studies seem to prefer using ‘mechanical’, ‘operational’ and ‘personal’ delays categorization (e.g., Visser and Stampfer 2003). Each definition set seems to have strengths and weaknesses. Regardless of the number of delay categories used in a time and motion study, there is always a need to add a generic ‘other’ category to accumulate time events that are either not recognized by the person carrying out the time study – or genuinely does not fit a category.

Other differences occur in the differing data interpretation methodologies. One clear example is that most central European countries prefer including delays up to 15 minutes into the work only time, denoting this with PMH_{15}. This means their published delays are only those greater than 15 minutes. There is no published data that suggests appropriate conversion factors to allow corroboration of either the PMH_{15} into PMH or the delay time itself.

In the field there is the inherent difficulty of obtaining representative samples of a typically erratic phenomenon from relatively short observation periods. This makes it difficult to translate into practice the results obtained from models able to predict work only productivity, otherwise very accurate and potentially useful. Stampfer and Steinmueller (2001) noted that for efficient generation of productivity models for harvesters it is simpler to only capture the data for the work time components and then use a delay model based on the literature. However, no such delay models exist except for individual values from specific time studies.

Little scientific work has addressed the development of reliable delay factors, and the translation of net production data obtained from scientific time-studies into scheduled time performance is obtained by applying empirical reduction coefficients, or using the results of studies coming from a long distance in space and time (Brinker et al. 1989). The application and/or extrapolation of empirical study results for the purpose of determining appropriate harvesting rates also requires an accurate understanding of delays. The utilization rate, which is defined as (SMH - delays)/SMH, determines the allocation of fixed and running costs (Miyata and Steinhilb 1980).

During an extensive research program to help promote mechanization of Italian operations, the National Council for Research (CNR) of Italy conducted a large number of time studies on a range of mechanized equipment. This included 34 complete harvester times studies, recorded on between 1998 and 2006. Such a large data set provides an opportunity to analyze in detail the delays associated with harvester operations. The goal of this study is to produce and analyze delay factors that can be applied to the estimated net work time productivity.

2. Materials and methods

Thirty-four complete times studies, recorded on harvesters between 1998 and 2006, were used for the analyses of delays. All the time studies were set up and carried out by the same principle investigator and with the same methods. All time elements and the related time-motion data were recording with Husky Hunter® hand-held field computers running Siwork3® time-study software (Husky Computers Ltd. 1991; Kofman 1995).

All the time studies used three clearly defined delay types;
(1) mechanical delays (breakdowns, saw-chain derail, saw-chain replacement)
(2) operator delays (rest, break, physiological, smoke, phone call), and
(3) other delays (including: waiting, interference, reconnaissance, refuel, preparation)

Delays caused by the study itself, including giving instructions and measuring logs have all been excluded. Delays for the main meal (if the operator took any) and relocation to and from site are also not included in the data sets. All other delays are included.

Each data set allows itself to be categorized depending on what the harvester was doing, and where it was doing it (see also column 1 in Table 1). The studies totaled 692 hours of observation (87 scheduled workdays) and ranged from 4 hours up to 59 hours (average 19.7 hours) for the individual studies. Utilization (defined as productive machine hours divided by scheduled machine hours) ranged from 49% up to 90%, with an average of 71.1%. Conversely, delays averaged 28.9% of the total scheduled time for the studies, comprising of 7.1% mechanical, 4.7% operator and 17.1% other delays.

In most published reports, delays are reported as a percent of the total scheduled time. Assuming just three delay categories, the scheduled machine hour can be by equation 1.

$$SMH = PMH + H_{mech} + H_{op} + Hoth \qquad [1]$$

Where: SMH = Scheduled Machine Hours
PMH = Productive Machine Hours
H_{mech} = Hours of Mechanical Delay
H_{op} = Hours of Operator Delay
H_{oth} = Hours of Other Delay

Normally delays are presented as a percentage of SMH. For example for Mechanical Delays (MechD) as expressed by equation 2.

$$MechD = \frac{H_{Mech}}{SMH} \qquad [2]$$

Where : MechD. = Mechanical Delay (%)

Expressed in terms of Utilization (%), we can derive equation 3 that separates out the three delay percentages. The last line rearranges the equation to isolate out Mechanical Delay.

$$Util(\%) = \frac{PMH}{SMH} = \frac{SMH - SMH\left(\frac{MechD + OpD + OthD}{100}\right)}{SMH} \quad [3]$$

$$\frac{PMH}{SMH} = 1 - \frac{(MechD + OpD + OthD)}{100}$$

So $$MechD = 100 - 100 \times \frac{PMH}{SMH} - OpD - OthD$$

Where: OpD = Operator Delays (%)
OthD = Other Delays (%)

Equation 3 shows that Mechanical Delays becomes a function that is also dependent on Operator and Other Delays. This assumes a level of dependence between the delay types. We tested for correlation among all three delay types, and none was found. This indicates that an operation that has, for example, above average mechanical delays, is no more likely to have either above or below average Operator or Other delays. Therefore, it makes more sense to report delays as an increase over the work related time elements (net productive time), as such a value is then transferable to other operations. To ensure a distinction, we will refer to a Delay Factor (still in %), which is to be added to the productive machine time.

In equation form the Total Delay Factor is just the summation of the three individual delay factors (Eq. 4) and the conversion of productive machine hours into scheduled machine hours is given in equation 5.

$$DF_{tot} = DF_{mech} + DF_{op} + DF_{oth} \quad [4]$$

$$PMH \text{ x} \left(\frac{DF_{mech} + DF_{op} + DF_{oth}}{100}\right) = SMH \quad [5]$$

Where: DF_{tot} = Total Delay Factor (%)
DF_{mech} = Mechanical Delay Factor (%)
DF_{op} = Operator Delay Factor (%)
DF_{oth} = Other Delay Factor (%)

The delay factor representation is used throughout the analyses and results.

To complete the statistical analyses, two-tailed t-tests were used to test for differences between categories in the delay data. We should note that these data sets were not collected with the intention of doing a delay comparison; there is no study design to balance operational, stand or terrain types. These results should therefore be considered indicative not definitive, and are analyzed for indications of trends.

Delay Length Distribution

As an additional part of the study all individual delay events were used to determine what a typical distribution for delays might be. In particular this is to address the issue of published productivity models where the delays less than 15 minutes are included in the work time (mainly the central European countries) with those that report all delays. The question therefore arises, what percent of delays are less than 15 minutes so that a correction factor can be applied for productivity comparison.

For 29 of the 34 data sets the original data collected was still readily accessible in a form whereby the individual cycles could be compiled. All cycles with a delay in them were aggregated for evaluation. In total, this amounted to 2151 individual delay events representing a total of 144 hours of delays.

3. Results and Discussion

All the delay data was separated according to the categories. Table 1 presents the Total Delay Factor (%) as categorized by the studies. The table shows the number of cases, the average delay for each category along with the standard error of the mean for the data set, in addition to whether or not the categories were statistically significantly different ($p<0.05$).

Table 1: Categories that allow the studies to be compared, breakdown of number of studies within the category, average total delay factor and standard error of the delay factor.

Categories	***n*, (#)**	**Average Tot.Del Factor, (%)**	**Std. Error (%)**
Italy	*26*	40.3	4.6
Other country	*8*	28.9	5.2
Hardwoods	*20*	34.0	4.6
Softwoods	*14*	43.7	6.8
Natural stands	*20*	**49.7**	4.7
Short rotation plantations	*14*	**20.8**	1.8
Dedicated machine	*12*	32.9	4.0
Excavator base	*22*	40.2	5.4
Felling and Processing	*21*	33.7	3.4
Processing	*13*	44.0	8.2
Hot deck	*7*	**62.6**	10.5
Cold deck	*27*	**31.2**	2.9
Cable yarder landing	*5*	**71.1**	13.0
Other	*29*	**31.9**	2.7

Note: Numbers in bold are statistically significantly different at the $p<0.05$ level.

Three combinations were statistically significantly different at the 5% level for the Total Delay Factor. Harvesters working in natural stands averaged a higher total delay than those working in short rotation plantations (49.7% versus 20.8%). Hot deck operations (62.6%), and those working at a cable yarder landing (71.1%), had very high total delays factors: once again, this result confirms the difficulty of achieving good unit balance in complex operations.

Table 2 breaks down the Total Delay Factor into the individual delay factors for the three delay categories. For Mechanical Delay Factor, mixed stands yielded statistically significant higher delay factors values than plantations. In addition, operations in softwoods also have a higher mechanical delay than operations in hardwoods: this might be related to the higher incidence of natural stands in the ‘softwood’ category. Although not specifically designed for forest operations, excavator-base units do not seem to be more vulnerable to mechanical damage than purpose-built machines; in fact the average mechanical delay factor is less for excavator machines.

Table 2: Average Mechanical, Operator and Other Delay Factors (%), with standard error in brackets, by study category.

Categories	***n*** *(#)*	**Average** $\mathbf{DF_{Mech}}$ **(%)** *(Std. Err)*	**Average** $\mathbf{DF_{Op}}$ **(%)** *(Std. Err)*	**Average** $\mathbf{DF_{Oth}}$ **(%)** *(Std. Err)*
Italy	*26*	8.6 *(1.3)*	6.0 *(0.9)*	**25.7** (4.4)
Other country	*8*	12.7 *(3.4)*	8.4 *(1.8)*	**7.8** (1.9)
Hardwoods	*20*	**6.4** *(0.8)*	5.4 *(1.0)*	22.1 (4.6)
Softwoods	*14*	**14.6** *(2.7)*	7.5 *(1.3)*	21.6 (6.5)
Natural stands	*20*	**12.3** *(1.9)*	7.6 *(1.1)*	**29.8** (5.3)
Short rotation plantations	*14*	**5.6** *(1.0)*	5.1 *(1.2)*	**10.1** (2.2)
Dedicated machine	*12*	12.0 *(2.8)*	**9.1** *(1.3)*	**11.7** (2.5)
Excavator base	*22*	8.2 *(1.3)*	**5.2** *(1.0)*	**26.9** (5.1)
Felling and Processing	*21*	**11.5** *(1.9)*	7.6 *(1.2)*	**14.6** (2.4)
Processing	*13*	**6.5** *(1.0)*	4.9 *(0.9)*	**32.7** (7.9)
Hot deck	*7*	7.5 *(1.3)*	4.9 *(1.3)*	**50.2** (10.5)
Cold deck	*27*	10.1 *(1.6)*	7.0 *(1.0)*	**14.1** (2.0)
Cable yarder landing	*5*	6.9 *(1.2)*	5.1 *(1.5)*	**59.2** (12.7)
Other	*29*	10.0 *(1.5)*	6.8 *(0.9)*	**15.0** (2.0)

Note: Numbers in bold are statistically significantly different at the $p<0.05$ level.

For the Operator Delay Factor column the only category that was statistically significantly different was the ‘dedicated machine’, as compared with the ‘excavator-base’. This might be related to the fact that over half of the operations conducted with dedicated machines took place in natural stands and on relatively steep terrain, placing a high stress on the operator, hence the need for more frequent and longer rest breaks. Not statistically significant, but possibly a trend, harvesters working in Softwood, Natural Stands and Felling all had higher Operator Delay Factors at about the 10% significance level, which may corroborate the above-mentioned inference.

All categories, with the exception of Hardwood/Softwood showed significant differences in Other Delays. Working on a cable yarding landing or on a hot deck, felling, working with an excavator base machine, as well as working in mixed stands all had clearly higher percentage of Other Delays, although the specific cause of delay could be different among these categories. The higher incidence of other delays associated with excavator-base units – for instance – could be related to the fact that all machines working under a yarder were excavator-base units. This may also explain the higher occurrence of these delays in Italy, where all the yarder operations in the study come from. As to mixed stands and felling, higher delays may depend on the more frequent need for reconnaissance and work planning.

Overall it should be noted that the Other Delay Factor is large, both in absolute terms as well as relative to the other two categories. If an Operational Delay category had been used it would have captured most of this data (preparation, waiting, interference, etc.).

Length of delay

Analyzing the 2151 individually recorded delay lengths from the 26 studies, Figure 1 shows the frequency of the delays broken down by delay type and duration of the individual events. We can clearly see that in a continuous time study, most of the delay events are less than 15 minutes in duration (94%).

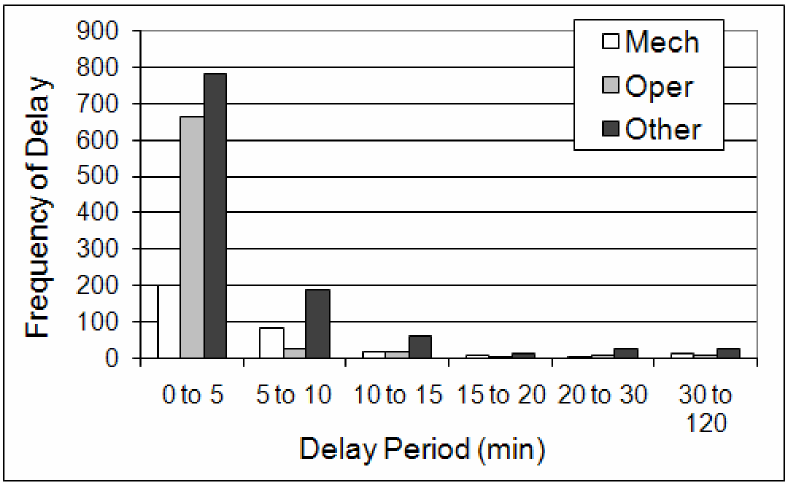

Figure 1: Frequency of the total number of delays, by delay type, that occurred during the 26 harvester studies for which the elemental time study data was still available, grouped by delay periods (*n=2151*).

However, it is not the number of occurrences, but the total delay time that has more relevance to the results of a time study. Figure 2 shows the accumulated time for each type and time category (that is the sum of time for all delay events of that given type and within that time category). 61% of all the delay time was recorded for delays that were less than 15 minutes in duration.

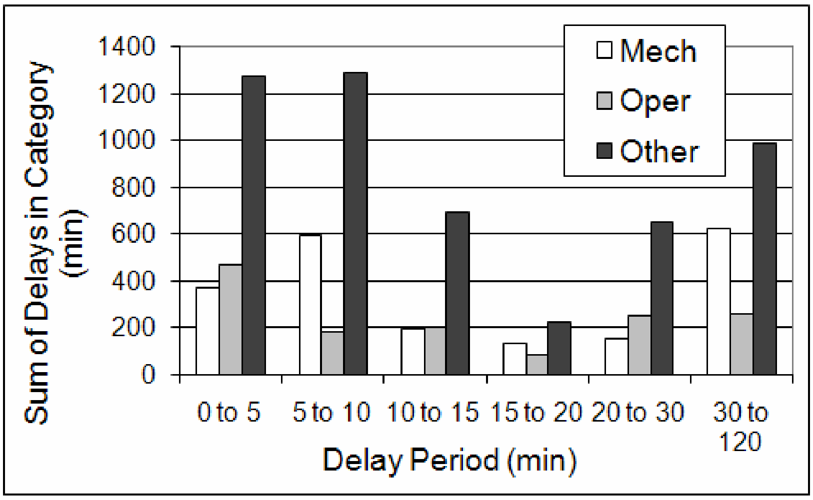

Figure 2: Sum of all delay times, by delay type, that occurred during the 26 harvester studies for which the elemental time study data was still available, grouped by delay period (*n=2151; sum of all delay time was 8936 min.*).

This would suggest that time studies that report productive time as including delays less than 15 minutes would represent the data very differently compared to time-studies of delay-free net productive time. We can make the point by using the average of these 34 harvester time studies, where delay-free productive time represents 72% of total scheduled work time (i.e. delays are 28% of the total).

If, productive work time is assumed to include all delay events less than 15 minutes in duration, utilization increase from 72 to 89%, whereas delays decrease from 28 to 11%.

Impact of length of study on average utilization

Another interesting hypothesis to test is the notion that as we study an operation for a longer period of time, we are more likely to capture more significant delay events. Perhaps stated more realistically, researchers are less likely to commence or continue a study if there are significant delays at the beginning or near the end of a study. Using the study data to review this hypothesis, we can chart Utilization versus Length of Study (Figure 3). Although a statistically significant ($p = 0.003$) decline in Utilization for increased study length is evident, this simple model only explains 27% of the variation ($r^2 = 0.27$). If one removes the data points associated with cable-yarding operations (the longest studies with the lowest utilization), then both the significance and the amount of variation explained by the model decreases. Hence, the association of a low utilization and a long study duration may be coincidental, not causal.

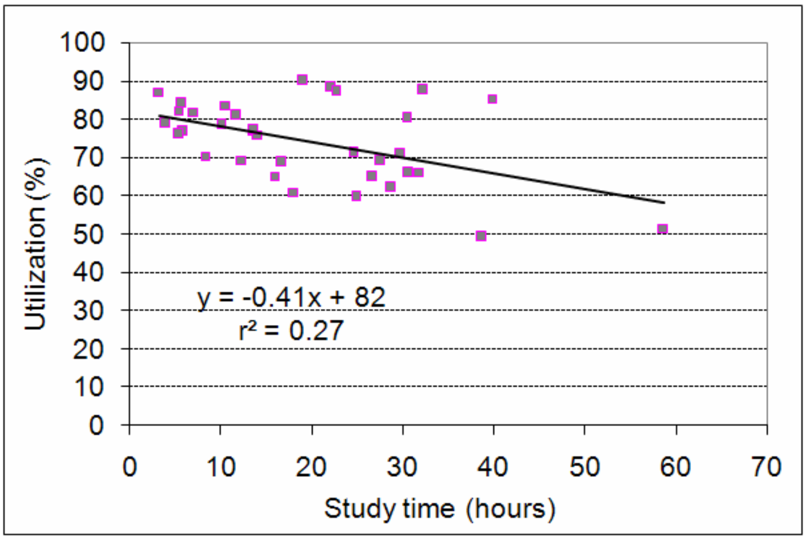

Figure 3: Utilization (%) vs. duration of time study (hours) for all the 34 harvester studies.

4. Conclusions

Time studies are an integral part of forest operations research. Their results are increasingly used for management decisions such as aiding in setting productivity targets, assessing payment schedules, optimizing systems and selecting among alternative machine choices. Published time and motion studies have shown that while it is possible to accurately capture and analyze work time related aspects of an operation, it is difficult to accurate assess delay information. Our analyses of 34 harvester time study data sets indicated that delays do vary significantly, not only just by machine type, but by stand and terrain variables. The availability of reliable delay factors makes it possible to generate ad-hoc data by relatively short time study sessions, potentially reducing the cost of harvesting optimization work. On most operations, net process time can be modeled quite well with a reasonably limited number of data points: if delay data can be excluded and a delay factor added to the net productive time, then the duration of individual time study sessions can be dramatically reduced and so can the cost of the investigation. In addition, researchers who use time studies must understand the possible inaccuracies as well as the nuances that even a standardized time study protocol may have, and compare the results of different studies with much caution.

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PERFORMANCE AND COSTS OF THE LOGGING RESIDUES BUNDLING IN MATURE SCOTS PINE STANDS

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Keywords: logging residues, forest utilization, bundling productivity, unit costs

Abstract: *Demand for energy is directly connected with a country's economy development. In the nearest future, according to the forecast, in Poland a tendency for higher energy consumption will be observed. On the other hand, contribution of fossil fuels in total energy production is limited. Fossil fuels cause definite changes in the natural environment, connected with the global climate warming, greenhouse effect and acid rain.*

The regulations of the European Union target to achieve 20% of energy needs from renewable sources by the year 2020. In January this year, the Commission put forward differentiated targets for each EU member state. Poland's target is 15%. For that reason, new renewable energy sources have been searched. One of the alternatives is to use biomass coming from forest areas. Depending on different utilization scenarios, possible forest biomass volume to be harvested for energy purposes is calculated from 3 to 5 mln. m^3. Until that time, logging residues have been utilized relatively seldom.

The main aim of this paper is to present the efficiency of the logging residue harvesting process. The research was carried out in mature Scots pine stands on clear cuts and in group cutting. Residues were bundled by a machine Timberjack 1490D, and transferred to the forest road site by a Zetor 11441 Foterra tractor with a Nokka MV92 trailer. For each machine a structure of working day, productivity rate, and unit costs were determined.

Productivity varied between 14.9 and 24.1 bundles per hour (5.7 – 9.3 m^3/h) depending mainly on the condition of a stand and the material prepared at the harvesting site. Direct unit costs reached 8.53 – 13.75 €/m^3 respectively. Forwarding productivity rate, by 200 m transport distance, amounted to 16.3 m^3/h, and the unit cost was 1.66 €/m^3.

1. Introduction

The increasing concentration of greenhouse gasses causes temperature increase on Earth. It seems that these changes are into a significant extent of anthropogenic origin. Man's activities and his continually increasing demand for energy result in climate changes. The tempo of these changes may be reduced by decreasing the amount of fossil fuels combusted in energy production processes (in Poland mainly coal), in favour of energy coming from renewable sources.

In the European Union countries the Directive (2001/77/WE) is in force, concerning support for the production of electricity produced from renewable sources on the internal market. The document recommends increased share of this type of energy on an EU scale to the level of 22% in 2010. Poland agreed to increase the share of energy from renewable sources to 7.5% by the year 2010. According to the new instructions contained in the Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, the European Union has set up new objectives to be achieved. In the case of Poland, in the year 2020, the level of 15% should be achieved in this matter.

One of possible solutions allowing to obtain energy from renewable sources is combustion of biomass, also that coming from forest areas. This may apply to round wood of low technical value, small-sized wood, and logging residues.

Potential size of the forest biomass that may be allocated to energy purposes, amounting to 3-5 mln m^3 wood per year, depends on the adopted scenarios taking into account the expected size of wood harvesting, the volume of logging residues biomass, the volume of wood biomass that is not subject to current utilization due to economic or ecological matters, and factors characteristic for the degree of economic and technological availability of wooden raw material harvesting (Płotkowski, 2007).

On the Polish market machines appeared for the disposal of logging residues. Some of the grind the waste and leave it on the surface of the clear-cutting area, which then constitutes a reservoir of nutrition substances for a newly established plantation. Other machines collect logging residues and process them in a manner to allow their transportation to economically profitable distances, usually not greater than 30 km. In other cases, logging residues are processed into chips and combusted in power stations. Chipping may be done directly on clear-cutting sites, at landings or at plants utilizing the chips.

The paper presents the technological process of production of bundles from logging residues using Timberjack 1490D machine. A bundle is a lump of compressed logging residues. The bundles were then transferred to the forest road site by a Zetor 11441 Foterra tractor with a Nokka MV92 trailer equipped with a crane HK 4166.

2. Purpose of the paper

The purpose of this paper is to analyze the technological process of production of bundles from logging residues using Timberjack Slash Bundler 1490D.
The individual aims of the study include:
- analysis of performance of machinery and equipment,
- analysis of a working day structure,
- economic evaluation of the entire process.

3. Material and method

One of the most important factors affecting work performance in the technological process of bundle production are terrain factors. The shaping of terrain determines the difficulty of performed work. Forest inspectorates with research areas were relatively easily accessible for machinery and equipment. The areas with numbers 1, 3, 4 and 5 refer to clear cuts made in stands with predominating pine trees. The area number 2 corresponds with the group cutting. Small terrain depressions appearing in those sections did not affect the movements of the machine. The analyzed areas had been prepared in advance for easier bundling. Logging residues were made into ridges (the first four areas) or transferred to lower areas and made into piles (the last area). The clear cuts were accessible by means of well-kept access roads, allowing for non-problematic forwarding to the assigned storage places. Characteristics of research areas is presented in Table 1.

Working time of Slash Bundler 1490D was divided as follows:
t_1 – efficient working time;
This work period included the following activities: the machine is standing by a pile of logging residues, the operator loads the material (branches) by means of a hydraulic crane into the throat of a pressing machine where a bundle is formed in a shape of a 2.50 running meter long cylinder with a diameter of approximately 0.70 m.

Table 1. Characteristics of research areas

Forest district	Ruciane 82m [1]	Ruciane 82l [2]	Dębowo 207 b, c [3]	Rozogi 106a [4]	Rozogi 106c [5]
Plot area [ha]	1.42	0.87	2.05	2.41	1.98
Tree species	Scots pine,	Scots pine, Picea abies	Scots pine, Picea abies	Scots pine, Picea abies	Scots pine
Stand age [years]	153	163	108	111	111
Merchentable timber volume [m^3/ha]	242.8	213.8	219.1	287.9	307.6
Number of bundles/all area	151	90	184	224	228
Number of bundles/ha	106	103	90	93	115

t_2 – auxiliary working time;
This includes the time of traveling between subsequent piles of logging residues, or approaching, in the case when the residues have been formed into appropriately long ridges.
t_3 – time of technical maintenance and refueling;
t_4 – time for trouble-shooting;
Time needed for removal of technical problems or production process errors.
t_5 – resting time;
Time used for resting and physiological needs of workers operating the machine.
t_6 – time of transport drives;
t_7 – time needed for everyday machine service.

In order to determine efficiency in a technological process, additionally the following data must be distinguished for calculations:
T02 – operational working time of the machine

$$T02 = t_1 + t_2 \quad (1)$$

T04 – shift working-time (production time)

$$T04 = t_1 + t_2 + t_3 + t_4 \quad (2)$$

T07 – general shift-time

$$T07 - t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7 \quad (3)$$

Calculation of the efficiency of work-time of Slash Bundler 1490D in a technological sequence comes out from the formulas:
Effective productivity (W01)

$$W01 = Q / t_1 \ [m^3/h] \quad (4)$$

where:
Q – volume of work done by the machine,
T01 – effective working time.
Operational productivity (W02)

$$W02 = Q / T02 \ [m^3/h] \quad (5)$$

where:
T02 – operational working time of the machine.

Productivity during shift working-time (W04)

$$W04 = Q / T04 \ [m^3/h] \quad (6)$$

where:
T04 – shift working-time.
Productivity during general shift-time

$$W07 = Q / T07 \ [m^3/h] \quad (7)$$

where W07 – productivity during general shift-time,
Q – volume of work done by the machine,
T07 – general shift-time.
Hourly costs of work of the bundler were determined on the basis of the data presented in Table 3. Having the hourly costs and work productivity, it was possible to calculate the costs of bundling, expressed in €/m^3.

4. Results and discussion

The machine operator transferred logging residues to by means of a hydraulic crane equipped with a gripping device into the throat of a pressing machine that shaped the material into a cylinder with a diameter of approximately 70 cm; after obtaining the programmed length, which in this case amounted to 2.50 running meters, the bundle was cut off to fall out from the other end of the throat of the feeder. As the bundle moved inside the pressing machine, it was automatically tied with a string. The amount of string used in the process was also programmed, and depended on the quality of logging residues. The finer the material, the more string was required. Average expenditure of string per one bundle amounted to approximately 40 to 60 m.

After 20 to 60 bundles were completed, the chain saw would be replaced. The frequency of the chain saw replacement depended on the amount of impurities in the piles, therefore manual preparation of the surface was preferred. Once every 130 – 150 bundles, fuel was pumped from auxiliary tanks to the main ones.

When calculating the productivity rate, it should be noted that the average volume of one bundle, on the ground of performed measurements, amounts to approximately 0.96 spatial meter. It should also be highlighted that in Poland at the moment there is no alternative for compressed logging residues. The collected information shows that forest inspectorates most often apply coefficient 0.4 corresponding to industrial thin and brush wood.

The share of the individual times appearing during one work cycle of bundle production was presented in Table 2.

Table 2. Work time structure for the TJ 1490D machine in the individual research plots

	Number of research plot				
Time type	1	2	3	4	5
t_1 [min]	286.7	178.3	363.2	348.3	338.1
t_2 [min]	52.1	65.6	49.5	46.7	68.1
t_3 [min]	48.6	33.9	47.2	52.4	57.0
t_4 [min]	46.0	18.4	17.9	35.7	16.9
t_5 [min]	34.9	26.1	36.4	49.0	41.3
t_6 [min]	22.6	26.7	38.7	52.3	26.2
t_7 [min]	12.4	12.1	20.3	17.1	19.8
Total [min]	503.3	361.1	552.9	584.4	567.5

On all the tested plots, most time was occupied by bundling and directly associated activities, such as transfer ring the material into the throat of the pressing machine, pressing, tying with a string, and cutting off, described as t_1 – effective working time, taking up approximately 60% of a working day (Fig. 1 and Fig. 2).

In the case of that time, there was no statistical discrepancies observed between preparation of logging residues into piles and ridges in clear-cut areas. In the group cutting area, the share of that time was slightly smaller, amounting to 49.4% (Fig. 3). Slight discrepancies in the clear-cut area appeared during auxiliary time t_2; with ridges arranged the share of that time amounted to up to 9.1%; however, in the case of approaches of the machine between piles, that time decreases to 8.8%. In the group cutting area that time was definitely longer taking up over 18% in the structure. This refers to much longer travelling between groups, and arranging logging residues into smaller piles. A relatively large amount of time was taken by technical operation (t_3) of the machine, amounting to approximately 9%, regardless of the stand condition.

The achieved productivity is presented in Table 3. During one hour, the machine produced 14.9 to 24.1 bundles. Comparing the achieved results with the literature data (Table 4), amounting to 6 to 24 bundles per hour, it should be noted that these values are from the top range of achievements. It should however be highlighted that the literature data refer to a very diversified tree stand condition, with significantly varying species. The research was carried out exclusively in mature stands, which with relatively high concentration of material per one unit of forest area allowed for significantly more effective work.

The lowest values were observed during work in the group cutting area where accumulation of logging residues was significantly smaller than in the case of clear-cut areas. Much higher was also labor consumption due to the machine needing to travel more. Comparing the manner of preparation of logging residues in the clear-cut area in the form of ridges and piles, it should be noted that better productivity, by about 20%, was achieved in the latter case, where the material was arranged in piles. Productivity achieved in shift working time (W04) amounts relatively to 7 to almost 11 m^3/h.

The costs of harvesting logging residues are an integral element of the rational and sustainable forest management, and are a basis for making an appropriate analysis of profitability of equipment or technology employment. The analysis of costs only include the production process – making a ready product which in this case is a bundled packed of logging residues. A company that owns the machine buys back fire brushwood at 3.5 €/m^3. The purchase of ready products is not included in cost simulation. Cost simulation includes one-man operation of the machine Slash Bundler 1490D. The presented costs do not include operator’s assistant who only helps in tougher working conditions.

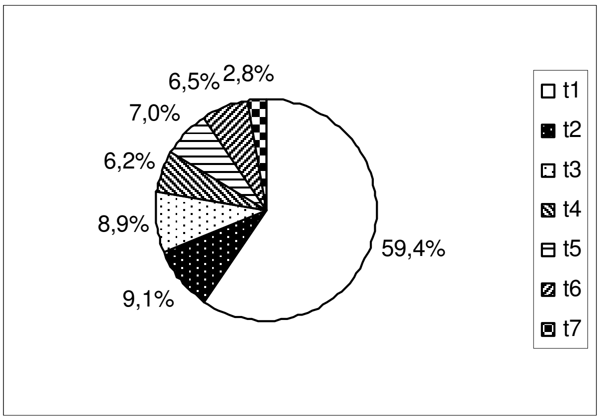

Figure 1. Structure of mean working times with the machine TJ 1490D in a clear-cut area with logging residues arranged into ridges

Table 5. presents initial data used for hourly cost calculation. These costs are presented in Figure 4. The analysis also includes transportation of bundles to the haulage road using a Zetor Forterra 11441 tractor with a trailer Nokka MV92. For a bundling machine, at assumed one-shift work time, these costs oscillate at a level of 79 €/h. The costs of forwarding amount to 27 €/h. It is possible to reduce hourly costs by extending machine working time during a working day. Taking this fact into consideration, work at bundle production is often arranged in two shifts.

Direct unit costs of bundle production calculated in relation to general shift working-time amount to 8.53 to 13.75 €/m^3. The cost of shifting the bundles to the forest road to a distance of approximately 200 m, with achieved average productivity of 16.3 m^3/h, amounts to 1.66 €/m^3.

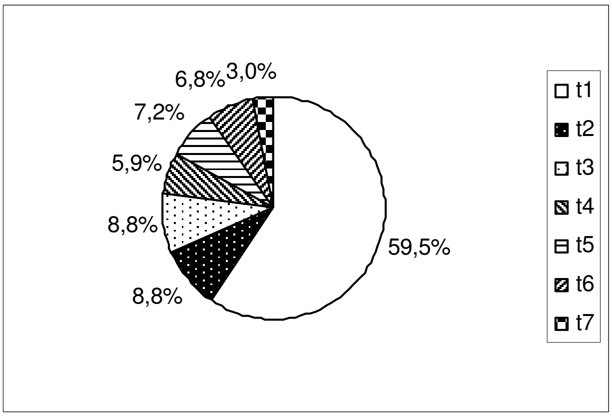

Figure 2. Structure of mean working times with the machine TJ 1490D in a clear-cut area with logging residues arranged into piles

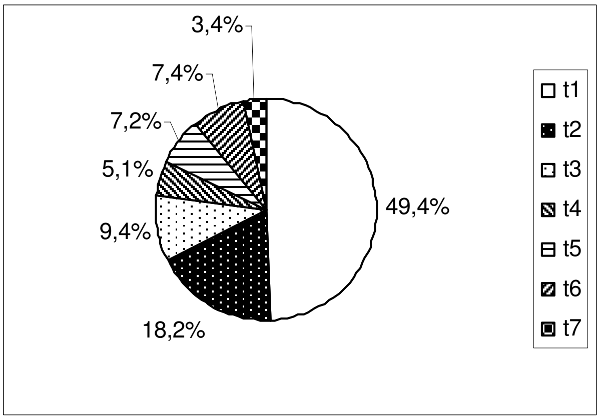

Figure 3. Structure of mean working times with the machine TJ 1490D within group cutting (with logging residues arranged into piles)

Table 3. Productivity in the individual research plots

Number of research plot	1	2	3	4	5
Number of bundles/work day	151	90	154	203	228
Average number of bundles/h	18.00	14.95	16.71	20.84	24.11
Q [m^3]	57,98	34.56	59.14	77.95	87.55
W01 [m^3/h]	12.13	11.63	9.77	13.43	15.54
W02 [m^3/h]	10.27	8.50	8.6	11.84	12.93
W04 [m^3/h]	8.03	7.00	7.43	9.68	10.94
W07 [m3/h]	6.91	5.74	6.43	8.00	9.26

Table 4. Specification of productivity in the logging residue bundling

Author	Machine	Productivity	Costs	Country	Stand conditions
Rummer B., Len D., O'Brien O.	Timberjack 1490D	6 bundles/h 11-19 bundles/h 24 bundles/h	130 \$/h = 82 €/h	USA	Lodgepole pine, (small whole trees) Lodgepole pine, ponderosa pine (logging residues) Ponderosa pine (whole trees)
Cuchet E., Roux, P., Spinelli, R.		11-24 bundles/h		France	chestnut , hornbeam, poplar and maritime pine (best results at two last species)
Kärhä K., Vartiamäki T.	Timberjack 1490D, Fiberpack 370	18.1 bundles/h		Finland	Norway spruce (clear cut)
Stampfer K., Kanzian Ch.	Timberjack 1490D mounted on a Man Truck	9-13 bundles/h	180 €/h	Austria	Norway spruce, (thinning)
Vonk H.	Timberjack 1490D mounted on a Truck	22 bundles/h		Germany	
Spinelli R., Nati C., Magagnotti N.		4.5 oven-dry tonne/h	159 €/h	Italy	

Table 5. Initial data used for calculation of hourly costs

Cost type	Timberjack 1490D	Forterra 11441 Nokka MV92
Purchase price [€]	410000	70000
Salvage value [€]	41000	7000
Wage [€/h]	4.5	4.5
Additional work costs [% of wage]	48	48
Interest expense [%]	7	7
Insurance, storage [% of purchase price]	1	1
Percentage of depreciation for repairs [%]	80	60
Amount of fuel [l/h]	10	8
Cost of fuel [€/l]	1.22	1.22
Percentage of lubricant consumption [%]	20	20

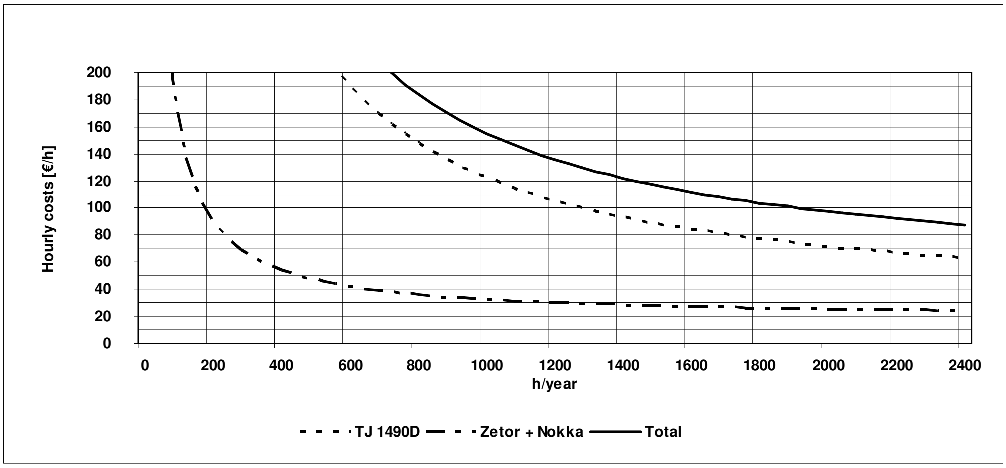

Figure 4. Direct hourly costs of operations of the bundling machine TJ 1490D, and skidding means for bundle transportation

5. Conclusion

On the ground of the performer research the following conclusions may be drawn:

1. Until the year 2004, in Poland, the most commonly employed method of logging residue disposal was its direct burning at the harvesting site. Despite simplicity of this action, the burning process has very negative effect on the environment in comparison to other methods. It creates a high risk of wood fire, destroys earth fauna, causes emission of harmful substances into the atmosphere, and the amount of minerals contained in conifer needles and small sticks are removed from the soil. Due to this fact, and with reference to the ban of burning branches directly on a clear-cut surface, mandatory in state-owned forests, other methods of their disposal are employed. One of the alternatives may be their bundling for power-production purposes.
2. In the European Union member states, with reference to the continually increasing share of renewable sources of energy in general energy consumption, there is a need for seeking appropriate technological solutions. These needs may also be satisfied by forest biomass created in the process of wood harvesting, produced in the form of bundles.
3. The achieved productivity during wood bundling by means of the Timberjack Slash Bundler 1490D oscillates at a level of 14.9 - 24.1 bundles per hour, which corresponds to 5.7 – 9.3 m^3/h. The work was performed in mature Scots pine stands. The highest productivity was achieved in clear-cut areas (with logging residues arranged into piles); the lowest – in group cutting.
4. Direct unit costs of bundle production calculated in relation to the general shift-time, amount to 8.53 to 13.75 €/m^3.
5. The adopted manner of logging residue utilization and clearing the surface leads to a reduction of costs incurred by forest administration on the preparation of the surface for forest regeneration. These costs are definitely lower in comparison to the insofar employed methods. Forest inspectorates obtain certain income due to the sales of the material, and at the same time, it only incurs costs related to shifting and arranging organic substance, remaining after wood harvesting, into piles.

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ESTIMATING THE PRODUCTIVITY OF CHIPPING OPERATIONS

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Keywords: Chipping, Productivity, Biomass, Modelling, Delays

Abstract: Due to a booming bioenergy sector, chipping has become increasingly popular all across Europe. Many operators have equipped for the purpose, but the large variety of working conditions found in the European forests makes it difficult to correctly estimate the productivity of each specific operation, leading to inappropriate price setting. In 2001, CNR released a freeware capable of returning reliable estimates of chipping productivity and cost, on the basis of user-entered input data. The model contains a set of predictive equations derived from the results of 102 field trials, conducted with 30 different machines, under a range of working conditions. In order to facilitate comparison with other estimates and to achieve methodological transparency, the equations are assembled into a simple *Microsoft Excel* workbook, and the costs are calculated with standard costing methods currently used in Forest and Agricultural Engineering. Since then CNR has continued to work on the subject, with the goal of updating and refining the model. Such work has included 41 validation tests and a separate study on the delay time typical of different chipping operation layouts. This work was concluded in 2008 and confirms that the model developed by CNR can provide reliable estimates of chipper productivity under a range of operational conditions. Current improvements include a correction factor for the chipping of log, and a set of statistically significant utilization rate figures for the most common occurrences. We believe that such a model can assist European foresters in keeping ahead with the growing biomass sector, thus helping them to seize an important business opportunity.

1. Introduction

Due to a booming bioenergy sector, chip demand has grown, to the benefit of logging companies that operate near the new plants. Chips have to be delivered regularly and in large amounts, which makes good planning a crucial issue. In turn, planning requires a correct estimate of chipping productivity and cost, otherwise shortfalls are experienced in both supply chain management and price setting. Underestimating chipping cost will eventually result in a financial loss for the operator, whereas an overestimate will make the operator much less competitive. Underestimating chipping cost will eventually result in a financial loss for the operator, whereas an overestimate will make the operator much less competitive. In order to assist logging operators, in 2001 CNR released a freeware capable of returning reliable estimates of chipping productivity and cost, on the basis of user-entered input data. The programme contains a set of predictive equations derived from the results of 102 field trials, conducted with 30 different machines, under a range of working conditions. The goal of the present study is to check and refine the model produced in 2001, with the specific purposes of: a) verifying the accuracy of the model in the light of current advances in chipping technology and b) providing reference values for the model delay factors.

2. The "Chipcost" Model

The model consists of a *Microsoft Excel 5/95, 5/97* and *97* workbook that can be downloaded directly from the IVALSA homepage free of charge. The model returns net chipping productivity, gross chipping productivity and overall chipping cost, based on user-entered specific information on working conditions and costing hypotheses (Spinelli and Hartsough 2001).
The interface worksheet is divided into three areas or modules: the productivity module accepts information on working conditions, necessary to estimate net productivity; the costing module accepts data on costing hypotheses, used for calculating the hourly cost of the chipping operation;

the results module shows the estimates of net productivity and hourly operation cost, and accepts information on expected delays in order to calculate the actual gross productivity and chipping cost.

Three separate equations are used for estimating the unit time consumption (net min/ton) of three distinct work phases, and namely: chipping, machine repositioning and other work. The equations were calculated through regression analysis of the results from 102 trials, conducted by CNR between 1997 and 1999. The trials involved 40 different chipping operators and covered 31 chipper models from 11 manufacturers. All the trials were carried out in Italy, except for three tests that took place on the north side of the Alps, where working conditions were comparable to the Italian ones. All terms included in the equations are highly significant ($p<0.01$), and explain a large proportion of variability, as the R2 values are 0.79, 0.48 and 0.73 respectively for chipping time, repositioning time and other work time.

The models only react to four variables: chipper power, piece size, chipper mobility and work site (landing or stand). No other effects – e.g. type and layout of material, crew size, or type of chipper (disc versus drum) – were significant in addition to those mentioned above. This is not to say that these factors did not have effects, but this study was not able to distinguish them for three reasons. For one, the number of data points (roughly 100) was too small to differentiate secondary effects from the background noise. Secondly, the study was based on commercial operations and not performed under controlled conditions. Thirdly, because most of the operations were in business to make money and were working with what they considered to be near-optimal configurations for their equipment.

Based on these inputs, the worksheet will return a figure for net productivity in green metric tons per productive machine hour. To reflect real working conditions, users must transform net productivity into gross productivity per scheduled hour. This is obtained by reducing the net productivity estimate by an appropriate utilization rate, which accounts for the eventual delays and represents the ratio between net time and total time. If the machine and operator spend 8 hours a day on the site but chip only 4 hours because of various delays (mechanical, organizational etc.), the utilization rate is 50%. The designation of such coefficient is left to each individual user, as the original study did not include the determination of delay times. Based on common experience, the suggested range was included between 35 and 70%

Chipping operation costs are calculated with standard hourly cost methods, and grouped under the two separate headings of ownership costs and operating costs (Miyata 1980). Main inputs include equipment purchase price, depreciation period, annual usage, fuel cost and labour rate. No specific unit is provided for the currency, so that users may enter the currency of their choice: of course, results will be consistent with the input data – Euros yielding Euros and so on. Separate columns are available for the separate costing of different machines eventually involved in the operation (e.g. chipper, prime mover, loader – which can have different depreciation periods and/or annual usage).

Finally, the operation cost is divided by gross productivity to obtain unit cost. Operators can use this information to balance options, according to their own operational and economic environment. Users can enter alternative choices and check the economic results of each alternative under the user's own working conditions.

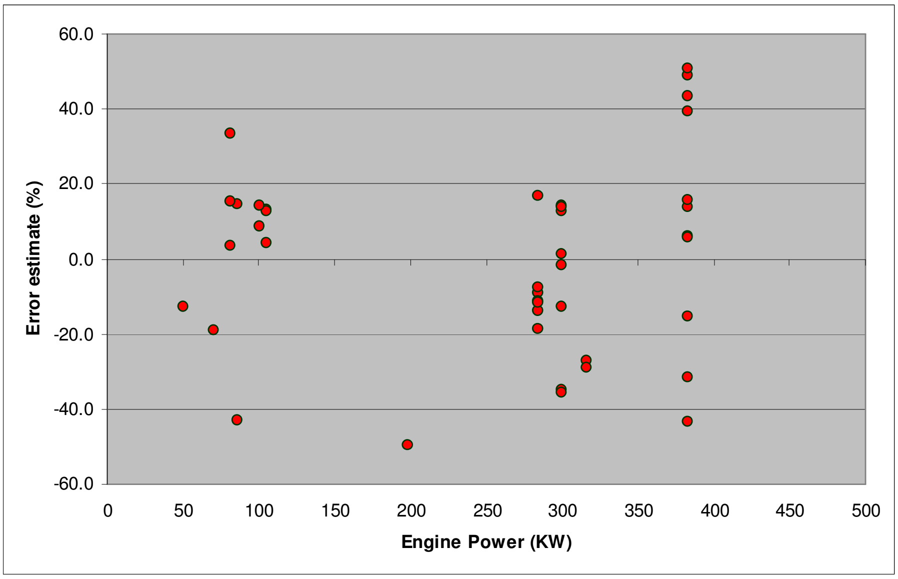
For its large and wide pool of source data, this model is probably unique in Europe. The high statistical significance and explained variance of its base equations make it a reasonably safe tool to predict operational performance as a function of specific working conditions. However, from the concise description given above two points emerge as critical, and namely the age of the model and the uncertainty about delay coefficients. We must therefore answer two questions: is the model still representative of current chipping operations, after almost 10 years from its development? Can we provide some reference utilization rates, based on scientific data?

2.1 Model validation

This work addresses the first question, and consists on a validation study obtained by comparing actual and predicted net productivity figures from 41 operations conducted between 2003 and 2007, well after the model had been designed. These tests covered 14 different operators and 10 machines, ranging in gross engine power from 60 to 380 kW. All machine configurations were included: tractor-powered, trailer-mounted, truck-mounted and self-propelled.

As an average, the overall error was below 1%, meaning that on a large data pool the model is indeed very accurate. However, individual errors ranged from -40 to +50 %, making the prediction of individual operations much less reliable (figure 1).

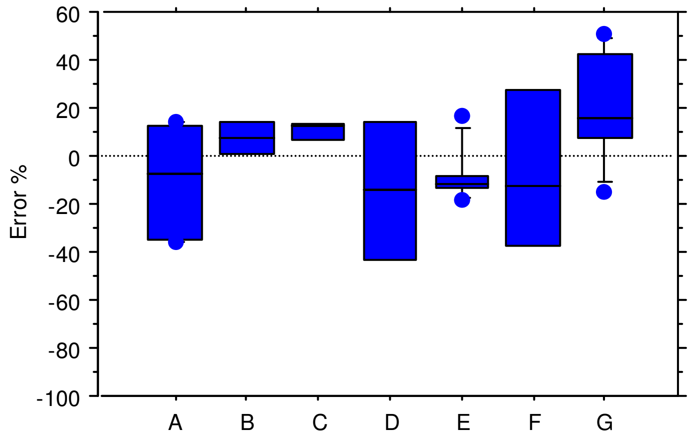
Figure 1 – Model validation: error of estimate (net productivity) vs. engine power



Subsequent analyses aimed at identifying the main sources of this uncertainty, starting from the variables included in the original model. Plotting the error against engine power and piece size did not give meaningful results, the error being evenly distributed among different categories, as expected. Better results were obtained by plotting the error versus variables that were not included in the original model, and namely operator and tree portion.

Operator skill is recognized as a main source of performance variability, and recent studies suggest that it may account for up to 40 % of the differences in productivity between otherwise similar CTL operations (Väätäinen & Ovaskainen, 2005). Its inclusion in performance prediction models has been the object of many efforts, old (Forestry Commission, 1990.) and new (Purfürst & Erler, 2006). Operator effect is also visible in chipping operation, as shown in figure 2, which plots the errors relative to 7 of the operators tested in this study. Since the studies were not conducted under controlled conditions, the statistical analysis cannot yield conclusive results, but it does suggest that operators are responsible for a good deal of the variability, tentatively estimated at the 10% level.

Figure 2 – Model validation: error of estimate for different operators



Tree part can represent another source of variability, since the shape of the piece being chipped may affect machine performance regardless of its actual weight, at least within certain limits. Intuitively, handling a regular 60 kg log should be easier than handling an oddly-shaped 60 kg top with branches. That is reinforced by statistical analysis: table 1 suggests that by excluding piece shape from the input variables, our model tends to overestimate the productivity obtained with the most irregular tree portions (tops and branches), while underestimating that achieved when handling more regularly shaped feedstocks (trees and logs). At least with logs, such difference results significant to a 0.03 level t-test, justifying the statement that model predictions should be increased by 15 % when specifically dealing with regular 3-6 m long delimbed longs.

Table 1 – Model validation: average error of estimate for different feedstocks

Type	**n**	**Avg.**	**Std. Err.**
Logs	5	-19.23[a]	9.80
Trees	12	-3.33[b]	6.76
Tops	18	4.43[b]	6.77
Branches	6	5.17[b]	4.44

Note: Different letters indicate values that are significantly different at the p<0.05 level.

3. Delays

Without a reliable estimate of delay time, it is difficult to translate into practice the results obtained from models that predict net (work-only) productivity, otherwise very accurate and potentially useful. That also applies to Chipcost, where a utilization factor is indeed provided, but its setting is left to the experience of the individual user.

In fact, the importance of delays in all phases of production was noted long ago (Conway 1982), but a major problem exists in the reliable recording and evaluation of such time. Little scientific work has addressed the development of reliable utilization rates, and the translation of net production data obtained from scientific time-studies into scheduled time performance is obtained by applying best estimates, as detailed time-studies are inherently short and may not accurately represent an erratic phenomenon as the occurrence of delays (Bergstrand, 1991).

Combining a larger number of detailed time studies into a larger data pool can be the starting point for objectively defining a range utilization rates, appropriate for different situations.

To this purpose, 61 time studies of chipping operations were used to conduct a thorough analysis of delays. All the time studies were set up and carried out by CNR and with the same methods. The pool of valid studies includes 39 of the operations mentioned in the previous paragraph, 12 studies extracted from the older data pool originally used for building the model, and an additional 10 studies conducted abroad. Overall, the data represent 524 hours of observation, equal to 65 working days. Delays caused by the study itself, including giving instructions and measuring logs have all been excluded. Delays for the main meal (if the operator took any) and relocation to and from site are also not included in the data sets. All other delays are included.

Table 2 – Utilization rates for different operational categories

Categories	n	Utilization (%)
Hardwoods	40	75.7
Softwoods	21	73.6
Slash and or tops	35	76.5 a
Logs and or whole trees	26	72.9 b
Chip at Landing	37	73.9 a
Chip in the Forest	24	76.6 b
Cold deck	52	74.6
Hot deck	9	77.1
Tractor (PTO) driven	15	73.7 ab
Trailer mounted	24	76.7 a
Truck mounted	7	66.9 b
Forwarder mounted	15	77.1 a
Small (<300 kW)	26	74.9
Large (>300 kW)	35	75.0

Note: Different letters indicate values that are significantly different at the p<0.10 level.

Individual utilization rates (defined as productive machine hours divided by scheduled machine hours) ranged from 53 % up to 92 %, with an average of 74 %. This value gets very near to the 75 % utilization rate indicated by Brinker et al. (2002) for chipping operations in the US, despite the strong Italian bias of the original data pool. This may indicate that the comparatively simple layout of chipping operations are much less affected by differences in site conditions than other machines. Anova testing was used to determine the eventual effect of different work factors, including place of chipping, chipper configuration, chipper size, operational layout and tree species (SAS, 1999). Table 2 shows that only three combinations were significantly different at the 10% level, and namely:

- chippers working on logs and or whole trees averaged a lower utilization rate than those working with slash and or tops (74% versus 76%), and most of this difference was attributed to organizational delays. Both the model and this validation study demonstrate that productivity is proportional to piece size, and it is higher when treating logs and whole trees: hence, this result may indicate a higher incidence of delays in those operations that are most productive. In other words, the more productive the operation, the more sensitive it is to poor planning: chippers with a high output impose a significant strain on the support fleet, as they require a steady flow of transport units to collect the chips;
- truck mounted chippers had a lower utilization rate compared to the other chipper types, and that corroborates the inferences listed above. Truck mounted chippers are bound to work at a landing, and are generally very powerful and exceptionally productive.

- chippers working at a landing had a significantly lower utilization rate than those working in the forest (74% and 77% respectively). Chippers working at a landing generally discharge directly into chip vans, and the resulting interdependence creates the main condition for the occurrence of organizational delays. This combines with the inherent higher productivity of landing operations, which makes them very vulnerable to poor operation management.

4. Conclusions

The productivity model designed by CNR in 2000 is based on a set of equations with high statistical significance, and capable of explaining a large proportion of the observed variability. In 2008 the model was further validated, by comparing its predictions with the real data recorded from 41 commercial operations. The average error was lower than 1 %, demonstrating that the model is still a reasonably safe tool to predict operational performance as a function of specified working conditions.

However, individual errors ranged from -40 to +50 %, making the predictions made on individual operations much less reliable. This is the effect of variables excluded from the original model, such as operator skill and feedstock shape. Statistical analysis suggest that operator skill can account for about 10 % of the variability, while feedstock shape may account for a further 10-15 %. The model tends to overestimate the productivity obtained with the most irregular tree portions (tops and branches), while underestimating that achieved when handling more regularly shaped feedstocks (trees and logs). Model predictions should be increased by 15 % when dealing with regular 3-6 m long delimbed longs. These indications may increase the accuracy of specific predictions.

The delay component of 62 operations was analyzed, in order to process reliable utilization factors, specific to chipping. The overall average utilization of the studied chippers was 74 %. Data suggest that delays increase with net productivity, so that the utilization rate can be lower in potentially more productive operations, such as those conducted at a landing or by a powerful truck-mounted units. Regardless of operation type, two thirds of the delays Regardless of operation type, two thirds of the total delay time are represented by organizational delays, which emphasizes the crucial role of operation management. Optimization measures should not be limited to the individual machine, but address the operation as a whole.

This study confirms that the model developed by CNR can provide reliable estimates of chipper productivity under a range of operational conditions. Current improvements include a correction factor for the chipping of log, and a set of statistically significant utilization rate figures for the most common occurrences. The model consists of a *Microsoft Excel 5/95, 5/97* and *97* workbook that can be downloaded free of charge at: http://www.biomassaforestale.org/ivalsa/file/chipcost.zip

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HARVESTING AND PROCESSING SYSTEMS FOR LARGE DIMENSIONED TIMBER (LDT) AS SHORT LOGS

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Abstract: Forest managers in southern Germany are facing two relevant trends in last decade: On the one hand *continuously growing large dimensioned timber (LDT) stock, especially softwood, are appropriate for harvesting. On the other hand timber industry is more and more interested in LDT as short logs (≤ 7 m).*
Essential changes of logging systems had to be implemented in order to meet both demands. This finally resulted in four cut-to-length processing systems for LDT developed and approved by the Forest Research Institute of Baden-*Württemberg (FVA) Germany; Department of Forest Utilisation in close co-operation with the Federal State Forest Service of Baden-Württemberg.*

1. Initial situation

The large dimensioned timber (LDT) stock, especially softwood, are growing continuously with a focus on the southern German federal states Bavaria and Baden-Württemberg. At the same time timber industry customers, are more and more interested in LDT as short logs [1, 3, 4]. A change from long log systems to short log systems increases the number of logs to be handled by factor 3 to 4. The well-established processing systems for long logs are not cost-effective due to additional sub-operations. Abandoning traditional long log processing systems and focussing on cut-to-length processing systems has two essential consequences. On the one hand an additional sub-operation, i.e. cross-cutting to short log assortments, has to be integrated into the processing system. On the other hand different skidding technology has to be used in order to cope with multiplied short log numbers.

The central challenge in developing cut-to-length processing systems was to integrate those changes into processing systems which are at least as competitive as long log systems concerning ergonomics and operational safety, impacts on the residual stand as well as economics. These demands are met best by processing systems which show the following main characteristics: performing the cross-cutting to short logs in the stand or close to the skid line and skidding the multiplied numbers of short logs by forwarder technology.

The FVA research approved four processing systems adapting the main characteristics of cut-to-length processing systems to increasing steepness of terrain and decreasing opening up with skid trails. The four processing systems have two aspects in common: On the one hand the systems have been developed for LDT harvesting by means of selective forestry in permanent mixed mountain forests which are characterised by high structural diversity and a high percentage of natural regeneration. On the other hand all felling and processing operations of LDT are carried out motor-manually in the four processing systems. Fully mechanized processing systems were not reliable so far, due to loading and manipulation limits of the machine [2].

2. Cut-to-length processing systems

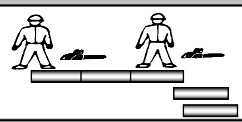
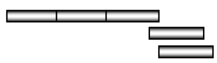
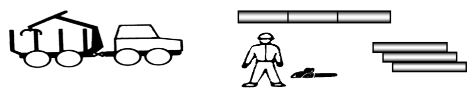
2.1 Todtmoos System

This processing system is adapted for stands with a systematic 40 m skid-trail coverage. The terrain inclination should ideally not exceed 30 %. This processing system is advisable for motor-manual felling and processing of softwood LDT with a minimum diameter breast height of 50 cm.

Central element is the relatively free choice of the felling direction meeting the demand to reduce the impact on the residual stand and the natural regeneration as well as the demand to fell the trees onto or across the skid trail (so called top-end-felling). The latter enables the team of two forest workers to crosscut a high percentage of short logs on the spot because a large extent of the felled trees are located within the crane zone. Outside the crane zone double or triple log length are processed and cross-cutting marks are attached. During the integrated forwarder skidding of single logs the double or triple log lengths are pre-skidded efficiently by the grapple of the forwarder to the skid trail and loaded on top of the single logs. Single logs, double and triple log lengths are skidded to the forest road where an additional forest worker performs the final processing.

The skidding and pre-skidding operations of LDT demand forwarders of high performance classes, with adequate crane lifting power which can manipulate logs, sometimes exceeding 2.5 m^3 (Figure 1). Additionally a winch is useful to skid log butts or pole length which happen to be too heavy or out of crane range. The high cubic meter performance of the forwarder is an essential reason for the generally reasonable costs of this processing system. The schedule for forest workers and forwarder has to be planned and organised accurately.

Figure 1: "Todtmoos System" motor-manual short log processing of softwood LDT with forwarder skidding

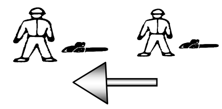
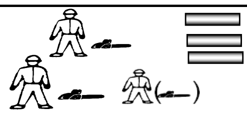
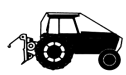
	Stand	Skid trail	Forest road / depot
Felling and processing			
Skidding and Piling (ev. final processing)			

2.2 Modified Todtmoos System

The Modified Todtmoos System is also adapted for stands with a systematic 40 m skid-trail coverage and a terrain inclination ideally not exceeding 30 %. The main differences of the Modified Todtmoos System compared with the Todtmoos System is that all trees are crosscut to short logs on spot by a team of two forest workers who are supported by a cable skidder driver (safety skidder) in terms of cross-cutting and pre-skidding the short logs into the crane zone (team of three forest workers). The forwarder skidding is not integrated in the motor-manual felling and processing phase but follows after this operation as a separated sub-operation.

The free choice of the felling directions allows maximum precaution in terms of the residual stand and the natural regeneration. The trees are felled by a team of two forest workers in direction to the closest skid-trail (so called top-end-felling). After felling forest worker 1 (FW 1) starts processing short logs (delimbing and cross-cutting) by the log butt. Forest worker 2 (FW 2) carries out the same operations as FW 1 starting his work in the lower crown third of the tree in direction to the top end. Meanwhile the skidder driver (FW 3) positions his machine on the skid trail for pre-skidding and pulls out the cable of the winch. Depending on the work progress FW 3 either starts with turning and pre-skidding of short logs or supports the other two forest workers by free delimbing in the upper crown third of the tree. While FW 1 prepares the next tree for felling, FW 2 and FW 3 finish the final processing (primarily delimbing) of the short logs, which have be turned and pre-skidded into the crane zone. At the end of this operation phase all short logs are located within the crane zone, ready for skidding. Skidding and Piling of the short logs is performed in a separate operation phase by a LDT suitable forwarder. No additional sub-operation is necessary in terms of a final processing on the forest road (Figure 2).

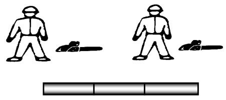
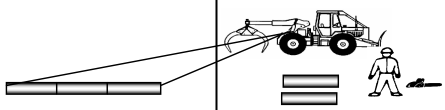
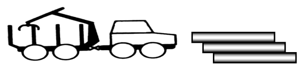
Figure 2: "Modified Todtmoos System" motor-manual short logs processing of softwood LDT with forwarder skidding.

	Stand	Skid trail	Forest road / depot
Felling			
Pre-skidding and processsing			
Skidding and Piling			

2.3 Triberg Two cable System

This system was developed for harvesting operations of softwood LDT in steep terrain with an inclination ranging from 30 to 50 % and an opening up with conventional machine roads. A team of two forest workers perform the motor-manual felling and processing of the LDT trees to a so called pole length (topped and delimbed whole tree length). Characteristically for this processing system is the pre-skidding of pole lengths with integrated cross-cutting and final delimbing at the machine road. An LDT suitable skidder with double drum cable winch and crane with grapple is used. The machine operator fixes the cable at the butt end of the pole length (standard uphill felling) and attaches cross-cutting marks using a measuring tape on the way back to the machine. The pole length is pre-skidded onto or across the machine road by the pull of cable fixed at the butt end and steered by crane (within crane zone). As soon as a cross-cutting mark is in an ergonomic favourable position, the skidder driver on the machine road stops the pre-skidding in order to perform a cross-cut. Afterwards the pole length is pre-skidded until the next cross-cutting mark is in an ergonomic favourable position for the skidder driver. This procedure is repeated until the whole pole length has been cross-cut to short logs. The skidder driver deposed the short logs at the side of the machine road to facilitate the final skidding. Outside the crane zone the pole length is steered by a 2^{nd} cable fixed on top-end of the pole length until steering by crane is possible. Furthermore the pre-skidding and cross-cutting to standard log length is continuing as described. The processing system finishes, like the two earlier described systems, with the efficient skidding and piling of the short logs with a forwarder suitable for LDT (Figure 3).

Figure 3: "Triberg two cable System", motor-manual short log processing of softwood LDT with a skidder and adjacent forwarder skidding.

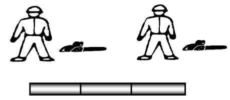
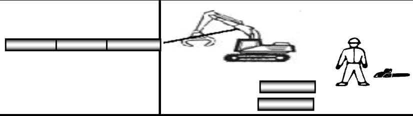
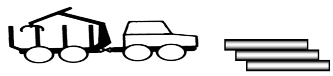
	Stand	Machine road	Forest road / depot
Felling and processing			
Pre-skidding with integrated final processsing			
Skidding and Piling			

2.4 Cable dredger System

A special challenge for logging systems are harvesting and (pre-)skidding operations in steep terrain. Normally tower cable logging systems are used for stands located in terrain with an inclination of more than 50 %. These high-tech systems are associated with comparable high harvesting costs. The cable dredger system is an alternative to tower cable logging systems in steep terrain which is opened up by machine roads with distances less than 150 m.

The LDT trees are felled motor-manually by a team of two forest workers. Trees standing next to the machine road can be felled parallel to the machine road and processed to short logs when there is no risk of short logs rolling downhill. A team of two forest workers perform the motor-manual felling and processing of the LDT trees to a so called pole length (topped and delimbed whole tree length) with attached cross-cutting marks. The pre-skidding is performed by a cable-dredger (chain dredger with integrated cable winch) standing on the machine road. Due to operational safety and organisational reason the pre-skidding starts not until the motor-manual felling and processing is finished. Under these conditions the cable dredger can play to its strength which are high stability against overturning and a high, pivoting cable guide assuring confident handling of pole lengths, sometimes exceeding 5 m^3. The combination of both advantages is reflected both in cost-efficient pre-skidding and a low impact on the residual stand. For the final processing by an additional forest worker the pole lengths are arrayed on the machine road by the cable dredger. In critical situations of the final processing the cable dredger can support the forest worker before the short logs are pilled at the side of the machine road, ready for skidding. The processing system finishes, like the three earlier described systems, with the efficient skidding and piling with a forwarder suitable for LDT (Figure 4).

Figure 4 : "Cable dredger System" motor-manual short log processing at the machine road with a cable dredger and adjactent final skidding by a forwarder.

	Stand	Machine road	Forest road / depot
Felling and processing			
pre-skidding with integrated final processing			
Skidding and piling			

3. Evaluation of the processing systems

3.1 Ergonomics and operational safety

All LDT systems have in common that physically demanding operations are carried out by machines (e.g. turning of the logs) or are additionally relocated from slop to machine road (Triberg two cable-, Cable dredger System). The permanent availability of machines on site additionally amend ergonomics and operational safety. Critical situation in operational safety can be mitigated by machine support (e.g. hung up trees) respectively unfavourable ergonomically conditions can be improved by occasional machine support (e.g. final processing). It must be pointed out that especially by the Cable dredger System, as by the other systems, work within the risk zone of a machine is critical in terms of operational safety. With regard to the operational safety laws work within the risk zone of a machine is only possible if permanent contact between machine and forest worker is given (e.g. integrated radio communication in the helmet) and the machine work is halted during the forest worker operations.

Beside this the opportunity of job rotation is given for the forest workers operating in teams of two persons. A shift of operational tasks reduces the specific physical impact of the work during the day.

3.2 Impact on soil and residual stand

Due to the relatively arbitrary felling direction there is a maximum possible protection of the residual stand and the natural regeneration in the Todtmoos System as well as in the St. Peter System.
Pre-skidding operations with the cable winch is an exception in the Todtmoos System. Normally all logs are lifted by the grapple of the LDT suitable forwarder crane (lift effect). Just the pre-skidding from double or triple log length by the crane of the skidder is a critical situation. The double or triple log lengths are lifted at one side by the crane and are pre-skidded into the crane zone. However this way of pre-skidding with the grapple enables a very sensible navigation of the logs which assures a low impact on the residual stand. Thus a minimum impact on the residual stand is assured, even in structural permanent forests with high levels of natural regeneration. All machines drive only on skid trails which represent a permanent opening-up grid. The functionality and trafficability of the skid trails is guaranteed by the low impact on the soil of this logging system.

The Modified Todtmoos System has also a low impact on the residual stand. The cross-cutting of short logs on the felling spot enable an integrated short distance cable skidding into the crane zone which assures a very low impact on the residual stand.

Both processing systems in the steep terrain base on felling parallel to the slope line. On the one hand this reduces the possibility to react individually on sensible stand structures. On the other hand the pre-skidding of pole length logs in slope line assures the protection of the residual stand and natural regeneration. Basic advantage compared to traditional long log harvesting systems is the lapse of pivoting the long log butts. In the Cable dredger System additionally the high, pivoting arch and the enormous lifting power of the crane contribute to reduce damages on soil and residual stand.

In all processing systems the crane is used as soon as possible to manipulate the pole length, the double or triple log lengths or short logs respectively. In the meantime pole lengths and double or triple log lengths are cross-cut to short logs as soon as reasonably possible. Both factors assure a high level in terms of a low impact on residual stand and soil.

3.3 Economics

A first estimation of the achieved productivity and the resulting harvesting costs of the cut-to-length processing systems are shown in the following table (Table 1).
The high capacity is caused by the very high piece-volume, which is obvious despite cross-cutting to short logs. Especially the high skidding capacity of the forwarder is remarkable. This is an important contribution to meet the demand of a quick and flexible supply with large dimensioned round wood of the timber industry. The efficiency of the skidding process compensates any inconvenience of costs due to triplication or quadruplicating of the handled log numbers in comparison to long log processing systems. Therefore short-log processing systems are a competitive alternative to long log processing systems including additional advantages in terms of impact of the residual stand as well as ergonomics and operational safety compared to the latter systems.

Table 1 Comparison of productivity and costs

Keydata of the processing systems	Todmoos	St. Peter	Triberg	Cable dredger
Performance (Cm/h)				
Felling/ processing	3 - 4	3 - 4	3 - 4	2 - 3
Pre-skidding / final processing		10 -12	8 - 10	13 - 16
Skidding	20 - 25	20 - 25	20 - 25	25 - 28
Costs (€/Cm)				
Felling/ Processing	8 - 12	8 - 10	8 - 12	8 - 15
Pre-skidding/ final processing		5 - 6	8 - 12	6 - 8
Skidding	4 - 6	3 - 4	4 - 6	3 - 5
Total (€/Cm)	**12 - 18**	**16 - 20**	**20 - 30**	**17 - 28**

3.4 Nutrient export

All presented LDT processing systems for short logs are characterized by an extensive processing of the felled trees to toped and delimbed pole lengths, double or triple log lengths or short logs on the felling spot. Consequently the level of nutrient export is not exceeding common levels for selective forestry due to the fact that branches and crown remain in the stand.

4. Conclusion

The presented cut-to-length processing systems for LDT softwood show two similarities: a professional performed motor-manual felling and processing as well as the efficient forwarder skidding.
The resulting harvesting costs are not automatically higher compared to conventional long log processing system despite the triplication or quadruplicating of the log numbers to be handled. At the same time a favourable impact on residual stand as well as ergonomics and operational safety is given by these cut-to-length processing systems.The introduced approaches of processing LDT short logs include options for flexible client orientation, flexibility in log measuring and -scanning between forest owner and timber industry, as well as transport and logistic optimisation (e.g. direct trailer loading).

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FULLY MECHANIZED LOGGING IN BULGARIA – FIRST STEPS AND PROSPECTS

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Keywords: harvester, forwarder, calculation of costs, snowbreak

Abstract: *Snow and wind calamities have many times given impetus to higher mechanized logging in Germany. Now, something like that seems to happen in Bulgaria. An early snow in the western part of the Balkan mountain damaged in December 2007 beech stands with a growing stock of more than 300 000 m³ in the forest district of Vitinya and its surroundings. Some 100 000 m³ of sawlogs have to be harvested before summer or they will become fuel wood and be sold at half price. The price of 42 €/m³ for beech sawlogs in Bulgaria is high enough to pay contractors from abroad to harvest them, where it is possible to do this by harvesters and forwarders. But the stands with higher inclination as about 35-40% are numerous. However, for cable crane systems is missing a real system of forest roads.*
Of course, snow and wind calamities are an extraordinary case. For ordinary cuts, harvester-and-forwarder teams from abroad are not yet competitive in Bulgaria. The costs of fully mechanized logging have to be diminished 2 times in order to make it competitive against the logging technology with chain saws and tractors or animals. Our calculations show that modern machinery, operated by Bulgarian teams, might become competitive in the near future.

1. Introduction

Before 1989, Bulgaria did even produce a small number of forwarders that – by the way – did not have much success. In the same period, harvesters were considered as something belonging to the woods of the Russian plains. The common forestry machine of Bulgaria was and still is the tractor. After the political changes, a severe economical crisis reduced the use of machinery to 2/3 of its level in 1989 and the horses started prevailing again with more than 55% of the hauled wood. But times change. Until 2006 Bulgarian National Forestry Board, managing 80% of the country's forests enjoyed a price comfort. However, since 2006 the logging costs have risen from 9 €/m³ up to 13 €/m³ and it is just the beginning (Anonymous, 2006). In 2007, we calculated 250 €/month to be a realistic tractor driver salary, all insurances and social costs included, but in early 2008 the National Forestry Agency (into which the National Forestry Board was transformed in the late 2007) decided for 330 €/month. Nevertheless, Bulgarian forestry sector is loosing its workers – they find better comfort and far better incomes in the construction sector and give up forestry.

2. Forest harvesting after natural catastrophes

Forest harvest by means of harvesters and forwarders costs in Germany some 25–35€/m³ for beech stands, according to skidding distance, whereas pine is less expensive – some 20–30€/m³. With Bulgarian average timber prices of 30 €/m³ and average logging costs of 15 €/m³ a German logging enterprise is not yet competitive in Bulgaria and in most cases it would not even cover its costs. Exceptions are natural catastrophes. Bulgaria is far away from Atlantic storms like Cyril but wind-blows, snow-breaks and forest fires occur nevertheless. Some terrain shapes facilitate wind-blows – in the forest district of Beslet on the western slope of the Rhodopes, a wind-blow occurs each 10 years that throws in one night a mass equal to the ordinary allowable cut for some years. An old statistics states that traces of natural catastrophes are stated in about 3% of the whole forest land. Bulgarian logging enterprises have not the capacity to harvest extraordinary volumes in real time to avoid deterioration of damaged wood. Thus, employing logging enterprises from abroad may reduce the losses.

Especially in Vitinya following technology seemed to be suitable: harvesting the sawlogs with machines to avoid their depreciation and harvesting the low quality wood by traditional means to avoid higher expenditures. The calculus follows in Tables 1 and 2.

Table 1. Cost and Benefit Calculation of a Combined Technology

Timber sort and technology	Logging costs €/m³	Timber price €/m³	Profit €/m³
sawlogs, logging firms with harvesters and forwardes from abroad	30	42	12
industrial wood and piled wood, Bulgarian logging firms with chainsaws, tractors and horses	18	23	5
total result	22	28.5	7.5

In Table 1, the total result has been calculated supposing that the sawlogs are 1/3 of the volume to harvest. A higher percentage of sawlogs would enhance the profit.

The financial output of the traditional technology has been calculated supposing that the beech logs will not be harvested fast enough and will deteriorate to industry wood or fuel wood (Table 2).

Table 2. Costs and Benefits of the Traditional Technology

Alternative	Logging costs €/m³	Timber price €/m³	Profit €/m³
chain saw + tractors or horses	18	23	5

The difference 7.5 – 5.0 = 2.5 €/m³ means a gain of 750 000 € for the whole volume of 300 000 m³. It is big enough to justify the employment of logging enterprises from abroad operating with machinery. However, the Forestry Agency still hesitates to make that first step. Legal obstacles are the official excuse, but the real reason is the opposition of Bulgarian logging firms which fear that foreign firms might destroy the market of man power. And as the deterioration of the beach logs does not wait we are likely to see that losses are not less instructive than gains.

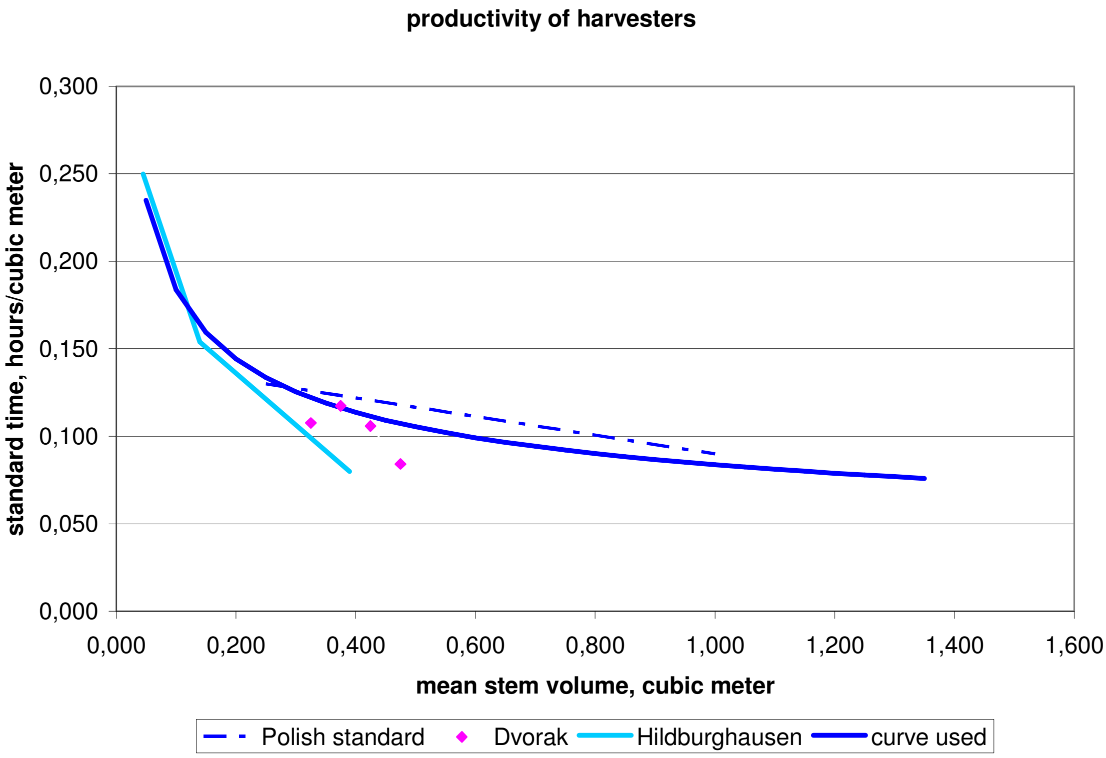
3. Heavy machines for ordinary cuts in Bulgaria

As a model to predict the development of the logging industry, we have used the construction sector the boom of which began in Bulgaria 10 years ago. Then, the construction enterprises used to buy second hand machines from abroad. Ten years later, they already buy new machines. Thus we have some reasons to believe that Bulgaria is going to become a buyer of second hand forestry machinery for a certain period of time.

To appraise the productivity of harvester-and-forwarder technology, Central European data were used. The productivity of forwarders was appraised according to the tariffs of the experimental station of Entenpfuhl in Rhainland-Pfalz (Staege, 1995), converted back by us into time tables. Being quite old (originating in 1995), they correspond strictly to second hand harvesters. Besides, they do not differ much from the time tables on which the tariffs of ThuringenForst are based.

To appraise the productivity of harvesters, a compilation of 3 sources was made – the time tables of Polish standard (Lasy panstwowe, 2004), the time tables of the experimental station in Hildburghausen in Thuringia and a recent study in the Czech Republic (Dvořák and Cechner, 2006) (Figure 1).

Figure 1.



The hourly costs were calculated according the pattern of KWF (Hofmann, R., 1994). The results are given in Table 3. The prices are in Bulgarian levas (BGN). As 1 BGN equals 0.5 €, this does not make the figures too difficult to understand. We used Bulgarian currency here in order to use the standard software of the Forestry Agency which naturally calculates in BGN. The hourly costs that are used for calculations by the Agency's experts have been calculated according the same pattern (Table 4). The transportation costs for men and machinery in Table 3 are set to 0 to ensure comparability with Table 4 by calculating of which they were also set to 0. It is because Bulgarian experts do not include transportation costs into the average costs per hour – they calculate them more precisely for each forest stand based on the real distance to villages and towns where people and machines can be based.

Table 3. Per Hour Costs Calculation for Second Hand Harvesters and Forwarders under the Conditions of Bulgaria

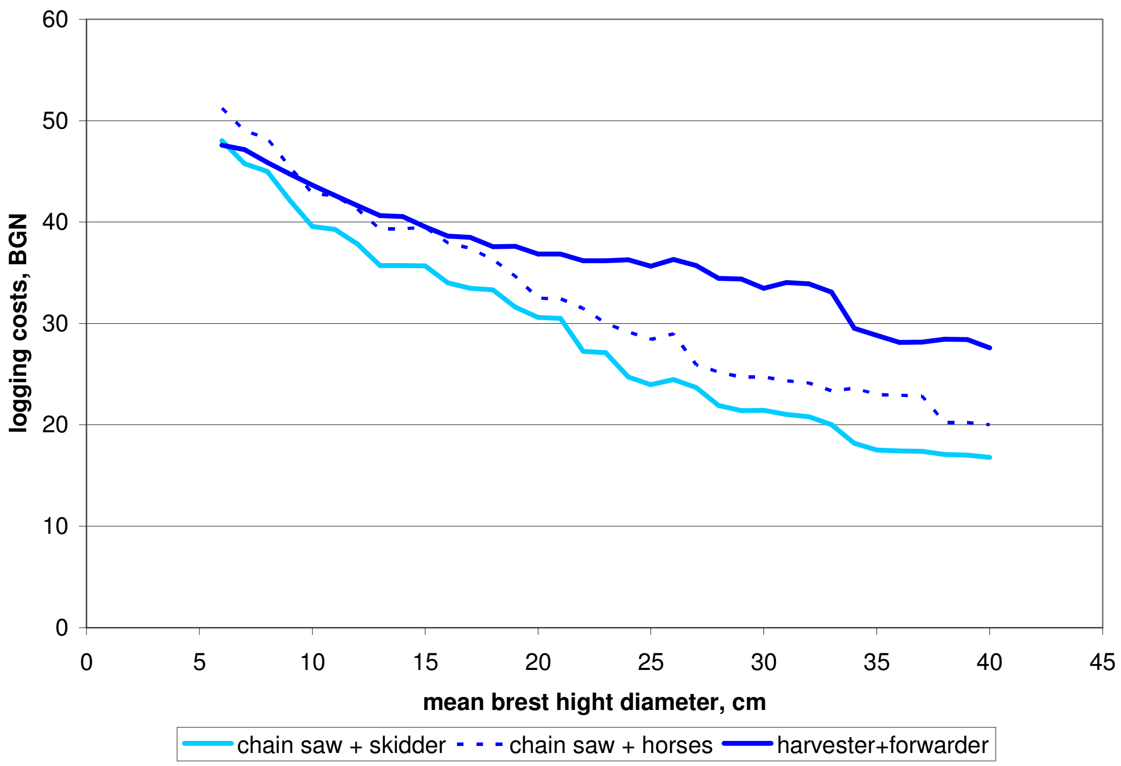
	Harvester	Forwarder
Basic data		
acquisition costs = *A,* BGN	500 000	300 000
interest rate = *i,* percent	8	8
amortization period = *N, years*	10.00	10.00
yearly working time, hours/year	2000	2000
repairs, % from amortization	90	90
fuel, L/hour	8	7
fuel, BGN/L	1.5	1.5
lubricants, % from the fuel	40	20
driver, BGN/month	650.00	650.00
other workers, BGN/month	450.00	450.00
other workers needed, number	0	0
garage, BGN/year	300	300
transport of personal, BGN/person/day	0	0
transport of machine, % from the transport of personal	0	0
casco insurance, % from the acquisition price	1.4	1.4
management costs, % from acquisition price	2	2
payment beforehand, % from salary and fuel	1.5	1.5
driver, BGN/hour	3.90	3.90
other workers, BGN/hour	2.70	2.70
calculation of costs		
I. Fixed costs		
interest, $Ai/2$, BGN/year	20 000	12 000
amortization = A/N, BGN/year	50 000	30 000
repairs, BGN/year	45 000	27 000
garage, BGN/year	300	300
management costs, BGN/year	10 000	6000
casco insurance, BGN/year	7000	4200
II. Variable costs		
fuel, BGN/year	24 000	21 000
lubricants, BGN/year	9600	4200
driver, BGN/year	7800	7800
other workers, BGN/year	0	0
payment beforehand of salary and fuel, BGN/year	621	495
transport of personal, BGN/year	0	0
transport of the machine, BGN/year	0	0
total, BGN/year	174 321	112 995
working time, hours/year	2000	2000
hourly costs, BGN/hour	87.16	56.50

Table 4. Per Hour Costs for Different Machines and Engines, Approved by the Bulgarian Forestry Agency

Machine or engine	BGN/hour
chain saw	5.82
horses	8.16
agricultural tractor, in a cutting and hauling brigade	21.31
agricultural tractor, without auxiliary workers	19.48
agricultural tractor, with one auxiliary worker	23.15
skidder, in a cutting and hauling brigade	33.32
skidder, without auxiliary workers	31.49
skidder, with one auxiliary worker	31.93
cable crane	43.30

To compare the financial efficiency of second hand harvesters and forwarders to the traditional technologies used in Bulgaria, the software of National Forestry Agency for appraisal of logging was used. The results are given in Figure 2.

Figure 2. Efficiency of Logging Technologies (*Pinus sylvestris*, skidding distance of 800 m, average terrain conditions, 20% of the stems are not suitable for sawlogs)



To understand the graph one should know that the skidding distance of 800 m is the average one for Bulgaria. 10 cm is the mean diameter of early thinnings, 20 cm is the mean diameter for both late thinnings and clear cuts and 30 cm is the mean diameter for the more sophisticated final cuts. It is also important to know that, for the costs of traditional logging technologies (chain saw + tractors or horses), a discount from 0 up to 30% is made according to the percentage of low quality wood (industrial wood or piled wood).

This discount reflects the existence of primitively equipped logging firms that use to be engaged to harvest low quality forest stands and are low-paid compared to well equipped firms with skilled workers. Of course, no such discount was applied to the appraised costs of firms equipped with harvesters and forwarders, even in the cases they are engaged for harvesting of low quality wood.

4. Discussion and conclusions

The precision of our results is sufficient to state that the financial conditions of employment of heavy machinery in Bulgaria exist even now. From Figure 2 it is evident that the costs for using of heavy machinery are comparable to the usual costs at least for thinnings and clear cuts. An invasion of logging enterprises from abroad is still impossible but the re-equipment of Bulgarian forestry sector could start. Thus, a process of acquisition of machinery could be predicted. Further arguments are (i) that in the neighboring Romania this process has already begun and (ii) that the yearly inflation above 10% rises all salaries and reduces the possibility to employ cheap man power.

The re-equipment with second hand or first hand machinery depends on the financial conditions – i.e. on the possibilities to obtain grants. The support from the state is decisive as it was the case in Germany and Czech Republic, for example. A better policy of education is also an absolute requirement.

The use of heavy machinery meets the resistance of the logging enterprises. Indeed, there is no real conflict of interests. The forwarders will not exterminate the horses – Bulgaria has enough forests where heavy machinery cannot be employed or it should not be employed – for ecological reasons. However, the machinery can contribute to augment the capacity of the logging enterprises which, for the time being, harvest no more than 80% of the yearly timber volume offered by the state (National Forestry Board, 2005, 2006, 2007).

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CABLEWAY LOGGING OPERATIONS AND RESIDUALS HARVESTING: CASES STUDY IN WINDTHROWN AREAS IN THE EASTERN ALPS – ITALY

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Keywords. Cableways, processor, chipping, bundling, loose transport.

Abstract. In the last years many devastating windstorms occurred in the central Europe have highlighted the vulnerability of our forest. Wood harvesting in mountain areas is often particularly difficult, due to terrain morphology. Cableways are in these circumstances the best choice, and the couple cableway plus processor is becoming more and more frequent in Italian Alps. As regard residuals harvesting spreadsheet models based on experiments, which return the delivered cost of biomass as a function of working conditions and costing assumptions can be used as a helpful decision tool. Chipping, bundling and transporting loose non-chipped residue are all viable options, and they are indeed applied on a commercial scale in several Countries, including Italy. Transporting loose non-chipped residue is the simplest method, which avoids investing in costly equipment. However, this system is constrained by the difficulty of fully exploiting vehicle payload: it is not suitable to the handling of fine slash, and is preferable only over short hauling distances.

1. Introduction

For a long time, in the Italian Eastern Alps, forest utilization and sawlog selling have been recovering a great importance especially from the economic point of view. In the last years, logging operations were affected by the great amounts of timber fallen down by devastating windstorms occurred in these areas. These events increased the difficulties in timber harvesting.

This paper describe some studies carried out in Fiemme valley (Trentino Alto Adige) on the Italian Eastern Alps. Cableways extraction systems were applied in different sites to harvest windthrown trees using different logging systems. The use of helicopter was also needed to mount intermediate supports.

According to the harvesting system chosen and the tree diameters the equipment needed for cross-cutting long logs or for further processing was selected and the Full Tree System and the Tree Length System were applied.

When the whole-tree method was applied, a wood processor was used and different chipping machines have worked to the landing to harvest residuals.

Infact in Italy, the rapid development of the bioenergy sector has boosted the biomass market: prices have increased very fast, encouraging better recovery of the existing resources and increasing imports of waste wood from neighbouring Countries. Logging residue represents an important wood source that can be exploited for energy purposes: hence the interest for new technologies that can reduce the cost of recovery and increase the share of logging residue within economic reach.

Logging residue originates from tree processing into traditional assortments, such as sawlogs and pulpwood. Processing can be conducted at the stump or at the landing, if whole trees are extracted. The latter case offers the advantage of concentrating residue, thus making recovery easier.

Here there is an example of residue already available at a landing – whether because trees have been processed there, or because the residue has been forwarded after processing in the stand. Under such conditions, recovery can be conducted according to one of the following three systems:

1 – chipping at landing (Fig. 3) and transporting the chips to the plant (Spinelli and Hartsough, 2001);
2 – bundling at the landing (Fig. 4), transporting the bundles (Andersson, 1999) to the plant and chipping them there just before consumption;
3 – transporting loose non chipped residue to the plant and chipping it there just before consumption (Ranta and Rinne, 2006).
It is worth analyzing these three recovery alternatives and to identify the conditions that make one preferable to the others. This way, managers can decide what harvesting method is best applied under their own specific work conditions.

2. Materials and Methods
The Fiemme valley is characterized by forests with the same age which are located in wide areas. The main commercial tree species in this area are: European Spruce (*Picea excelsa Link.*), Silver Fir (*Abies alba Mill.*), Larch (*Larix decidua Mill.*).
Two different working sites for a total of six lines were analysed:

- in the first site a traditional heavy yarder was used and three lines were mounted. In this site helicopters were needed to transport and assemble supports;
- in the second one a mounted mobile tower yarder was used for a total of three lines in three different stands.

In table 1 are shown the dendrometric features of the logged areas.

Dendrometric features	Site 1	Site 2		
	1 – 2 - 3	4	5	6
Basal area (m^2/ha)	41	41	36	48
Total basal area (m^2)	1005	734	730	1070
Average height (m)	22	29	28	26
Growing stock (m^3/ha)	496	522	481	563
Total growing stock (m^3)	12148	9402	9277	12502

Table 1 ***Dendrometric features of the logged areas***

The forestry surface of the windthrown area in the first site was around 6 ha and the total amount of fallen trees was estimated in 2500 m^3. In the other site the logged area was around 1 ha and the estimated wood amount was of 1000 m^3.
The total length of the lines has been between 300 and 1000 metres and the number of supports needed was between 1 and 4 (Table 2). In the shortest lines the timber extraction was carried out by a mobile tower yarder (lines 4, 5, 6).

The operational parameters of the seven cable cranes were measured (Table 2) and working times were collected in hundredth of minute (min/100) on a total of 70 working days.
Extraction and assembly times were recorded separately for each phases (Berti et al., 1989) and productivity was then calculated.

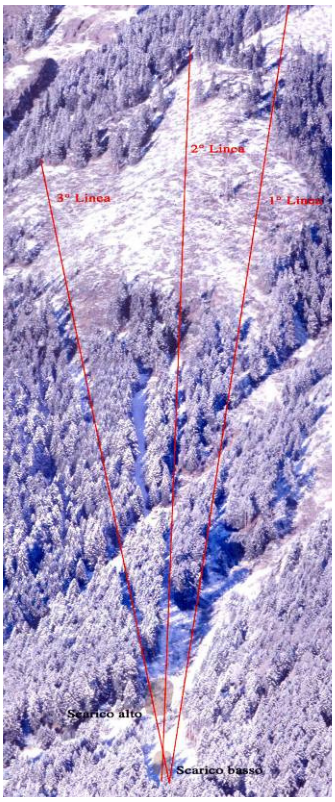

Fig.1 ***Cableways tracks (1°working site)***

Fig. 2 ***Support assembled by helicopter***

Cable crane	Heavy yarder			Mobile tower yarder		
Skyline number	1	2	3	4	5	6
Yarder	Wyssen W40		Seik Ardea	Adler MPS 650		
Carriage	Seik SFN 30/60			Bako BK 20 2R		
Total yarding distance (m)	1013	1041	881	319	299	319
Average slope (%)	45	37	35	38	33	11
Total level difference (m)	452	388	305	122	98	35
Supports	3	3	4	1	1	1
Skyline Ø (mm)	30	30	30	18	18	18
Mainline Ø (mm)	12	12	12	11	11	11
Haul back line Ø (mm)	-	-	-	9	9	9
Average extraction distance	519	577	564	150	161	185
Average bunching distance	23	28	25	20	19	19

Table 2 Cable crane operational parameters

3. Results

The two sites were different for the cable yarder system employed and for the extraction distances. In the first one the average extraction distance was between 519 and 577 metres, while in the second one between 150 and 185 metres. Bunching distances were also lower in the second site. Extraction direction was carried out downhill on both sites.

Average measured mounting and dismounting time showed that the mobile tower yarder system (site 2) were 4 times lower compared with the traditional one (site 1 – Table 3).

This result was due firstly to the higher mounting difficulties for the traditional yarder, secondly for the longer yarding distance and then for the needed superior number of supports in the line 1,2 and 3 of the site 1.
The mounting time analysis for hectometre of line length showed instead a difference of only the 30 % between the two systems.
This supports were artificial finger, they were mounted using an helicopter. Therefore a reduction of mounting time and operators effort was got. The average helicopter working time was 24 minutes per support and the cost was 600 € each (25 € per minute). In this time are included the following phases:

- support loading time;
- transportation;
- helicopter hovering on site (for the right support positioning);
- returning time;
- holding time.

Line	Lenght	Mounting time	Dismounting time	Total time	Total time
	m	h man	h man	h man	h man/hm
1	1013	225	52	277	27.34
2	1041	106	61	167	16.04
3	881	85	70	155	17.59
4	320	34	11	45	14.06
5	266	25	13	38	14.28
6	318	36	20	56	17.61
Average 1-3	978	139	61	200	20.32
Average 4 -6	304	32	15	46	15.31

Table 3 ***Cable cranes mounting times***

As far as extraction time concerning it is important to highlight an average amount of delays in the two yarder systems around 30 % compared to the gross time, except for the line 1 (delays 43 % of the gross time). Delays are mostly due to the difficulties of logging operation in windthrown forests, in the details:

- casual distribution of the fallen trees on the area;
- timber load arrangement;
- lateral bunching;
- cable crane adjustment;
- carriage;
- mainline overlapping on the skyline.

Extraction time							Mounting dismounting time	Gross time	Total productivity
	Productive time	Delays	Gross time	Volume	Productivity		Total gross time		
					Net	Gross			
Line	h man	h man	h man	m³	m³/h man	m³/h man	h man	h man	m³/h man
1	354	269	623	712	2.0	1.1	277	900	0.79
2	442	203	645	1064	2.4	1.7	167	812	1.31
3	178	79	257	379	2.1	1.5	155	412	0.92
4	131	58	189	281	2.1	1.5	45	234	1.20
5	29	16	45	120	4.2	2.7	38	83	1.45
6	153	87	240	456	3.0	1.9	56	296	1.54
Average 1-3	325	184	508	718	2.2	1.4	200	708	1.01
Average 4 -6	104	54	158	286	3.1	2.0	46	204	1.40

Table 4 ***Working times and productivity***

The average load volume per carriage running in the line 1,2 and 3 it was of 1,65 m³ and of 1,11 m³ in the other.
In the lines number 1,2 and 3 gross productivity was rather moderate and comprised between 1,1 and 1,7 m³/h man; this is due firstly to the long extraction distances and then to the high amount of delays measured in the site 1. In the other lines (4,5 and 6) the gross productivity resulted between 1,5 and 2,7 m³/h man. These data are similar to those achievable in not windthrown areas of conifer crops (Hippoliti and Piegai, 2000), where the tree marking felling decision system is applied, with timber rather bunched under the line.

4. Residuals Harvesting – Research Approach


Fig. 3 Chipping residue at landing


Fig. 4 Bundling at landing

Concerning residual harvesting data used for the comparison refer to a Jenz HEM 560D truck-mounted chipper, equipped with a 335kW independent engine and a hydraulic loader for chipper feeding, and to a Timberjack 1490D truck-mounted slash bundler, also equipped with a hydraulic feeding loader. As to the third option – i.e. the transportation of loose non chipped residue, the model refers to a truck-and-trailer unit with special enlarged load bays and hydraulic loader. All the three operations were studied in detail, accurately measuring work time, delay time, delivered tonnage and transportation distance (Spinelli et al., 2006a).
Since the goal is to know when one of the three systems is preferable to the others, the three systems have been modelled through statistical analyses (SAS, 1999), and the models have been used to conduct a simulation aimed at comparing system performance under varying work conditions.
Before analyzing the results of this simulation – however – it is best to set some reference points, in order to better understand the different processes and to avoid errors in the interpretation and application of the results.

1 – transporting bundles or loose non chipped slash all the way to the plant is only advisable when the plant is equipped with a high-output stationary chipper. Using such machine results in a dramatic reduction of chipping cost, which partly offsets the higher cost of transporting loose residue or the additional cost of bundling (Spinelli and Magagnotti, 2005);

2 – transporting loose non chipped residue has already been applied with some success both in Austria and in Finland (Ranta and Rinne, 2006). In Italy this system is used on a commercial scale by some contractors in the Italian Northeast (Spinelli et al., 2006 b). However, the procedure can only be applied to an appropriate mix of tops, discarded logs and fine slash: it is unlikely that it can give favourable results when used for fine slash only, which aggravates the main drawback of loose slash transportation – i.e. the very low bulk density and the consequent difficulty of fully exploiting vehicle payload (Rawlings et al. 2004). For the same reasons, the profitability of transporting loose slash drops very quickly with transportation distance, and the system is only suitable to short hauls. In general, the advantage of transporting loose residue is the dramatic reduction of the investments in dedicated machinery – such as a mobile chipper or a bundler, which may cost between 300,000 and 400,000 €;

3 – bundling has two main limits: first of all, it represents an additional processing step, and secondly it runs at a much slower pace compared to chipping. In fact, a bundler hourly cost is almost the same of a chipper with almost twice its productivity. The main advantage of bundling is logistics: while chippers generally need a truck by the side to receive the chips they expel from their spouts, bundlers are completely independent, as they can stack the bundles on the ground for later collection by transportation units (Johansson et al., 2006). This prevents any problems with coordinating the chipper and the truck fleet, which may cause considerable delays – possibly offsetting the productivity edge of the chipper. Joint chipper and truck operation also requires larger landings, which can accommodate a chipper and a truck at the same time. On the contrary, a bundler can be used on smaller landings, since the transport vehicle can move in after the bundler has finished with its job.

5. Results

Simulation was based on the experimental data shown in Tables 5 and 6, respectively for slash processing (chipping or bundling) and transport: these data were recorded on well-organized operations, as shown by the very limited incidence of delays. The tables refer both time consumption and machine productivity to the oven-dry tonne (odt) in order to provide unambiguous reference.

Process	Chipping	Bundling
Work (min/odt)	7.5	10.0
Other (min/odt)	0.5	2.4
Delay (min/odt)	1.0	0.9
Delay (% of total time)	10.8	6.8
Productivity (odt/h)	6.7	4.5

Table 5 Productivity of chipping and bundling

	Product		
	Chips	Bundles	Slash
Truck			
Load (odt)	6.3	5.9	3.5
Travel on forest road (km/h)	14	14	14
Travel on country road (km/h)	30	30	30
Travel on state road (km/h)	52	52	52
Load (min/trip)	50.3	20.7	17
Weight and Unload (min/trip)	8.4	21.6	10.8
Delay (min/trip)	8.1	8.1	8.1
Truck-and-trailer			
Load (odt)	16.0	15.0	9.6
Travel on forest road (km/h)	14	14	14
Travel on country road (km/h)	21	21	21
Travel on State road (km/h)	50	50	50
Load (min/trip)	127.7	52.6	117.0
Weight and Unload (min/trip)	21.0	48.3	18.7
Delay (min/trip)	10.1	10.1	10.1

Table 6 Productivity of transportation

As to chipping at the plant, data collection highlighted the high productivity of stationary chippers, which reached 16.7 oven-dry tonnes/hour with bundles and 14.4 oven-dry tonnes/hour with slash.
Data about machine and personnel costs were assembled in a worksheet and used to calculate:

- the maximum distance within which transporting loose non chipped slash is less expensive than transporting chips or bundles;
- the amount of chipping delay that can be accepted before bundling becomes a less expensive option.

These simulations were conducted for two different cases, and namely: 1) landing size and road standard allow using truck-and-trailer units for transportation, and 2) landing size and/or road standards force resorting to trucks for transportation.
Bundling proves to be the least efficient option: on the contrary, transporting loose non chipped residue emerges as the cheapest alternative, when transportation distance does not exceed 40 km. Of course, this is only true for relatively large-sized slash: it is very difficult to assemble a significant load with fine slash, after taking away the tops and all the stemwood with a diameter above 10–12 cm.

The operations observed were indeed conducted on residue obtained after delimbing trees and topping them to a diameter of 18–20 cm. Although the chipping chain is much cheaper than the bundling chain, the former is very sensitive to organizational problems: a chipper can work effectively only if a truck is placed by its side to receive the chips, and it is not always easy to guarantee a good co-ordination of the chipper and the truck fleet. Therefore, chipper work can be slowed down by recurring waiting delays, which can be considered normal and acceptable if their incidence is contained within certain limits. In our previous simulation runs, we have assumed an average delay between trucks of 5 minutes, which is certainly acceptable: as delays grow increasingly long, chipping cost becomes higher, and at a certain point it will reach the same value as bundling cost. Beyond that figure, bundling becomes a preferable option.

The results of a simulation conducted for increasing chipper waiting time, assuming a transportation distance of 35 km, 2 of which on forest roads, 10 on country roads and the remaining 13 on state roads highlight that if transportation is performed by trucks, chipping is preferable to bundling until the average waiting time between the departure of a truck and the arrival of the next one is below 40 minutes.
When truck-and-trailer units are used, the chipper can afford an average waiting delay of almost an hour and a half, before bundling becomes a better alternative. Finally, there is a third possibility, namely that the landing is too narrow for accommodating a chipper and a truck-and-trailer unit at the same time, but it can indeed accept the truck-and-trailer if the chipper was not there: in such instance, bundling would allow upgrading to the more efficient transportation unit, whereas chipping forces resorting to simpler, less efficient trucks. If this is the case, chipping is preferable only if waiting delays can be contained within the average value of 20 minutes per load.

6. Conclusions

Data analysis highlighted the opportunity of using different cable crane extraction systems in windthrown area of conifer high forests. The following parameters were determined:

- productivity;
- working systems;
- range of utilization.

The use of helicopter resulted useful for the artificial fingers mounting time reduction above all in those cases where there not any trees available on the logging area. The introduction of the processor allowed a reduction in the number of workers at the landing, but it is necessary a good synchronization between the cable crane operations and the processor. This will avoid delays in the logging operation due to the mound of timber at the landing.
Moreover with the processor the risk for the operators during cross cutting operations is reduced, above all with windthrown trees.

Concerning chipping, bundling and transporting loose non chipped residue are all viable options, and they are indeed applied on a commercial scale in several Countries, including Italy. Each alternative has its advantages and drawbacks, which must be carefully evaluated in order to make the choice that is most appropriate to the specific situation. Transporting loose non chipped residue is the simplest method, which avoids investing in costly equipment. However, this system is constrained by the difficulty of fully exploiting vehicle payload and it is not suitable to the handling of fine slash.

Chipping at the landing is technically the most effective method, but it requires close co-ordination of the transportation fleet. The number of units assigned to the operation must reflect both chipper capacity and transportation distance: excessive waiting erodes the productive edge of chipping at landing, and favours the other two methods. Bundling represent an additional process and therefore increases the total cost of recovery: however, it has the advantage of independent operation and prevents much of the organizational problems related to chipping at forest landings. If local logging companies are not organized well enough to guarantee close operational co-ordination, bundling becomes a better alternative – especially if the slash is fine, which excludes transportation of loose non chipped residue.

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EMISSIONS FROM THE "LARIX" CABLEWAY SYSTEM OPERATION PHASE

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Abstract: *The paper presents an assessment of the life cycle operation phase of forest cableways Larix 550 and Larix 3T with respect to environment load with emissions. Based on the consumption of fuels and lubricants the paper quantifies the amount of emissions in two scenarios (minimum consumption and maximum consumption) with a special focus on GHG emissions. Calculated are emissions for diesel fuel and for the alternatively applicable rape-seed methyl ester (RME) and a calculation is also made of emissions originating from fossil sources.*

1. Introduction

Anthropogenic greenhouse gases essentially affect the climate and a reduction of their emission into environment is one of primary objectives of the current EU environmental policy. In order to achieve the goal, it is absolutely necessary to increase the share of energy from renewable sources where in fact a zero balance of CO_2 originating from fossil resources can be expected.

Nowadays each product is loaded with a certain share of primary fossil resources and hence with a share of Green House Gas (GHG) emissions into environment. The impact of any technology (system) or product onto environment can be assessed by LCA methodology which can identify inputs and outputs including their environmental impact (ISO 14040-2 standards).

Berg (1996 and 1997) compared emissions from motor-manual and mechanized technologies in clear felling and shelterwood felling on the basis of the amount of burnt fuel. His works demonstrate that mechanized technology loads environment with emission substances rather more than motor-manual technology, and that shelterwood system puts on environment a greater load of CO_2 and NO_x emissions than clear-felling system due to a higher number of machine passes and their lower productivity.

The expected CO_2 emissions can be determined on the basis of molecular formula, carbon-hydrogen ratio (C:H), energy content and other factors (Calais and Sims, 2006). Table 1 presents some basic fuel types, C:H ratios, energy contents and CO_2 emissions from the fuel combustion on stochiometric basis.

Table 1: Energy contents and CO_2 emissions by individual fuel types on the basis of chemical formula

Fuel	Chemical formula	Average molecular weight	Approximate C:H ratio	Energy content (MJ/l)	Energy content# (MJ/m^3)	CO_2 emissions (g/MJ)
Gas	$\sim CH_{3.85}$	18.2	1:3.85		38.2	51.3
LNG	$\sim CH_{3.85}$	18.2	1:3.85	25.0		51.3
CNG	$\sim CH_{3.85}$	18.2	1:3.85		38.2	51.3
LPG	$\sim C_3H_{7.8}$	49	1:2.6	25.7		60.2
Petrol	$\sim C_{5.4}H_{10.7}$	80	1:2	35.2		65.8
Diesel (fuel)	$\sim C_{15.2}H_{22.2}$	212	1:1.9	38.6		65.8
Methanol	CH_3OH	32.04	1:4	15.8		60.8
Ethanol	CH_3CH_2OH	46.07	1:3	23.4		64.3
RME biodiesel	$\sim C_{13}H_{29}O$	201	1:2.29	33.3		85.0

Source: AGO, 2000; Lide et al., 1999; Anyon, 1998
at standard temperature and atmospheric pressure

The simple calculation of greenhouse gases based on the C:H ratio is rather naive because the emissions and their composition are affected also by other factors. Moreover, the energy content in fuels was measured also by other authors. Grägg (1994, 1998, 1999) and Furholt (1995) established fuel energy content as follows: EC3 (Swedish Environmental Class 3 Fuel) = 36 $MJ.l^{-1}$, EC1 (Swedish Environmental Class 1 Fuel) = 35.3 $MJ.l^{-1}$, and RME (Rapeseed Methyl Ester) = 33.1 $MJ.l^{-1}$. Altin et al. (2001) determined the energy content of diesel fuel at 36.14 $MJ.l^{-1}$, McDonell (1996) mentions the value of 36.55 $MJ.l^{-1}$ for diesel and 35.67 $MJ.l^{-1}$ for a mixture with 25% of semi-refined rapeseed oil and 75% of diesel.

Emissions generated in combustion can be related to the engine output power where they depend on thermal efficiency, i.e. on the capacity of transforming fuel energy to engine efficiency. Thermal efficiency of engines depends on the rate of compression and on the octane or cetane number of the fuel. Hamilton (2000) presented the relation between thermal efficiency, compression ratio and octane number for carbureted spark-ignition engines (see Table 2).

Table 2: Relation between the rate of compression, octane number and the thermic efficiency of engine (Hamilton, 2000)

Rate of compression	Minimum octane number	Thermal efficiency
6:1	81	25%
7:1	87	28%
8:1	92	30%
9:1	96	32%
10:1	100	33%
11:1	104	34%
12:1	108	35%

Emission factors need be expressed at the best for each machine separately or the machines should be at least put together to form appropriate groups. Emission factors of various machine groups are studied and regularly updated by the United States Environmental Protection Agency (USEPA, 1985). Tables 3 and 4 present emission factors for various machine groups with both spark- and compression-ignition engines.

Table 3: Emission factors of compression-ignition engines in various machines as related to engine output power ($kg.kWh^{-1}$)

Pollutant	Track-type tractor	Wheeled tractor	Wheeled dozer	Scraper	Grader
CO	2.88E-03	9.84E-03	4.70E-03	3.28E-03	2.06E-03
Formaldehyde	2.28E-04	3.78E-04	2.15E-04	3.75E-04	1.62E-04
NO_x	1.05E-02	1.60E-02	1.09E-02	1.00E-02	9.57E-03
PM_{10}	9.28E-04	1.70E-03	5.51E-04	1.06E-03	8.38E-04
SO_2	1.14E-03	1.14E-03	1.16E-03	1.21E-03	1.17E-03
VOCs	1.01E-03	2.36E-03	5.00E-04	7.40E-04	4.80E-04

Pollutant	Wheeled loader	Tracked loader	Off-highway truck	Roller	Miscellaneous
CO	3.63E-03	3.03E-03	4.70E-03	8.08E-03	6.16E-03
Formaldehyde	2.64E-04	1.34E-04	2.95E-04	2.63E-04	2.72E-04
NO_x	1.18E-02	1.25E-02	1.09E-02	1.75E-02	1.48E-02
PM_{10}	1.08E-03	8.78E-04	6.73E-04	1.04E-03	1.21E-03
SO_2	1.15E-03	1.14E-03	1.19E-03	1.34E-03	1.25E-03
VOCs	1.59E-03	1.49E-03	5.00E-04	1.30E-03	1.35E-03

Table 4: Emission factors of spark-ignition engines in various machines as related to engine output power ($kg.kWh^{-1}$)

Pollutant	Wheeled tractor	Scraper	Wheeled loader	Roller	Miscellaneous
CO	1.90E-01	2.51E-01	2.19E-01	2.71E-01	2.66E-01
Formaldehyde	3.41E-04	3.86E-04	2.98E-04	3.43E-04	2.98E-04
NO_x	8.54E-03	6.57E-03	7.27E-03	7.08E-03	6.48E-03
PM_{10}	4.84E-04	4.40E-04	4.21E-04	5.27E-04	4.06E-04
SO_2	3.04E-04	3.41E-04	3.19E-04	3.73E-04	3.54E-04
VOCs	7.16E-03	8.48E-03	7.46E-03	1.24E-02	8.70E-03

Conversion from kWh to MJ : 1kWh=3.6 MJ
PM_{10} – particular matters up to 10 microns and less
VOCs - volatile organic compounds

Emissions generated by combustion however do not include all noxious substances emitting into the environment from the use of fuels. A general comparison must take into account leakages of operation fluids and the share of emissions generated in the extraction, production, transport and distribution of fuels. Emissions developing during the production of fuels were studied by Davison and Lewis (1999).
The work objective was to quantify the emission load on environment required for an extraction of functional unit of production (m^3) by cableways.

2. Material and methods

Cableway types assessed within the study were Model Larix 550 and Model Larix 3T. The powering and transport unit was a farm tractor.

The cableway Model Larix 550 is designed as a complete superstructure on the farm tractor (ZETOR 8540, 9540, 10540, or comparable types NEW HOLLAND, SAME, STEYR, JOHN DEERE), which provides a considerable advantage for passability through the terrain and alleviates laboriousness of cableway construction in the field. The cableway can be used universally with a possibility of timber skidding down the hill (100-550 m), up the hill and on the plain, with a fully suspended or semi-suspended load. Based on the terrain character the assembly can be made with a running line or with a skidding line. Basic technical parameters: pulling force 35 kN, reach 550 m, carrying capacity 2 tons, time consumption for track construction 4-8 hrs.

The cableway Model Larix 3T is a follow-up to Model LARIX 550 from which the concept was adopted with the running line, capstan and suspension onto the rear and front three-point linkage of a tractor. It differs in a reinforced load-bearing structure, simplified design and operation, greater capacity of drums and line boards. Carrying capacity of Model LARIX 3T is increased to 3 tons and reach up to 850 m.

Exhaust emissions generated from the fuel were calculated as a sum of emissions produced by fuel combustion (Efc) and emissions produced during the fuel production, transport and distribution (Efp). In fuels that are products of photosynthesis in which plants assimilate carbon dioxide from the atmosphere the total balance is calculated without the share of CO_2 assimilated in this way. Anon. (2002) informs in the section on greenhouse gas balances that the fossil carbon content in RME amounts to 3.6 % and the biomass carbon content is 69.7 %.

The calculated exhaust emissions resulting from fuel combustion (Efc) take into account the energy content of fuel, emission factors related to the engine output power, and the thermal efficiency of the fuel combustion process. The calculation was made using the below formula:

$$Efc = Fc \cdot Ef \cdot Cv \cdot Te \qquad (1)$$

where:
Efc – Exhaust emissions from fuel combustion ($g.FU^{-1}$)
Fc – Fuel consumption ($l.FU^{-1}$)
Ef – Emission factor ($g.MJ^{-1}$) of engine output
Cv – Calorific value ($MJ.l^{-1}$)
Te – Thermal efficiency

Emission factors used for the calculation were those of wheel tractors (Table 3), only the calculation of CO_2 emissions was made with the emission factor at 263 $g.MJ^{-1}$ of engine output adopted from Athanassiadis (2000).

The calculation of emissions generated during the fuel production, transport and distribution (Efp) was based on the fuel energy content and emission factors.

$$Efp = Fc \cdot Ef \cdot Cv \qquad (2)$$

where:
Efp – emissions generated in the phase of extraction, production, transport and distribution ($g.FU^{-1}$)
Fc – fuel consumption ($l.FU^{-1}$)
Ef – emission factor ($g.MJ^{-1}$)
Cv – energy content ($MJ.l^{-1}$)

The emission factors used were those holding for Austria (i.e. CO_2 - 6.8 $kg.GJ^{-1}$, CO - 5.0 $g.GJ^{-1}$, NO_X - 39.1 $g.GJ^{-1}$, VOCs – 87.9 $g.GJ^{-1}$, SO_2 – 45.1 $g.GJ^{-1}$, CH_4 – 15.7 $g.GJ^{-1}$, PM – 1.1 $g.GJ^{-1}$) adopted from Davison and Lewis (1999). Only the emission factor of 0.0862 used for HC was adopted from Athanassiadis (2000).

Emission load related to the consumption of oils was calculated as a sum of emissions emanated in the production of oils (Eop) and emissions generated in the reprocessing of used oils for the purposes of combustion (Eor). Emissions arisen in production were calculated on the basis of emission factors adopted from Ragnarsson (1994) and Marby (1999) see Table 5. Emissions generated in the transport and reprocessing of used oils for the purposes of combustion were calculated on the basis of emission factors adopted from Lenner (1990) and from Stripple and Wennsten (1997) see Table 6.

Table 5: Total emissions from oil production phase ($g.l^{-1}$)

	CO_2	CO	HC	NO_X	PM
RBO	747.25	1.1294	0.9288	5.6169	0.315
MBO	260.92	0.077	2.64	2.662	0.31

RBO – rapeseed based oils
MBO – mineral based oils

Table 6: Total emissions from oil transport and reprocessing ($g.l^{-1}$)

	CO_2	CO	HC	NO_X	PM
Transport	20.4	0.09	0.022	0.27	0.01
Reprocessing	64.1	0.01	0.0001	0.13	0.01
Total	84.5	0.1	0.0221	0.4	0.02

Emission load by oil production (Eop) was calculated on the basis of oil consumption data and on the basis of emission factors as:

Eop = Oc . Ef (3)

where:
Eop – Emissions emanated in the production of oils ($g.FU^{-1}$)
Oc – Oil consumption ($l.FU^{-1}$)
Ef – Emission factor ($g.l^{-1}$)

Emission load from the transport and reprocessing of used oils for combustion was calculated on the basis of emission factors and oil consumption. Emission load from the transport for combustion was calculated only in oils used for this purpose.

Eor = Oc . Ef (4)

where:
Eor– Emissions emanated during transport and reprocessing ($g.FU^{-1}$)
Oc – Oil consumption ($l.FU^{-1}$)
Ef – Emission factor ($g.l^{-1}$)

3. Results

The calculation of emission load on environment was made separately for emissions emanated from the use of fuels and for emissions arisen from the use of oils. As an alternative fuel can be RME, a calculation was also carried out of emissions emanated in using RME. As to the use of diesel oil it can be stated that all emissions originated from fossil sources. In the case of RME, however, a certain amount of emissions originates from renewable sources and therefore, emissions from fossil sources were calculated for the use of RME (in tables designated as RME*). Scenarios for oils were set up according to different types of oils used.
The minimum total CO_2 emission load on environment by cableway operation was determined at 4.8 $kg.m^{-3}$ of wood extracted from stump to roadside in the case of scenarios most favorable in terms of the emanation of emissions. Detailed minimal emissions associated with the consumption of fuels and with the consumption of oils and lubricants are presented in Table 7.

Table 7: A minimal emissions emanated from the consumption of fuels ($g.m^{-3}$) and oils ($g.1000\ m^{-3}$)

	CO_2	CO	HC	NO_x	PM
Efc Diesel	4510.27	47.41	1.82	77.09	8.19
Efp Diesel	294.90	0.24	3.74	1.70	0.05
Total diesel	**4805.17**	**47.65**	**5.56**	**78.79**	**8.24**
Efc RME	4510.27	32.71	0.36	94.82	6.31
Efp RME	1187.63	1.43	1.27	8.18	0.40
Total RME	**5697.90**	**34.14**	**1.63**	**103.00**	**6.71**
Total RME*	**1420.59**	**3.12**	**1.29**	**103.00**	**6.71**
Eop ($g.1000\ m^{-3}$)	4885.88	2.66	40.55	47.16	5.04
Eor ($g.1000\ m^{-3}$)	1132.30	1.34	0.30	5.36	0.27
Total oils ($g.1000\ m^{-3}$)	**6018.18**	**4.00**	**40.84**	**52.52**	**5.31**

Efc RME calculated on the basis of emission increase or decrease RME and EC3 adopted from Athanassiadis (2000)
Efp RME calculated on the basis of emission factors adopted from Ragnarsson (1994)
RME* calculated emissions originated only from the fossil sources

4. Discussion and conclusion

The emission load on environment from the fossil sources is markedly lower with methylesters (RME and/or SME), the fact speaking for their preferred use. A question is, however, their practical application as related to engine functionality and service life.

The productivity of cableways is significantly affected by felling methods, possible pre-bundling and by the number of choker setters as published by Visser and Stampfer (1998). These authors presented a markedly improved productivity of cableways (30-40 %) as compared with the power saw if the felling is made by harvester and if the logs are pre-bundled. As to the number of choker setters they concluded that in sites prepared in this way it is useful to have only one choker setter. The study was made both in deciduous and in coniferous stands. The employment of harvester technologies for logging operations in broadleaved stands is unsubstantiated in the conditions of the Czech Republic and results in considerable problems. This is why a lower energy consumption and emission load for using harvester in logging can be expected according to Visser and Stampfer (1998) only with the cableway working in spruce stands.

Fuel consumption was measured in main felling operations. Berg (1997) studied the environment load with fossil fuels at different forest operations. He found that as compared with the clear felling the share of emissions is higher by 10 % and 20 % in felling and skidding operations, respectively in the shelterwood system. The calculations suggest that fuel consumption is by about 10 % higher in the shelterwood system.

The share of CO_2 emissions from fully mechanized harvesting system in the national context of countries with high forest coverage such as Sweden was calculated to be 1% (Athanassiadis, 2000). By using methylesters in diesel engines of mechanized logging technologies the expected considerable reduction (by up to 70%) of CO_2 emissions originating from fossil sources will be accompanied by a 30% increase of NO_x emissions.

5. Acknowledgement

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COMPETENCES OF FORESTRY GRADUATES AND EUROPEAN LABOUR MARKET – WORKING FOR A EUROPEAN GRADUATE ANALYSIS

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Keywords: papers, uniformity, format, style

Abstract: *Uniformity in format is a desired attribute for papers included in the Proceedings of this conference. This paper is written in the recommended format. It outlines the required page length, spacing, margins, font sizes, headings, references, quotations and other aspects that lead to an appealing visual image.*

Looking back we find that in many countries numbers of forestry graduates seem to have matched the needs of employment in the forestry sector for long time. Probably nobody can prove this, and surely the situation in different countries was very different.

The situation in the 1990s has been reviewed by Lewark, Pettenella & Saastamoinen (1998).[6] The authors had experienced difficulties in doing this, as only in a few cases data were just ready to take, and definitely there was no standardized way of assessment and presentation. Also it is notable, that the available data have been collected by universities in some cases, associations in others. And there were few cases where real specialists did surveys of the whereabouts of graduates in a regular manner.

Meanwhile the methods of graduate analysis have been developed further and standardized procedures would be possible, but application would need cooperation and agreements between universities. The graduate surveys in the field of higher forestry education in Europe have been mostly stand-alone events, even if the advantages of comparable approaches and data are obvious. Presently in SILVA Network we try to lay ground to coordinated approaches of graduate analyses in higher forestry education in Europe. An important step on this way is the knowledge of what has been done and what is going on – what do the universities know about our graduates? At the annual conference in Copenhagen in May 2008 the experiences will be collected and presented and possible ways ahead will be discussed.

[4] President of SILVA Network; Deputy Coordinator of IUFRO education group 6.15.00

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[6] Lewark, Siegfried; Pettenella, Davide; Saastamoinen, Olli, 1998: Labour markets for university educated foresters: recent developments and new perspectives. Wageningen: Proc. Workshop "New Requirements for University Forestry Education" 30.7.-3.8.1997. DEMETER Series 1, 69-88

IMPROVING HELICOPTER PILOT TRAINING WITH ON-BOARD GPS

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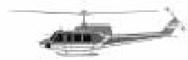
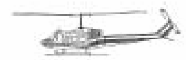
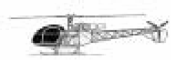
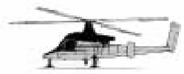
Abstract: *Helicopter yarding is incredibly versatile due to its ability to avoid many of the obstacles that encumber ground based and skyline systems. Helicopter yarding is employed for a variety of reasons including site sensitivity, urgency to remove or deliver the product, lack of access, and slope of the terrain. Because of the high cost of helicopter yarding, maximizing productivity is critical. There are many site and stand factors that affect productivity. Pilot experience is also known to be an important productivity factor. On-the-job training of new pilots can be very expensive through loss of productivity (opportunity cost). Basic time and motion studies can show differences in productivity. Using an on-board GPS system to capture elemental time study data that is geo-referenced makes it possible to isolate, in detail, during what phase of the turn cycle a trainee is not efficient. Using data collected at two different sites, basic productivity curves were developed for each element of the yarding cycle. For these case studies, the trainee pilot was losing most of his time positioning the helicopter for hooking the logs, although reduced acceleration and maximum top velocity was also noted. With detailed feedback from an onboard GPS system, the trainee pilot and or trainer can focus the improvement efforts reducing overall costs.*

1. Introduction

Helicopter yarding is incredibly versatile due to its ability to avoid many of the obstacles that encumber ground based and skyline systems (Conway 1976; Burke 1973). Today this yarding system is employed for a variety of reasons including site sensitivity, urgency to remove or deliver the product, lack of access, and slope of the terrain. The use of helicopters in forestry continues to grow. Where there were only a handful of firms offering the helicopter logging services in the early 1970's (Conway 1976), today the Helicopter Association International estimates almost 175 forestry or logging companies use helicopter logging as a principal means of yarding timber (Bruce 2003).

The variety of helicopters used is also fairly extensive. Table 1 indicates the manufacturers and models used in British Columbia, Canada. Helicopters are typically rated by payload capacity which ranges from 1134 kg for the Eurocopter Lama to 12727 kg for the Boeing CH234.

Table 1. Specifications for helicopters commonly used for logging in British Columbia, Canada (Dunham 2003).

Manufacturer	Model	Rated payload capacity (kg)	Engines (no.)	Engine power [b] (kW)	Diameter main rotor (m)	Diameter tail rotor (m)	Diagram
Bell	204B	1814	1	820	14.6	2.6	
Bell	205A	2268	1	1044	14.6	2.6	
Bell	212	2268	2	671 (each)	14.7	2.6	
Bell	214B	3636	1	2185	15.2	2.6	
Boeing	V-107 II	4773	2	932 (each)	15.5	n/a	
Boeing	CH-234LR	12727	2	3039 (each)	18.3	n/a	
Sikorsky [c] Sikorsky [c]	S-64E S-64F	9072 11340	2 2	3356 (each) 3579 (each)	22 22	5 5	
Eurocopter	SA-315B Lama	1134	1	640	11.0	1.9	
Kaman	K-1200	2722	1	1342	14.7 (×2)	n/a	
Kamov	KA-32A	5000	2	1645 (each)	15.9 (×2)	n/a	
Sikorsky	S-58T	2268	2	700 (each)	17.1	2.9	
Sikorsky Sikorsky	S-61N S-61N Shortski	3629 4084	2 2	1044 (each) 1044 (each)	18.9 18.9	3.2 3.2	

[a] Helicopter capabilities will vary with flight conditions and installed options.
[b] Engine power at takeoff.
[c] Now manufactured by Erickson Air-Crane Inc.

Despite its wide use, helicopter yarding is a relatively high cost extraction method. While Hartsough et al. (1997) found ground based skidding to account for approximately 20-25% of the stump to truck operation costs, helicopter yarding ranged between 65 and 78% of the stump to truck costs (Krag and Evans 2003; Dunham 2003). Currently Helicopter ownership costs are at least \$500 per hour for the smallest machine, up to approximately \$4500 for the larger machines.

Helicopters have various designs and abilities. The type of helicopter used will influence speed, angle of ascent, and maximum payload (Conway 1976).

The operation will be dependent on equipment and personnel, for example the firm chooses which helicopter to use, who to employ, and level of support the operation will receive. Of course this is complicated by reality and can be constrained by available technology, labor markets, and limited capital.

Optimizing the payload is a key factor in achieving efficient yarding (Burke 1973; Hartsough et al. 1986). The location and layout of the log landing is also a crucial factor. The primary concern is the yarding distance, which generally is the distance from the hook point to the log landing (Burke 1973). Weather not only limits when operations may occur, but it also influences helicopter capability during operations. The density of the air impacts both the ability of the helicopter to achieve lift and the horsepower of the engine (Wagtendonk 1996).

Other operation dependent factors that may influence productivity are the pilots themselves. When a helicopter yarding organization employs a pilot new to logging work, they are likely to experience higher costs (Warren 1996; Stampfer et al. 2002). Stampfer et al. (2002) shows that an experienced pilot delivered 59% more volume to the landing than a trainee-pilot did.

With the high cost and wide range of factors affecting helicopter yarding, sound formulas for estimating and evaluating yarding system production should be available. New technology allows us to more accurately measure the helicopter yarding process and better predict the production rates at future sites. Recent forest operation research used ground based equipment with on-board Geographic Positioning Systems (GPS) to conduct more precise production and site impact analysis (McDonald et al. 2002, McDonald et al. 2000).

Heinimann and Caminada (1996) recommend employing GPS to gather more precise data on helicopter operations. Using onboard GPS, these activities can be mapped (Figure 1).

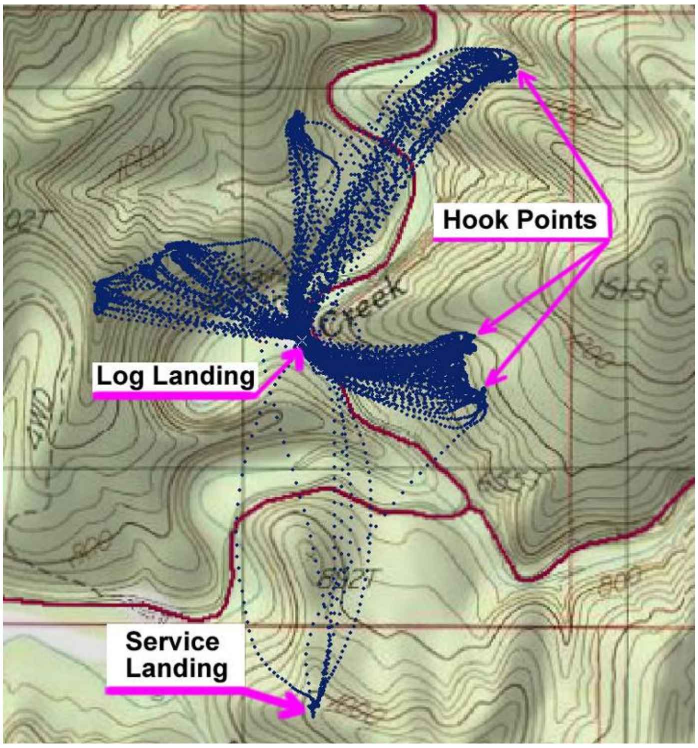


Figure 1. Mapped helicopter yarding data from an on-board GPS unit.

On-board GPS can aid the helicopter yarding industry. This study aims to demonstrate this by measuring the impact of pilot experience on productivity. Knowing where a trainee-pilot is likely to need the most improvement may assist the industry in selecting optimized training routines.

2. Methodology

The data used for this paper is part of a larger comprehensive study into measuring helicopter productivity using GPS and GIS analyses. It includes over 35 days of helicopter data gathered at 9 different sites on 3 different helicopters. At two specific locations the operation included an inexperienced pilot, which for the purpose of this study is defined as a pilot with less than 100 hours flying in logging operations (Warren 1995). Both sites were thinning of a mixed conifer stand, in the Pacific Northwest, yarded in the summer.

At each site an attempt was made to capture at least 30 turns, whereby the inexperienced and experienced pilot flew consecutive yarding cycles ensuring consistency in weather, stand and terrain factors. GPS data was collecting using a Trimble Geo XT with EVEREST technology mounted on board the helicopter. Location information was gathered at one-second intervals. The data was downloaded from the GPS unit at the days end.

Some basic programs were developed to aid the evaluation of the data, including auto location of the four phases that make up a typical turn cycle. Landings were located using position with a 35 meter radius. Hook points were identified using velocity and altitude with a 20 meter radius. Outhaul and inhaul were velocity and position dependent. The programs used the GPS data, landing coordinates, and radii input by the researcher.

Describing the Helicopter Yarding Process

The process of helicopter yarding can be broken into yarding cycles, turns, and elements. The basic definition for a cycle is leaving the service landing, flying a number of turns and returning to the service landing. The basic definition for a turn is leaving the log landing and traveling to the location of the payload (outhaul), picking up the payload (hooking), returning to the log landing with that payload (inhaul), and releasing the payload at the log landing (unhooking). Each segment of the turn just described is an element.

Beginning at the service landing the helicopter will fly to the harvest area and begin yarding logs. During the hooking element there will often be a person, the hooker, on the ground with pre-choked logs ready to be connected to the hook at the end of the helicopters long line (Figure 2). The pilot locates the hooker and maneuvers the hook near the hooker. Then the hooker slides the chokers into the hook. The pilot then lifts the logs off of the ground and clear of the forest canopy.

Figure 2: A hooker putting the chokers onto the hook.

The inhaul element begins and the pilot flies toward the log landing. At the landing the pilot sets the logs on the ground in the drop zone and releases the chokers from the hook (Figure 3). With the load released, the pilot clears the log landing and enters the outhaul element, flying back to the woods for another load of logs. If chokers are needed, they may be attached to the hook prior to departing the log landing (Figure 3). The entire process, hook, inhaul, unhook, and outhaul is commonly referred to as a turn. If no problems occur, this continues for 60 to 90 minutes, until the helicopter must be refueled. The pilot must then return to the service landing for fuel. When the helicopter is in the hooking, inhaul, unhooking, or outhaul elements, this is called the yarding cycle. When the helicopter is flying to or from the service landing or being fueled or repaired, this is called the service cycle.

Figure 3. Left: Helicopter at the drop zone (unhooking), and right, helicopter with chokers going to woods (outhaul).

Table 1. Description of the numerical variables and time components.

Type	Name	Description	Unit
Dependant-Variables	Outhaul	Time for the helicopter to fly from landing to hook point	sec
	Hook	Time at ‘hook point’, which is defined by a radius of 20 meters around the actual hook point	sec
	Inhaul	Time for the helicopter to fly from hook point to landing	sec
	Unhook	Time at ‘landing’, which is defined by a radius of 30 meters around the actual landing	sec
	TurnVol	Sum of the log volumes extracted in one turn	kg
Covariables	TreeVol	Average log volume	kg
	ExtDist	3d extraction distance	meter
	ElvChange	Change in Elevation	meter
	Slope	Slope between landing and hook point	%
	TreeTurn	Number of logs per turn	number
Factors	PilotEx	Pilot experience, as defined by 100 flying hours in logging	0 / 1
		Turn that includes dropping off a bundle of chokers	0 / 1
	ChokDrop	Turn that includes picking up a bundle of chokers	0 / 1
	ChokPick		
Time	Vel	Max velocity (Flyout and FlyIn)	m/sec
	Accel	Max Acceleration (Flyout and FlyIn)	m/sec2
	Decell	Max Deceleration (Flyout and FlyIn)	m/sec2

Statistical analysis was carried out using SAS JMP 7.0, including basic mean comparisons as well as linear regressions to build the models. Comparison of means was tested at the 0.05 level, whereby stepwise model development used a threshold of 0.10 for parameter inclusion. Specific Helicopter and site information is considered confidential by the helicopter companies, and hence not reported here.

3. Results

Case study 1

Average extraction distance was 1028m (range 476 to 1457), with an average payload of 3528 kgs and 2.9 logs. The total average cycle time was 194 sec (3 min 24 sec); whereby 48, 66, 56 and 24 seconds were used on average for outhaul, hooking, inhaul and landing respectively. This resulted in an average productivity of 71 tons/PMH. Average Elevation change was only 30 m.

An initial review of productivity data indicates a significant difference between the in-experienced and experienced pilots (40.7 versus 82.2 tons/PMH). However many factors can influence productivity so it would be more correct to build a productivity model with pilot experience as a block factor.

A basic productivity equation is;

$$\text{Eq (1): Prod (tons/hr)} = 106.2 - 33.5 \times \text{PilotEx} - 17.5 \times \text{ChokDrop} - 19.6 \times \text{ChokPick} - 0.02 \times \text{ExtDist} - 0.05 \times \text{ElvChang} \quad (r^2 = 0.79)$$

Equation 1 indicates that under similar conditions, the inexperienced pilot produces 33.5 tons/PMH less.

Analyzing the available data in more detail, we can look at the four phases of the turn to identify specific differences.

For the Outhaul phase, time from Landing to Hook point should just be a function of extraction distance and change in elevation, as well as the block factors ChokDrop and PilotEx.

$$\text{Eq (2): OutHaul (sec)} = 0.055 \times \text{ExtDist} - 0.092 \times \text{ElvChange} + 28.5 \times \text{ChokDrop} \quad (r^2 = 0.65)$$

So for outhaul the pilot experience factor was not significant. We can also look at both maximum acceleration as well as average velocity during the Outhaul phase to confirm this difference. The inexperienced pilot had a slightly higher average velocity (145 m/sec) than the experienced pilots (126 m/sec), as well as a slightly average maximum higher acceleration (3.1 versus 2.7).

For the Hook phase, we would expect the number the total payload weight and number of logs, as well as pilot experience to influence the total hook time.

$$\text{Eq (3): Hook (sec)} = 8.4 + 0.011 \times \text{TurnVol} + 84.7 \times \text{PilotEx} \quad (r^2 = 0.74)$$

This indicates that the inexperienced pilot takes more than twice as long to hook up the load.

For the inhaul phase, we might expect the payload, the elevation change and the extraction distance, in addition to pilot experience to be important factors.

$$\text{Eq (4): InHaul (sec)} = 31.5 \times 0.021 \times \text{ExtDist} + 8.3 \times \text{PilotEx} \quad (r^2 = 0.42)$$

Neither elevation change nor the payload was significant, and the experienced pilot was in fact flying a little faster during the inhaul phase. Once again we can look at the details of velocity and acceleration. The experienced pilots on average flew a little faster (105 versus 100 m/sec), accelerated away a little quicker (1.9 versus 1.6 /sec2) and were able to decelerate the helicopter a little quicker when approaching the landing (1.7 versus 1.4 m/sec2).

For the unhook phase of the flight, the size of the payload, the number of logs, in addition to the pilot experience and whether or not they pick up a bundle of chokers might influence the length of time over the landing area.

$$\text{Eq (5): Unhook (sec)} = 16.9 + 14.9 \times \text{PilotEx} + 26.5 \times \text{ChokPick} \quad (r^2 = 0.65)$$

Although neither the size of the load nor the number of trees influenced the time over the landing unhooking a load, the experienced pilot took on average 7 seconds less, and on average it took 13 seconds to pick up the chokers.

Overall, it is clear from this short data set (2.5 hours of data) that we can clearly identify that the inexperienced pilot should focus on the hook phase of the operation – where there is clearly the largest difference.

Case Study 2:

Average extraction distance was 1770m, with an average payload of 3300 kgs and 4.4 logs. Average element times were 50 sec out, 69 hooking, 52 sec back and 25 at landing for a total average cycle time of 196 sec (3 min 26 sec). This resulted in an average productivity of 68 tons/PMH. Average Elevation change was only 25 m and the average distance was 1045m (range 36 to 2819m). Average velocity was 80 km/hr on the outhaul, and 68 km/hr for the inhaul.

However, there were clear differences between the experienced and inexperienced pilot. Overall, the productivity was 77 and 38 tons/PMH for the experienced and inexperienced pilots respectively.

Eq (6): Prod (tons/PMH) = 99.1 – 36.3 x PilotEx – 12.9 x ChokDrop – 13.4 x ChokPick - 0.013 x ExtDist – 0.9 x NumLogs ($r^2 = 0.73$)

The equation for the Outhaul phase is;

Eq (7): OutHaul (sec) = 0.039 x ExtDist – 0.011 x ElvChange + 19.8 x PilotEx + 23.5 x ChokDrop ($r^2 = 0.70$)

Unlike case study one; the inexperienced pilot is some 20 seconds slower on average flying out. For the hook phase:

Eq (8): Hook (sec) = 15.5 + 0.008 x TurnVol + 64.6 x PilotEx + 2.32 x NumLogs ($r^2 = 0.60$)

Similar to case study 1, there is a large difference in the length of time it takes the inexperienced pilot to hook. For the flight back

Eq (9): InHaul (sec) = 18.6 x 0.030 x ExtDist + 0.07 x ElvChange + 16.4 x PilotEx ($r^2 = 0.42$)

Again, the experienced pilot is somewhat faster by on average 16 seconds. Finally, for the unhook phase:

Eq (10): Unhook (sec) = 17.0 + 19.7 x PilotEx + 22.1 x ChokPick ($r^2 = 0.64$)

For this phase in particular, all of the parameter coefficients are almost identical to case study one.

The results analyses have focused primarily on the experience pilot factor. A closer review of individual parameters, such as the impact of distance, either picking up or dropping off chokers, or simply the length of each phase in the overall cycle on productivity provides valuable production management information.

4. Conclusions

Integration of new technologies can provide significant opportunities to improve productivity of existing timber harvesting operations, and thereby reduce costs. This study has demonstrated the opportunity for using onboard GPS for the benefit of identifying training needs for inexperienced helicopter pilots flying in logging operations. Although some automation of the data interpretation was achieved during this study, opportunities exist for improved data synthesis.

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USING GIS APPLICATIONS IN ROAD NETWORK DEVELOPMENT TAKING INTO CONSIDERATION SOIL EROSION

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Keywords: soil erosion, forest road network, GIS.

Abstract: *In order to realize a quantification of soil erosion in a perimeter of 56.5 ha situated in Tarlung basin one has observed and characterized more areas. Each plot has a distinct number recorded with the aid of a GPS Garmin 60CSx.*
On the basis of terrain observations, the eight testing plots have been characterized from the terrain erosion point of view. Using SAGA GIS we made the linear interpolation of these points (Kriging). Applying specific SAGA modules we were able to determine both the high erosion degree areas and those with less erosion degree creating Thiessen polygons.
Using The NETWORK 2000 program that takes into consideration only the economic criterion, the volume and the wooden mass, we changed the logical function by introducing the erosion Index calculated with Ciortuz method.
The algorithm's function is to minimize the objective function. By using GIS and with the help of Network 2000 one can choose the most convenient ways. In order to simulate into the Network 2000, without any access to the source code, we have inserted for the areas with high erosion risk, higher values for cost_var and fixed_cost in the Link Editor. The program has avoided the high erosion area.

1. General frame

1.1.Introduction

The development of the road network must ensure accessibility into the forest in order to realize the complex work of forest administration.
The most important factor, beside the technical ones, which determines the drawing and the development of the road network, is the economic one. A road should be ideal, cheap and should provide a maximum transport of wooden mass in order to be completely used in the process of exploitation. Due to nature diversity, this is not possible in reality.
On the basis of economic criteria, Woodam Chung and Dr. John Sessions (Network 2000) have developed a program which underlines the most convenient way between a wooden mass point and the deposit platform (using intermediary points , the quantity of wooden mass to be transported, the transport cost and the road cost) .This program is based on an algorithm derived from Sullivan's Algorithm (1987).
The ecological factor is very important in developing the road network. To prevent ecotope destruction due to road network development, a suitable barometer would be establishing the degree of soil erosion

1.2. Methodology

In order to realise a quantification of soil erosion in a perimeter of 56.5 ha situated in the Tarlung basin one has observed and characterized more areas. Each plot has a distinct number which has been recorded with the aid of a GPS Garmin 60CSx.
The GPS accuracy has been of ±4 m. Plots' description was mainly used to observe the type and the vegetation status. The role of plots' positioning is to observe the homogeneous areas in order to create a mapping of the whole area.
Thus, plots 1 and 2 have been positioned on the pasture land. Plot number 3 has been positioned in a passing area with unhealthy forest and high slope. The fifth plot has been positioned in a rare forest but with a smaller slope. To the river, the forest remained unchanged and, therefore, it was no need of other testing plots. Down, on plots number 6, 7 and 8 there was a high slope and the forests in this area have been included highly protected forests.

2. The establishment of soil erosion and its influence on the development of road network.

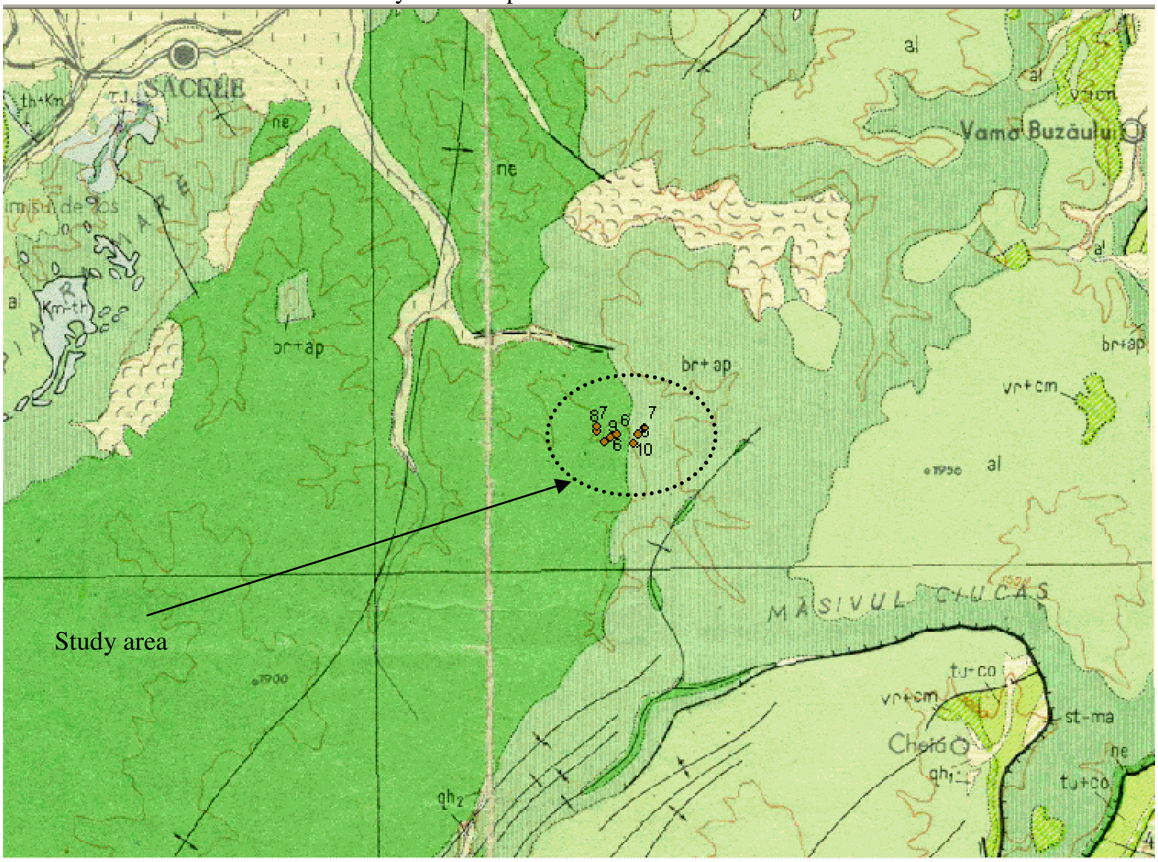
2.1. Determining the territory's degree of erosion through the Ciortuz method

Rain erosion as a natural process takes place on all the bended grounds but it reaches brutal forms only in certain conditions. Therefore, each territory has a certain degree of erosion.
There are certain factors which intervene in the process of rain erosion: the bedrock under layer, the relief, the climate, the soil, the vegetation and the human factor. Moreover, if the bedrock, the relief, the climate and the soil become circumstances to accelerate the process, the vegetation, especially the forest one, protects the ground.
To characterize a territory through the erosion process one can use the Ciortuz method, which is a system based on indexes frequently used in science (geography) and in technology (silvotechnique). The working system refers to the following factors: the rock type from the bedrock, the territory's morphological slope, the rain factor, the soil texture and the vegetative factor.
The indexes' sum for the first four terms, meaning the erosion factors, reflect a certain predisposition to erosion.
The fifth factor, the vegetative factor, is the resistance one, thus the mathematic difference between average values of this index and the total of the other 4 indexes creates and erosional index which can reflect the territory's degree of erosion.

Index table of the quantifying variables

Nr. Crt.	Factors and symbols		Existent situations	
1	Rock	R	hard rock medium erosive rock soft rock	1 2 3
2	Slope	I	10% in watershed, until 20% on slope 11-30% in watershed, 21-60% on slope over 30% in watershed, over 60% in slope	1 2 3
3	Rain factor	P	precipitations until 600mm precipitations 601-1000mm precipitations over 1000mm	1 2 3
4	Soil texture	T	middle texture low texture fine texture	1 2 3
5	Vegetative factor	V	ponds and agricultural lands productive pastures and forests normal pastures and forests	1 2 3

On the basis of terrain observations referring to the bedrock and erosion indexes, the eight testing plots have been characterized from the terrain erosion point of view.Plot number 6 has received the maximum value, having a very high degree of erosion.
All of the testing plots are predisposed to erosion because of the geological bedrock structured in this perimeter in two areas: the first one characterized with a bedrock highly disposed for erosion and the other one which consists of more clay than the previous one.

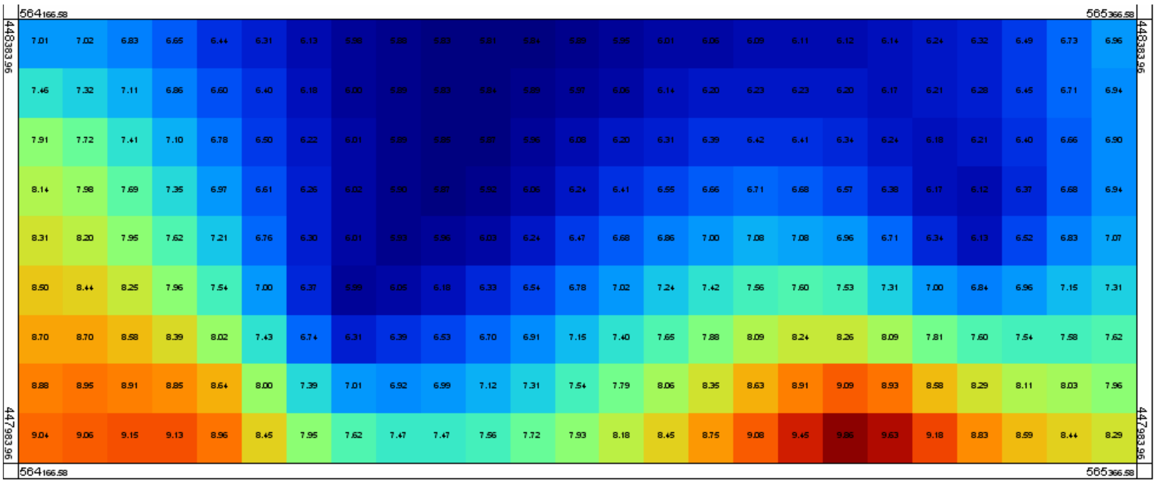


Geologic location of the study area

After the download of the point form the GPS Garmin 60CSx, we have put to each one the index's value into an attribute field which shows the erosion degree from that area.

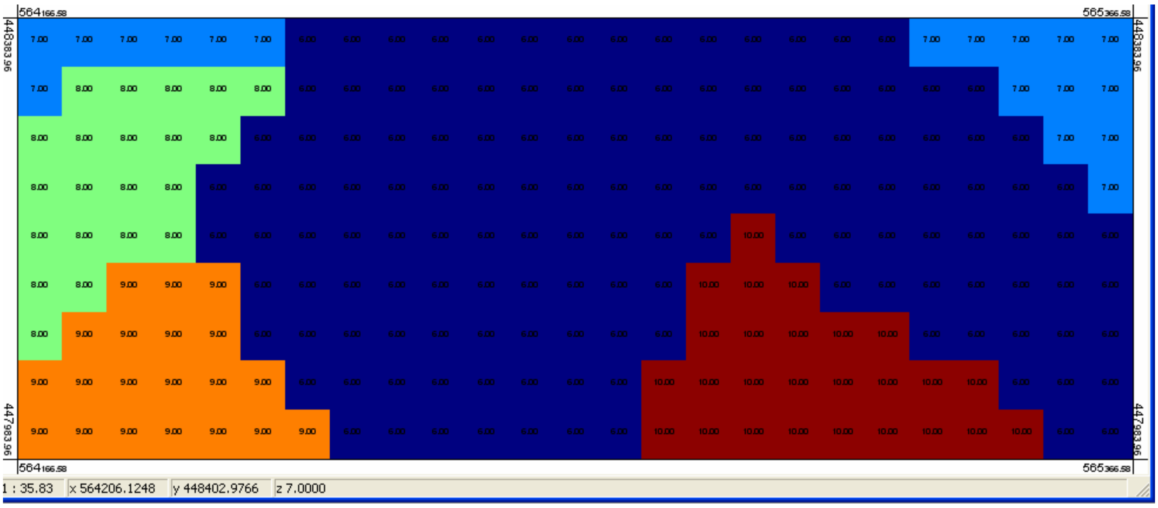
2.2. The establishment of erosion influence areas over the road network.

Knowing the eight points' position and attributing all the points with the erosion degree with the aid of the SAGA program , we made the interpolation of these points (Kriging). Thus, a grid perimeter has resulted. This grid is made of cells and each cell has an index which shows the cell's erosion degree. This has been determined through linear interpolation.



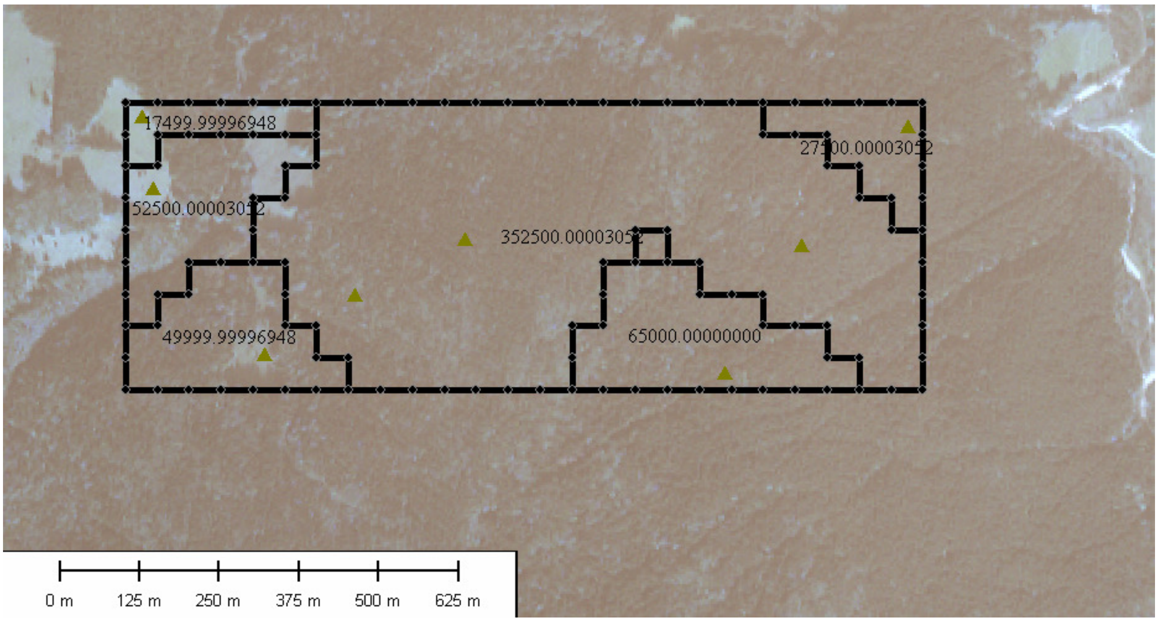
Grid representation of the interpolated data

As a result of applying some specific SAGA modules through the Nearest Neighbour Method, we was able to determine both the high erosion degree areas and those with less erosion degree. This SAGA module described Thiessen polygons which represent the specific areas where some points' influences could be felt.



Grid representation of the Thiessen polygons

Thus, the grid was regrouped and the cells gathered around the testing plots took over the plot's index. For a better erosion plot description it is necessary to create more testing plots.
The SAGA exported polygons on the basis of Thiessen polygons describe the area and the perimeter which is a very important thing in exactly establishing the terrain percent. This percent can be used in the network development without any erosion risks or increasing erosion predisposal.

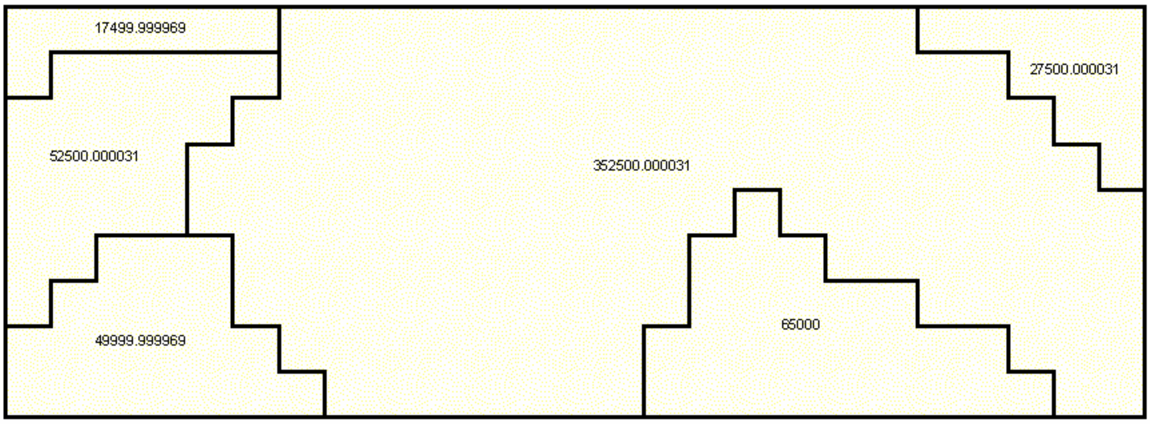


Plots and Thiessen polygons location (on a 10 m satellite image IKONOS)

The most suitable area to develop the network, after drawing the polygons is the blue one which presents the sixth index's value as shown in the previous image.

In the western side, the other areas are influenced by the lack of forest vegetation, and building a road would lead to an erosion increase, especially in a area with a erosion predisposed layer. In the eastern side the slope has influenced the index's value.

The highest values are in the southern side. Because of the high slopes, bad sanitary status of the forest and the reduced firmness, the erosion degree is higher in the southern side than in the others.



Thiessen polygons area distribution

2.3. The Erosion Index in the NETWORK 2000 Program

The NETWORK 2000 program takes into consideration only the economic criterion, the volume and the wooden mass.

The algorithm is based on the following objective function:

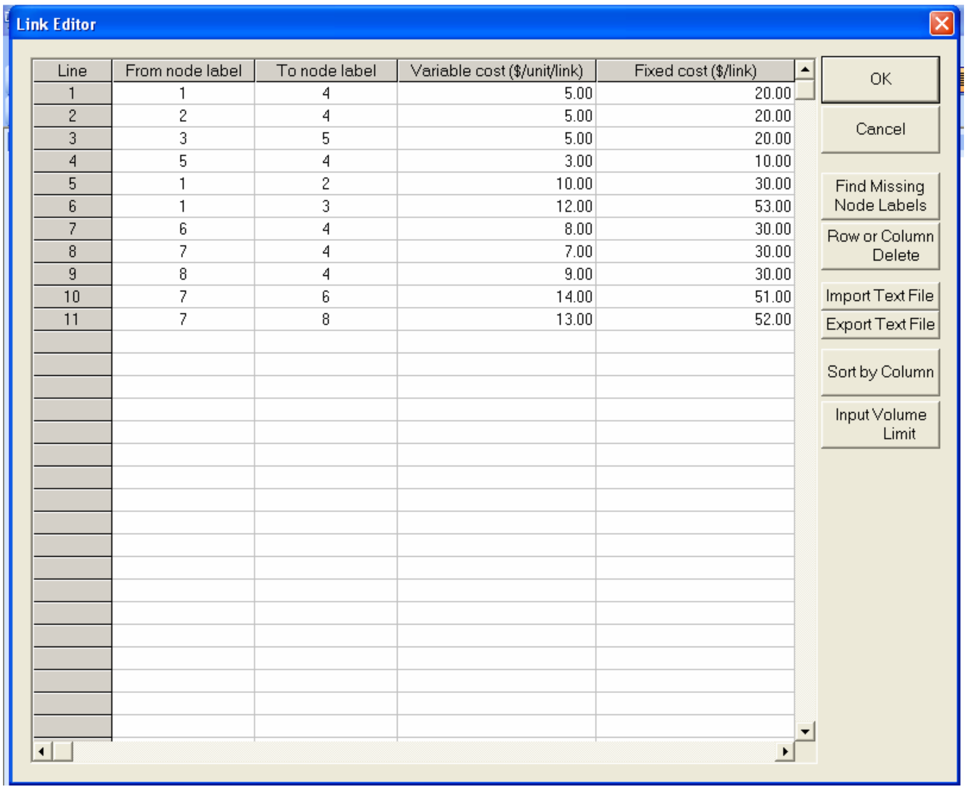
$$f(x)=\sum_{i=1}^{e}\left[\left(\text{var\_cos}t_i \cdot vol_i\right)+\left(\cos t\_fixat_i \cdot B_i\right)\right] \qquad (1)$$

var_cost – the cost for the wooden mass volume transport in the point i ($/vol)
vol – the volume for point i
fixed cost – the fixed cost for point i; how much money are spent to reach the point

The algorithm's function is to minimize the objective function. Thus, for using the previously calculated erosion index through the Ciortuz Method (Ic) we must insert it into the program's algorithm, in its objective function.

$$f(x)=\sum_{i=1}^{e}\left[\left(\text{var\_cos}t_i \cdot vol_i\right)+\left(\cos t\_fixat_i \cdot B_i\right)\right]+I_c \qquad (2)$$

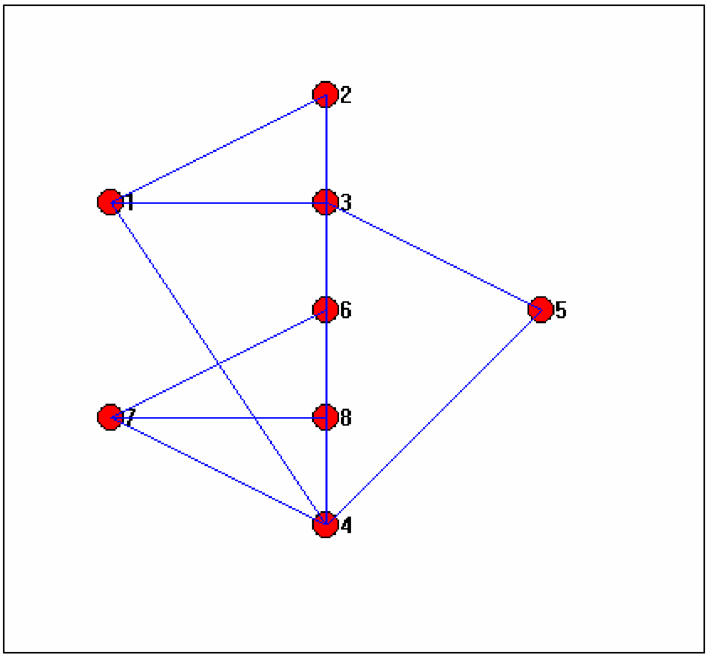
The higher erosion predisposition is leading to a higher value for the objective function.
Since the aim is to minimize, to reach the optimum solution, we must exclude the roads which go through areas with high erosion risk. Using the GIS, which can work on a cell level (in raster) and be able to generate the shortest roads and with the help of Network 2000 one can choose the most convenient ways.
To simulate into the Network 2000 without any access to the program script, we have inserted in the areas with high erosion risk, higher values for cost_var and fixed_cost in the Link Editor



Line	From node label	To node label	Variable cost ($/unit/link)	Fixed cost ($/link)
1	1	4	5.00	20.00
2	2	4	5.00	20.00
3	3	5	5.00	20.00
4	5	4	3.00	10.00
5	1	2	10.00	30.00
6	1	3	12.00	53.00
7	6	4	8.00	30.00
8	7	4	7.00	30.00
9	8	4	9.00	30.00
10	7	6	14.00	51.00
11	7	8	13.00	52.00

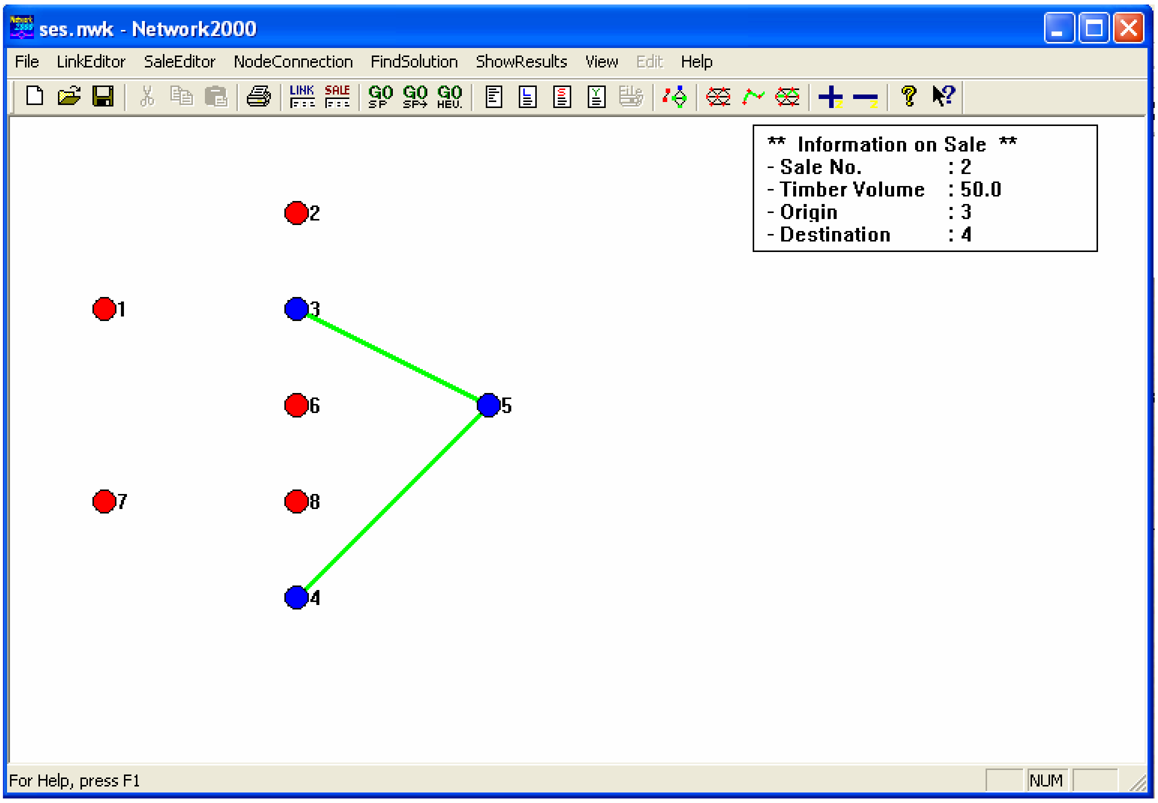
Link editor used in NETWORK 2000 to quantify soil erosion

Point connections have been presented in the following way :



Plots connections

The program has generated the following method by using the generative option for suitable ways, taking into consideration that all the wooden mass must be gathered in point number 4 (having the smallest erosion degree)



Best route calculation (taking into consideration soil erosion)

Thus, the program has avoided the high erosion area and has chosen the area with less erosion in the high slope and poor forest area's detriment.

3. Conclusions

Taking into consideration soil erosion regarding road network development have several implications economical and ecological. Using GIS we can work with large data sets and we can have a better approach incorporating information into an unitary system.

Using SAGA, an open-source program, we wanted to underline the increasing accessibility of GIS programs, because there are many other programs, free or not, that can be useful in road network development

Having a grid with the mapping of the erosion in the area were will be constructed a road network, and with an algorithm able to generate the most convenient ways, we can choose the best path for the network, not for the present economic fares yet for the future fares (road maintenance, rehabilitation etc.)

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COMBINED LOG AND ENERGY WOOD PROCESSING OF LARGE DIMESNIONED TIMBER (LDT) IN STEEP TERRAIN

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Keywords: energy wood; stem wood; co-production; combined production; fierce competition

Abstract: In Germany wood as a renewable, climate neutral resource gains increasing importance regarding the future energy mix. In the meantime traditional processors of timber complain about decreasing quantities of round wood resources and increasing acquisition costs, caused by the concurrence of non-energetic and energetic use of timber. The question in controversial discussion is concerning a responsible use of wood resources in terms of balanced utilization cascades.
The Department of Forest Utilisation of the Forest Research Institute (FVA) Baden-Württemberg, worked intensively on the research of possible solutions for a combined production of stem and energy wood in the past years.

1. Initial situation

A responsible way of resource use has been related nearly exclusively to the use of stem and industry wood in a non-energetic way in the forestry sector so far. This traditional utilisation and marketing strategy is changing due to booming markets for energy wood for a few years now. The exponentially increased prices of fossil fuels have led to a growing concurrence of the traditional non-energetic and the energetic utilization of wood.

For generating power and/or heat out of wood large-scale plants with a boiler output of more than 500 kW are inevitable. The established energy wood supply chains for these plants are based on wood chips as primary product. In the following energy wood processing is considered as wood chip supply chain.

The hitherto existing approaches in Central Europe for the supply of wood chips concentrate on two main tendencies: in small-dimensioned timber stands the whole tree is chipped on the one hand (pure energy wood bucking method), in large-dimensioned timber stands logging residues are used as energy wood after maximised stem- and industry wood bucking (traditional bucking method). Approaches for a systematically combined production of stem and energy wood have, apart from few regional evolutions, just marginal importance at the moment.

This situation is mainly caused by the low wood chip revenues in comparison to stem or industry wood assortments, as well as additional organisational effort and expenses associated with the energy wood supply. Low piece-volumes and low yields per hectare of the energy wood result in unfavourable performance and cost levels leading rapidly to non-profitable revenue situations with given profit margins for wood chips. Therefore it is a central task to optimise the complete supply chain in order to achieve a favourable profit situation in combined production systems with stem and energy wood. A critical factor in this optimisation is the bucking, as it has an essential impact on the piece-volume of the manipulated products.

The Institute of Forest Utilisation and Work Science/University of Freiburg developed a bucking concept, strengthening both the advantages of energy wood processing after maximised stem and industry wood bucking (traditional bucking method) and the pure energy wood bucking – the so-called “log PLUS concept”. The Log-PLUS concept is focussing exclusively on two products: stem wood and energy wood. On the one hand stem wood bucking is optimised by limiting the stem wood to “high-quality-high-price” logs. On the other hand the energy wood is additionally optimised by this strict stem wood bucking guideline due to the transition of low quality stem wood amounts to energy wood. The log-PLUS concept assumes that the loss of stem wood amount is compensated by lower processing costs along the whole supply chain, a better piece-volume relation of the energy wood as well as an increase of the total energy wood amount.

2. Sample design and sample area

These basic assumptions of the log-PLUS concept have been scientifically analysed by the FVA for softwood large dimensioned timber stands in steep terrain in comparison with a traditional bucking concept. Furthermore the FVA analysed the general adequacy of approved processing systems for a combined production of stem and energy wood.

Large dimensioned timber (LDT) has been specifically selected for the trials because of the following basic parameters [1; 3; 4]:

- national forest inventories show growing stocks of large dimensioned timber
- favourable piece-volume with increasing age and DBH of the stands
- decreasing saw wood quality (German "HKS" quality scheme) in the crown with increasing age and dimension of the stand
- increasing relative compact wood percentage and decreasing non-compact wood percentage in the crown of LDT stands in comparison to small dimensioned wood stands (upgrading wood chip quality)

The bucking guidelines of both analysed bucking concepts differed in the way that in the log-PLUS concept quality "D"-logs and logs of the crown segments were excluded in contrast to the traditional bucking concept. In addition the stem wood minimum topping diameter of the log-PLUS concept was 45 cm, 9 cm above the traditional alternative. In both concepts exclusively 5 m short logs were bucked.

The trial was located in the southern Black Forest in a fir LDT stand with a DBH of 62 cm over bark of the felling stand. The stand was situated on extremely steep terrain with an average inclination of 65 % and an opening up with machine roads in distances between 90-150 m (Figure 1).

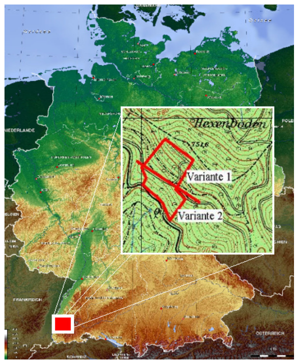
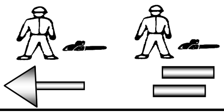
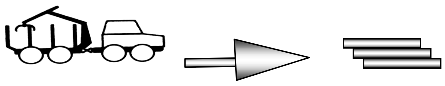


Figure 1: The sample area „Staufen"

The slightly modified Cable dredger logging System [2] was chosen for the combined processing of stem and energy wood. Characteristically for this system is a team of two forest workers who performs the motor-manual felling and processing of the trees to pole lengths (delimbed whole tree length) with attached crowns. A cable dredger pre-skidded these pole lengths to the machine road, where they were finally processed by an additional forest worker (cross-cutting and final delimbing). Both product groups (stem and energy wood) were skidded and piled by a LDT suitable forwarder. The energy wood was piled on large-scale depots at favourable locations for the supply chain logistic (i.e. switching of containers). The chipping of the energy wood was performed by a truck chipper (Figure 2).

Figure 2: Pictogram of the cable dredger system

	Stand	Machine Road	Forest Road/ Depot
Felling and Processing			
Pre-Skidding with integrated Final Processing			
Skidding and Piling			
Chipping			

3. Results of the trial

3.1 Yield and quality distribution

In total approximately 1.000 m³ of stem and energy wood were processed during the trial in Staufen. The distribution of the processed wood amount differed depending of the bucking concept in terms of product groups.

The average energy wood percentage of the log-PLUS concept exceeded the traditional concept by 13 percentage points. This modified wood volume distribution in terms of product groups resulted in piece-volume changes of the pole lengths with attached crown. The average piece-volume of the log-PLUS concept was reduced by 15 % while the average piece-volume of the energy wood was increased by the factor 1.5 compared to the traditional concept. Despite this reduction of the stem wood piece-volume the average stem wood piece-volume still exceeded 2 m³ ub. The increase of the average piece-volume of the energy wood by 0.5 m³ ob to more than one m³ ob caused an improvement of the performance and cost data in this alternative. The development of an estimation scheme for energy wood yield was enabled by the research data of the "Staufen"-trial and other comparable trials focussing on Norway spruce and White fir (Table 1).

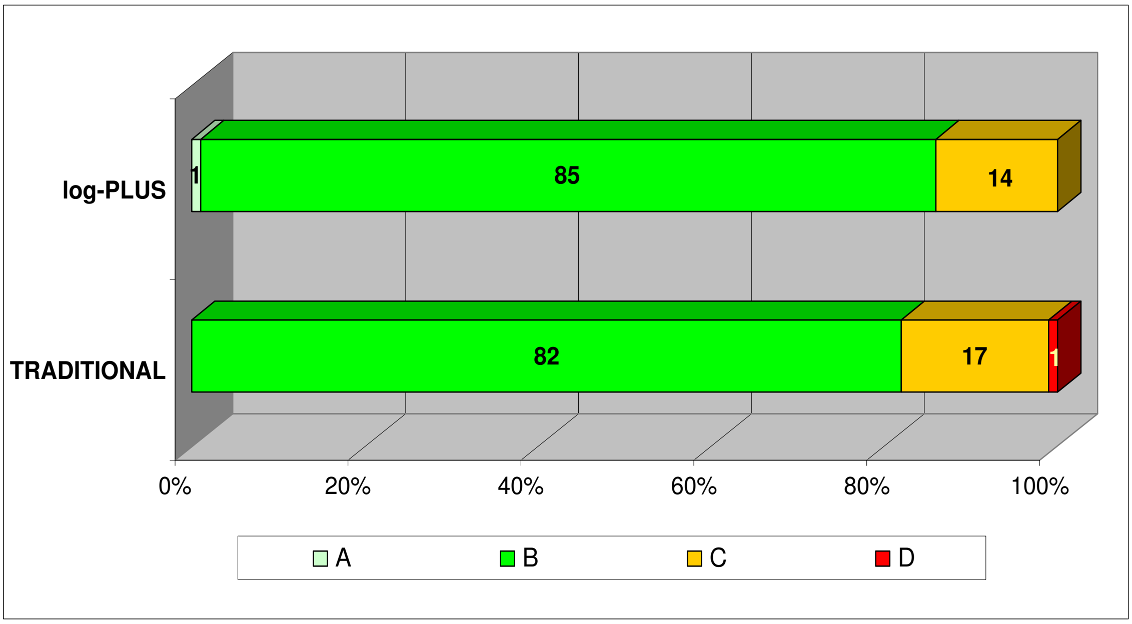
Table 1: Estimation scheme for energy wood yield

ONE cubic meter ... accomplishes ... energy wood						
sorting	stem wood (m3 ub)			whole tree (m3 ob)		
	DM	m3 ob	bulk m3	DM	m3 ob	bulk m3
TRADITIONAL	0,1	0,1	0,4	0,1	0,1	0,3
log-Plus	0,3	0,7	1,7	0,2	0,4	1,0
mixture	0,2	0,4	0,9	0,1	0,3	0,7

A maximised stem and industry wood yield is covered by the traditional bucking concept in this table. In contrast the log-PLUS concept represents an equally stem and energy wood orientated bucking concept. These two extreme bucking concepts are balanced by a mixed concept (stated "mixture" in tab. 1) which

can be assumed, to cover the majority of bucking concepts actually in use by forest managers. The presented factors represent no theoretical energy wood potential but match the actual useable technical energy wood potential.
The bucking concept affected not only the distribution of the wood amount by product groups and the average piece-volume but also the distribution of the stem wood quality. An amendment of the stem wood quality of approximately 4 percentage points could be stated in the log-PLUS concept in comparison with the traditional alternative focussing on the classification “B and better” of the German “HKS” quality scheme (Figure 3).

Figure 3: Distribution of the stem wood quality



These differences had also an impact on the stem wood revenues. The average stem wood revenue of the log-PLUS concept was 82,6 EUR per m^3 ub which is approximately 1.5 % higher than the traditional bucking concept. The quality-caused revenue advantage of the log-PLUS concept could not compensate the deficiency of the reduced stem wood yield in total. Considering the average total revenue per m^3 the traditional bucking concept produced with 69.6 EUR/m^3 a higher average total revenue by approximately 5.8 EUR/m^3 (about 9 %) compared with the log-PLUS concept.

3.2 Performance and Cost

In general the modified Cable dredger System has been approved for combined production of stem and energy wood, which is obvious by high performance levels of all sub-operations at last. Both bucking concepts show favourable cost levels with processing costs of 17 to 23 EUR/m^3 ub (without chipping free on forest road) and approximately 28 EUR/m^3 ub (with chipping free on forest road) in steep terrain (Table 2).

Table 2: Performance and Cost data of the Staufen trial

STAUFEN trial	TRADITIONAL			log-PLUS		
	stem w.	energy. w.	total	stem w.	energy. w.	total
performance (m3 / working hour)						
felling and processing	3,3	1,0	4,3	2,9	1,7	4,6
pre-skidding w. cable dedger	16,3	5,1	21,4	16,2	10,3	26,5
final processing	33,8	10,7	44,5	32,7	19,2	51,9
final skidding w. forwarder*	18,4	5,8	24,2	12,2	7,1	19,3
chipping of energy wood*	0,0	33,1	33,1	--	46,2	46,2

Compared with the traditional alternative the log-PLUS concept attains a generally more favourable cost- and performance level in the overall view (table 2 blue column "total"). Varying reasons can be named for the differing cost- and performance levels concerning the sub-operations:

- In felling and processing reduced log processing in the crown has an positive impact (reduced delimbing, cross-cutting, etc.).
- The pre-skidding with cable dredger is dominated especially by the relation of stem to energy wood (attached crown) per tree, i.e. from the log processing in the crown. Due to the increased processing in the crown (reduced total skidding volume) in the traditional concept the pre-skidding velocity per tree of the cable dredger is not affected significantly, but the reduced relative skidding volume causes an unfavourable performance and cost level compared with the log-PLUS concept.

STAUFEN trial	TRADITIONAL			log-PLUS		
	stem w.	energy. w.	total	stem w.	energy. w.	total
costs (EUR / m3)						
felling and processing	4,2	1,3	5,5	3,2	1,9	5,0
pre-skidding w. cable dedger	6,3	2,0	8,3	5,1	3,2	8,3
final processing	1,2	0,4	1,6	0,9	0,6	1,5
final skidding w. forwarder*	4,5	1,4	5,9	4,7	2,8	7,5
chipping of energy wood*	--	6,7	6,7	--	5,4	5,4
total costs w/ o chipping	16,2	5,1	**21,3**	13,9	8,4	**22,3**
total costs	--	11,8	**28,0**	--	13,8	**27,7**

* - in m3 m.R.; remaining numbers in m3

- For the final processing especially the number of logs per pole length, i.e. the relative stem wood percentage, was important, being more favourable in the log-PLUS concept.
- Regarding the final skidding with forwarder the log-PLUS concept achieved an unfavourable performance and cost level compared with the traditional alternative. The crowns of the log-PLUS concept were more voluminous reducing the loading capacity, both by solely energy wood skidding as well as in the mixed skidding of stem and energy wood, with negative impacts on performance and costs.
- The chipping of the energy wood with a truck chipper is primarily influenced by the piece-volume of the energy wood logs.

In both trials the costs for the energy wood chipping on the forest road represented approximately 20 - 25 % of the total costs of the processing system. The chipping of the energy wood represents thus the most cost intensive sub-operation of this supply chain (table 2). To optimise the efficiency of the chipper two elements are important: Optimisation of the logistics supply chain (availability of empty containers) and reduction of unproductive working time by optimised energy wood piling (large-scale energy wood depots, favourable switching areas for containers). A relevant impact is caused by the piece-volume of the energy wood segments as well as the yield per hectare, furthermore.

4. Evaluation

4.1 Operational safety and ergonomics

The additional supply of energy wood has no negative impact on ergonomics or operational safety. Regarding the sub-operation “felling and processing” the log-PLUS concept creates an even more favourable situation due to decreased degree of log processing in the crown.

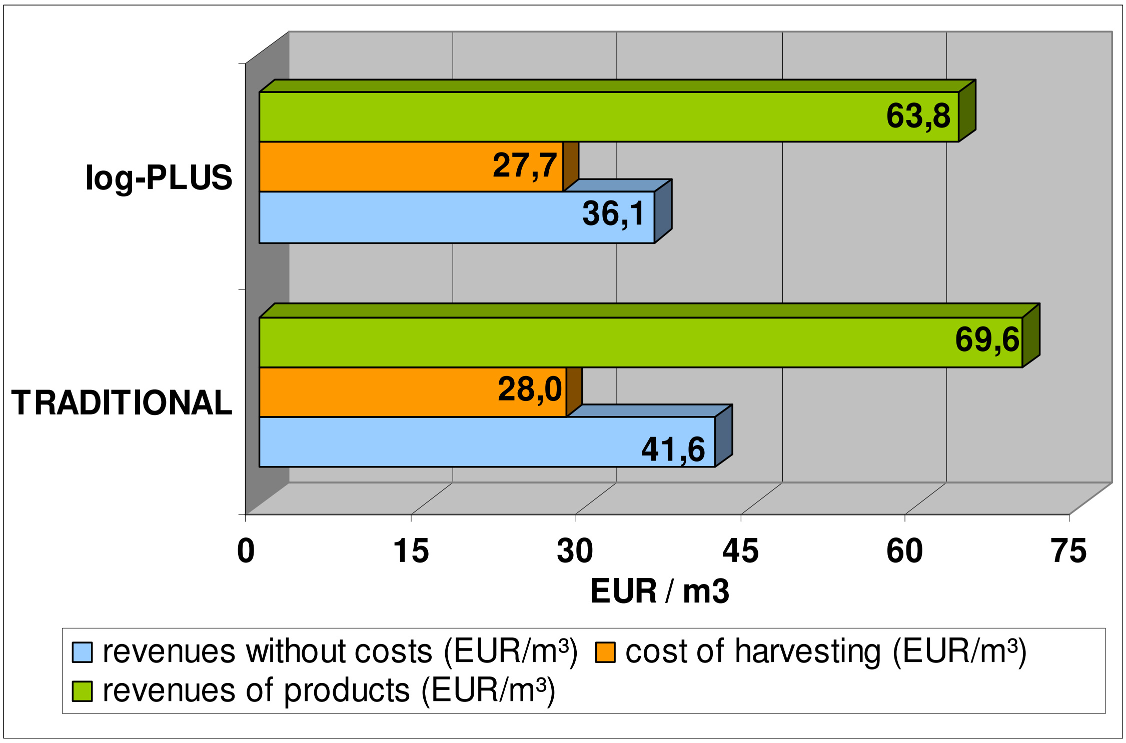
4.2 Impact on residual stand

The most relevant factor is has the transport length of pre-skidded or skidded assortments concerning the impact on the residual stand. In the “Staufen“ trial pole length with attached crowns were pre-skidded by the cable dredger in an extremely steep slope. Both factors potentially increase the risk of negative impacts on the residual stand.
The results of the impact analysis show no significant differences in regard to the bucking concept, but in regard to the stand density after felling. In stand areas with a low average tree distance (6 – 7 m) the percentage of damage was approximately 25 %. In contrast the percentages of damage was approximately 15 % in stand areas with a higher average tree distance (9 – 10 m).

4.3 Economics

The economical evaluation of processing or bucking system is measured by the contribution margin, which is calculated by the difference between revenues of products and harvesting costs (revenues without cost of harvesting). Relevant influencing factors are ecological factors like stand and inclination of the terrain but also operational factors like bucking strategy and processing system.
The average total revenues of the log-PLUS concept was reduced by 9 % compared with the traditional alternative due to the differing distribution of stem and energy wood percentage as result of the bucking guidelines.
The changes of distribution of stem and energy wood, due to bucking, resulted in the “Staufen” trial in a reduction of the average total revenue by 9 % in the log-PLUS bucking in comparison with the traditional bucking. The revenues without harvesting costs even show a difference of 15 % at the expenses of the log-PLUS concept (Figure 4).

Figure 4: Economical overview subdivided in bucking variations



The log-PLUS concept could not compensate the deficiency of the reduced stem wood yield in total, despite various positive effects in terms of quality distribution of the stem wood as well as performance and cost data.

5. Conclusion

Since 2005 the FVA Baden-Württemberg analysed trials evaluating approaches of a combined production of stem and energy wood. Especially aspects were focused concerning energy wood optimised bucking concepts (log-PLUS concept) in comparison to traditional bucking alternatives as well as the general adequacy of approved processing systems for a combined production of stem and energy wood.

The "Staufen" trial showed that …

- slightly modified processing systems are adequate in terms of an efficient combined production of stem and energy wood
- in tendency the log-PLUS concept shows a favourable quality distribution of the stem wood as well as favourable performance and cost data
- these advantages could not compensate the deficiency of the reduced stem wood yield in total
- critical impacts on the residual stand are caused in areas with low average tree distances (6 – 7 m)

Finally the combined production of stem and energy wood is an interesting approach which can be realized efficiently by slight modifications of established logging systems.

Anyhow the limiting factor for a combined production of stem and energy wood is, especially concerning the log-PLUS concept, the low revenues for wood chips in comparison to non-energetic assortment revenues.

6. References

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HIGHER FORESTRY EDUCATION, THE BOLOGNA PROCESS AND THE ROLE OF SILVA NETWORK

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Keywords: competences, curriculum development, BSc, MSc forestry programme, networking

Abstract: *The Bologna conference in 1999 initiated far-reaching changes of the complete system of higher education in Europe and started a process of a dimension not know hitherto. An internet search with the keyword "Bologna Process" with result easily in more than five million hits. Also in higher forestry education practically all study programmes are becoming due for fundamental revisions, which have already been started some years ago in many places and are in different stages of realisation now. The ideas of the Bologna process with, giving the new curricula at the University of Freiburg as an example.*

It is not surprising that the Bologna Process and its consequences are discussed also at many conferences on forestry education, among others at the annual meetings of the Silva Network. The meeting in Wageningen in 2005 concluded (Lewark et al. 2006) : "The Bologna Process aims at an improved mobility by standardisation of structures of curricula. Even in following this direction – mostly with three plus two years for Bachelor and Master curricula –a huge diversity is likely to persist. The importance of the local situation seems to have a lasting impact on both the type of universities and the contents of the academic forestry education. There will be no uniformity, but different profiles of curricula in different places, which – with a growing mobility – highly increases the students' opportunities for individual qualification profiles. The universities will cooperate, even share resources in joint activities like teaching, but they will also compete more than before." Networks do become more important tools for international cooperation and for the international performance and image of universities and programmes. Next to organising meetings, this cooperation could find a form in a website comparing forestry and/or natural resource management curricula, thus continuing the initiative of the SILVA Network in the Wageningen 1997 symposium."

1. The Bologna process

1.1 Dimensions and ideas of the Bologna process

One of the main driving forces of curriculum development leading to fundamental changes in many European countries today lies in the Bologna process. In particular and probably most obvious there were changes from a one stage curriculum to a Bachelor-Master system as shown for Freiburg (cf. 2.2), but many other ideas and initiatives are connected with the Bologna process.

The Bologna conference in 1999 initiated far-reaching changes of the complete system of higher education in Europe and started a process of a dimension not known hitherto. An internet search with the keyword "Bologna Process" with result easily in more than five million hits. The Bologna process has been named after the University of Bologna, one of the oldest European universities, dating back to the year 1088. In Bologna the second of the biennial now so-called "Bologna conferences" has been held and led to the Bologna declaration.

[7] President of SILVA Network; Deputy Coordinator of IUFRO education group 6.15.00

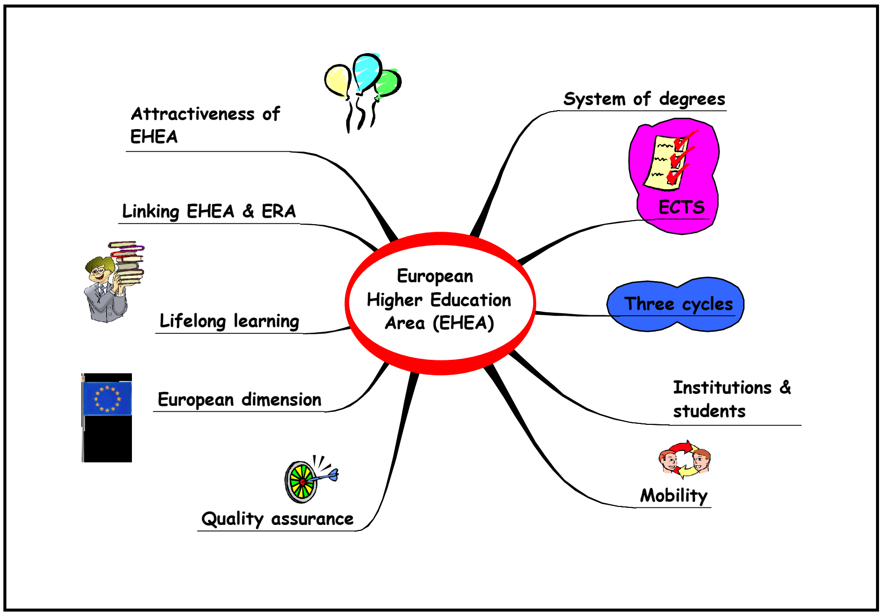

Figure 1: The Bologna process aims at creating a European Higher Education Area (EHEA) and is described in ten dimensions

The Bologna Process worked over different conferences of the ministers responsible for higher education: Sorbonne, Paris 1998 – Bologna 1999 – Prague 2001 – Berlin 2003 – Bergen 2005 – London 2007 (– Benelux 2009). The Communiqué of the Berlin conference "Realising the European Higher Education Area" formulates some aims:

> "Ministers reaffirm the importance of the social dimension of the Bologna Process. The need to increase competitiveness must be balanced with the objective of improving the social characteristics of the European Higher Education Area, aiming at strengthening social cohesion and reducing social and gender inequalities both at national and at European level. …
> Ministers take into due consideration the conclusions of the European Councils in Lisbon (2000) and Barcelona (2002) aimed at making Europe 'the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion' and calling for further action and closer co-operation in the context of the Bologna Process."

Also in higher forestry education practically all study programmes are becoming due for fundamental revisions, which have already been started some years ago in many places and are in different stages of realisation now. Some concepts, chances, risks and obstacles will be dealt with in this paper, using the curriculum development at the Faculty of Forest and Environmental Sciences at the University of Freiburg as an example, and finally looking back to discussions at Silva-Network conferences.

1.2 State of Bologna process in 2007 – stocktaking

For the Bologna conference in London 2007 a stocktaking has been done using scorecards, which gives an overall picture of the state of the process as well as a detailed account of the state in the 46 member countries of the Bologna process according the issues implementation of the three-cycle degree system, quality assurance, recognition of degrees and study periods and linking higher education and research

(Anon., 2007a). The results are well documented on state level as well as aggregated for all states (Rauhvargers, 2007).

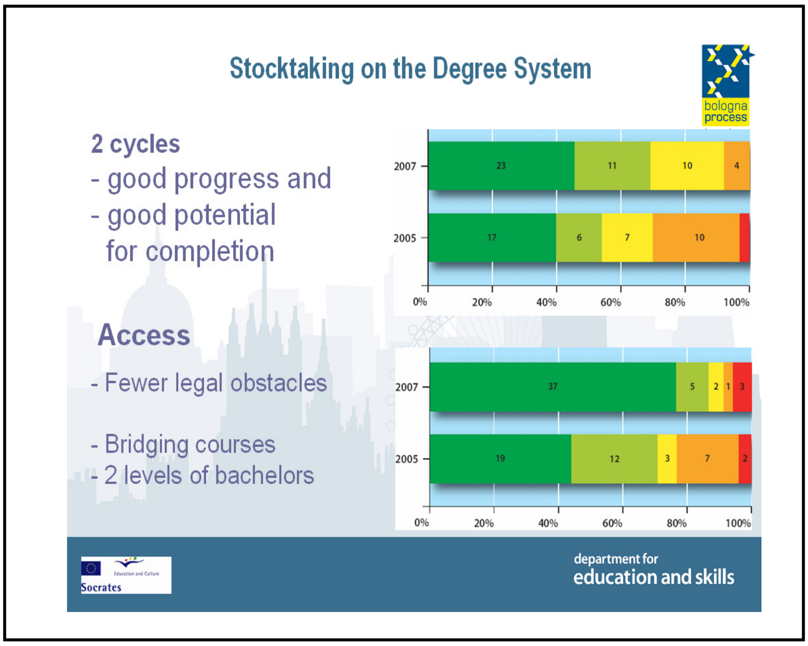

Figure 2: The state of implementation of degree systems in the Bologna process in the 46 signatory states according to the stocktaking process (Rauhvargers, 2007)

Conclusion 1 from the stocktaking report states (Anon., 2007a):

> “ The stocktaking results show that there has been considerable progress towards achieving the goals set by the Ministers in Bergen. …
> The Bologna Process has driven the process of higher education reform at national level. Higher education institutions, their staff and students, business and social partners, and international organisations are more actively engaged as partners in implementing the Bologna Process than was previously the case. The sharing of expertise has contributed to building capacity at both institutional and national levels so that there has been measurable progress across all participating countries.

At the same time the European students also evaluate the state of the process, with students’s eyes (Anon., 2007b): The student voice:

> “…in some countries student representatives are not regarded and treated as equal partners by Governments, institutions and other stakeholders.
> Some … principally regard students as troublemakers, no matter what they say or do. Only in a few countries, a sustainable partnership exists”.

1.3 Dominance of ministers versus participation of universities

The Bologna process has been started and is being organized top-down, i.e. by the European Ministers of Higher Education and the national representatives of the rectors or presidents of the universities. Accordingly the stocktaking is done on national level and represents general descriptions on developments going on. It goes without saying that there are huge differences between countries and between universities within countries. So the analysis of the situation in forestry education needs a much closer look and may reveal deviations of the shape of a single forestry curriculum from the general situation in a country.

The top-down approach also touches the self-understanding of universities with a certain "academic freedom", which together with traditions and structures again is different in different countries. More and more detailed regulations have to be considered in the creation of the new curricula. This may improve the learning/teaching situation by modernized approaches, but it may also downlevel and homogenize it.

In the case of Freiburg a block teaching system (teaching modules of one to three weeks length) has been successful over ten years. Opposed to didactical development it had to be substituted by a traditional hour based system again, as compatibility with other curricula at the university was wanted. That consequently meant less learner orientation and project based learning, which had been an achievement of the curriculum introduced ten years before. Also there was less flexibility in learning and teaching methods, as every modul had to be fixed in the regulations. Waiting for regulations on state level before decisions on faculty level, or changing again after decisions have been overthrown by these regulations was an additional problem, perhaps a "children's disease".

1.4 ECTS, workload, mobility

A common European labour market for university graduates is another goal of the Bologna process. This has a structural side. But also the graduates have to be fit for it, they have to achieve the necessary competences to use it – this includes language skills, intercultural competence and a general mobility in thinking and attitudes as prerequisites. Probably the best or only way to work for these competences is by mobility during education, through studying abroad, in other countries, through internships and many other ways of moving in other countries with open eyes.

SILVA Network (cf. section 4) has worked for mobility of students and teachers from its start. Now there seems to be a new challenge, as first experiences with the Bachelor curricula, at least with forestry students in Germany, indicate, that international mobility is going back as compared to before.

On the structural level an instrument for acknowledgement of study credits as well as performance and exam results has been created through he ECTS (European Credit Transfer and Accumulation System). Use of ECTS is in different stages of realisation as seen from the stocktaking report (in Freiburg introduced already in 1995).

Connected to ECTS and the general ideas of Bologna process are so-called workloads of students as new bases for constructing curricula instead of teaching hours of teachers, which is another great innovation. On the way to realize this and harmonize conditions in different European countries we find different lengths of teaching periods as well as different times of these teaching periods. So 60 credits for a fully and succesfully studied academic year means different things in different countries.

2. Changes of forestry curricula

2.1 Competence orientation

> “While the 2007 stocktaking found that there has been good progress on specific action lines and indicators, it is not enough to look at these in isolation because all aspects of the Bologna Process are interdependent. There are two themes that link all action lines: a focus on *learners*, and a focus on
> *learning outcomes*.
> If the Bologna Process is to be successful in meeting the needs and expectations of learners, all countries need to use learning outcomes as a basis for their national qualifications frameworks, systems for credit transfer and accumulation, the diploma supplement, recognition of prior learning and quality assurance. This is a precondition for achieving many of the goals of the Bologna Process by 2010.”
> (from conclusion 2 of the stocktaking report states (Anon., 2007a)

Competences connected to tasks in forestry become more and more exemplary, as completeness of knowledge for all possible challenges in the working life is less feasible then ever. Generic compentences are gaining weight. Because of developments on the labour market preparing students for occupations outside of forestry is necessary and must have consequences for curricula of higher forestry education.

This also means that it is not sufficient any more to characterize forestry curricula in terms of contents assuming that the compentences going with these subjects are commonly agreed and self understood. Schuck (2007) as well as earlier Huss & Schmidt (1998) have analyzed and discussed missions and objectives of higher forestry in this respect.

2.2 The example of the forest sciences curricula at the University of Freiburg

The study programmes at the University of Freiburg show a typical transformation from a one cycle (diploma curriculum, 9 semesters) to a two cycle system (6 plus 4 semesters for Bachelor and Master curricula) (Figure 3), further a diversification from a faculty with one curriculum till 1999 to a merged faculty (forestry, geography and hydrology in a Faculty of Forest and Environmental Sciences) with a multitude of curricula (Figure 4) (Fink, 2005, 2008).

The third cycle according to the Bologna terminology is also undergoing changes: from the PhD student as a junior scientist primarily working on his or her PhD thesis to a third cycle student with a standardized schedule and an obligation of taking courses and earning credits – a change of approach from a system traditional in Germany to a system with a British tradition, which is still under discussion.

4. Networking and the role of SILVA Network

> “International organisations dealing with forestry education have many important tasks to perform in order to support Forestry Education Institutions in the adaptation to a new phase.”
> “At meetings, international organisations can provide neutral fora to national and international experts to share and discuss experiences. These international fora are often a unique occasion of dialogue for professors or experts to meet with people from different geographic areas - which is not very common - and to learn about complete different situations.” (Romeo & Souvannavong 2004).

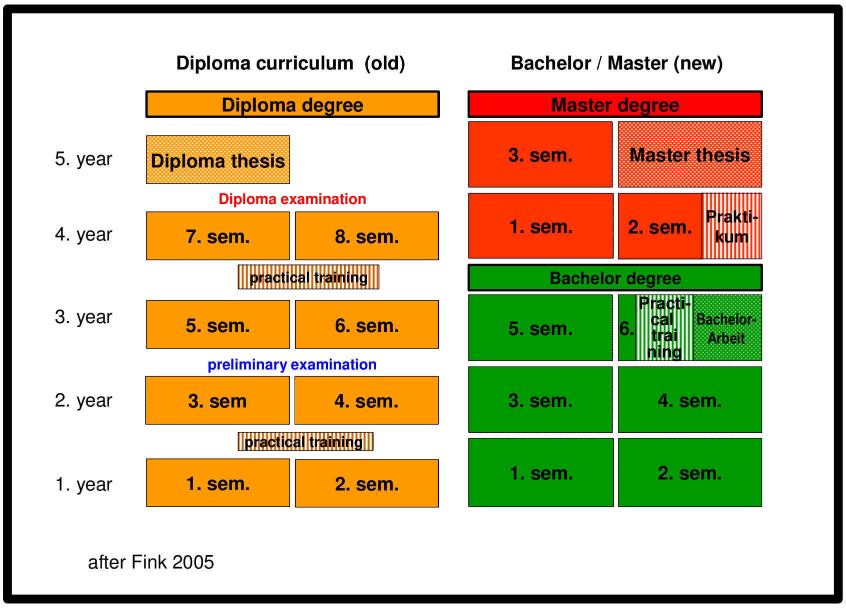

Figure 3: As shown here for Freiburg in many European countries the curriculum system recently changed from a one stage curriculum to a Bachelor-Master system (after Fink 2005)

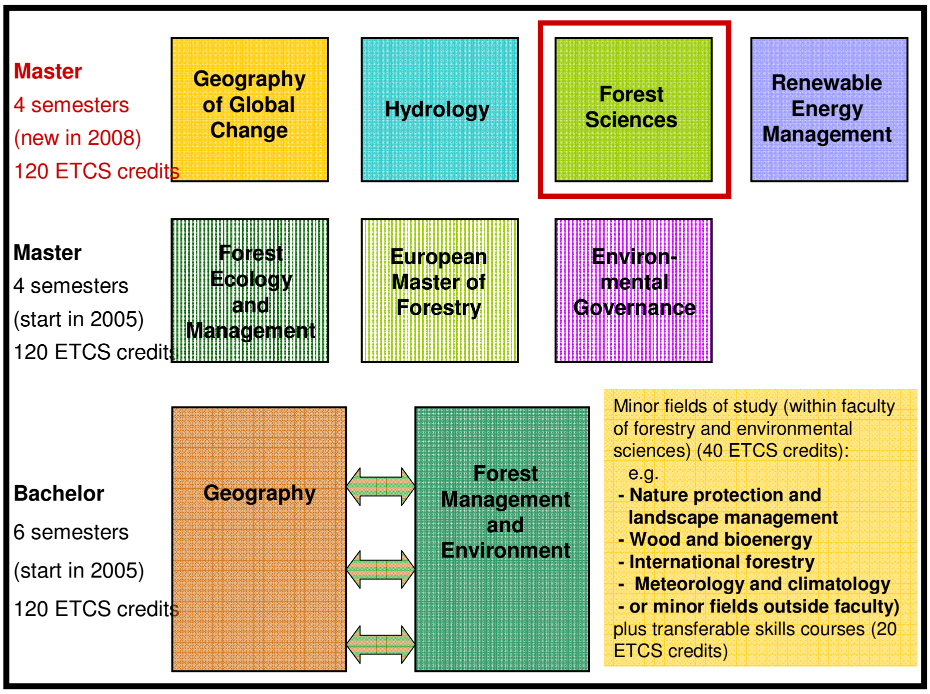

Figure 4: Diversification of curricula at the University of Freiburg (after Fink 2008)

SILVA Network, ANAFE and SEANAFE, the IUFRO Education group, unit Education, gender & forestry and the group Education and Research in Silviculture are examples of such networks. Participants of these international organisations or networks in most cases are universities or single faculties, in other cases networks, learning mostly is done during meetings and from proceedings. But the work done in the networks is very much depending on personal initiative of individuals, which is a strength and a limitation. It is certainly a big challenge to link the networks, which needs much travelling. It seems to be typical that the networks have more active and less active phases, they emerged and sometimes even are abandoned

The European network on forest science education on university level is SILVA Network (www.silva-network.eu) with close to fifty member faculties in 25 European countries (Lewark, 2008). The first ten years of SILVA Network have been described by Pitkänen et al (2004). During the second decade, from 1997 to 2007, SILVA Network has been based at the University of Joensuu, with Paavo Pelkonen as president, and further grown and developed.

The International Partnership on Forestry Education (IPFE, www.ipfe.info) was started in North America as a reaction to declining student numbers, in order to share ressources and experiences and serve as a network of networks.

One students' network deserves special mentioning: IFSA , the International Forestry Students' Association, which is a very dynamic network cooperating with all the other networks mentioned (www.ifsa.net).

5. Objectives and reality of the Bologna process – a résumé

The Bologna process will create a new landscape of higher education in Europe. This landscape, the overall picture is only partly recongnizable from the level of a teacher in any of the numerous forestry curricula throughout Europe. He or she will participate in this process, if all works well, in a curriculum commission creating the new curricula and new learning/teaching modules or adapting existing ones. In doing this he or she will come across many aspects of the Bologna process with impact on his or her working and teaching (and probably also researching) situation – some of them have been discussed here, based on the experience of the author at Freiburg, but also in accreditation and quality assurance processes elsewhere.

It is not surprising that the Bologna Process and its consequences are discussed also at many conferences on forestry education, among others the annual meetings of the Silva Network as platforms for exchange of ideas, information on ongoing processes and experiences,. The meeting in Wageningen in 2005 concluded (Lewark, Schmitdt and Bartelink, 2006) :

> "The Bologna Process aims at an improved mobility by standardisation of structures of curricula. Even in following this direction – mostly with three plus two years for Bachelor and Master curricula –a huge diversity is likely to persist. The importance of the local situation seems to have a lasting impact on both the type of universities and the contents of the academic forestry education. There will be no uniformity, but different profiles of curricula in different places, which – with a growing mobility – highly increases the students' opportunities for individual qualification profiles. The universities will cooperate, even share resources in joint activities like teaching, but they will also compete more than before."
>
> "Recent developments indicate that competition among universities will get a stronger international dimension in the coming years, both from a quantitative point of view (student numbers), and a qualitative one (quality of education and research). On the other hand, universities can take advantage of international cooperation. An important condition for mutual benefits is to take advantage of each others niche

expertise. This means: do not try to cover the whole world (Europe) in your curriculum, but foster your local speciality."

"Apparently, there is no such a thing as the Forestry curriculum. National, regional or local conditions will and should strongly determine the contents of forestry curricula. Not only the economically important issues like forest cover and importance of the forest industry for the BNP but also socially and politically important issues like the focus on production (among others timber) and reconstruction after the (second world) war or some political change-over, and richness and amount of leisure time play a role. Ecological conditions (e.g. boreal versus Mediterranean) are also reflected in the various curricula."

"Curricula contents should reflect societies' needs. The growing number of curricula on nature conservation and natural resource management can hence largely be explained by changing emphases in societies on the preservation of the natural environment, where forestry generally is considered one of the land-use types. The question should thus not be whether forestry and natural resource management can co-habit in one curriculum. Whether the focus is on natural resource management in general, or on forestry in particular, is largely a matter of focus, determined by local (regional) conditions. In the boreal zone, for instance, wood production (an important part of forestry) plays a key role from an economic point of view, which may legitimate the development of 'pure' forestry curricula. In many Western European countries, characterized by high population densities and high pressure on nature, more emphasis is put on the conservation of natural resources, including forests. Adapting curricula is thus not only a matter of responding to pan-European development like the Bologna-declaration; it should strongly be related to what is considered the backyard of the university (e.g. region, country), which is echoed in the needs of societies."
Further, "networks do become more important tools for international cooperation and for the international performance and image of universities and programmes. Next to organising meetings, this cooperation could find a form in a website comparing forestry and/or natural resource management curricula, thus continuing the initiative of the SILVA-Network in the Wageningen 1997 symposium.

"Finally, future forestry and future nature management require both future (i.e. different from now) scientists and field officers who also speak the language of partners from other disciplines. Universities, when developing curricula, should take that into account."

A main objective of the Bologna process is shortening the study time for the majority of students, who would be ready for the labour market with a BSc, whereas the others would go on with a master's programme or come back for a master's programme after some years of occupational experience. In reality it seems that the labour markets are not well prepared for BSc graduates in many European countries.

Many other topics have to be discussed including: quality assurance and accreditation or new subjects like forest & health or gender issues, among others. The role of e-Learning over the last ten years has been growing remarkably (Längin, Ackerman and Lewark, 2004), which opens new chances for interuniversity cooperation also in forestry courses.

The state and the universities primarily seem to want compliance with stipulations and are happy if the faculty meets them, but often do not care about the learning process. Didactical considerations with the paradigm of learner orientation play a minor role in the process, even if didactical centers are established on state and university level.
A crucial problem with evaluations and accreditations is, that the standards of quality in peer reviews will always reflect the insights and the level of consciousness of the reviewers (Cobb, 2007). If we have a

dominance of structural approaches and little regard of learning processes, accreditation will also be done solely on the basis of structures.

Summing up at the end: Let's see the big idea, the great innovative approaches to be realized, the big chances of the transformations accordings to the Bologna process. Among the things working nicely already I would name for instance ECTS (cf. 1.4). Another achievement is the chance of rethinking direction of study after the Bachelor study and perhaps continuing with a Master programme from a different field.

Let's look at the problems on the way as pointed out as challenges, worthwhile to overcome, like the seemingly reduced international mobility of forestry students as compared to before. And let's work together to improve education, students and teachers of the European countries and worldwide. Networks like SILVA Network, which has worked for mobility of students and teachers from its start, networks of forestry education with much personal knowledge of colleagues with similar questions, problems and backgrounds are helpful and at the same time very rewarding for those joining in.

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MODELLING OF ALLOCATION EFFECTS ON SUSTAINABILITY IN THE EUROPEAN FOREST-WOOD-CHAIN WITHIN THE FIELD OF FORESTRY TO INDUSTRY INTERACTIONS

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Statement of the problem

The Brundtland report (1987) describes sustainable developments as such that "meet the needs of the present without compromising the ability of future generations to meet their own needs"[8] and the European Union pledged themselves to transfer this principle of sustainability to all economic sectors. Europe's forestry's growth chances and competitiveness are particularly linked to the aspect of sustainability: only if forests, which are a natural and renewable resource, are managed sustainable at all levels (ecologic, economic and social), they yield great future chances in a regional perspective as well as in a global context.

Therefore, sustainability issues within

- Harvesting methods
- Transport and Logistics systems
- Wood quality and Allocation

are of particular interest, and will be determined in this work by means of system analysis and (business) process modelling, calculating indicators for economic, environmental and social aspects

Scientific approach

Firstly, today's present situation, the aim as well as the corresponding processes are determined.

Secondly, for the modelling and calculation of the processes of the European FWC a professional modelling software is used, in this case ARIS Architect. Consequently, the individual processes of the from tree harvesting and wood transport to the provision of pre-processed materials fed into industrial processes are described as value-added process chains and event-driven process chains (EPCs). Loops, decision points and variants are described as they are. For a later point in time, modelling of scenarios is planned.

Within the EPCs it is possible to link the individual activities (sometimes also called "functions") with economic, environmental and social indicators, such as production cost, energy consumption, employment, GHG, … . Those indicator represent a selected and balanced set from IPCC and MCPFE indicators. Values for these individual indicators are either calculated within this model itself, or by already existing partial models for allocation, wood quality, transport and harvesting.

In the consequence, all processes and activities are linked with numeric values (eg m³ sub, tkm, €/m³, …) for each indicator, which assess the process's sustainability. Those can be summed up per chain alternative, thus comparing the sustainability of different alternatives on basis of hard figures for all three levels of sustainability.

[8] UN, General Assembly, A/RES/38/161, 1983

(3) the main findings
shall be found in the determination, calculation, modelling, and subsequent optimisation of

- Timber and fibre characteristics
- Interaction between wood quality, processing and product quality (sawlogs, pulpwood, bio-energy)
- Quality characteristics of raw timber
- Methods of planning and production (harvesting methods)
- Transport methods and systems

Overall target: Analysis of effects and consequences of changing framework conditions

(4) implications for further research or for practical use:
more information about product as well as process characteristics will strive towards a better – and more sustainable – choice of methods applied. This will have an economic, as well as an environmental and social output.

ANALYSIS OF LOGISTIC PROCESSES AND OPTIMISATION POTENTIAL OF THE WOOD SUPPLY CHAIN SUPPORTED BY SPECIAL METHODS OF PROCESS MODELING

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Keywords: Wood supply chain, process optimization, process modeling

Introduction and purpose

The supply of round wood requires effective logistics and optimized configurations of material and information flows. The wood supply chain between German forestry enterprises and wood industries is characterized by different kinds of interactions, participants, dispersed work places and techniques of electronic data handling. Consequently various kinds of operative and administrative activities have to be coordinated. To find out ways of improving economical operation strategies, this research project aims for a complete presentation of existing wood supply chains including all parts like forestry enterprises, service industry (felling and transport enterprises) as well as the wood industry. Using a selected suitable rural region, the research analyses the status quo of existing forest wood supply chains as well as the potential of optimizing the supply chain regarding the improvement of the economic basis of the sector.

Research objectives

To develop sustainable concepts of optimisation along supply chains logistical data like times and costs are collected for defined activities applied to the main processes of the wood supply chain: Harvest planning and preparation of harvest cut, harvesting operations, wood sale and wood transport. Possible savings in time, costs, distances and specific enterprise organisations are analyzed. Different actors, workflows, assortments and harvesting methods are considered.
Additional to a case and time study based research of all operational procedures of the supply chain, the processes will be modelled with the tool of special business software (ARIS by IDS Scheer). Especially "event-driven process chains" are used.
Furthermore the configuration of forest specific and general modern information and communication technologies are implicated to improve information flows.

The output of defining different activities and processes, collecting logistical data and modeling processes is focused on the following main considerations:
Analyses of flaws:

- Logistic problems within the wood supply chain from forest enterprise to wood industry
- Temporal efforts and resulting costs
- Sites of fractures in the information flow
- Problems in using information and communication technologies
- Overflow/underflow of information and missing communication
- Consequences of calamities to the course of processes
- Deficient logistic integration of felling and transport enterprises
- Deficient implementation of the customers' requirements

Optimization potentials:

- Costs and time improvement by conceiving optimized supply chains
- Optimized application of information and communication technology
- Prevention of interrupted material and information flows by modeling efficient processes
- Logistical integration of service industry

Implementation

The results of this research project will enable the forest enterprises and the wood industry to rationalize the forest wood chain and to find efficient ways in organizing the wood supply.
Particular emphasis is placed on the development of a tool for visualising and modeling processes and to the impact of modern information and communication technology to the management strategies of forest and wood enterprises.

MATCHWOOD – FROM TREES TO PRODUCTS – PRODUCT-SPECIFIC ALLOCATION OF RAW MATERIAL TO THE WOOD INDUSTRY –

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Keywords: MatchWood; Forest Warehouse, supply-chain-management, logistic, wood properties; roundwood, allocation; optimization, utilization

Abstract:
The development of forest utilization concepts relies on modern techniques which are spatially precise and actual, considering the forest structures and the industrial demands as well. The cutting volume, the timing of intervention and the harvesting method should be aligned to the requirements and demands of the wood industry in the sense of a "Forest Warehouse".

The "Forest Warehouse" itself is the interface between the forest resource with its natural diversity and heterogeneity and the uniform product lines in the wood industry and allows to provide a product-oriented roundwood supply to the wood industry. Besides the quantitative supply with the required raw material, precise information about the wood properties are essential for an optimal product- and production-design. The concept of this "Forest Warehouse" allows the assessment of cutting volumes and the corresponding wood-quality in a position-specific way.

Considering the requirements of the wood industry on the roundwood, the efficiency can be increased. This leads to a reduction of the overall costs due to a customer-specific allocation of the roundwood. Quality failings, culls, sorting procedures and breakdowns can be minimized by delivering the required dimensions with the requested wood properties to the particular product lines of the wood industry.

To accomplish such a product-specific allocation of roundwood, concepts and instruments are developed within the research project "MatchWood – From the standing tree to the wood product: Added Value by process-optimization within the scope of a close-to-nature forestry". Among others, concepts and IT-tools like laser scanning, routing or stack management are involved.

IMPLEMENTATION OF MODERN TECHNOLOGY ON GREEK FOREST CONDITIONS

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Keywords: digital terrain model, geographical information system, global positioning system, implementation

Abstract: The digitized data management supported also by modern technology, like the digital terrain model (D.T.M.), in collaboration with the geographical information system (G.I.S.), and the global positioning system (G.P.S.), can contribute to the better ecological management and protection of the forests. The target of the present paper is the connection of two different scientific fields, the Global Positioning System (G.P.S.) with the Geographical Information Systems (G.I.S.), and its implementation on Greek forests. The contemporary technology of computer science provides a tool for structure and management of the graphic and descriptive information in a holistic environment. This tool is the G.I.S. The G.I.S. as a depiction tool is used to demonstrate the spatial data of an image. The continued progress of computer technology provides new potentialities for the traditional practical work of Forestry, because it combines the office where they process the data with the field works, using also digital maps and interactive bidirectional communication via palmtops and G.P.S. The measurements have been performed in 2008, at the Taxiarchis-Vrastama University forest, in the forest area “Solinaria”. The digital photogrammetric plotting of the research area will be used as the base for the database development in GIS environment. As we can see from the implementation of the present operation on forests, it is useful in the piloting of firefighting vehicles, or wood transportation machinery, on the digital map and in contact to the base, and also in harvest and forest road network planning and mapping in mountainous steep terrain, in the control of forest cadastral diagrams and thematic maps. The management of the digital information with the help of the modern technology, as is the Digital Terrain Model (D.T.M.), in collaboration with the Geographic Information System (G.I.S.) and the Global Positioning System (G.P.S.), can contribute in the better ecological management and protection of forests; especially the Mediterranean ones. The digital information can be useful in other applications such as:
- Photogrammetrical backgrounds of forest maps.
- Environmental Impact Assessments (E.I.A.)
- Fires.
- Land planning (Uses of land).
- Wine -growing and Olive-growing cadastre.

DEFINING ASSORTMENT STRUCTURE OF EVEN-AGED BEECH STANDS ACCORDING TO STANDARD HRN EN 1316-1:1999

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Keywords: common beech, assortment structure, Croatian Standard HRN EN 1316-1:1999

Abstract: Research was carried out in even-aged beech stands in continental part of Croatia, at Forest Administration Bjelovar, "Bjelovarska bilogora" management unit. In Croatia, share of beech is 36% in ratio of mixture and a similar share is in growing stock and year's timber mass marked for felling. The subject of research was probability of appearance of roundwood timber assortments in trees according to the type of felling and the difference between shares of roundwood timber assortments according to diameter class and type of felling. On the basis of the research results, new assortment tables were made according to Croatian Standards HRN EN 1316-1:1999. Research was carried out on a sample consisting of 787 trees in thinning felling, 788 trees in preparatory felling, 862 trees in seeding felling and 645 trees in final felling. An overall number of 3082 exemplary trees were included in the research. The age of the felling areas studied was between 59 and 91 years in the preliminary yield (thinning), 94 to 110 years in preparatory felling, 100 to 112 years in seeding felling, and 98 to 114 years in final felling areas. Using random selection, a sample of exemplary trees was made. Sample consisted of all beech trees marked for felling on predetermined azimuth lines. This way, shares of trees marked for felling were: 14.5% in thinning felling, 12.3% in final felling, 11.3 % in seeding felling and 10.7% in preparatory felling. Also, it was explored the probability of appearance of trees consisting of A, B, C and D assortment quality classes. Share of A class assortment quality was only 3.2% in thinning felling and 8.0% in preparatory felling. However, share of A class assortment quality was higher in seeding felling – 40.3% and 53.0% in final felling. Probability of appearance of B class assortment quality in seeding felling was 79.2% and in final felling was 86.7%. In thinning felling, share of B class assortment quality was 34.5% and in preparatory felling 44.2%. Probability of appearance of C and D classes of assortment quality was similar in all felling types. Total shares of C class assortment quality were 88.9%-95.4% and share of D class assortment quality was 97.6% in thinning felling and 99.7% in final felling.

The average participation of assortments in diameter classes and in different felling types was calculated using parabolic regression equation:

A quality class: Thinning felling and preparatory felling: $y = -0.0014x^2 + 0.0248x + 0.0209$, $R^2 = 0.7297$

Seeding felling and final felling: $y = 0.0008x^2 + 0.004x - 0.0014$, $R^2 = 0.8934$

B quality class: Thinning and preparatory felling: $y = -0.003x^2 + 0.0586x - 0.0844$, $R^2 = 0.7897$

Seeding felling and final felling: $y = -0.0027x^2 + 0.468x - 0.0752$, $R^2 = 0.7749$

C quality class: Thinning and preparatory felling: $y = 0.0006x^3 - 0.0182x^2 + 0.159x - 0.167$, $R^2 = 0.7254$

Seeding felling and final felling: $y = 0.0013x^3 - 0.0344x^2 + 0.2582x - 0.2800$, $R^2 = 0.8544$

D quality class: All felling types: $y = 0.0012x^3 - 0.0281x^2 + 0.1768x - 0.0165$, $R^2 = 0.3585$

Fuelwood: Thinning and preparatory felling: $y = -0.0035x^3 + 0.0779x^2 - 0.5357x + 1.4263$, $R^2 = 0.9746$

Seeding felling and final felling: $y = -0.0015x^3 + 0.0424x^2 - 0.3701x + 1.2265$, $R^2 = 0.9192$

Waste: All felling types: $y = -0.0004x^2 + 0.0094x - 0.0059$, $R^2 = 0.9593$

Timber assortment tables which take into consideration type of felling as one of the inputs, provide a more reliable estimate of assortment structure of the felling area and more precise planning of timber mass marked for felling. In this case, as a distinguishing factor, we took the selection criterion for marking trees for felling which is applied for the types up to, and including, the preparatory felling. For that reason, timber assortment tables were made separately for thinning and preparatory felling, and separately for seeding and final felling. Seeding and final felling show by ca 11% higher shares of top quality timber assortment (A and B class) than thinning and preparatory felling. On the other hand, thinning and preparatory felling show by ca 11% higher shares of lower quality timber assortment (C and D class) than seeding and final felling.

LOGGING OPERATION AND TREE FALLING TYPES IN FORESTS OF IRAN

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Keyword: Wind threw, mass movements, logging, forest

Abstract: A tree can fall due to several reasons such as storms, heavy snow, and earth quake or earth movement. Violence of this catastrophe relies on the forests and earth mass types. Commercial forests of Northern part of Iran are located at the latitude 35° 46′ to 36° 58′ and longitude 48° 30′ to 54° 30′. Hardwoods with 253 m^3/ha stand of these forests which are resistant against wind threw. In Northern forests of Iran are among mountainous forests with deep brown Forest soil. These forests are exposed to earthquakes, and earth mass movements which can causes tree falls even old high trees in forests. Logging operation can be conducted using semi – mechanical systems by chainsaw and the conversion and traditional extraction is done by beasts. Due to road destructions, and lack of the possibility for skid road network development, skidders can not be used in this area. If managers' purpose was to develop logging mechanism, it can be done by means of light machines.

Introduction

The commercial forests of Iran are located in longitude 48° 30′ to 54° 30′ and latitude 35° 46′ to 36° 58′. This moderate forest is a green belt stretching over the northern slopes of Alborz mountain ranges and covers the southern coasts of the Caspian sea. It has a total area of 1.9 million ha, which 60% of its stock growth is passed from logging age. Hyrcanian or northern forests of Iran stretch up to an altitude of 2300 m above sea level and encompass different forest types thanks to their 80 trees and shrub species. The forests are dominated by *Fagus orientalis Lipsky*, *Quercus castanifolia C.A.M.*, *Alnus glutinosa Gaertn* and it is exclusive site for some valuable species like *Populus caspica Bornm*, *Gleditsia caspica Desf*, *Parrotia persica Mever*, *Pterocaria fraxinifolia (Lam.) Spach, Acer laetum* and *Carpinus betulus L.*
These forests are seeding crop, uneven aged and combined by different broadleaves species and varying in type, age, diameter and height. This condition has the important role in trees establishment and strength against of wind. The moderate climate of Hyrcanian forest is formed because of southern and southeast winds movements on Caspian sea and their accident to Alborz mountain. This phenomenon made suitable situation for creation of Hyrcanian forests without strong wind and storms.
Forest damage caused by wind and snow is a serious economical problem concerning forestry. The timber damaged by storm is difficult to harvest especially during winter months and is typically low value timber. In addition, fallen and broken trees destroy power lines causing shortages in electricity supply, which may have very severe consequences in remote agricultural areas (Pellikka and Järvenpää, 2003).
Wind not only causes extensive damages to trees in many parts of the world, it also has more subtle effects on the growth and morphology of trees and forest ecology as well. Wind damage to trees has historically been the field of silviculture, but increasing recognition of the importance and complexity of the subject has recently got people involved from many other disciplines.
Due to the global climate changes, it is believed that the risk of further and stronger storms is increasing. In order to better understand the effects of wind on individual trees, forest stand and forest ecosystem, and further to practice the management of forests, it is necessary to summarize the research results related to this subject (Stacey *et al.* 1994; Jiao-jun *et al.* 2004).
Forest damage caused by wind depends on several factors: meteorological factors (wind speed and precipitation), topographical factors, forest stand characteristics, tree species and factors related to landscape, especially openness.
In this paper, we describe the different shapes of trees falling and the methods of their logging and extraction in Hyrcanian forests of Iran.

Most important commercial species of Hyrcanian forest

Beech (*Fagus orientalis Lipsky*): is the most commercial species of Hyrcanian forests. The extension of this species is started from elevation about 600 m and reached to 1800 m. the maximum diameter and height of beech trees are 180 cm and 50 m, respectively. Its sound age is limited to 250 year. The most of beech trees with about 100 -130 cm diameter and 30 - 35 m height in moderate and high elevation of Hyrcanian forests are sensitive to windfall (Fig. 1).

Fig 1. *Fagus orientalis Lipsky* in Hyrcanian forest of Iran (Lattalar site)

Hornbeam (*Carpinus betulus L*): Are the second main commercial and numerous species in Hyrcanian forest of Iran. This species is extended to 1500 m elevation from sea level. The maximum diameter and height of Hornbeam trees are 120 cm and 35 m, respectively. Also, its sound age is limited to 150 year. The most of Hornbeam trees with about 60 -100 cm diameter and 20-30 m height in moderate and low elevation of Hyrcanian forests are sensitive to windfall (Fig. 2).

Fig 2. *Carpinus betulus L.* in Hyrcanian forest of Iran (Lattalar site)

Acer (*Acer laetum*), Oak (*Quercus castanifolia C.A.M.*), Alder (*Alnus subcordata*) also are other main commercial trees in northern forest of Iran. These species with about 60 -120 cm diameter and 25-35 m height in all of the Hyrcanian forests are sensitive to windfall.

The coniferous species such as *Cupressus sempervirens var. horizontalis* and *Taxus baccata* are rare in northern forests of Iran and is restricted to ecologically specific area. Majority of these areas are protective and unlogging (Sabeti, 1994).

Soil condition

The soil type of Hyrcanian forests is originally forest brown in low land and in elevations is randzine. The soil is deep and its drainage is good because of terrain slope. Depth of soil facility the trees rooting and in many cases, the roots is extent about one meter in soil. Also surface extension of trees roots is suitable. Therefore, many of windfall trees replace the soil of own area more than 2 m^2. Soil depth, slope gradient and geological characteristics (Marl layer) are causes the mass wasting and tree falling.

Different shapes of trees falling in Hyrcanian forest

Trees falling in commercial forest of Iran are generally occurs by the storm. The majority of wind felled trees are old, high and individual (Fig. 3). Landslide or mass wasting is the second reason of falling trees. In mountainous regions of hyrcanian forest, mass wasting falls a group of trees in erratic form and mobilize them during failure. At this condition logging operation is so difficult and hazardous(Sarikhani, 2001) (Fig. 4).

Fig 3. Windfall trees in Hyrcanian forest of Iran (Lattalar site)

Fig 4. Landslide and group of felled trees

The methods of logging and extraction

For logging of the felled trees in Hyrcanian forest, administrative stages and emission of necessary justification should be done. Then delimbing and assortment of trees perform by chain saw. These felled trees in order to situation and their economical availability for skidders, may be bucked in to sections with coefficient of 2.6 or 2.8 m (maximum length is 10.4 or 11.2 m). If trees availability for skidders isn't possible or felled trees are outspread and individual, utilization of them haven't economic explanation. These trees are converted to traditional dimensions as cross tie (2.60 × 27 × 15) cm and lumber (280 × 32

× 14) cm and etc. then go out from forest by mule. When the mass wasting causes the falling of the trees in different groups, the situation and stability of ground haven't the suitable conditions for arrival of skidders. Therefore, traditional assortment and extraction methods are done.
Protect undamaged trees during salvage operations. Avoid selling undamaged timber as salvage unless a future timber harvest is impossible. More money can be lost selling good trees in a poor market than is made salvaging damaged trees. However, it is a good idea to remove as much of the damaged timber as possible in order to reduce fire hazard, minimize insect infestation, and lower site preparation costs. Wind damaged trees may not qualify as saw timber because of the internal damage they suffered.

The suitable machines for skidding
The skidding equipments which are used in Hyrcanian forests include of ancient machines such as Russian crawler Zetor and Romanian Taf E_{655} associated with new skidder machines of Canadian timber jack 450_C and HSM from Germany (Fig. 5).

Fig 5. Skidding machines in Hyrcanian forest a) Timber jack 450_C b) HSM

The forest structure, trees dimensions and slope condition in Hyrcanian forest of Iran are made impossible the use of feller buncher, harvester and forwarder. Among these machines, zetor have better efficiency and productivity in damaged stands and disturbed area. Because it is light and crawler, Therefore zetor can easily move in the destroyed lands.

Results

In order to dangers of traditional assortment of felled trees (due to wind or mass wasting) and also because of increasing the timbers additive value during the extract them as logs, it is necessary that used of logging machines for utilization and extraction the felled trees in Hyrcanian forest of Iran.
At present, 2 m^3ha^{-1} wind fall and broken trees (generally more than 3000000 m^3) are existent in northern forest of Iran. Thus, designing the suitable machines for logging of felled tress may have better economic performance. To access of this purpose, it is necessary that the logging of these trees carry out by chain saw and their skidding are done by light and rapid machine. These machines should be easily traffic on weak and sensitive ground. The tiny, light and quickly machines are providing the possibility of economical performance for dispersed falling trees.
According to Päätalo (2000), unmanaged pine stands are more susceptible to break and uproot by wind than managed stands. The susceptibility of unmanaged stands is caused by low tapering of the trees. However, forest management can also increase susceptibility. Several studies have shown that managed forests are more susceptible. The trees are most vulnerable for wind damage few years after thinning before the crowns have grown wider (Nykänen *et al.* 1997). It has been also noted that in unmanaged stands trees get support from each others and can stand the impact of snow and wind better (Peltola *et al.* 1997).

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COMPARING THE EFFECT OF FACTORS AFFECTING DAMAGE TO THE SURFACE OF LOGS BY FUNCTIONAL MECHANISMS OF HARVESTERS

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Keywords: harvesters, harvester heads, damage to log surface

Abstract: Losses resulting from the economic depreciation of sold wood due to the decrease of its quality and price are mostly caused because of the occurrence of quality and quantity defects originating during the production of logs. At the harvester production of assortments, the occurrence of these defects is mostly affected by determined physiological, technological and environmental factors. The weight of felled trees and assortments produced from them, growing season and, last but not least, the occurrence and thickness of branches rank among physiological factors. These factors cannot be changed or affected by man on a short-term basis. Badly selected pressure of delimbing knives and feed roles or badly sharpened or blunt cutting and delimbing mechanisms rank among technological factors. Badly selected type and size of a harvester and its felling and delimbing head or bad training, experience and carefulness of an operator can be considered to be environmental factors. Numerous field measurements were carried out in principal felling of even-aged spruce stands. In the course of these operations, Through the analysis of values obtained data were acquired and by their synthesis effects of particular factors were deductively determined on damage to logs.

<u>Factors determined:</u>
Physiological factors. *The frequency and the diameter of branches* - at cutting off large-diameter or numerous branches, it is necessary to exert more labour for their proper cutting off. This energy is transferred to the felled/processed tree by feed rolls and at exceeding certain limits their slipping can occur. Thus, damage to logs occurs in the place of the contact of these feed rolls with a stem.
Diameter class - the diameter of a produced assortment is directly related to the origin of production cracks, surface damage of logs by feed rolls and imperfect delimbing the logs. Production cracks are a result of the different resistance of wood at longitudinal and transverse loading. Smaller strength of wood across the fibre (at bending stress) results in its longitudinal split. The larger the diameter of a cut off assortment the larger its weight and thus the larger bending stress and the subsequent origin of production cracks. Damage to logs caused by feed rolls and imperfect delimbing is affected by the higher concentration of large-diameter branches and smaller thickness of bark in upper parts of a tree.
Technological factors. *Badly selected pressure of delimbing knives and feed rolls - slipping the rolls occurs as well as increased damage to the stem surface and imperfect delimbing or also incising the knives into a log.*
Badly sharpened or blunt cutting and delimbing mechanisms - blunt delimbing knives cause incomplete delimbing (chipped, ripped out or left residues of branches on the log surface). Energy necessary for cutting off branches is higher than in using sharp knives. Thus, larger damages can occur on the log surface due to slipping the rolls. Imperfect sharpening the cutting mechanism causes slow cross-cutting and thus extending the time of the effect of pressure on wood fibres in a critical point, ie in the place of cut where uncut wood fibres are not able to keep the weight of a cut off branch and rupture or ripping out the branches from the assortment occurs.
Environmental factors are dependent on activities of man being thus also most affected by man. If the bad type of a harvester or its head is selected or if the harvester operator is badly trained then a useless damage to produced assortments can occur.
Synergy of particular factors. Due to the interaction of particular factors their increasing above a tolerable limit occurs. Therefore, it is necessary to lay stress on the elimination of all removable factors causing defects.

TIME AND EFFICIENCY ANALYSIS OF HARVESTERS CTL 40 HW

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Keywords: logging, harvester, time-analysis, efficiency, cost
Abstract: *The experimental logging to be presented is a part of the international project "Development of Ecologically Compatible, Highly Productive Methods of Timber Harvesting for Central European Forests" (forstINNO; COOP-CT-2005502681). In this summary we present the most important results concerning this topic.*

1. Introduction

The specific features of the harvester head CTL 40 HW ("hardwood") are:

- It is able to cope with winding trees because there is only one pair of knifes and a flexible top knife.
- It has a hydraulic system which is optimized for cutting thick and steeply rising branches.
- Its saw does not tend to jump out of the bar while cutting multiple trees as much as known from standard heads.

The head has shown good technical results at oak, beech, hornbeam, nut and chestnut trees, but also at multiple stems in France and dense stands of robinia in Hungary.
The best results can be expected in stands with 25 cm DBH maximum (the felling diameter must not be more than 40 cm).

2. Data collecting

There is data available on the experimental fellings with harvesters, equipped with felling adapters from 9 different locations in five countries in the form of digitized data sheets with predefined contents. The part times were recorded in different dimensions.
An example of the first row of such a data table is shown in Table 1 (Iván, Hungary, skidding trail 1, day 1)

Time study "harvesting"   Location: Iván/Hungary   Data sheet no. 1

1	2	3	4			5				6			7			8	9	10
cycle	positioning [min]	species	conformation			branches				forks			assortment 1	2	3	cross cutting and delimbing [min]	other [min]	comments
1	0:02	R	X			X				X			4			0:27		
2	0:33	R	X			X				X			3			1:00		
3	1:04	R		X			X			X			3			1:25		
4	1:34	R	X			X					X		3	2		2:22		
5	2:27	R	X			X					X		3	2	2	5:04		
6	5:19	R	X			X					X		1	1	1	5:53		
7	6:01	R	X			X					X		4	1	1	7:08		
8	7:11	R		X			X			X			1	2	1	7:55		
9	8:45	R	X				X			X			2	2		9:28		
10	9:39	R	X			X				X			5	2		11:05		
11	11:07	R		X		X					X		3	1	1	13:05		
																	13:05-14:40	Chain change
12	15:06	R			X	X				X			3	1		15:15		
13	15:18	R		X			X			X			3			15:34		

Table 1 Data sheet

Based on the data in the data sheet we made the following modifications, calculations:

- we assigned weight numbers based on the different forms of the trees proportional to their difficulty
- time values given is seconds were calculated to thousands of seconds

- operation part-times and cycle times were calculated from the continuous time measurement data (locating a tree, processing, other times, productive cycle time – t_C minutes/cycle
- we determined the average volume of the different assortments (v;m^3/piece) produced on different locations and skidding trails)
- we summarized the number of assortments (N;piece) and their net volume (v, m^3/piece
- We summarized the assigned points expressing the 'difficulty' for each tree

Tables 2 show a data sheet completed with the calculations above (Iván, Hungary, skidding trail 1, day 1)

Time study "harvesting" no. 1 **Location: Iván/Hungary** **Data sheet**

1	2	3	4			5				6			7			8	9	10	11				
cycle	Positioning	Species	comform.			branches				forks			assortment			cross cutting and delimbing	Other	comments	Cycle time	assortment	volume	difficulty	Specific time
													1	2	3								
	[min]															[min]	[min]		(min)	(piece)	(net m3)	(point)	(min/m3)
1	0:02	R	1			1				1			4			0:27			0,45	4	0,052	3	8,65
2	0:33	R	1			1				1			3			1:00			0,55	3	0,039	3	14,10
3	1:04	R		2			2			1			3			1:25			0,42	3	0,039	5	10,68
4	1:34	R	1			1					2		3	2		2:22			0,95	5	0,131	4	7,25
5	2:27	R	1			1					2		3	2	2	5:04			2,70	7	0,397	4	6,80
6	5:19	R	1			1					2		1	1	1	5:53			0,82	3	0,192	4	4,25
7	6:01	R	1			1					2		4	1	1	7:08			1,25	6	0,231	4	5,41
8	7:11	R		2			2			1			1	2	1	7:55			0,78	4	0,238	5	3,29
9	8:46	R	1				2			1			2	2		9:28			1,55	4	0,118	4	13,14
10	9:39	R	1			1				1			5	2		11:05			1,62	7	0,157	3	10,30
11	11:07	R		2		1					2		3	1	1	13:05			2,00	5	0,218	5	9,17
																	13:05-14.40	Chain change	1,58	0	0	0	XXX
12	15:06	R			3	1				1			3	1		15:15			0,58	4	0,085	5	6,86
13	15:18	R		2			2			1			3			15:34			0,32	3	0,039	5	8,12

Table 2 Data sheet completed with the assigned weight numbers

3. Time analysis

The equation for the specific time (t_{sp};minutes/m^3) was calculated just occasionally, for the sake of control, because this can be calculated from the equation for the cycle time by dividing each side of the equation with V.

This way we have the 3 – 4 independent variables for the pre-defined equation form. We can perform correlation and regression analysis with the following assumption:

$$t_C = f(N;V;P)$$

thus

$$t_C = c * N^{\alpha} * V^{\beta} * P^{\gamma}$$

The time-equation from the last columns of Table 2 is for example the following 4 parameter function (Iván , 1. Day):

$$t_C = 0{,}843 * N^{0{,}294} * V^{0{,}466} * P^{0{,}553}$$

The t values for the exponents are as follows: t_N=1,70; t_V=4,75; t_P=3,65.

The following values characterize the reliability of the function:

R=0,600; R^2=0,36; H_r=52,3%; F=34,7;

Where H_r is the relative error, F is the value of the F test.

The results of the similar calculations on the other data sheets are shown in Table 3, providing a good insight into the inner relations.

Country	Location	Part data	No. of trees	tC/tSp	c	αN	βV	γP	tN	tV	tP	R	R↑2	Hr (%)	F
HU	IVÁN	1. Day	189	tC	0,843	0,294	0,466	0,553	1,7	4,75	3,65	0,6	0,36	52,3	34,7
		1.Day	189	tSp	0,841	0,295	-0,533	0,554	1,7	-5,43	3,66	0,46	0,21	52,3	16,4
		2. Day	150	tC	0,971	0,303	0,332	0,229	1,5	2,91	1,37	0,59	0,35	50,6	25,8
	SOPRON	2. trail	75	tC	1,18	0,035	0,505	0,779	0,13	3,03	3,13	0,58	0,34	57,3	12,1
		3. trail	70	tC	2,15	-0,062	0,585	0,671	-0,24	3,22	2,68	0,55	0,3	54,1	9,7
		4. trail	74	tC	1,31	-0,159	0,728	1,238	-0,52	4,09	4,71	0,66	0,44	55,2	17,6
		5. trail	80	tC	2,06	-0,086	0,659	0,811	-0,33	3,7	3,57	0,67	0,45	56,2	20,6
FR	ALLONDANS	thinning	230	tC	0,105	0,691	-0,026	0,717	0,02	-0,00	5,83	0,7	0,49	46,7	71,2
		thinning	230	tC	1,27		0,666	0,717		12,05	5,85	0,7	0,49	46,6	107,3
		clearcut	241	tC	35,92	-0,692	1,264	0,095	-0,01	0,02	0,9	0,63	0,4	48	52,9
		clearcut	241	tC	3,026		0,573	0,095		11,07	0,9	0,63	0,4	47,9	79,6
LT	DOTNUVA	1. trail	172	tC	0,446		0,256	0,788		4,61	4,41	0,45	0,2	46,8	21,7
		2. trail	100	tC	24,832	-1,234	1,5	1,278	-0,01	0,01	5,24	0,57	0,33	42,3	15,3
		2. trail	100	tC	0,275		0,266	1,278		3,55	5,27	0,57	0,33	42,1	23,2
		3. trail	53	tC	1,738		0,3	-0,140		2,89	-0,45	0,38	0,14	41,8	4,2
PL	WEJHEROWO	sum	99	tC	0,579	0,486	0,281	0,484	1,76	1,93	1,52	0,59	0,34	63,7	16,4
		sum	99	tC	1,386		0,493	0,602		6,01	1,92	0,57	0,32	64,4	22,6
	ZAPOROWO	1. trail	61	tC	4,495	-0,387	1,092	0,509	-1,12	3,56	1,55	0,71	0,5	54,7	19,6
		1.trail	61	tC	1,549		0,768	0,573		7,44	1,77	0,71	0,5	54,8	28,6
		2. trail	64	tC	8,011	-0,686	1,279	0,653	1,8	3,7	1,79	0,7	0,49	53,2	19,5
		2. trail	64	tC	1,17		0,689	0,704		6,23	1,9	0,68	0,46	54,2	26,6
		3. trail	43	tC	57,576	-1,335	1,707	0,477	1,38	1,88	1,07	0,58	0,34	53,8	6,5
		3. trail	43	tC	1,267		0,47	0,575		2,98	1,29	0,55	0,3	54,4	8,6
D	IDAR-	1. trail	37	tC	5,271		0,953	-0,164		5,53	-0,42	0,69	0,47	51,5	15,3
	OBERSTEIN	2. trail	19	tC	0,11		0,297	1,458		0,7	2,14	0,59	0,34	68,7	4,2
	kl. Fläche	3. trail	87	tC	0,896		0,377	0,288		3,17	1,53	0,35	0,12	55,6	5,9
	gr. Fläche/	10. trail	55	tC	1,452		1,003	0,587		7,07	2,85	0,74	0,55	48,1	31,6
	Hang	11. trail	44	tC	0,031	0,788	-0,430	1,157	0	-0,00	3,95	0,63	0,4	42,5	8,6
		11. trail	44	tC	0,225		0,358	1,157		2,18	4	0,63	0,39	42	13,2
		12. trail	65	tC	0,062	0,917	-0,389	0,663	0	-0,00	3,06	0,62	0,38	51,1	12,5
		12. trail	65	tC	0,643		0,528	0,663		3,52	3,09	0,62	0,38	50,7	19
		13. trail	44	tC	0,631		0,831	0,813		4,46	2,41	0,69	0,47	56	18,2
		14. trail	49	tC	0,361		0,48	0,948		3,07	3,14	0,6	0,36	49,6	12,8

Table 3 Time functions and their tests

The four parameter equations calculated on some of the datasets did not get parameters because of multicollinearity, or because of implicit mathematical relations within the function. (For example V=N*v, where v is the average volume of a single assortment). In these cases N is left out of the independent variables.

4. Efficiency analysis

Based on the functions norm tables can be calculated. Such a table is shown in Table 4., using the first function for the dataset Iván, Hungary (tsp; minute/m3). The reciproc values recalculated to m3/hour provide the efficiency under different conditions.

N (Assortment)	V (Volume)	P (Difficulty)	tSp (spec.time)	Productiveness
piece	(m^3/tree)	point	(min/m^3)	net m^3/hour
1	0,02	3	12,436	4,825
1	0,02	5	16,504	3,636
1	0,04	3	8,595	6,981
1	0,04	5	11,406	5,260
1	0,06	3	6,924	8,665
1	0,06	5	9,189	6,530
1	0,07	6	9,364	6,408
2	0,05	3	9,362	6,409
2	0,05	5	12,424	4,829
2	0,07	3	7,825	7,668
2	0,07	5	10,385	5,778
2	0,09	3	6,844	8,767
2	0,09	5	9,083	6,606
2	0,11	6	9,029	6,645
3	0,06	3	9,575	6,267
3	0,06	5	12,706	4,722
3	0,08	3	8,213	7,305

Table 4 Normtable and productiveness

Finally we calculated the average conditions of the experimental areas and the average efficiencies and time structures which can be calculated from these values. These values are shown in Table 5.

Land	Place/Region	Part-data	∑ Tree	∑ Assortments	∑ Volumen	AVERAGE DATA m3/Tree (V)	Assort./Tree	Volum./Assortm.	Difficulty	GAZ	∑ Timedata RAZ	Pos.	Cross cut	Other
		Day/Skid road	Piece	Piece	net m3		Piece (N)	m3/Piece (v)	∑ Point (P)	Min.	Min.	Min.	Min.	Min.
H	IVÁN	1. Day	189	899	27,35	0,145	4,76	0,030	4,05	274,93	251,08	34,38	216,70	23,85
		2. Day	150	594	15,28	0,102	3,96	0,026	4,00	162,10	153,15	37,97	115,18	8,95
	SOPRON	2. Skid road	75	341	11,65	0,155	4,55	0,034	4,55	221,77	133,64	28,80	104,84	88,13
		5. Skid road	70	344	13,79	0,197	4,91	0,040	5,03	200,08	168,18	38,30	129,88	31,90
		4. Skid road	74	353	15,4	0,208	4,77	0,044	4,43	169,27	167,74	29,58	138,16	1,53
		3. Skid road	80	341	13,11	0,164	4,26	0,038	3,95	284,02	151,41	31,93	119,48	132,61
FR	ALLONDANS	Thinning	230	1129	30,48	0,133	4,91	0,027	4,59	361,88	264,10	58,13	205,97	97,78
		Final cutting	241	924	25,87	0,107	3,83	0,028	5,17	340,60	268,87	47,96	220,91	71,73
LI	DOTNUVA	1. Skid road	172	512	16,44	0,096	2,98	0,032	4,02	181,63	131,93	49,75	82,18	49,70
		2. Skid road	100	314	8,16	0,082	3,14	0,026	3,62	94,60	72,13	37,07	35,06	22,47
		3. Skid road	53	150	3,83	0,072	2,83	0,026	4,28	60,57	45,99	17,97	28,02	14,58
PL	WEJHEROWO	Total value	99	518	39,01	0,394	5,23	0,075	3,63	280,85	211,77	37,55	174,22	69,08
	ZAPOROWO	1. Skid road	61	297	19,70	0,323	4,87	0,066	3,98	94,05	89,85	25,50	64,35	4,20
		2. Skid road	64	360	20,87	0,326	5,63	0,058	3,41	293,67	91,07	21,93	69,14	202,67
		3. Skid road	43	219	12,94	0,301	5,09	0,059	3,77	78,68	73,43	23,45	49,95	5,25
D	Idar-Oberstein	1. Skid road	37	128	8,06	0,218	3,46	0,063	6,3	44,43	37,98	14,42	23,56	6,45
	kl. Fläche	2. Skid road	19	54	2,48	0,131	2,84	0,046	5,58	16,92	16,42	7,27	9,15	0,50
		3. Skid road	87	274	17,81	0,205	3,15	0,065	4,82	79,08	70,51	32,00	38,51	8,57
	gr. Fläche/Hang	10. Skid road	55	253	20,24	0,368	4,60	0,080	5,67	90,32	88,18	26,17	62,01	2,14
		11. Skid road	44	224	17,92	0,407	5,09	0,080	6,41	77,95	65,52	17,22	48,30	12,43
		12. Skid road	65	308	24,02	0,370	4,74	0,078	6,25	96,05	90,50	21,40	69,10	5,55
		13. Skid road	44	209	14,66	0,333	4,75	0,070	6,32	57,62	53,70	14,10	39,60	3,92
		14. Skid road	49	223	15,61	0,319	4,55	0,070	6,29	67,50	64,70	17,95	46,75	2,80
	Sum total:		2101	8968	394,68	5,15	98,90	1,16	110,12	3628,57	2761,85	670,80	2091,02	866,79
	Average:		91,35	389,91	17,16	0,22	4,30	0,05	4,79	157,76	120,08	29,17	90,91	37,69

Land	Place/Region	Part-data	Timestructure in % from GAZ Pos.	Cross cut.	Other	Timestructur in % from RAZ Pos.	Cross cut.	∑ Pos. + C. cut.	Productivity net m3 RAZ Hour	GAZ Hour
		Day/Skid road								
H	IVÁN	1. Day	12,51	78,82	8,67	13,69	86,31	100	6,54	5,97
		2. Day	23,42	71,05	5,52	24,79	75,21	100	5,99	5,66
	SOPRON	2. Skid road	12,99	47,27	39,74	21,55	78,45	100	5,23	3,15
		5. Skid road	19,14	64,91	15,94	22,77	77,23	100	4,92	4,14
		4. Skid road	17,48	81,62	0,90	17,63	82,37	100	5,51	5,46
		3. Skid road	11,24	42,07	46,69	21,09	78,91	100	5,20	2,77
FR	ALLONDANS	Thinning	16,06	56,92	27,02	22,01	77,99	100	6,92	5,05
		Final cutting	14,08	64,86	21,06	17,84	82,16	100	5,77	4,56
LI	DOTNUVA	1. Skid road	27,39	45,25	27,36	37,71	62,29	100	7,48	5,43
		2. Skid road	39,19	37,06	23,75	51,39	48,61	100	6,79	5,18
		3. Skid road	29,67	46,26	24,07	39,07	60,93	100	4,99	3,79
PL	WEJHEROWO	Total value	13,37	62,03	24,60	17,73	82,27	100	11,05	8,33
	ZAPOROWO	1. Skid road	27,11	68,42	4,47	28,38	71,62	100	13,16	12,57
		2. Skid road	7,47	23,54	69,01	24,08	75,92	100	13,75	4,26
		3. Skid road	29,80	63,49	6,67	31,94	68,02	100	10,57	9,87
D	Idar-Oberstein	1. Skid road	32,46	53,03	14,52	37,97	62,03	100	12,73	10,88
	kl. Fläche	2. Skid road	42,97	54,08	2,96	44,28	55,72	100	9,06	8,79
		3. Skid road	40,47	48,70	10,84	45,38	54,62	100	15,16	13,51
	gr. Fläche/Hang	10. Skid road	28,97	68,66	2,37	29,68	70,32	100	13,77	13,45
		11. Skid road	22,09	61,96	15,95	26,28	73,72	100	16,41	13,79
		12. Skid road	22,28	71,94	5,78	23,65	76,35	100	15,92	15,00
		13. Skid road	24,47	68,73	6,80	26,26	73,74	100	16,38	15,27
		14. Skid road	26,59	69,26	4,15	27,74	72,26	100	14,48	13,88
	Sum total:		541,22	1349,93	408,84	652,92	1647,04	2300,00	227,78	190,76
	Average:		23,53	58,69	17,78	28,39	71,61	100,00	9,90	8,29

Table 5 Summary table

As a control we used the measured and calculated average values for the area in Iván (1. Day) and with the first equation we calculated the average efficiency:

$$t_{sp} = 0.841 * N^{0,295} * V^{-0,533} * P^{0,554}$$

$$t_{sp} = 0,841 * 4,76^{0,295} * 0,145^{-0,533} * 4,05^{0,554}$$

t_{sp}= 8,09 minute/m^3; 0,135 hour/m^3; 7,41 net m^3/hour.

The calculated value shows a minimal deviation from the global efficiency value for the operation. The main part of the difference comes from the logarithmic transformation of the data in the process of fitting.

5. Graphical display of results

Based on the functions we can show the inner time relationships using graphs (Figure 1 and 2)

Figure 1. Cycle time as a function of V and P (N = 5 = const.)

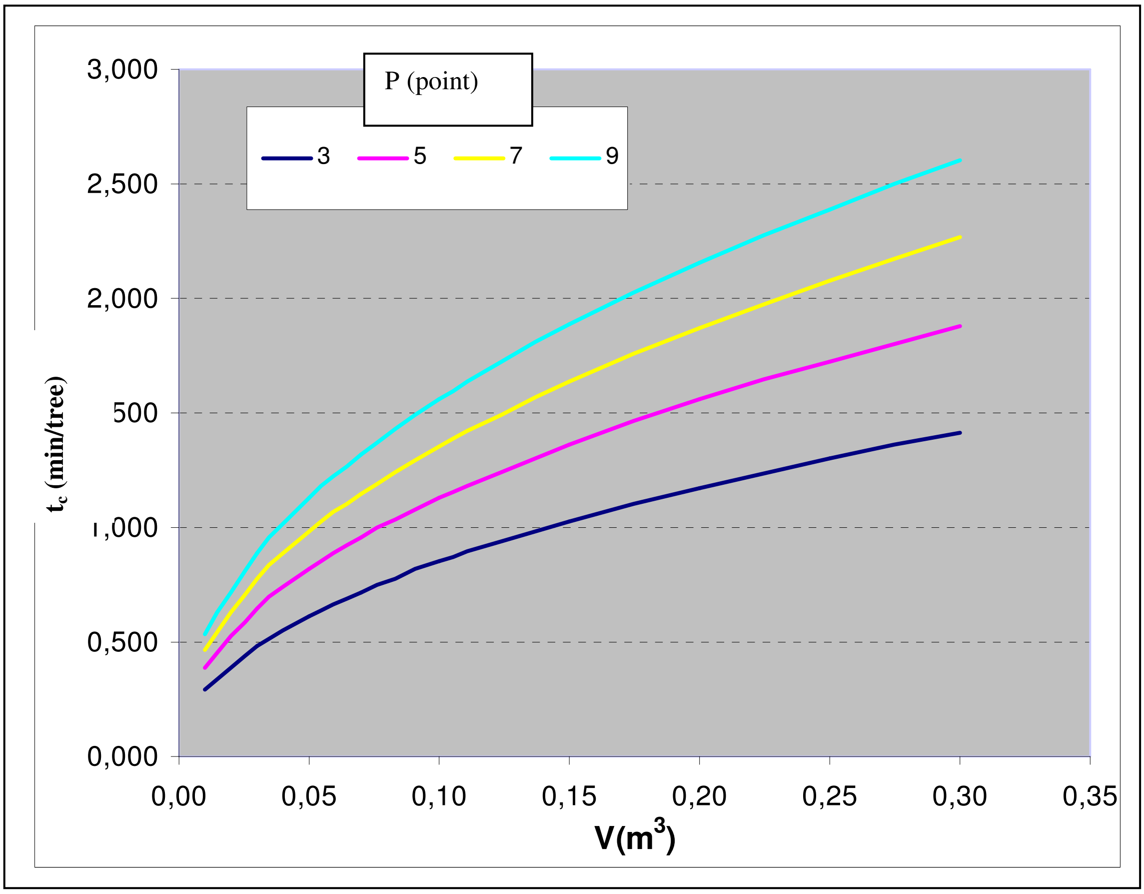
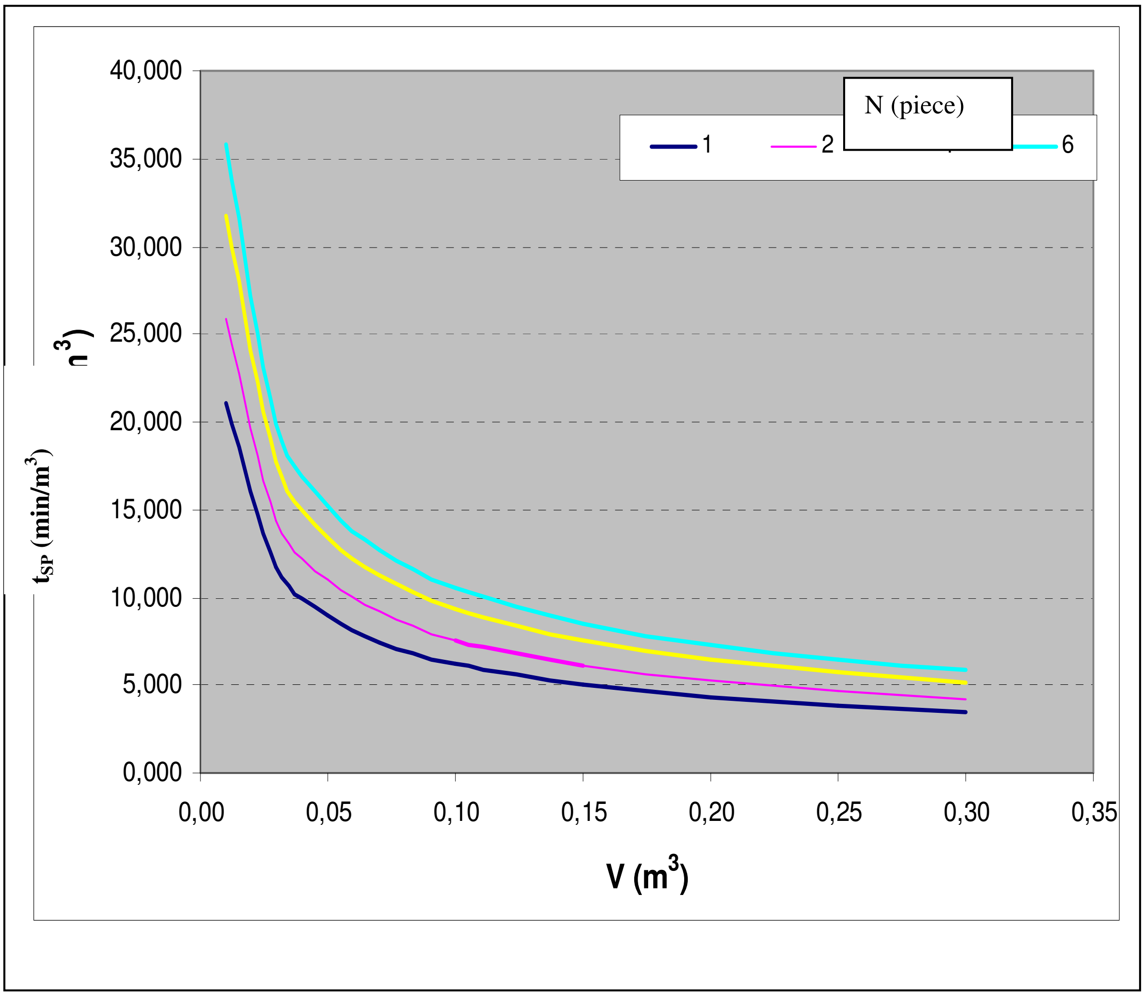


Figure 2. Cycle time as a function of V and N.   (P = 4 = const.)



We presented the most important productivity data based on three different trails - small (Iván 1. day), medium (Wejherowo) and large (Idar-Oberstein, trail 13) average productivity – on Figures 3 to 7. The efficiency values are in m^3/hour (E).

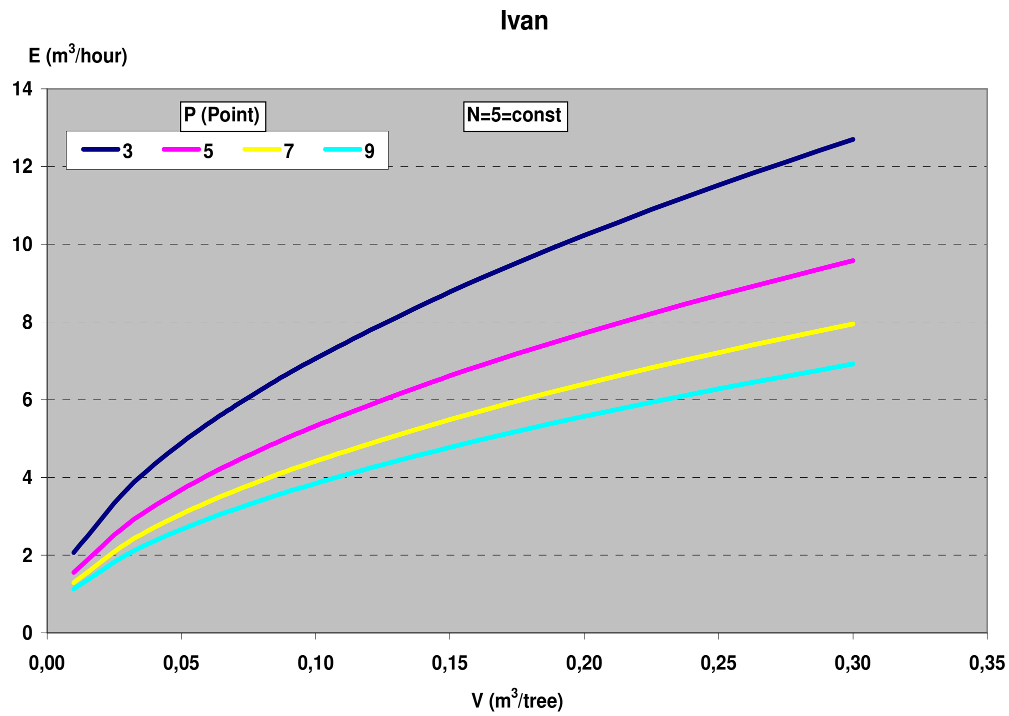


Figure 3 Efficiency in trail Iván 1. day with constant *N*

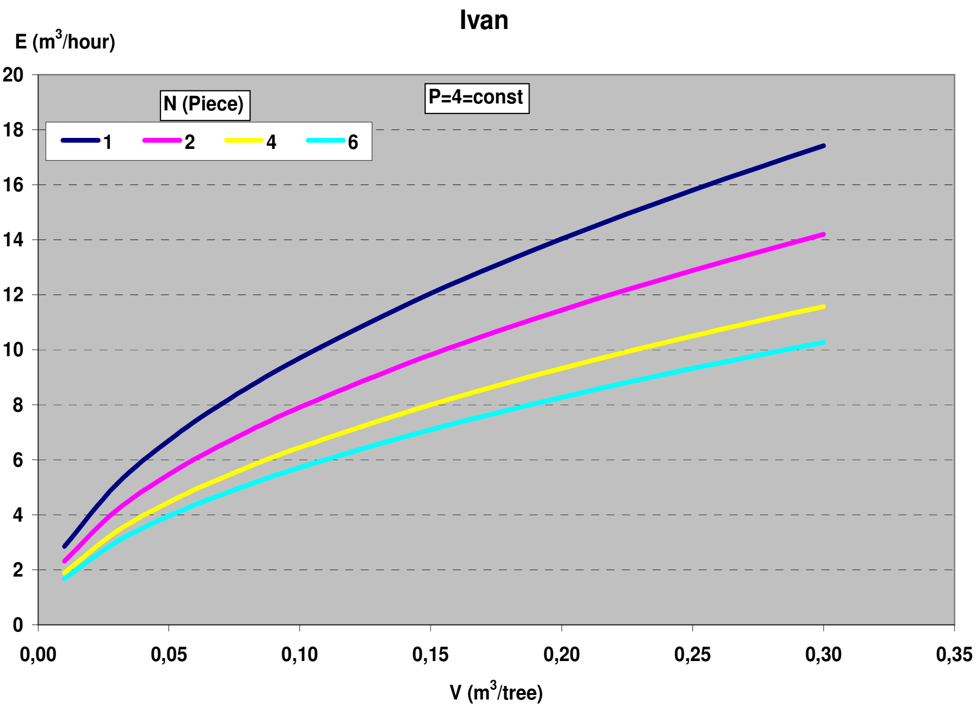


Figure 4 Efficiency in trail Iván 1. day with constant *P*

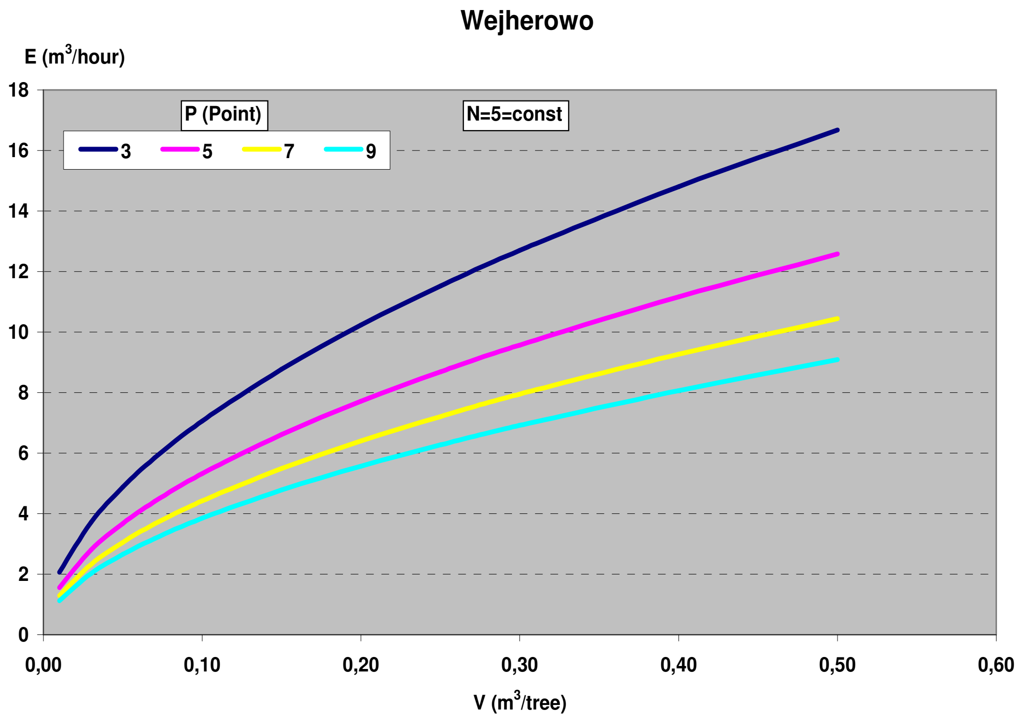


Figure 5 Efficiency in trail Wejherowo with constant *N*

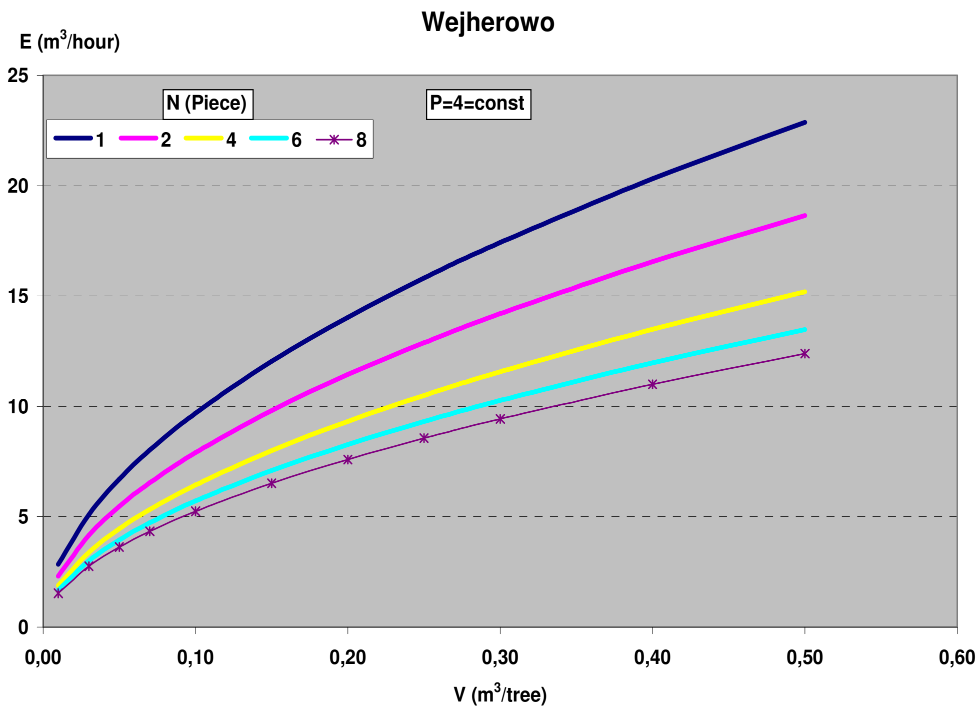


Figure 6 Efficiency in trail Wejherowo with constant *P*

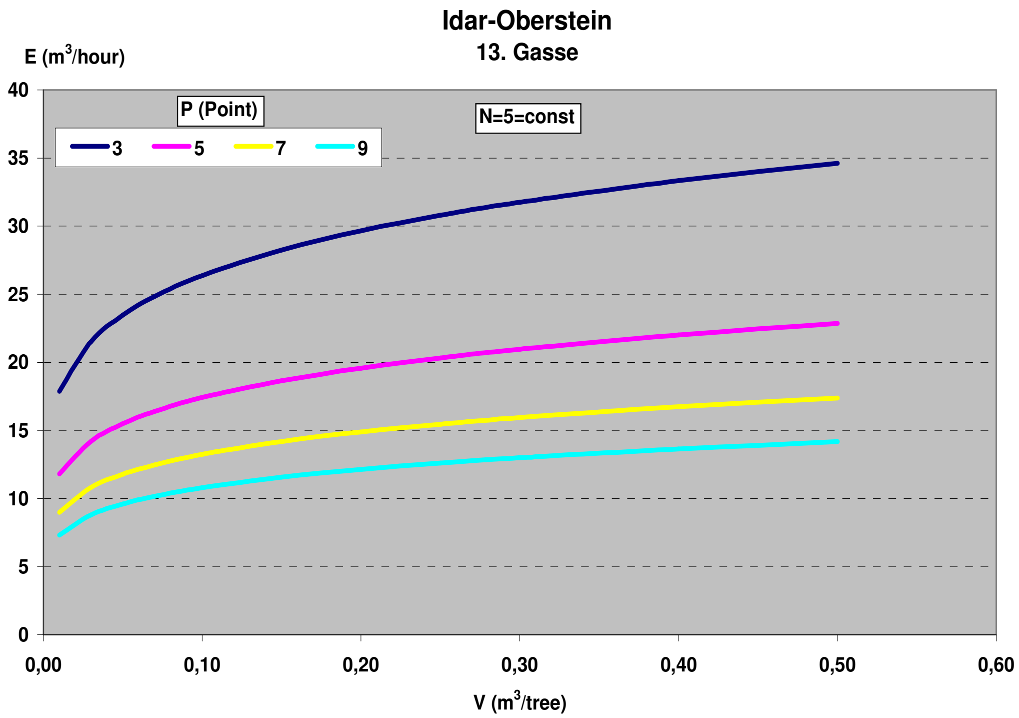


Figure 7 Efficiency in Idar-Oberstein, trail 13. with constant *N*

The summarized values of the time structure can be presented on a pie-chart (Figure 8 and 9)

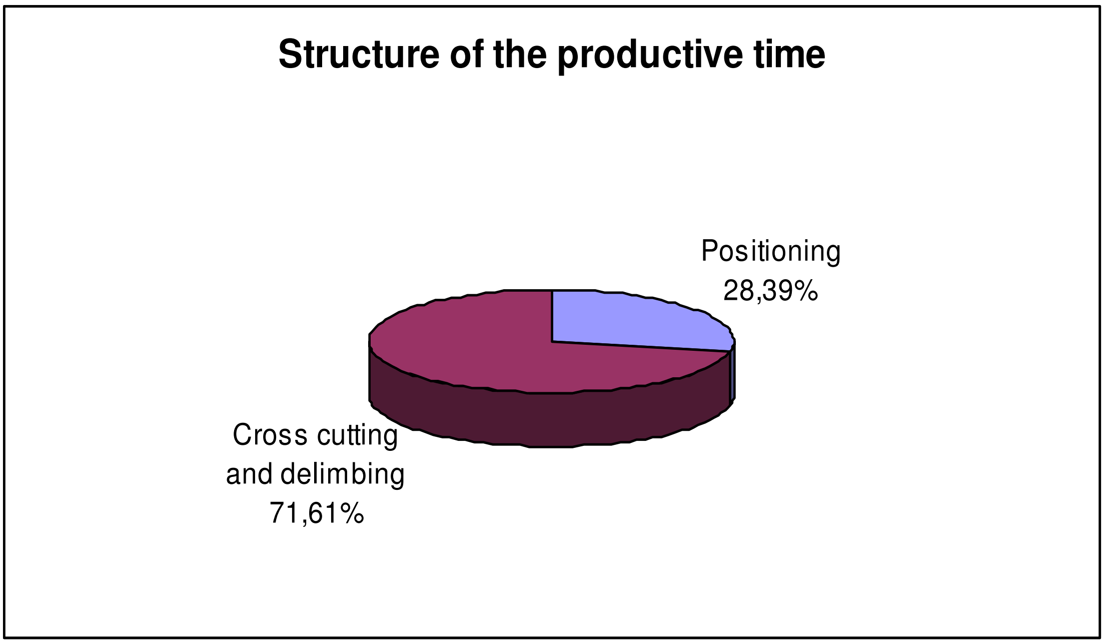


Figure 8. Structure of the productive work time

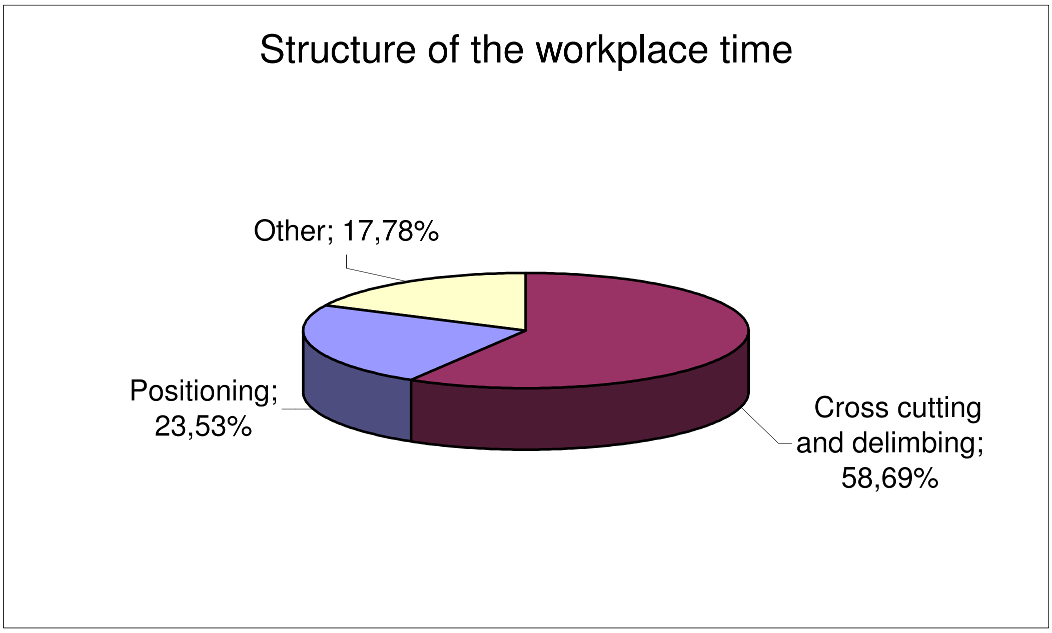


Figure 9. Structure of the workplace time

6. References

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EFFICIENCY ANALYSIS OF MECHANISATION WORKING UNITS IN CROATIAN FORESTRY – DEA APPROACH

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Keywords: forestry, efficiency, Data Envelopment Analysis (DEA), environment, hazardous waste

Abstract: In the Republic of Croatia (RC) forests and forest land cover 2.5 million of hectares or 44% of the total area of RC. 81% of forests are owned by the state, and the remaining 19% are privately owned forests. The annual allowable cut in state-owned forests is up to 4.9 million m^3. In accordance with the Forest Act the company „Hrvatske šume" ltd. Zagreb (Croatian Forests – CF) manage the state-owned forests. CF mostly rely on their own capacities for felling, processing, skidding/forwarding and transportation of wood, as well as for the construction of forest roads. These capacities are organised in 13 mechanisation working units (MWUs). The efficiency of MWUs was estimated by the application of 'Data Envelopment Analysis' (DEA). DEA is a well-known non-parametric method for the assessment of relative efficiency of comparable decision making units with different inputs and outputs. By linear programming, DEA models determine empiric efficiency frontier based on data of used inputs and achieved outputs of all decision making units. Efficiency level is calculated for each production unit, and consequently efficient and inefficient units may be differentiated. By use of the DEA, the efficiency level was determined for 13 MWUs operating within CF, projections were made of inefficient units against the efficiency frontier, and sources and levels of inefficiency were established. The assessment of MWUs' efficiency was carried out using the basic CCR and BCC models, which are also the most frequently applied DEA models. For every MWU, the number of employees and the number of mechanized means of work were entered into the model as inputs. Outputs were represented by the quantity of hazardous waste generated in maintenance of mechanisation and by the value of monetary gain/loss incurred by MWUs. The research shows that the working units, i.e. maintenance of forestry mechanisation, generate less than 500 tons of hazardous waste on an annual basis, which is a share lower than 0.25% of the total annual quantity of hazardous waste in RC. Per one machine that amounts up to 420 kg of tyres disposed annually, 375 kg of solid waste and 109 litres of motor and hydraulic oils. The results of the determination of MWUs' efficiency by the basic DEA models show that the average efficiency was 0.608 (CCR model). This means that the average (assumed) MWU, if it wishes to conduct business at the efficiency frontier, has to produce 64.5% more outputs with the used input level, i.e. achieve proportionally lower quantity of waste and higher profit. According to BCC model, the efficiency was 0.792 on the average, meaning that an average MWU, if it wishes to be efficient, must produce 26.3% more outputs (increase of profit i.e. decrease of waste). Two MWUs are relatively efficient according to CCR model (15.4%), and 7 MWUs (53.8%) according to BCC model. The quantity of produced outputs has a higher impact on inefficiency than the quantity of inputs used by the MWUs (output oriented models). Considering outputs, financial result achieved by individual working units proved to be a slightly more significant source of inefficiency. It is, however, considered that special significance and attention should be given to hazardous waste as the second output compared. The research shows that the 'Data Envelopment Analysis' may be a very useful tool both at a strategic and operational level of decision making in forestry.

EXPLOITATION AND PRODUCTIVITY CHARACTERISTICS OF THE NEW CROATIAN SKIDDERS ECOTRAC 55 V AND ECOTRAC 120 V

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Keywords: skidder, exploitation characteristics, productivity, daily output, unit cost

Abstract: *This paper presents exploitation characteristics and research results of the Croatian skidders ECOTRAC 55V and ECOTRAC 120V productivity in timber skidding in hilly and lowland regeneration fellings using the half-lenght method. The average load per cycle is 1.80 m^3 for the ECOTRAC 55V skidder and the average piece volume is 0.64 m^3. The achieved average load per cycle for the ECOTRAC 120V skidder is 2.78 m^3, and and the average piece volume is 0.35 m^3. For the skidding distance of 300 m, on skidding trail and felling site, and 50 m on landing, the total time per cycle of the ECOTRAC 55V is 14.76 min, standard time is 8.20 min/m^3 and daily output of the skidder is 58.53 m^3. The ECOTRAC 120V skidder total time per cycle is 30.28 min, standard time is 10.89 min/m^3, and daily output of the skidder is 44.08 m^3. Daily cost of timber skidding by the ECOTRAC 55V skidder for the distance of 300 m is 164.76 EUR/day or 2.82 EUR/m^3. On the other hand, for the skidder ECOTRAC 120V, for the same distance, it amounts to 217.86 EUR/day or 4.94 EUR/m^3. Comparing the two work sites while researching the productivity of skidders it is obvious that the productivity mostly depends on average load volume, skidding speed, working time on the felling site and on the landing.*

POSTER SESSION 2: ***Strategies for solving forest catastrophe***

APPLICATION OF FOREST OPERATIONS IN STANDS AFFECTED BY VARIOUS CALAMITIES IN POLAND

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Abstrakt: This article presents the procedure undertaken after effects of natural disasters on the territory of Poland. The aim of the paper is to present the forest operations in post disaster stands, considering the types of disaster, type and cost of forest operations and problems with the storage and sale of timber. The analysis was carried out in regard to the stands affected by wind, snow, floods. The volume of timber obtained from the post disaster stands as a percentage of allowable annual cut was 3 to almost 50%. It is established that the most frequent natural disasters in Polish forestry are snowbrakes. During the elimination of the natural disaster effects, the processes based on manual-machine operations were dominant until the end of the 90-ties. At present, a significant increase in the fully mechanised forest operations can be observed. The analysis of the average timber prices in the Polish market did not demonstrate downward tendencies during an increased demand of the raw timber from the post-disaster stands.

EVALUATION OF REFORESTATION TECHNOLOGIES IN WINDBLOW AREAS IN LATVIA

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Key words: windblow, reforestation, tree species

Abstract: First known storms disastrous to Latvia's forests were recorded in June 10, 1795 and in May 10, 1872. Then the storms of October 1967 and November 1969 followed, which totally blew down 28 – 30 million cubic metres of wood in the forests. In January of 2005, the storm in Latvia blew down more than 6 million cubic metres of wood. The hurricane Cyril blew down 500 000 cubic metres of wood in Latvia.

The listed storm damages in Iecava forestry in July, 2001 State forests only had affected area of 89.8 ha.. As the storm happened in summer, the damages were equal to birch stands – 41.9 ha and pine stands – 41.5 ha. Damages in spruce stands were only 6.4 ha.

Reforestation is much more complicated in the areas damaged by windblows. Therefore it is necessary to use different reforestation technologies for a successful and quality reforestation of the damaged areas.

The major problem in windbolw areas is the pulled out stumps. They make the movement of soil preparing and reforestation machinery more complicated. So a quality reforestation becomes the key issue.

After working the damaged areas, reforestation had to be curried out. In order to perform reforestation successfully, soil preparing shall be carried out. Soil preparing was possible in the damaged pine areas, because the majority of pines were broken, and only individual stumps were torn up.

Without any reforestation analysis, everything seems to be without problems. In birch areas damaged by storm, it was not possible to prepare soil for establishment of plantings. Therefore these areas – approximately 70% were left for natural reforestation. In 27% of the damaged birch areas it was possible to prepare soil, but the birch planting material was missing. In order to solve the problem, the areas were planted by spruce plants.

Comparatively, the pine (41.5 ha) windblow areas were the best, because the soil preparing machinery was able to work there without big problems. The most suitable soil preparing mechanisms in such areas were TTS –Delta and Bracke. These mechanisms prepared soil qualitatively.

Unfortunately, there were problems with the pine planting material. It was not enough for all the prepared areas. Therefore almost a half or 41.69% of the damaged pine areas were reforested by spruce plants.

Spruce stands as a fact, suffered the least from the storm in comparison to pine and birch stands. This could be explained by the birch and pine stands taking the majority of wind gusts upon themselves, while spruce stands are not so reachable for wind gusts in summer.

The majority ~ 94% of the damaged spruce areas were reforested with spruce. ~ 6% were left for natural reforestation, because it was not possible to carry out any aforestation works.

When evaluating the storm outcome elimination in general, a conclusion follows out that the forest areas damaged by storm of July, 2001 being under supervision of Iecava forestry, are successfully reforested with the appropriate tree species.

The storm in 2001 has damaged 89.8 ha of forest in the territory under supervision of Iecava forestry. The damages include: birch stands – 41.9 ha, pine stands – 41.5 ha, spruce stands – 6.4 ha. In a part of the damaged areas the previous tree species were restored: birch – 70.88%, pine – 44.58%, spruce – 93.75% . In a part of damaged areas a change of tree species has taken place: birch >>> spruce – 27.45%, pine >>>spruce -41.69%, pine >>>birch – 13.73%.

AN INVESTIGATION ON PRODUCTIVITY OF GANTNER YARDER AT WINDBLOWN FOREST STAND IN TURKEY

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Key Words: Gantner Skyline, Logging, Steep Terrain, Turkish Forestry

Abstract: Because of difficulties in the timber extraction phase, machine usage with the technological development, has become more and more important in wood extraction at the steep terrain. Generally there are two stages in the transportation of raw wood material from forest. The first one is to transport the products from forest compartment and the second one is to transport the products from the stacked or main storage areas to trading storage and factories.

In the first stage of raw wood transportation, there are different extraction systems in Turkish forestry operation. One of those primer raw wood transportation vehicles is the forest skylines. Within the forest skylines, the Gantner long distance sledge skyline was studied at windblown coniferous forest stand conditions in Artvin forest district in Turkey.

In this study, softwood timbers were transported by Gantner sledge skyline from forest towards downhill. Working conditions affecting productivity of the skyline were investigated at the windblown harvesting areas.

In addition to those, the real times of work phases, total travel time and nonworking time were determined. Daily productivity of Gantner skyline was determined at the windblown forest stand conditions. Data obtained from harvesting areas was statistically evaluated and the factors that effected, on total study times were determined.

FOREST CONSTRUCTIONS FOR PROTECTION AND HARVESTING OPERATIONS BEFORE AND AFTER FOREST FIRES IN GREECE.

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Keywords: forest fires, protection, opening up, harvesting, GIS

Abstract: Climate changes produce increase of the temperature and therefore enhance the forest fire risk. In Greece during summer 2007 in 7 prefectures 70 people lost their lives and 147230 Ha of forest were burned. This study focuses on the forest opening up model concerning both the prevention and suppression of forest fires as well as the view points (spots) either manned or using video cameras. The harvesting method that can be used after the fire destructions is also studied in relation to soil protection constructions, in order to minimize the erosion and the torrential conditions. The present study took place in two different forest ecosystems: in the recently destroyed by fire region of Ancient Olympia and in the forest complex of Lailias. Digital orthophotos and high resolution satellite images were used in order to produce and analyze spatial data using Geographical Information Systems (GIS).Initially, Digital Elevation Models were generated, based on photogrammetry and forest areas as well as the forest road network were mapped. Road density, road distance, skidding distance and the opening up percentage were accurately measured for the forest complex of Lailias. Opening up zones (buffers) were placed according to the existing skidding methods which are tractors equipped with wire ropes and drought animals, taking into consideration the topographical relief. After that the proposed opening up model, which consists of mobile cable crane 300m uphill and drought animals 200m downhill, was examined and its opening up percentage was spatially evaluated. Terrestrial fire protection zones (500m downhill, 300m uphill) were also set based on the technical capabilities of the Greek fire-engine brigades for both study areas. A view shed analysis using the DEMs was also performed in order to locate the most effective view points, ensuring the quick activation of fire fighting procedures. Three points were proposed for each forest area. Finally, conclusions and suggestions have been drawn about the environmental compatibility of forest protection and wood harvesting works. In particular the contribution of modern technologies such as digital photogrammetry, remote sensing and Geographical Information Systems is very important, allowing reliable, effective and fast process of spatial analysis contributing to a successful planning of opening up works and fire protection. The proposed opening up model is better than the existing one (opening up percentage 67.61%) and more compatible with the environment causing less damages during skidding to forest ecosystems, especially after fire. The spatial distribution of forest road network indicates places which are not protected against forest fires. Additionally the percentage estimation of single, double or multiple opening up for harvesting operations and protection of the examined areas was calculated in order to propose rational improvements where necessary.

DIGITAL TERRAIN MODEL - GEOINFORMATIC MODEL - HARVESTING OPERATIONS AFTER FIRES

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Keywords: digital terrain models, forest thematic maps, geoinformatics, harvesting operations

Abstract: Until few years ago, the opening up of forests was carried out with the machinery of the time, based on purely technical and financial criteria. In this paper an optimizing road layout using a digital terrain model (D.T.M.) is described in addition with the recording of forest fires' data, their entry in a digital database also as a geo-entry in a geoinformatic model and finally the harvesting operations after fires that took place in level of forest office. Terrain data can be obtained from ground surveying and photogrammetric techniques or from contour line digitizing. D.T.M. can be used in combination with G.I.S. for the creation of land information system in the cadastral offices or in the forest service. A D.T.M. provides spatial and topographic information for logging feasibility analysis and estimating logging operation costs. This kind of model is usually being implemented in a computer. Developing a useful model requires an accurate estimation of operation costs; such as road cost modules. A timber volume layer enables identification of the timber sources spatially, by which we can consider not only clear-cut treatments but also group selection cutting systems and even individual tree selection operations, which are usually used in Mediterranean forests. Geographic Information System (G.I.S.) technologies and their optimization techniques have become available during the last decade. Finally, there are applications of D.T.M. in the control of forest cadastral diagrams and thematic maps, in the production of forest maps, as well as for the protection and rational management of the natural environment, also harvest and forest road network planning and mapping in steep mountainous terrain, and the development of geoinformatics models for the forecasting of fires and optimization of the land uses or the harvesting operations after fires especially in Mediterranean forests. The combination of D.T.M. with information, as the plant cover, the temperature of air and the direction of winds can contribute in the better prevention and repression of fires. Still it can contribute in the better planning of observatories for direct warning of fire. Other applications are the remote detection of fire, the forestry and administrative handlings of prevention, the recording of the burnt areas etc. Will be presented elements that concern the number of fires, the areas and species that were burned and finally the by year's of intervention in level of forest inspection. The D.T.M. helps in the better and more rational growth, protection and exploitation of mountainous regions. Finally, the relevant conclusions were drawn, and the relevant proposals were made.

DIACHRONIC RECORDING OF HARVESTING PLACES COMPARE TO LAND USE CHANGES

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Keywords: diachronic recording, land uses, digital thematic maps

Abstract: Apart from the clearly cadastral information in the open cadastre, they can be registered in the future and additional information, that constitutes means for the objective of same aims of rational organization and development of the country. The success of a completed cadastral system presupposes it can correspond in the aims of protection of forest land, forest environment and provide reliable information useful in all the sectors of forestry activity but also for the setting out of rational forest policy. For this it's working out should become in such a way that it contains the recording of spatial and not perigraphical data. Aim of present paper is the diachronic recording of harvesting places in steep terrain in mountainous region in combination with the land use changes and the follow-up of them in the near or distant future in order to give persuasive answers in a line of reflections, in relation with the multifaceted management of Greek forest land and its prospects and its offer. This offer is differentiated diachronically, transregionally and at type of forest. With the essential changes in the policy and the strategies for the forest land in European and world level, is judged imperative the need is given as much as possible more completed, from each opinion, answer in these questions with useful adviser and driver the investigation of future tendencies of land uses. For the geo-reference of the maps, the digitalisations, the geo-entries, the acreage calculations, the measurements of lengths, the elaboration and creation of maps, the production of the digital terrain model, the suit of programs ARCGIS (ArcInfo – ArcView – ArcMAP) of the ESRI was used. From the results a small increase of land use is observed for settlements and a big increase in forest areas while the agricultural areas and bare are decreased. That means that over the years, an effort of both nature and responsible institutions, to increase the percentage of forests, while correspondingly the agricultural exploitation is abandoned, mainly because of the low production and the multi-disintegration of agricultural lot, main characteristic of the Greek reality. The determination of land uses which are disputed should be done by mixed committees where representatives of Geotechnical Chamber of Greece (G.C.G.) will participate, Technical Chamber of Greece (T.C.G.) in subscription with the local self-government and the decisions should be made on the basis of productivity. The digital maps of land use help in the development of mountainous regions, via Local Development Plans (L.D.P.) as a tool for the better exploitation of the region, for the facilitation of products' and materials' distribution, for the construction of works, extension of provincial network, management and improvement of meadows and leas. The digital maps of land uses can help to the more immediate and more effective fighting of possible fires in mountainous regions with the information that they provide, as well as in the assessment of destruction's size that they caused and in the drawing of invaluable conclusions on the species that they harmed.

EVALUATION OF LOGGING DAMAGES IN MOUNTAINOUS FORESTS LOCATED AT NORTHERN PART OF IRAN

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Keywords: logging damage, sustainable management, soil disturbance, wood transportation

Abstract: *Mountainous Hardwood forests in Northern part of Iran are difficult and hazardous to logging due to their steep slopes and sensitive ecosystem. Damaging effects of logging on forest ecosystems Include: soil compaction and disturbance, damages on stands and other vegetation covers which can delay the forest reclamation process. In this study, the logging damage in three parcels of Talar and Tajan zone forest were evaluated. Sampling was done via a random systematic inventory using 0.1 ha circular sample plots and 0.01 ha sample plots in order to study the injuries of stands and regeneration, respectively. Harvesting was done in the direction of skid trial with 12 m width and a hundred percent inventory. As the results of this study, the damages resulted from cutting operation and skidding were 3/2% and 4/8% respectively. Damages on stand, caused by cutting operation were 13/6 % and the ones resulted from skidding processes (total logging damages) were 15/5%. Depth and intensity of injuries made by tree cutting process were mostly on tree boughs, their barks and Cambium, while during transporting process, bark, Cambium and wood of residual stands had been damaged. The above mentioned problems could be significantly decreased via preparing a comprehensive exploitation plan as well as establishing a monitoring system and properly training during the operation.*

1. Introduction

Nowadays, a rapid progress in forest logging processes requires applying various harvesting systems. Developing and applying these systems for different conditions are based on considering economical criteria and bioenvironmental effects such as damages on the residual stands and soil (Limbeck Lilienau, B, 2003). Applying different harvesting systems for cutting the trees and transporting them will undoubtedly resulted in some damages on the residual stand, soil and seedling. Although, some part of these damages can be ignored but any deal of them may be accepted. Injuries resulting from logging operations may reduce the resistance of trees and produce more decays and different diseases (Thomas 1998, Rice et al 2001) studying the damages of logging operations and Introducing appropriate trends of logging may play, an important role in preventing from irrecoverable damages. Purposes of this research are as follows: to Determine the amount and rate of logging damages on regeneration and residual stand in different stage of cutting and transporting the trees, their creation reasons and to offer proper logging procedures in order to reduce damages on forests, as the result logging processes will be important and many significant damages would be prevented: and finally, lower operation expenses will be needed for forest conservation. Some of conducted researches in this course are as follows:

(Majnounian 1997) logging damages on stands in Lavij forests (North Iran) managed via shelter wood system were calculated about 47/3% of which 95/4% was related to the first 2meters of tree. Most of these wounds were deep and damaged some part of cambium and wood meanwhile, the taller the sapling, the higher the damages.

(Nyland 1994) showed that the created injuries on stand boughs during the logging operation always lead to produce low valued yields these kind of significantly deep wounds, are most often occurred during

skidding operation, on the other hand, there is a significantly relationship between logging damages, density and stand volume in hectare.
(Vasiliauskas 2001) According to the results obtained by who measured the damages on stands during the logging operation. The highest logging damages were related to tropical forests and the maximum damages of logging operation occurred during wood transportation which produce wounds with area more than 200 cm^2 and leads to reduce the age off tree and severe attacks of fungus.
(Pulkki 2001) compared the damages resulted from three logging methods including , whole-tree-system and tree- length and cut- to- length systems , According to his results whole- tree- system , among these three methods, involves the highest level of damages.
(Limbeck Lilienau, B, 2003) Studied on residual stands damages during forest mechanization process in Austria. The result showed that a combination of wheeled harvester- forwarder system leads to achieving the lowest damage levels on residual stands and the fewest damages on tree as compared with two other combinations Track harvester- forwarder and harvester- cable yarder systems.
(Iskandar et al 2006) Studied the damages occurred during different logging operations in (Eastern part of Kalimantana, Indonesia). According to their results, damage level in a stand depends on three parameters including volume in hectare, number in hectare and Length of skid trial. In addition, damages are mostly observed in Heights lower than 50 cm of tree which resulted from skidding operation.

2. Material and Methods

2.1. Study Area

The studying area is located at northern forests of Iran, in southern part of sari. Table 1 shows the total characteristics of the parcels. The determined parcels include average conditions of all forests in Mazandaran province. The findings of this study can be generalized to all forests located at these provinces.

Table1. General characteristics of studying parcels.

cutting method	Slope (%)	Altitude(m)	Forest type	Area(ha)	Parcel	series
Femel schelleg and improvement and clear cutting	**15-40**	**750-930**	**Beach_ hornbeam**	**45/2**	**17**	**Waston**
Improved and selection cutting methods	**25-70**	**300-930**	**Beach_ hornbeam**	**57**	**28**	
Femel schelleg cutting	**30-70**	**1550-1750**	**fagetum**	**58/5**	**7**	**Alandan**

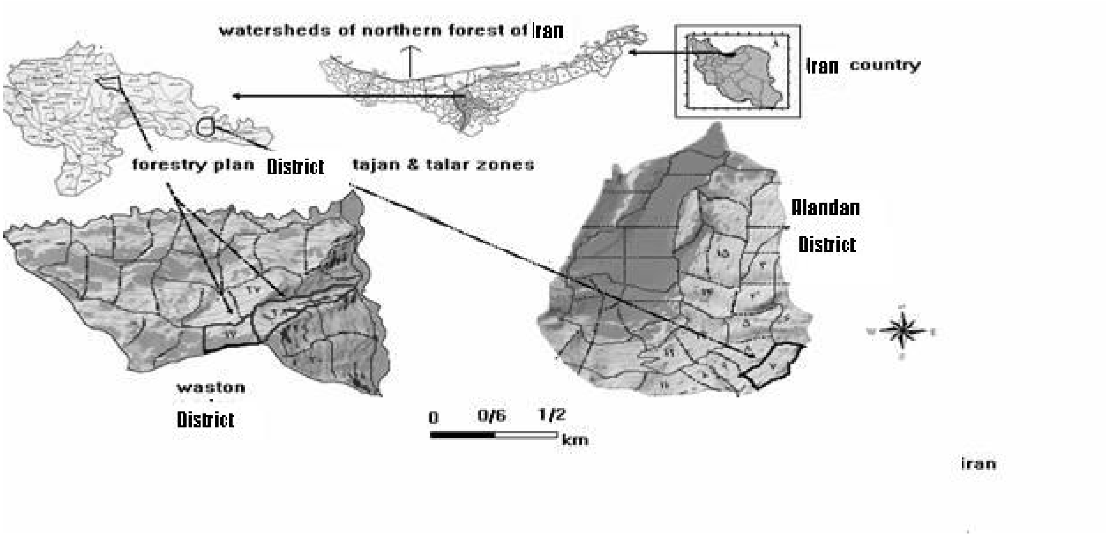

Figure 1: study area

2.2. Data collection:

In this study, damages on forest stand and seedling during logging operations (felling and transporting the tree) were assessed. As for regeneration, damages were recorded as number of wasted saplings and damaged ones. This was performed using 0/01 ha sample plots and a 100 ×150m net, meanwhile the numbers of damage sapling in hectare were estimated using control sample plots , on the other hand , damages on residual stand were measured using to 0/1 ha sample plots and a 200 ×150m inventory net. Inventory was performed to study the damages resulted from wood transportation through skid trial and their margins. Inventories in this area have been started from the very beginning to the end of skid trial in a width of 12m (6m from two sides of skid trial center) (Figure 2).

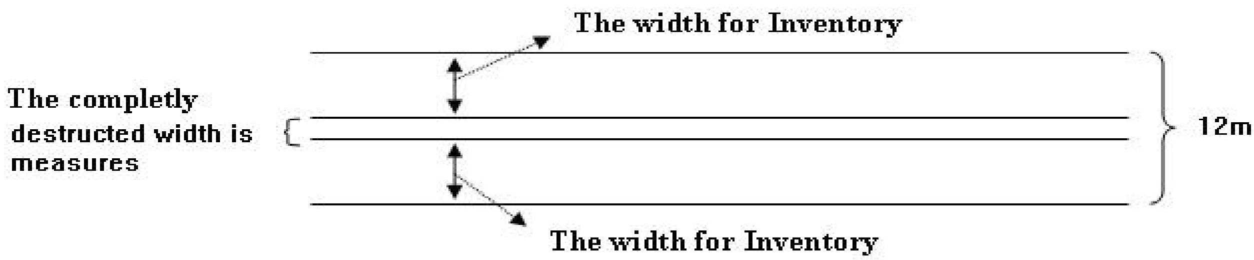

figure (2) Inventory in skid trial

3. Results:

Ratio Estimation method was used to determine the accuracy of obtained results. This method is usually applied to evaluate the qualitative data: while we want to know about the outbreak or absence of a characteristic. Thus in this study, this method is used for studying the injuries or health of samples and estimating the result them.

1. studying the damages after cutting operation:

This phase (figure3) shows the frequency percentage of damages on residual stand after cutting operation. According to the obtained results, Among 593 total number, 478 number samples were safe and healthy and 61 sample were damaged. After the cutting phase the damage extent on entire stand was between two following amounts.

$$8/1\% < p < 19/1\%$$

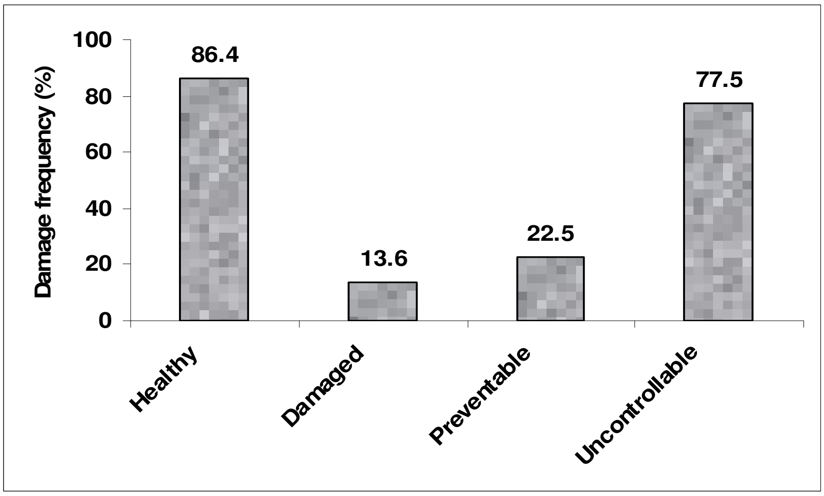

Figure (3). Stand damages after tree cutting operations.

After measuring the damages occurred on stand, it is necessary to estimate the amount and intensity of those damages. Intensity of damages and their horizontal extension in terms of tree area are shown in figure (4) and table (2).

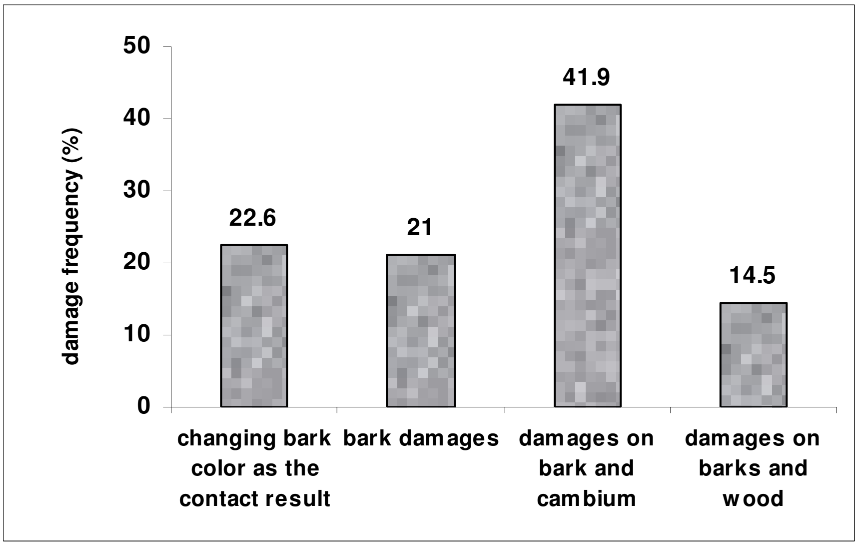

Figure (4). Damage frequencies regarding wound intensity in stand.

Table (2). Damage extent to tree Perimeter after cutting.

More than 50% of tree Perimeter	30 - 50% of tree Perimeter	10-30% of tree Perimeter	Less than 10% of tree Perimeter
6/5%	3/2%	24/2%	66/1%

Figure (5) shows the damages on regeneration following the cutting phase. As it's shown in this figure, amount total number of 2848 studying samples of generation damages, 2756 samples were health, 60 samples were damaged and 32 numbers of them were ruined there is a probability of about 95% that damages on regenerations, in total stand, after the cutting phase, are:

1/6% < p< 4/8%

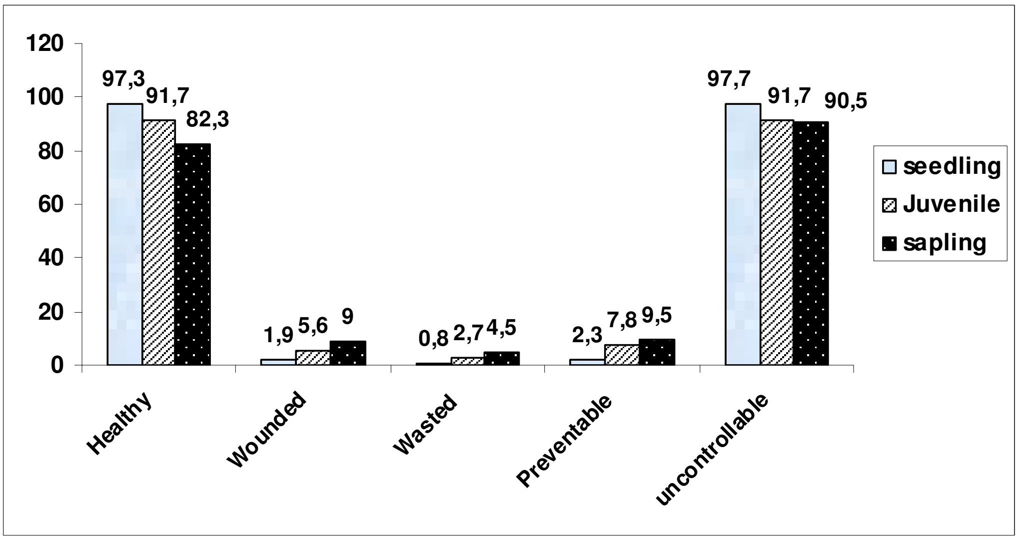

Figure (5). Regeneration damages after cutting.

2. Studying the damages after wood transportation frequency percentage of damages occurred on stand after wood transportation phase are shown in figure (6). According to this figure, total number of studying sample was 568. In sample areas and skid trials. After finishing wood transportation, 480 numbers of them remained safe and health, 88 samples were damaged. The amount of damages on seedling parts of entire stand may be as follows to probability of 95%.

11/2% < p< 19/8%

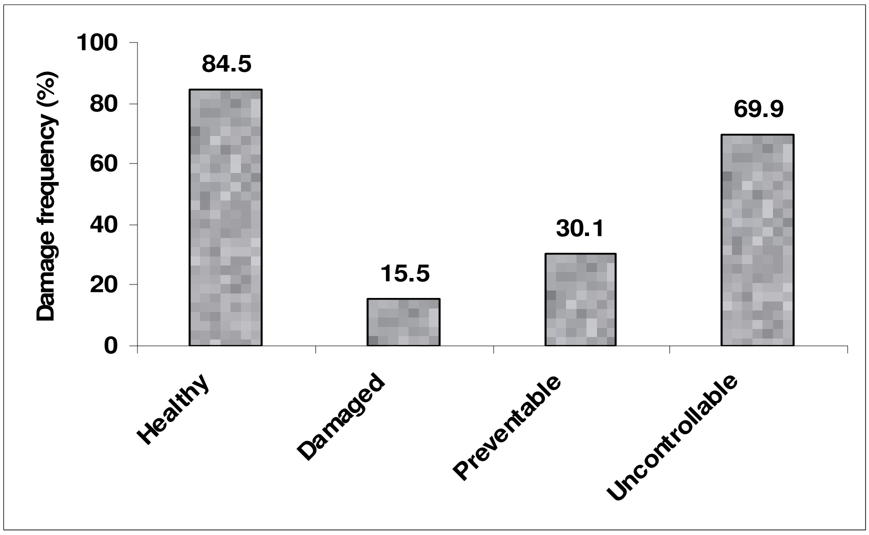

Figure (6). Stand damages after wood transportation.

Damage intensities and their horizontal extension to tree area (in stand) after transporting phase, are shown in (figure 7) and Table3.

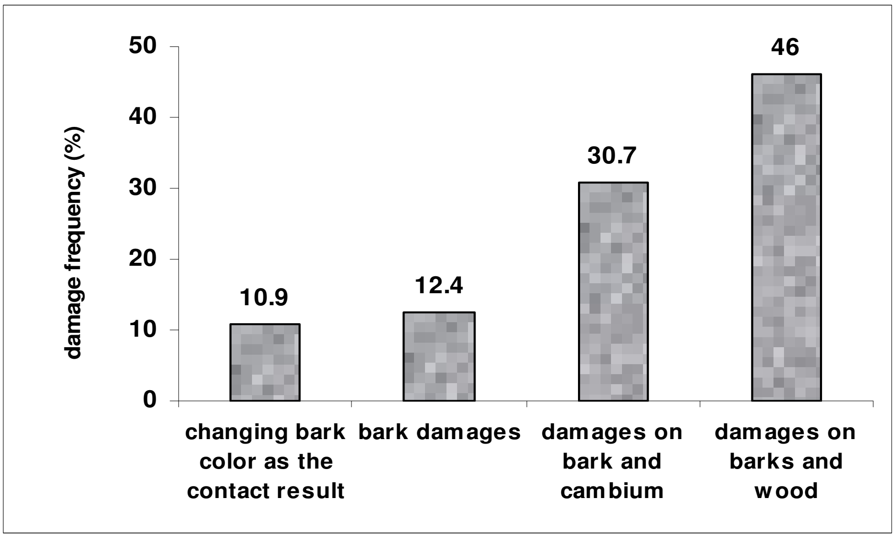

Figure (7). Damage frequencies as regard to wound intensity on stands after transporting.

Table (3). Damage extent to tree Perimeter after wood transportation.

More than 50% of tree Perimeter	30 - 50% of tree Perimeter	10-30% of tree Perimeter	Less than 10% of tree Perimeter
8/8%	6/5%	16/8%	67/9%

Figure (8) shows the damages on regeneration after wood transporting phase. As it can be observed, among total 2960 samples of regeneration damaged in sample plots and skid trials, 2818 numbers remained healthy, 86 numbers of them were wounded and 56 samples were wasted. Damage scale occurred on regeneration parts in total stand after transporting phase are, (probability of 95%).

2/4% < p< 7/2%

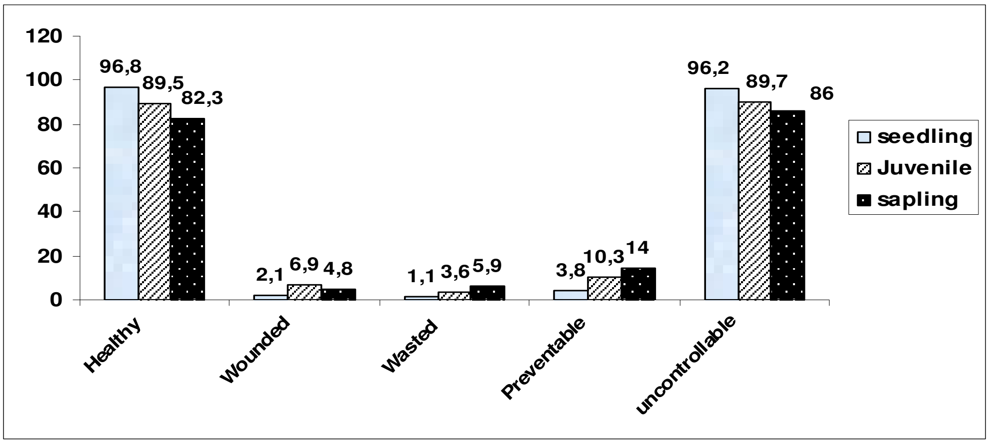

Figure (8). Regeneration damages after wood transporting.

Results and Discussion:

To estimate and minimize the logging damages is considered as the only treatment for forest survival and stability this treatment results in continuity of forest productions as well as producing higher qualities of yields. Results of studying the damage scale on a stand show that 13/6% of damages was related to remained stands, 3/2% to the regeneration which 1/9% of them were related to damages on Juvenile. A direct relationship exists between the damage scale and the age of plant species, and their height, so that a percent about 6/32% were observed for cutting damages. (Majnounian 1997) reported that the damage extent on seedling and Juvenile groups approximately 20/7%. He expressed that there is a direct relationship between the plant age and the damage level, so that the damage on sapling was 39%. These results have been proved by the results of our study. Results of measuring the depth of damage on stand occurred after cutting phase shows that tree barks and cambium endured the deepest damages, while the damage intensity was less than 10% of tree area. According the results of (Limbeck Lilienau, B, 2003) study, maximum damages intensities by harvester was less than 10% of tree area and they just involved bark damages, they found that higher damage intensity and bigger damaged area can be hazardous and they may lead to the physiological weakness of trees as a result of bacteria and fungus attacks. As for wood transportation which involves total damages, the extent of damages on regeneration was 4/8%.(Tashakori 1996) estimated the total damages on regeneration, after the operation was finished, as 15/8% which includes the damages made human beings. Measuring the depth of damage on stand after wood transporting phase shows that the maximum damages were related to barks, cambium and wood with an intensity of less than 10% of tree area. (Limbeck lilienau 2003) reported this amount of damages as for transporting phase using aerial cables. According to (Nyland 1994) findings, the very deep wounds on tree stands occurred during (logging operations were remarkably waste. He also expressed that these kinds of wounds are mostly related to skidding phase. (Pulkki 2001) introduced the factors involved in deep wound creation and damages on wood as follows: the changes in logging methods and increasing the tree length during wood transportation. According to (Iskandar et al 2006) the maximum logging damages were related to wood transporting operation in addition, longer paths increase the logging damages. In this study, 5% of damages were preventable. These damages have been made as the results of applying an appropriate felling direction or using improper tools. Obviously, applying a proper working procedure as well as suitable devices associated with property training the working groups during the felling, conversion and transporting phases reduce the damages and increase the additional value of productions.

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PERMANENT INFRASTRUCTURES AS POSSIBILITY TO COPE WITH FOREST DISASTERS

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Keywords: Infrastructure, Forest Roads, Forest Disasters, Forest Management

Abstract*:* The major disasters affecting forests and forest management in Europe are storm and fires. Most of the scenarios for global change predict weather conditions with higher risks for storm events and fire risk situations. Forest infrastructures, primarily forest roads in combination with public ones, play an essential role in coping with such situations. For forest fires the permanent infrastructure of forest roads is the critical element to fight fires with land based equipment and to minimize the impact to the environment as well as damages to property. In the case of storm damages in contrast the road infrastructure is the element to minimize the economic damage for the affected forest owners.

Based on the available databases, this paper tries to outline the situation in the European Union on existing infrastructures for the two mentioned disasters - fire and storm. Forest inventories don't really provide the relevant information. This paper combines several non-forest data sources on national and regional level to show the current situation. A comprehensive analysis of fire and storm risk vs. infrastructure is given. Finally the paper identifies the lack of information in the European forest data sources in this respect.

DEVELOPMENT OF A DECISION-MAKING TOOL TO MANAGE WINDTHROW DAMAGES IN THE WALLOON REGION (BELGIUM)

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1. Introduction

When an unexpected windthrow event occurs, the extent of damage may rapidly increase to reach a crisis level. Therefore, it requires a suitable and fast reaction by the public authorities and the concerned owners as well as by the whole sector of wood transformation. Unfortunately, in many cases, the extent of the damage, the complexity of the situation and the major distress of the actors don't make it possible to have a clear and reliable view of the problem within a time necessarily very short, wood being a perishable biological material.
The aim of this research, which is a regional priority, relates to the realization of a decision-making tool thought not under the constraint of the urgency, when trees are lying down on the ground, but established on the basis of real dramatic cases already experienced in the past. The tool is dedicated to political and administrative services but, to be effective, calls upon a broad collaboration with all the partners of the wood sector.

2. Methodology

The tool consists in computer software integrating plenty of data's, real or simulated, in an organizational scheme taking into account the whole operations of windthrow management (sale, harvesting, transport and transformation). This method is based on the theory of Dynamical Systems and on accepted working hypotheses.

Various stocks are connected by flows, themselves modulated by a whole series of factors (capacity of purchase of wood, harvesting and transport capacity, etc.). The idea is to identify various operational strategies and to compare them in order to allow a reflected, fast and calculated decision when the crisis situation due to the calamity happens.

3. Results

Some procedures were already developed in order to have overall estimates of the affected volumes quickly after the storm. In the hours which follow the windthrow, an overall estimate of the damage at the regional level is made on the basis of the Continuous Review of the Walloon Forest Resources (IPRFW). These global data are entered in the computer software to run the model. In the following days of the storm a local estimate within each quartering is made to constitute the sale catalogues.

Another part of interest is wood conservation after windthrow. To limit the crisis, it may be useful to stock quantity of fresh wood. Several methods have been compared from profitability and wood conservation angle and some storage places have been identified to anticipate the next calamity.

4.
Conclusions and prospects

With the help of this tool, crisis management will be faster and more accurate then now but still not complete. We want to incorporate these results in a global windthrow plan managed by a crisis cell. However, it will be necessary to ensure a periodic check of the data to maintain the tool constantly operational. The data will also have to grow rich by the experience feedbacks of windthrow events in the Walloon region or in bordering countries.

IMPROVING FELLING AND THINNING FOR COPPICE AND YOUNG HIGH FOREST STANDS IN ALPINE CONDITION: THE CASE OF TRENTO PROVINCE

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Keywords: time study, cable crane systems, coppice

Objectives
The Province of Trento is considered one of the most active forest area of Italy. The forest area covers more than 344 000 ha and the 80% is owned by public institutions. Coppice stands represent 22% of the forest area.
In order to maintain and to improve the quality of coppice and young high forest stands, one of the activities of Provincial Forest Administration (PFA) is to support felling and thinning. PFA is used to manage felling and thinning directly with its own forest working crews in the public forest properties. Cut wood from coppice stands is designed for firewood assuring the right of forest use. Forest operations are paid partly by PFA, partly by the forest owner (usually a Commune) and partly by the final beneficiary.
Felling and thinning are usually operated in alpine marginal areas. Forest working crew operates under difficult operative conditions where cable crane is often required for the tree extraction. PFA is thus oriented to increase the forest operation efficiency in thinning through managing specific working systems. In order to analysis the efficiency of the specific working systems managed by PFA, five working systems were investigated and compared.

Materials and methods
A systematic recording and a critical examinations was sorted out for five selected working systems. In all the selected working systems, the extraction was performed by cable crane. Thus investigations concerned three cable crane systems: sledge yarder, mobile tower yarder and combined system between sledge yarder and mobile tower yarder. The method study was based on stop-watch study. Therefore the five working systems were compared in terms of productivities and costs.

Results
According to the different factors affecting the productivity and the applied working method, the investigated working systems evidenced a high variability in terms of productivity and costs. Productivity can range from 15 to 5 t/h and cost from 8 to 25 €/t.

Conclusions
Combining sledge yarder with mobile tower yarder evidenced interesting productivity and cost. Also the cut evidenced some remarkable results. In the extraction, transportation of cut to length bundles with a length of 3-4 meters evidenced some positive consequences: it showed remarkable productivity but also a safer working condition in respect of the full tree extraction.

METHODS AND TECHNOLOGIES IN FIRST THINNINGS AND PROSPECTIVES FOR DEVELOPMENT IN BULGARIA

Dinko Dinev, Georgi Tassev

Abstract: Studies have been carried out in the directions as following: 1/ a selection of a technological scheme appropriate to the available means used when the cuttings are to be taken out; 2/ the improvement of the methods of growing; 3/ the establishment of plantation stability and total productivity, etc.

There are predominantly manual and less - mechanized means of cutting - which have been used in our country for clearances. When clearances are made, a growth of productivity occurs, as in dependence of the tools and means utilized in cutting operations. It is also to be noted the effect caused by the size of the young species to be cut, as the type of the tool and means, to be used for, depend upon that. The results come to demonstrate, when undergrowth (or undergrowth grown up to a certain size) is available, light chainsaws and motor clearing saw shall be used as expedient means, being in a combination with knives or axes. As for the mechanized cutting out of the clearances, it is not practiced; that is why there are some proposals to be made as about a larger introduction of such a technology to be provided for, which one to be of a greater productivity and efficiency.

When thinning out (bushing) is made, there are the trees diameter and the plantations fullness which ones exercise the main influence onto. The technological schemes are considered to be a priority of these cuttings, as it is therein when an infrastructure is provided to be created, for the first time, in plantations: roads, technological corridors etc. It is also important the type of the tool used for cutting, being the efficiency noted, as following: when there are trees which thickness is below 5-7 cm, being a motor clearing saw used, while if the trees diameter is over the above cited size, a light chainsaw shall be used for.

When cuttings were studied, the problem was reduced to their improvement and to the obtaining of better economic results.

AGRICULTURAL TRACTORS, ADAPTED AND MODIFIED, TO BE USED IN BULGARIAN FORESTRY

Dinko Dinev, Georgi Tasev, Konstantin Asparucho

Abstract: It results sometimes inefficient, in the forests, the use of high price tractors, such ones as the specialized are. It is possible the agricultural tractors to be used for small-scale forestry operations, where various technological equipment is provided for. Such kinds of tractors are the adapted and the modified ones.

The adapted agricultural tractors are being prevailing on, due to their lower add value, to their simpler constructions, to their greater adaptability to repair and lower costs for that purpose, and for a number of other reasons.

The analysis, made of the situation in our country, as regards to the modified tractors, comes to prove that is the wheel agricultural tractor which results as the most rational to be used, being thereto added, or separated from, or replaced therein, manipulators, haulage trailers, wood processing machines, means for chemical and fire-precaution activities, soil processing and others. When the scheme, proposed therein, is used, its economic efficiency will lead to a reduction of the capital and exploitation costs and to a faster introduction of the above cited means into our forestry.

While there is some experience, in Bulgaria, as regards to the adapted tractors, but no view in prospective, for the future, almost nothing results to be done for the modified ones.

That is why we have been trying, both from the theoretical and practical point of view, to illustrate which are the possibilities and the perspectives for it in our country.

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ENVIRONMENTAL COMPROMISE BETWEEN CABLE AND GROUND LOGGING SYSTEMS IN GREEK FORESTS

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Keywords: cable and ground logging systems, forest opening up, forest road

Abstract: The road network is a work of infrastructure, capable in contribution substantially in the sustainable development and exploitation of mountainous regions. The opening up with roads of low cost for the Greek forests began from 1956. In sustainable managed forests, roads, their network and technical specifications have to be in accordance with natural conditions and land uses, expected logging operations and landscape aesthetics. In mountainous steep terrain ground logging systems in combination with cable logging systems are recommended because of their favourable economical-ecological balance. The Forest Road construction deals with the study of elements of setting out and the construction of forest roads, which present particular requirements, while simultaneously they are of essential importance for the most excellent opening up of forests, the rational exploitation of these and the development of sylviculture. Generally speaking the constructions follow criteria that are necessary and capable in order to protect the environment and the viable or better sustainable development of a region. The existence of a compatibility control of a technical work with the natural environment is necessary, particularly when the road runs an area with steep terrain. Up to now forest roads which were constructed by the forest service improved their passage areas without creating big problems in the ecosystem. Aim of the particular paper is the investigation of the compromise between cable and ground logging systems and how this can be done in Greek forest conditions. For the achievement of this goal, a terrestrial on-the-spot investigation and advanced specialized information systems were used, like Geographical Information Systems. Contemporary cable systems require denser road networks. The combination between ground logging systems and cable logging systems in steep mountainous areas sooner or later will become an unavoidable dilemma because of the developments in cable logging systems, interventions in infrastructure, or spatial variations in applied harvesting technology. The results should be consistent to the goals and harmonized at the strategic (policy), tactic (planning) and the operational (design) levels. Only then the compromise between cable and ground logging systems can be environmentally acceptable and cost-effective in regard to the Greek forests. Opening up plans can provide an improved and proper basis for environmental construction works, contribute to feasible compromise between cable and ground logging systems and facilitate sustainable forest management.

TIMBER HARVESTING BY URUS M III FOREST SKYLINE ON SNOW IN STEEP TERRAIN: A CASE FROM ARTVIN, TURKEY

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Key Words: Timber harvesting, Logging on snow, Urus M III forest skyline, productivity

Abstract: The most common harvesting method applied in Turkish forestry is cut-to-length where the trees are cut, felled, delimbed, topped, and bucked into the various lengths by using chainsaw at the stump area. Then, debarking is handled by hand tools such as axes. In the most regions of Turkey, the application of mechanized harvesting equipment is currently very limited due to low labor costs and high fuel costs. Although, the equipments have been increasingly used in the regions with intensively managed forests over 80% of the logging operations in Turkish forestry are still practiced by using man power as skidding or sliding, which are subject to technical, ergonomic, and environmental problems. In Turkey, URUS MIII cable systems have been in use since the end of 1970s. The actual usage of cable systems is not very high, but in mountainous parts of Turkey such as Artvin region, this cable system is very often the only reasonable possibility for wood extraction.

In this study, the effectiveness of roundwood extraction by Urus M III skyline on snow was investigated in four harvesting sites (Site-1,2,3 and 4) in Artvin, Turkey. The ground slope and line slope range from 55 to 70% and 30 to 35%, respectively. The forest products yarded were spruce, fir, and beech. Data obtained from the time studies in harvesting units were entered into the computer and listed in the data tables indicating work phases. Permanent time consumption technique was used during the uphill and downhill transportation by Urus M III. Measuring time consumption phases were; X_1: arrival of the empty carriage to loading area, X_2: pulling the hook and hooking the logs, X_3: pulling the load to carriage and locking, X_4: pulling the loaded carriage to unloading area, X_5: unhooking the load, and X_6: delay time. The statistical analysis was performed to investigate the effects of number of piece, log length, log diameter, and log volume on total transportation time.

Transportation distance and worker number range from 200 to 400 m and 5 to 7, respectively. Productivity of Urus MIII skyline was determined in Site-1, 2, 3 and 4 as 5.87 m^3/h, 6.82 m^3/h, 4.08 m^3/h, and 1.69 m^3/h, respectively. The average relative productivity value was 11.23 min/m^3 and 35.26 min/m^3 for uphill and downhill logging, respectively. The results derived from this study indicated that Urus M III forest skyline should be used for logging on snow effectively and uphill logging should be preferred to downhill logging in order to increase the productivity or effectiveness of logging by Urus M III forest skyline.

AN ASSESSMENT ON THE OPTIMIZATION TECHNIQUES AT HARVESTING OPERATIONS ON MOUNTAIN FORESTS

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Keywords: Wood harvesting, optimization techniques, mountain forests.

Wood harvesting is more expensive and more difficult operations especially on mountain forests. Hence, it is needed a good planning. The aim of a plan is producing of the optimum solution by assessing of all relevant factors. The cost minimization is the major manner during harvesting planning. There are many factors in cost component. Beside these factors, there are technical and environmental restrictions at.
Wood harvesting is composed by cutting, primer transport (skidding, yarding etc.) and secondary transportation. Primer and secondary transport of wood have complicate components. The operational cost and time minimization are main targets of the planning. These objects are in restrictions of used techniques, machines, environmental effects and topographical features.
There are many common optimization techniques to be developed for decision making under restricting factors. Some of these are used for harvesting operations. The aim of this paper is introduce and assessment of optimization techniques for forest harvesting operations.

FOREST LOGGING INFLUENCES ON STEEPY SLOPES TO THE SOIL AND TO THE REMAINING TREES IN THE MOUNTAINOUS AREAS FROM ROMANIA

Gheorghe Sparchez, Ilie Oprea, Iordache Eugen,

Derczeni Rudolf

Abstract: It is know that by logging activity are made damages to the remaining trees, to the seedling and to the soil. The total values of the damages are in relation with a several factors that can be grouped in more categories:

- the site factors, respectively the nature of the solidification bedrock (characterized by the geomorphological resistance), the field declivity, the depth of the soil, the climatic conditions during the logging a.s.o.;
- the biocenotic factors, respectively the stand composition, the stand and seedling density;
- the technical – economical factors, respectively the applied cutting method, the logging technology that are used a.s.o.;
- The researches objectives that were followed in the present paper
- establishing the damages that were made to the remaining trees in correlation with the field declivity and with the means that are used for wood skidding;
- establishing the damages that were made to the soil, respectively the litter disarrangement, the dislocation of the humus layer, the ruts form.

The researches were made in mixed stands (beech and coniferous), located in the mountainous area in which were made cuttings for transformation to the selection system.

The stands were located near the City of Braşov on the lower part of the Postăvaru Massif and are part of the eight compartments from the No. V Noua Management Unit with 131ha total surface.

The geological substratum is represented by polygene conglomerates with middle geomorphological resistance. The main relief form is the slope with 20^0 … 40^0 declivities, with undated configuration and altitude between 660 and 1050m. The main soil are with prevalent loamy – sandy texture in A_0 layer and loamy or loamy – clay in the B_t layer.

The logging method was trunk and mast.

The observation on the itinerary and on the sample plots was the research method that was used to evaluate the damages that were made to the remaining trees. The research plots were oriented on the line of the steepest slope having a quadrant shape with 20m flank. For the “first skidding” and yarding operations, the observations were made along the animal yarding and tractor trails on 5m distance from the trails axis.

The following observations were made in each sample plot: the number of the total trees, the total harvested trees, the number of trees on steep were countered and for the trees on steep were appreciated the species the damage type and the dimension of this and also were measured the diameter of each tree.

The results of the research regarding the damages made to the remaining trees are:

- the damages increase, as is normal, in accordance with the distance increasing;
- on the slopes with declivities higher than 60% the damages has the maximum values;
- on the slopes with declivities under 60% the damages register low values than for the highest declivities;
- in case of steeper slopes, the trees that are located on the in the lower part of these has the higher damages;
- in comparison between the yarding made by hauling and the one made by animals, the damages are more reduced for the second case;
- the damages made to the trees during the animal yarding along the steepest slope has as results a maximum damage of the trees located on downhill;

- in case of tractor trails, almost of damages are located near the trails;
- the percentage of the total soil disturbance is between 2,5 and 12% and the dislocation indexes are between 13,57 and 43,69%. Taking into account the fact that it is undertaken the layers that are located near the surface in which are concentrated the main humus quantity, it is appreciated that the nitrogen loss in the soil are in direct correlation with the wood mass that are skidded;
- during the wood logging process were made important changes to the living soil cover starting from litter disarrangement till to a powerful soil degradation. These damages are lower than the one that are made in even stand cuttings.

The main methods that are recommended to reduce these damages are:

- limitation of hauling usage in the skidding process;
- making the logging in the periods when the soil is dried or is covered with snow;
- limiting the trailing and half – trailing during the skidding;
- introducing the logging with skylines, where is possible.

GPS-BASED DESIGN OF SKYLINE CORRIDORS AND SOFTWARE SOLUTIONS FOR ANALYZING OF CABLEWAY SYSTEMS

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Keywords: cable crane logging, real time DGPS, cable crane project, computer program GNEZDA, safety, project paper layout

Abstract: An operational forest planning system for locating, measuring and determination of cableway components was developed by use of the sub-meter GPS receiver. Real-time differential corrected terrain data, dimensions and quality of cable crane location, anchors, tail tree, necessary and potential intermediate supports or terrain obstacles were collected and used in PC software package. New developed software is able to do analysis of skyline logging systems. By using specified technical data of cable crane, wire ropes, carriage specifications, safety requirements and ropeway system, new developed computer program accurate calculate approximations of optimized and operational safely skyline project. Project includes graphic projection in horizontal and vertical layout.

Using real terrain and updated data of technical specification of chosen cable crane allow us to get verified realistic cableway project. Cable crane specification, such as tower height, number and anchoring cables specification, demanding geometry of anchoring and skyline fields, can be stored in program database and can be updated from other sources (e.g. Machine lists database). Calculations include line tensions, height and tensions on intermediate supports, anchoring geometry of tower and tail tree, working loads, deflections of skyline and other parameters including safety checking of components dimensioning and dangerous areas. Skyline approximations are based on Pestal's work: "Seilbanen und Seilkrane für Holz- und Materialtransport". Cartographic maps and terrain model used in program enable situation and profile schemes of skyline projects and calculations of skyline or carriage height above the ground. Program software enable use of free internet cartographic material and rectifies it with Differential Global Positioning System coordinates of at least two points: tail tree location and cable crane location. Terrain height profile under skyline can be created from map contours or from Digital Terrain Models. After that works software in own created local cartographic projection independent from underlay source in situation or in profile view. All approximations are calculated from available realistic input data (position, height, altitude and cable crane specification) of cable crane line components.

Additionally it is possible to manage and save any photo material taken at terrain design. Photo documentation can be useful to machine operators at setting up of cable crane. New program offers possibility of automated preparation and print of paper version of operational plan as engineer's project. Layout can be created only when project satisfied all safety requirements. Result is optimized, regular, safe and verified cableway project. All projects are stored within program created workplace folder. Evident and systematic overview of all cable crane project documentation is available. PC program GNEZDA® was developed following concept of easily solved and understood engineering work. Name GNEZDA comes from Slovenian cable logging pioneer Štefan Gnezda (1907 – 1990). He constructed, operated and promoted wood skidding with self constructed mobile yarder and carriage known as 'idrijski zvlek' already in 1932. Poster presents a new praxis approach to design of cable crane corridors and preparation of operational cableway project.

FOREST CABLEWAYS AND THEIR USE IN FOREST MANAGEMENT

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Keywords: forest cableways, classification, differentiated use

Abstract: Of the total area of EU forests, "cableway terrains" represent at least 20%, however, the actual proportion of cableway yarding amounts to only about 3% allowable final cut. In the Czech Republic, the situation is similar: "cableway terrains" represent about 18% and only 2.5% wood is skidded by cableways. There are three or four main reasons why the actual volume of wood skidded by cableways is markedly lower as against real possibilities or theoretical requirements, viz. (1) rather high costs for cableway yarding, (2) wood can be more easily obtained (so far) in plain forests, (3) the forest road density in many mountain areas is not consistent with the reach of current medium-distance cableways, (4) there is the lack of skilled personnel for the operation of cableways. Current ideas of the road network in mountains: to decrease road spacing to less than 1000 m, the optimum density of main forest roads 20 – 25 $m.ha^{-1}$, to construct the road network from local materials without bituminous surface, to leave out the construction of slope roads ("tractor" roads) and to concentrate on building main forest roads passable year round. In the Czech Republic, the main road density is 13.8 $m.ha^{-1}$, the density of other roads 46.6 $m.ha^{-1}$. The use and manufacture of forest cableways in the CR is of rich tradition, because for the first time, a forest cableway was used for skidding purposes as early as the second half of the 50s of the 20th century. For its construction, an American military winch Waukesha was used by the Forest Research Station Krtiny. The winch was completed with a track cable pre-stressed by a tackle. A carriage with a fall block moved along the cable. Thus, extraction of wood to the cableway line was made possible, which was revolutionary at that time. At present, however, it is quite common. By means of the cableway, more than 10 thousand m^3 wood was skidded uphill from extensive areas in the Jeseníky Mts. after a wind disaster within three years. The later construction of a universal cableways for downhill and uphill operations was, however, more complicated and difficult. After initial stopgap designs consisting in completing a one-drum winch with the second (reversible) drum mounted instead of one rear wheel of a tractor, a number of various principles of forest cableways was developed in the Forest Research Station Krtiny using one-, two- and multi-drum winches. At present, the **integrated series of modern forest cableways Larix is manufactured there**: a <u>two-cable system with a track line and a haul-back line</u> Larix Kombi H for short and steep slopes up to 220 m devised particularly for clear felling (working load 1.5 t). The cableway can be equipped with a tower and thus its reach is increased up to 330 m. It is supported by a three-point 70 kW tractor hitch; a <u>three-cable system with a track line, haul line and haul-back line</u> Larix Hydro (working load 3 t) is equipped with a stationary 94 kW engine. Its power is transmitted by separate hydraulic circuits for each of drums; the system is equipped with a tower, reach 700 m; a <u>system with a track line, running line, guide line, lifting line and straw line</u> Larix 3T (working load 3 t) or L 550 (working load 2 t) is supported by a farm tractor and equipped with a tower, reach up to 550 m. The cableways are equipped with an operational automatics and can be used both at tending felling and principal felling including clear felling. To evaluate the effectiveness of cableways, a mean annual efficiency is a fundamental indicator. In cableways type Larix 550, they make 4400-5300 m^3, in type Larix 3T 6200-8300 m^3. Total costs of cableway skidding induced by mounting and dismounting the equipment are dependent on the length of the cableway line and felled wood concentration. Minimum felling concentration when cableway skidding is considered to be profitable under present prices of wood ranges between 0.3 and 0.4 m^3 per 1 m cableway line. However, extra-economic reasons can predominate over purely economic reasons (salvage felling, sanitary felling, urgency of tending measures etc.). Variable times of the cableway erection and costs related to the time increase with the cableway length, however, at the same time, a longer cableway line results in higher volumes of felled wood. Thus, the length of an optimum cableway line ranges from about 160 to 420 m.

SLOPE STABILIZATION PROCESS OF THE FOREST ROADS

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Keywords: Slope stabilization, forest roads, stabilization methods

Extended Abstract: One of the most important issues during the construction and performance of forest roads is the process of slope stabilization and therefore, many kinds of methodologies have been developed (Eskioglou et al., 2006).

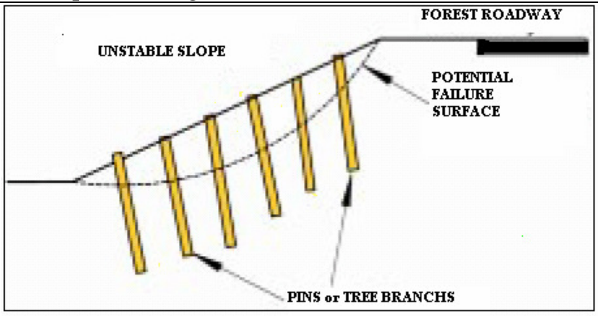

Figure 1. Stabilizing Method with tree branches or recycled pins with grass seeds inside.

The needs for an environmentally friendly technique to mitigate the problem generated by soil instability and the incidence of erosion have been provoked the appearance in recent years of two different eco-technological concepts: ground bio-engineering and eco-engineering (Norris et al., 2008, Sommers et al. 2000). In the present research work, slope stabilization was performed on a forest road by using different types of grass or vegetation, and also similar methods, in order to stabilize them (Fig. 1).

From the simplest methods such as seeding, mulching or planting, to the most complex ones that integrate different engineering techniques using very different materials (live crib walls, vegetated gabions, etc.), we describe the uses of vegetation for increasing slope stability and restoring and preserving degraded land. The use of eco-engineering techniques against rock fall in mountainous areas has also been considered (Stokes et al., 2004). Finally, the possibilities of combining both eco- and bio-engineering techniques are described. This application results not only stabilize the slope from the road cut but also accept the environmental aspect that we must follow in constructions of forest roads type B' and A'.

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ERGONOMIC ASPECTS OF ARTIFICIAL PRUNING OPERATIONS

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Keywords: artificial pruning, physical workload, subjective sensation of fatigue.

Abstract: Artificial pruning is an operation performed in stands of age classes I and II. Its objective is to precede self-pruning in order to obtain the widest possible clear wood zone. The main tools used in this operation are hand saws (in artificial pruning °I to 3 m height) and extension arm saws (self-pruning °II and III to 5 – 6.5 m), providing very good pruning quality. Artificial pruning is physical work, involving a large group of muscles of upper limbs and the trunk. It is performed while standing. Forest is the work environment. Workers performing pruning operations are exposed to different types of loads, directly affecting their well-being and health. The study analyzed physical and environmental work load and subjective sensation of fatigue.
Artificial pruning is an operation which involves a selected group of muscles and is characterized by an especially high repeatability of movements. In order to limit the adverse effects of repetetive work should be performed by several teams working side by side.

Work in pruning is performed under changeable environmental conditions dependent on weather conditions. When pruning with hand saws workers usually stand below the site from which branches are cut off. Sawdust formed as a consequence of cutting fall down on them and they are at risk of cuts and abrasions. Because of saw movements the tree vibrates, resulting in the fall of dust, bark particles and needles. Workers are at risk of dust getting into their eyes and different types of particles getting under their clothes. It is thus necessary to provide eye and head protection for workers.
The subjective sensation of physical fatigue and high levels of energy expenditure are connected with the monotony of work and high loads for selected muscles groups.

During the performance of pruning operations ailments appear relatively early and last throughout work time. The most frequent sites of the sensation of pain are upper limbs and shoulders. The most intense pain was located in the area of palms and wrists. In pruning °I the hand with which the worker moves the saw is more at risk of pain. In pruning °II the sensation of pain in both limbs becomes more evident and intensive
The level of energy expenditure rises with increasing height from which branches are removed using hand saws and it is comparable to that of loggers.

WORKING POSTURES DURING TREE FELLING USING CHAINSAW

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Keywords: working posture, woodcutter, tree cutting, chainsaw

Abstract: Operations carried out in forestry are characterized by considerable arduousness associated primarily with physical effort. This refers, in particular, to the motor-manual timber harvesting with the assistance of the power chainsaw. It is estimated that about 90% of timber harvesting in Poland is carried out with this tool. The degree of the workload of woodcutters, apart from high energy expenditure, is affected significantly by the enforced posture during work and the static workload associated with it. Pains of the lower part of the spinal column are the most frequent ailments diagnosed among chainsaw operators. Complaints associated with the musculoskeletal system are additionally aggravated by unfavorable weather conditions.

The investigations comprised 13 woodcutters carrying out cutting in clear-cut stands and late thinnings. All the employees were right-handed. The cutting of 120 trees was analyzed – 53 in clear-cuts (beech, pine, spruce) and 67 in late thinnings (pine, spruce, birch, alder, beech). All the cutting operations were filmed. The film was then used to determine working postures during the cutting and their duration. Next the determined postures were catalogued according to the degree of their enforcement.

Working postures adopted during tree cutting with the chainsaw can be divided into 5 groups: standing straight (1), standing bent with straight legs (2), standing bent with bent legs (3), squatting (4) and kneeling – kneeling down on one or two knees (5). Standing bent postures were the most frequently used – 74% of woodcutters. The characteristic feature of the majority of working postures during cutting with the chainsaw was a significant (over 45°) bending forward of the back accompanied by the twisting of the trunk. In the case of posture 2, the back bending reached or even exceeded 90°. The back bent during cutting is the result of the place of cutting which is situated close to the ground. On the other hand, the twisting of the trunk is forced largely by the construction of the chainsaw – the placement of the supporting and controlling handles. Another characteristic feature of the observed working postures was the resting of the right elbow on the knee, which allowed relieving the arm and provided additional support and force. The use of the additional point of support was observed in all working postures, except 1.

TRACTIVE FORCES, SLIP AND SLOPES

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Keywords: Timber Harvesting, Steep Terrain, Traction Performance, Downhill Slope Force,

Abstract: Forestry in Germany operates between a growing demand for timber products and increasing ecological requirements. Especially harvesting operations in inclined areas cope with these sometimes competing aims: On the one hand larger resources and therefore utilization potential but on the other hand an ecosystem which is particularly sensitive to unadjusted harvesting operations. This project is financed by the Federal Ministry for Food, Agriculture and Consumer Protection and deals with a soil specific model for traffic ability based on the traction performance under level conditions.

Drawbar pull measurement with a forwarder determine the traction performance. The resulting relation between wheel slip and tractive force can be compared with the downhill slope force which is derived from the gravitational force of the forwarder and the inclination angle. The traction performance allows to define an ecological limit based on an accepted wheel slip level and determines an absolute limit for self propelled machinery by the maximum tractive force. The tests are performed on two different soil types at varying soil moisture. In addition to the soil properties different configurations (e.g. tire pressure, tracks, chains) of the test machine (forwarder) are included.

The economic utilization of wood resources in inclined areas often depends on the application of high mechanized harvesting. An inappropriate machine usage can lead to serious damages and consequently traffic ability is ruined by a few passes. Utilized for a well organized harvesting operation the results of the project can lead to safe and ecological timber harvesting operations in inclined areas and therefore to an increased timber mobilization from these areas.

QS-HARVESTER MEASUREMENT– A SYSTEM OF QUALITY ASSURANCE CREATES TRANSPARENCY AND ACCEPTANCE FOR THE MEASUREMENT BY HARVESTER OF TIMBER LENGTH AND DIAMETER

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Summary: In collaboration with forestry entrepreneurs and manufacturers, the KWF implements the Skogforsk developed system of quality assurance for the measurement by harvester of timber length and diameter to the German market. The new system improves the reliability of bucking and the quality of the product. The processed timber data collected by the harvester can also be used to improve logistics in forestry. The system is based on random sampling of trees that the harvester operator measures manually using a digital calliper. The readings are then sent in the form of a control file to KWF, where they are compared with those made by the harvester. The results are fed back to the harvester operator, the machine owner, the forest owner, and others. The KWF as an independent auditor monitors the results continually, and visits every machine if necessary to verify that the specified procedures are being followed.
Altogether we believe that the system:

- makes repeat measurements in the forest obsolete
- presents a reliable control measurement
- improves grading quality
- increases the reliability of production data for logistics
- facilitates the comparison between different machine types and components
- provides the forest entrepreneur with an important quality statement

Motivation

The business partners need a reliable verification about the harvester measurement for business use.

The harvester head tree measuring device requires re-calibration to deal with changing conditions in the forest, especially in response to:

- Severe changes in weather (frost)
- changing sap conditions (bark removal)
- changed tree characteristics, wood quality or DBH (new stand)
- Modifications of the harvester head (replacement, repair) or changed settings (feed speed, delimbing pressure)

The calibration is verified by regular control measurements. These regular control measurements are the starting point for the quality assured harvester surveying system.

The random control stem method Scandinavian machine manufacturers in coorperation with Skogforsk have developed an extension in StanForD (Standard for Forestry Data and Communication), which provides a reliable control of the harvester measuring system. Currently, this new procedure has not yet achieved full-scale distribution in Skandinavia. However, the required functionality can already be activated in harvesters in the German speaking countries.

First results

Initial practical trials have shown that the functionality tests of the random control stem method were successful for most machinery systems. Where necessary, the German software was adapted in cooperation with the individual manufacturers. In addition to this, it was also possible to identify the hardware and software versions required by the individual machine systems in order to acquire the functionality through upgrading.
The random control stem method is the first procedure that verifiably ensures the reliability of the harvester measurement and grading quality.

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