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Potential Use of Cable Yarding Systems in Romania

Master Thesis

of

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Vienna, March 2011

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1 Introduction

1.1 Problem

After the political regime change in 1989 when democracy took the place of the communism and especially in new enlarged European Union, Romania became very attractive to important foreign and also domestic investments in the timber industry most of them in the processing industry represented by sawmills, panel mills, furniture. Due to the wide range of forest resources, during the last years some improvements were done in timber harvesting also, but generally speaking the forestry chain is not characterized as ecologically-oriented, suffering from problems starting with the timber harvesting and finishing with the processing.

Romania, as most of the ex-communist countries (Ukraine, Bulgaria, Slovakia, etc.), doesn't have a very developed forest road network. At the end of 2007 it had a density of 6.5 m/ha only. This is very far from the European countries with a similar landscape like Germany with 45 m/ha, Switzerland 44 m/ha, Austria 45 m/ha, France 26 m/ha (TRANSYLVANIA UNIVERSITY BRASOV, 2004).

The forest roads in Romania are built mainly in the valleys and the slopes are not accessible. This has an old thinking behind, which states that the building of forest roads creates ecological problems by the breaking up these slopes. But due to high extracting distances, the current practice is to build up skidding roads for which usually bulldozers are used, or roads are created just by following the same path. These roads can reach 3 to 4 km in length.

Thus, skidding is the main technique used for timber extraction in the Romanian forests. It is well known that these practices create high site and stand damages. The most important site damages are considered as rut depths, soil compaction and erosion, whereas the site damages are considered to be mechanical injuries created to the residual trees and advanced regeneration.

When the slopes of the secondary water streams are not very steep, they are also used as skidding paths which have also very destructive ecological consequences for the water habitats and water quality.

In case of steep terrain, where skidders can not be used and building of skidding roads is expensive, hand delivery is also quite frequently used for timber extraction.

Another method for difficult slope conditions is horse logging. Even though the productivity is very low they are used to avoid other investments for road construction.

But from an ecological point of view, all of them have high destructive impacts. One big problem is the lack of knowledge in field of use of the harvesting techniques and the damages made to site and stand.

All these problems were pointed out during the process of forest certification by FSC started in 2003. Now a high share of the state owned forests are certified, but these problems are underlined and these practices must be changed. For example, it is forbidden to use the river valleys as skidding tracks and also to pass them without protecting with small bridges. It is also forbidden to build skidding roads. The FSC commission evaluates every year what has been done for eliminating these weak points.

It is still not possible to apply strictly these standards because this means that a high amount of timber from the mountainous areas could not be harvested.

For handling the chain of problems it is necessary to increase the forest road network density, to improve the training and the state should interfere with regulations and possible subsidies or financings for the purchasing of new machines (harvester, forwarder, tower yarder).

The problem is rather complex and therefore the thesis will be focused on the timber harvesting in steep terrain, especially the most difficult conditions where are found the highest ecological damages and the lowest accessible areas. In summary, the main problems are the damages made to the stand and site, inaccessible forest areas. In this master's thesis will be discussed harvesting using the cable yarding systems which have fewer sites and stand impacts than conventional ground-based systems. This technique is not new for Romania, because until the Revolution from 1989 these systems were used but due to the high operating costs, they were taken out step by step.

Will be also studied the volumes available in our topic areas which can be harvested with the cable yarding systems and according to this, the number of the machines necessary to harvest these volumes.

1.2 Objectives

The aim of the master thesis is to find the share of the harvestable volume from Romania which can be extracted by using the cable yarding systems and the number of the machines needed. In detail the objectives are:

1. estimating the possible use of cable yarding systems for one subunit of the National Forestry Administration – Romsilva (Brodina) which is situated in Suceava District split into tower yarders and sledge winches
2. extrapolation of the results to the whole Romanian forest area according to the annual cut
3. calculation of the needed number of tower yarders and sledge winches for harvesting the volume resulted from the analyses

The results of this study have importance as decision support for the forest owners from the ecological point of view as a suitable harvesting solution. They are as well important for the potential investments or for the cable yarding equipment producers from the available volume and the number of machines which can be used.

2 Background

2.1 Forest Conditions in Romania

According to the statistical report SILV 1 Romania has at 31.12.2007 a total area of the forest stock of 6,484,572 ha (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007). This ranks Romania on a middle place through the EU countries, dominated by France (15.2 millions ha), Germany (10.4 millions ha), Italy (9.9 millions ha), Poland (8.7 millions ha) and ending with Austria (3.5 millions ha), Czech Republic (2.6 millions ha), Slovakia (2.0 millions ha).

The ownership structure shows that the state forests cover 57% from the total area, but Romania is still in the process of re-ceding ownership of the forests to the former owners or their descendents (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

In Figure 1 the forests public ownership of the administrative – territorial authorities are represented usually by the town or village halls and the forests private ownership of juridical persons with private rights are represented by parishes or other kind associations.

From a total area of the forest stock of 6,484,572 ha, the land covered by the forest has an area of 6,314,937 ha and the rest of 169,635 ha is represented by land for cultivation needs, administration, forest roads, nonproductive areas, occupancies and litigations, temporary taken out from forest stock (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

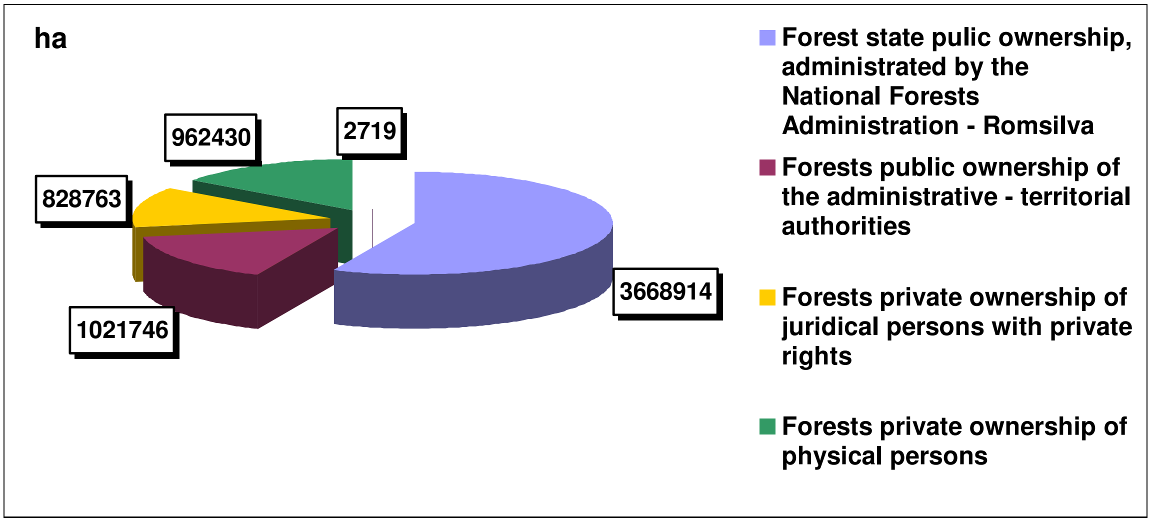


Figure 1. Distribution of the forest area due to the ownership structure (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

It is expected that the state forests will cover at the end of the restitution process around 35%, but this depends on the documents that prove the inheritance rights of the descendents to get back the forests or other land properties. Another point is that the state is interested in buying forest land from the owners, so an exact approximation of the future coverage of the state forests can not be done.

The national forest stock area represents 27.2% from the total country area, while the European average is 32.4%, which is strictly related to the variety of the Romanian landscape (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

Romania benefits, from the landscape point of view, from a very balanced distribution of the total area: 31% mountains, 36% hills and plateaus and 33% plains and flood plains. On the map, the mountains are colored with dark brown covering the ring around the centre, then the hills colored with light brown are making the transition to the plains which are covering the extremities of the country and colored with green.

Figure 2. Physical and administrative Romania's map (ro.globalcom.ro)

The forests distribution due to the relief shapes shows that 52% are mountainous forests, 37% hilly forests and the rest of 11% are situated in the flat land (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

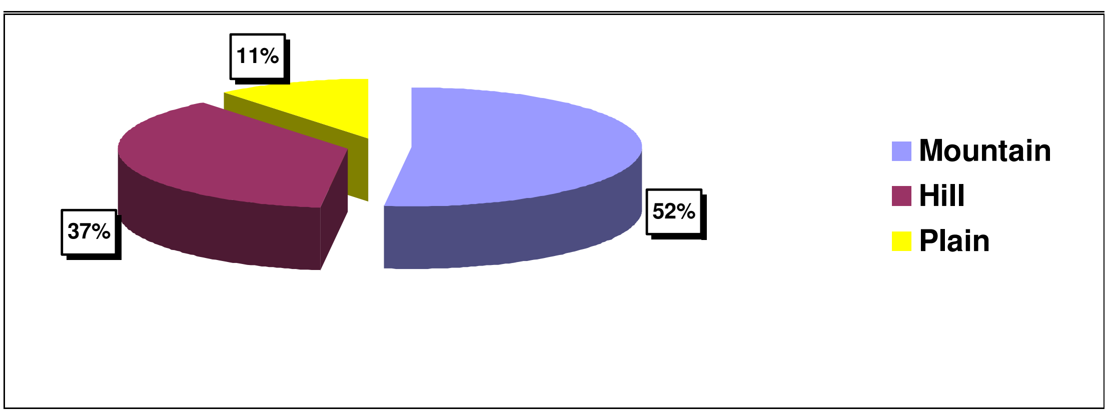


Figure 3. Distribution of the forests due to the relief shapes (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

As it is expected, the forests are mostly located in the mountains where the coniferous species are colored in dark green, then the coverage decreases towards the hills where we find mixed forests, coniferous and broadleaves, colored in green and then only broadleaf species colored in light green, reaching the lowest share in the plains where the forests leave the place for the agricultural lands.

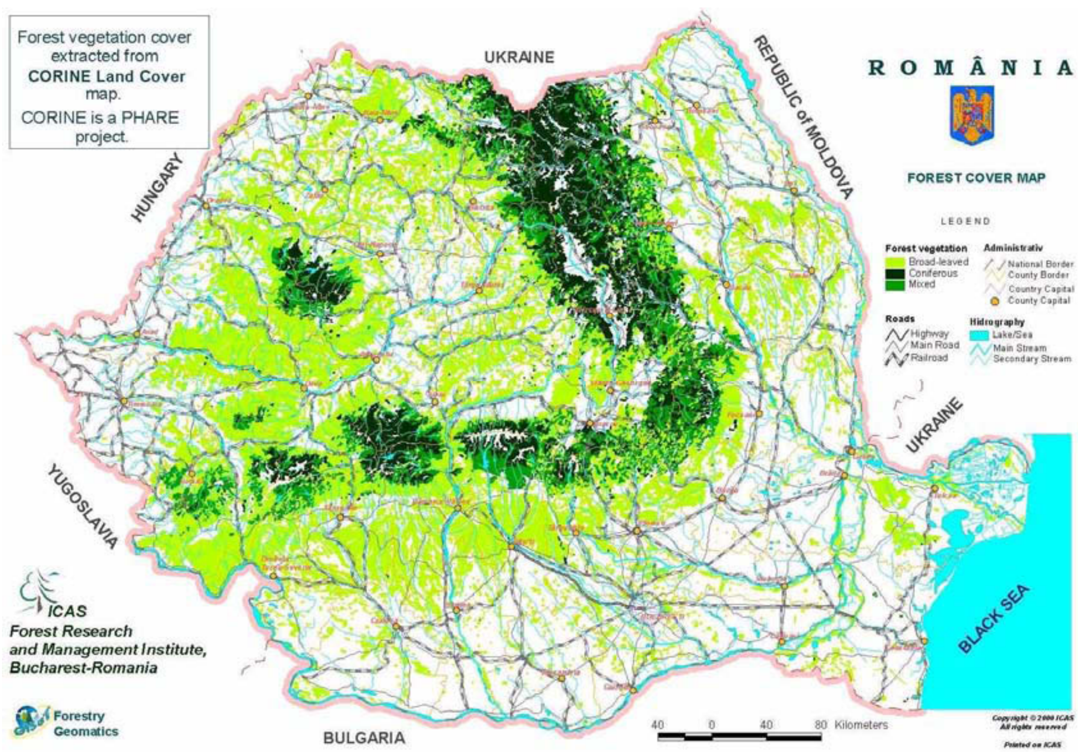


Figure 4. Forest vegetation cover (FOREST RESEARCH and MANAGEMENT INSTITUTE, 2006)

The slope gradient for the Romanian forest area was calculated by Assist. Eng. Eugen IORDACHE from the department of Cable Yarding System and Forest Transports, Transylvania University Brasov, Faculty of Silviculture and Forest Engineering. It was processed a Landsat image from May 2004 with a resolution of 30 m using the software ERDAS 9.0 and ARCVIEWGIS 9.1.

In this analysis the slope gradient is divided into 3 groups: 0-35%, 36-50% and >50%.

Table 1. Terrain description (FACULTY of SILVICULTURE and FOREST ENGINEERING, 2007)

Slope gradient [%]	Area [ha]	Share [%]
0 – 35	4,767,716	74
36 – 50	1,251,255	19
51 – 194	465,601	7
TOTAL	**6,484,572**	**100**

Figure 5 presents the terrain slope of the Romanian forests in percents colored with yellow for the areas with gradients between 0 and 35, orange for 36 to 50 and brown for the areas steeper than or equal with 51%.

Analyzing the slope gradient distribution on the map, we find the areas with a high density of steep slopes situated in the Meridional Carpathians (middle range, oriented East-West) and in the Northern part of the Occidental Carpathians (oriented Northwest - Southeast).

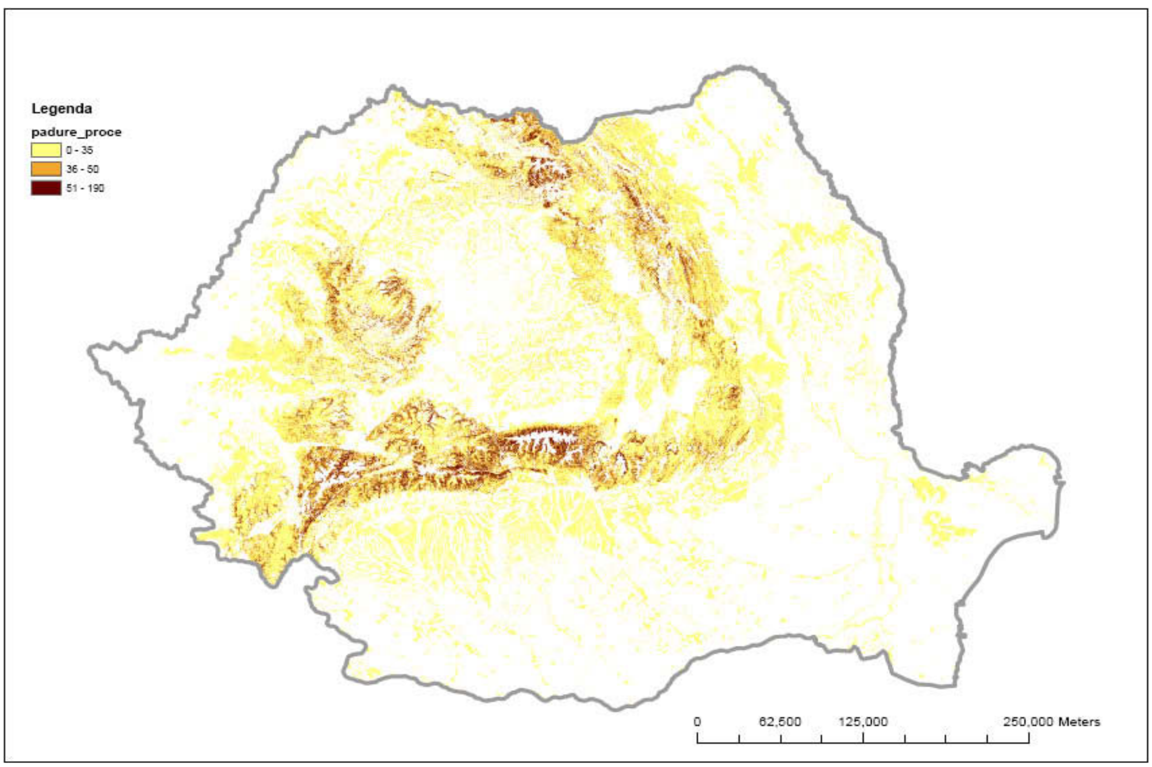


Figure 5. Terrain slope of the Romanian forests (FACULTY of SILVICULTURE and FOREST ENGINEERING, 2007)

The distribution of the forest area coverage due to the species composition shows that the Romanian forests are dominated by beech (32%) and coniferous (30%), the rest (38%) being covered by oak and other hard and soft wood species (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

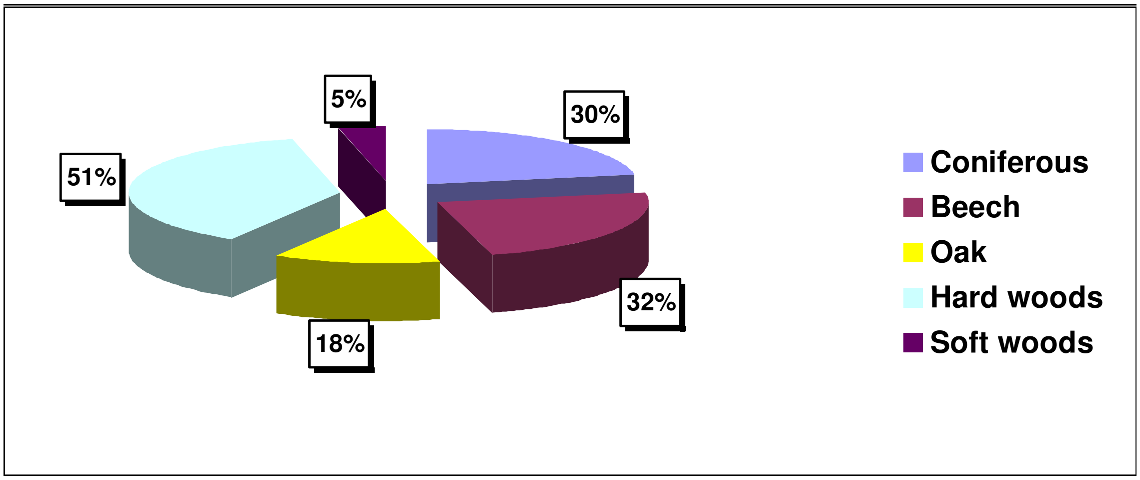


Figure 6. Species composition of the Romanian forests (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

The total standing timber volume is about 1,413 millions m^3. Comparing with the distribution due to the area covered, the forest stock is dominated by coniferous (39%), followed by beech (37%) and the remained 24% by oak and other species (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

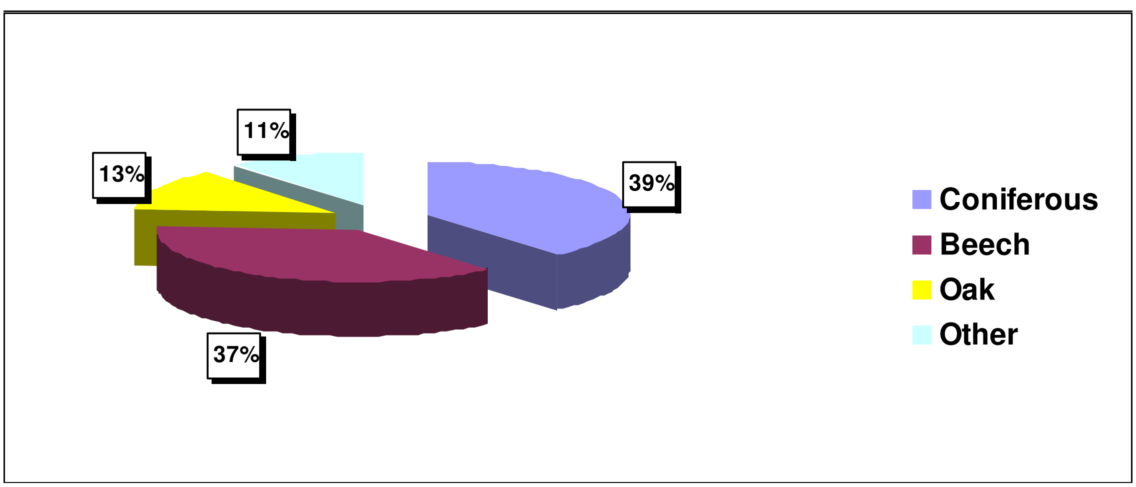


Figure 7. The standing timber volume due to the species composition (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

The average volume per hectare of the forests which constitute the forest stock is 218 m^3/ha while Switzerland has 336.6 m^3/ha, Austria 325 m^3/ha, Germany 319.9 m^3/ha, Slovenia 282.6 m^3/ha, France 190.8 m^3/ha, Sweden 107.4 m^3/ha, Finland 88.7 m^3/ha and Greece 45.2 m^3/ha.

Romania has also a high annual growth of 5.6 m^3/yr/ha, whereas the European average is 4.4 m^3/yr/ha.

The annual allowable cut of the Romanian forests is 22.3 millions m^3 (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

The report of the forest area per inhabitant has a value of 0.29 ha/inhabitant, very close to the European average which is 0.30 ha/inhabitant (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

The Government Decision nr. 1262/17.10.2007 approved a total volume of 18.5 millions m^3 to be harvested from the Romanian forests in 2008 distributed to the different ownership structures as follows:

Table 2. Annual cut distribution (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

Regulation	Volume mill. mc				
	Total	Distribution due to the ownership structure:			
		Administrative territorial authorities	Physical and juridical persons with private rights	Forest vegetation from the forests not included in the national forest stock	National Forests Administration - Romsilva
HG nr. 1262/2007	**18.5**	**3.41**	**4.25**	**1.02**	**9.82**

The state forests have the highest share of the annual cut (53%) followed by the forests owned by physical and juridical persons with private rights (23%) and the rest by the other kind of property rights.

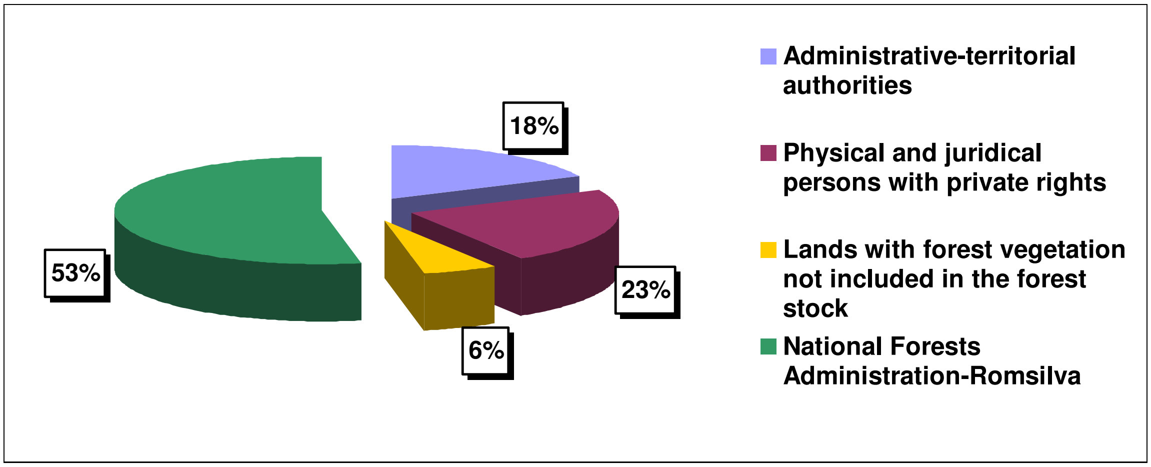


Figure 8. Annual cut distribution (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007)

2.2 Road Network

As it was already emphasized, the forest road network is one of the most important problems of the Romanian forestry. According to a study from 1959, made by the Department of Silviculture, only 40% of the forests were considered accessible, the transport network having the following structure: paved roads (10%), forest railways (13%), cable yarding systems (4%), skidding roads (55%) and public roads (18%) (GIURGIU, 2006).

At the end of 2007, the Romanian forests were supplied by a total road network length of about 34,000 km, out of which approximately 31,000 km are forest roads (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

The existing roads where is developing 90% of the total forest transport gives an average road network density index of 6.5 m/ha. This road network provides an accessibility of 65% for an average extracting distance of 2 km (AUSTROPROJEKT, 2008).

The existing road network is not uniformly spread on the entire area of the forest stock, thus the forests of some districts have 7 m/ha and in the flat area they have only 3 to 4 m/ha (MINISTRY OF AGRICULTURE, FORESTS and RURAL DEVELOPMENT, 2007).

But this problem has strong connections in the past. Given a lack of financial funds, correlated with low timber prices and a bad utilization of the wood resources, skidding roads, water transports, narrow railways were adopted as temporary solutions for supplying the forest stock. These were used until the working-out of the commercial harvesting forest resources, usually virgin forests. Only in a few cases, such as The Romanian Orthodox Church Fund from Bucovina, which set up a permanent forest road network, creation of the Austrian forester Josef Opletal (1913).

The deficiency of the road network has a lot of consequences at different levels, such as:

- non correlation between harvesting the annual cut with the annual allowable cut of every management unit and, as a result, there are over cuttings of the accessible areas

- non realization of the thinnings and sanitary harvests at the right time, with negative effects on the forest development and phytosanitary condition, and also the depreciation of a high share of wood

- high harvesting costs, with high labor costs, material and energy, mostly due to high extracting distances

- the impossibility of developing a proper tourist infrastructure and hence a bad revaluation of the forest's recreation potential.

2.3 Harvesting Systems

The timber harvest should not be done in the forest's detriment and its role for regularization of the water flows, keeping of the terrain stability or protection of the biodiversity.
The timber industry was and remains a branch with a high relevance for the Romanian economy, the favoring factors being, between others, the timber resources in respect of quantity and quality, long tradition and experience, multiple uses of the wood products for the human being.

Romania has a long forestry tradition which was influenced by the political regimes during its tumultuous history. A very benefic one was during the Habsburg and afterwards the Austro-Hungarian Empire when a very good cartographic database was developed, as well as inventories, management plans and a good transport network with forest roads and railways.

Bucovina, situated in the North of Romania, is the most forested area and was under the direct Austrian influence. At that time, the state owned about 200,000 ha, compact forest area where was applied a good forestry policy which contributed to the development of the management planning, infrastructure and timber industrialization. This forest area was afterwards given in the administration of The Romanian Orthodox Church.

In 1948, after the communists took the political power, the state nationalized all the land properties from the owners and a massive change was applied in the forest policy through the centralization of the management and the decisions. The forests were confronted with over-harvesting due to the states necessities and in the North with large clear cuts for fulfilling some war duties to the Soviet Union.

After 1989, when the democracy started to be implemented in Romania, the forestry policy started also to change from a centralized regime to a more opened one. In the same time, began a process of retrocede the forests to the former owners.

The harvesting systems used were also influenced by the forestry policies.

a. History

Before 1989 for felling, delimbing and cross cutting were used chain saws produced mainly in Soviet Union (Ural, Drujba 4, etc) and Romania (Retezat) which were big, heavy and hard to manipulate. The Russian chain saws have petrol engines with one cylinder and two-stroke and the weight higher than 10 kg without bar and chain. The particularity is that the bar can be rotated at 90^0 for felling the standing tree.

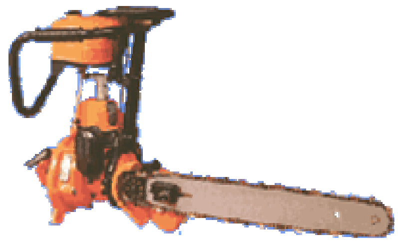


Figure 9. Drujba 4 (www.benzopily.ro)

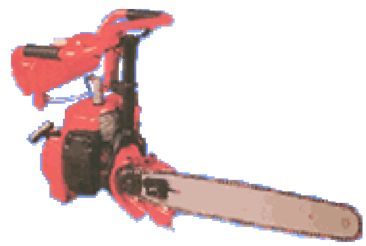


Figure 10. Ural (www.benzopily.ru)

The extraction was done with tractors (U650), skidders (TAF), horses, cable yarding systems (FPU 500, FP 2) and the transport with forest trains and through the water streams.

The tractors are usual farming tractors two or four-wheel drive adapted for the forest work with more weight on the front side to ensure the stability on the slopes when they drive uphill. Other adjustment for timber extraction is a metal hack in the back side and winches for hauling the logs which are lying on the hack.

Figure 11. Tractor U 650 (images.google.ro)

The skidder TAF is a four wheel drive machine which has a pusher blade in the front, articulated in the middle for driving in difficult conditions, a strong metallic shield and a winch in the back side. As in the tractor case, the load is also semi-suspended.

Figure 12. Skidder TAF 654 (crisanmarius.blogspot.com*)***

The cable yarding systems, FPU 500 and FP 2, are Romanian made and equipped with Diesel engines. FPU 500 has a maximum skyline length of 500 m and FP 2 1,500 m.

The forest trains are running on special railways which have a narrower gauge than the usual ones. They are propelled by steam engines which transform the thermal energy into mechanical work.

Figure 13. Forest train (img528.imageshack.us)

The transport by water can be done using the natural water streams or channels special constructed for this. In this way were transported from forest to saw mills the logs from the coniferous species. This is the explanation why, in that times, the saw mills were located close to the rivers.

Figure 14. Logs transport through water flows (birou_promovare_turism.lx.ro)

b. State of the Art

After 1989, Romania took contact with modern technologies, but in forests harvesting, the first changes are in the use of modern chain saws (Stihl, Husquarna, etc.). The tractors and the skidders are very similar with the old systems with small improvements and imported engines like Perkins for skidders.

Figure 15. Skidder TAF 900 (www.maviprod.ro)

The cable yarding systems disappeared completely due to high maintenance and running costs. The old systems are still produced with small improvements but without big success.

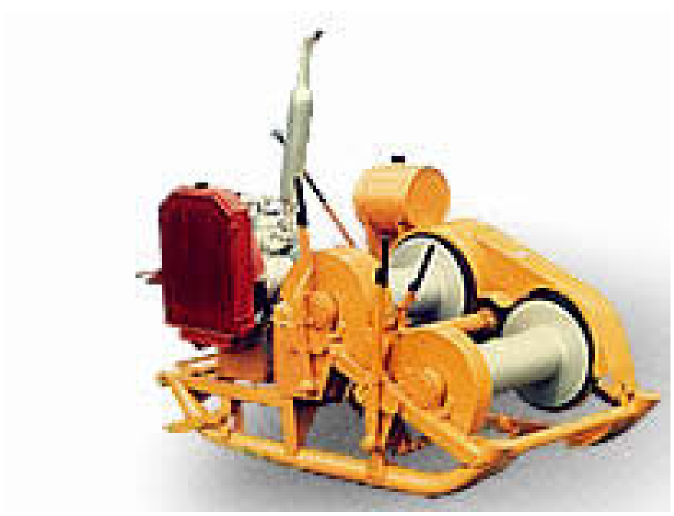


Figure 16. Cable yarding system FPU 500 (www.maviprod.ro)

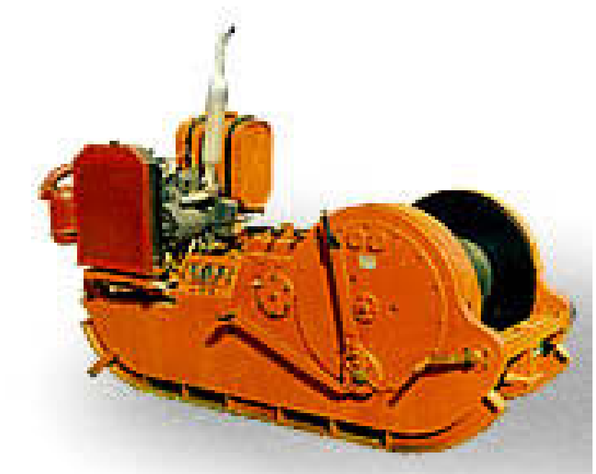


Figure 17. Cable yarding system FP 2 (www.maviprod.ro)

So, the felling is done with the chain saws and the extracting with tractors, skidders, and horses for very steep slopes. For big slopes is also very common to use hand delivery via gravitation.

Process	Forest		Assortment	Mechanization
	Stand	Roadside		
Felling Delimbing Cross Cutting	Chain Saw		Stem	Partly Mechanized
Extracting	Farm Tractor with Winch, Skidder			

Process	Forest		Assortment	Mechanization
	Stand	Roadside		
Felling Delimbing Cross Cutting	Chain Saw		Stem	Partly Mechanized
Extracting	Horse, Hand Delivery			Not Mechanized

Remarks
Felling, delimbing and cross cutting with chain saw in the stand. Extracting the stems with farm tractor with winch in accessible areas and skidders, horses or ground logging in steep terrain.

Figure 18. Harvesting systems and flow processes

The most spread harvesting system is the felling, delimbing and toping with the chain saw and the extracting with the skidders or tractors. Through the toping it is eliminated the top of the tree and the rotten parts. The rest is extracted in stem length for increasing the productivity. The sorting and the cutting into assortments is made on the forest road or in log yards. The crew usually has 4 to 5 people: a driver, a choker setter, an assistant of the choker setter and one or two chain saw operators. Sometimes one or two people more are employed for cleaning the plot. The productivity of such a system for an extracting distance of maximum 1 km is about 4.5 m^3/PSH_{15} for the main cutting and about 3 m^3/ PSH_{15} for the thinnings with a cost of about 11 EUR/m^3. In the case of the thinnings with small average volume per tree, can be used additionally horses for collecting the logs and making bigger piles.

For the harvesting with horses the crew usually has 3 to 4 people, one for fixing the logs in the forest, one for discharging the logs, and one or two chain saw operators. As in the previous case, there are additional one or two people more for cleaning the plot. The productivity is lower depending on how many horses are working and the price is the same.

For the cable yarding systems the crew has usually one or two chain saw operators, one choker setter, one winch operator and one for landing.

The combination harvester forwarder is not very common for the Romanian forestry.

In the last years a few companies started to buy harvesters, forwarders or cable yarding systems, but the timber harvested with these modern technologies represents a very low share.

3 Methodology

3.1 Study Area

The specific case study was done in Suceava subunit of National Forestry Administration – Romsilva (RNP – Romsilva), subsidiary Brodina. This has a total forest state owned area of 13,317 ha divided in 2 production units, U.P. II with 7,279 ha and U.P. III with 6,038 ha (FOREST RESEARCH and MANAGEMENT INSTITUTE, 2005). In Romania the forest area is grouped in production units, U.P., which are divided in subunits, u.a. (management units).

The forest area is supplied by a forest road network of 76.7 km out of which 10.5 km are public roads and 66.2 km are forest roads. This gives an average road network density of 5.8 m/ha.

For U.P. II there are 28.6 km roads divided in 10.5 km public roads and 18.1 km forest roads. Reported to the forest area of 7,279 ha, this gives a road network density of 3.9 m/ha. But the total forest area served by this road network is 8,071 ha, 792 ha being private forests. Thus, the road network density for the whole forest area becomes 3.5 m/ha.

The second production unit, U.P. III is served by 48.1 km forest roads. Reporting this to the forest area of 6,038 ha, results into a road network density of 8 m/ha. As it is the case in U.P. II, there are also private forests with a total area of 4,157 ha. This means that the total area is 10,195 ha, which gives a road network density of 4.7 m/ha.

Considering now the entire forest area from Brodina, including the private forests (4,949 ha), gives a total forest area of 18,266 ha. Reporting now this area to the total roads length (76.7 km), gives a road network density of 4.2 m/ha (FOREST RESEARCH and MANAGEMENT INSTITUTE, 2005).

There are 2 different methods for the characterization of the road network. One refers to the distance between roads, road spacing expressed in meters (m), and the other shows the ratio between the road network length and the forest area, road network density expressed in meters per hectare (m/ha). The first approach is more suitable for the plain areas and for a good developed network in the mountain areas for showing the slope accessibility. The second one is specific for the hill and mountain areas (TRANSYLVANIA UNIVERSITY BRASOV, 2004).

For setting the suitable conditions for the cable yarding systems the threshold slope gradient from which is recommended to use these modern technologies was taken from the literature. The aim of the studies is to find the upper limit of the slope gradient until which harvesters, forwarders and other technologies which are cheaper than the cable yarding systems can be used. These thresholds usually depend on the soil depth, soil moisture, texture etc. In this study I chose the most frequent mentioned slope gradient from which it is suitable to use the cable yarding, which is 40% (STAMPFER, 2008).

For processing the maps was used ArcMap – ArcView option from ArcGis9 software and this uses the degrees for the slope gradient. Accordingly, for the classification of the slopes, it was calculated the threshold of 21.8^{o}.

The slope gradient deducted from these maps shows that for U.P. II 36% and for U.P. III 32% of the area is higher than 40% slope gradient. Taking now into account the whole study area, gives 34% of the area steeper than 40%.

Table 3. Slope gradient for U.P. II

Slope gradient [%]	Area [ha]	Share [%]
< 40	4,659	64
> 40	2,620	36
TOTAL	**7,279**	**100**

Table 4. Slope gradient for U.P. III

Slope gradient [%]	Area [ha]	Share [%]
< 40	4,106	68
> 40	1,932	32
TOTAL	**6,038**	**100**

On the maps the areas with slopes steeper than 40% or 21.8^0 in ArcGIS, were colored from orange to red according to the slope gradient, while the others were not colored (Map 1 and Map 2). Additionally were chosen the layers with the water flows, roads and plots.

3.2 Concept of Terrain Analysis

The plots were analyzed one by one considering the treatments proposed by the management plan and the relief steepness. The ones with difficult terrain conditions, areas with slope gradients higher than 40% or 21.8^0 in ArcGIS, and high potential harvesting volume were taken into consideration. Sometimes, even the potential volume was not very high, but the terrain steepness was very pronounced, the plot was still considered in our analysis.

In these plots the most suitable paths for the cable yarding were designed. As typical in Romania, the forest roads are mostly situated along the valleys. Thus, these paths were drawn from the forest road to the top of the mountain. Then the horizontal distance and the height as difference between the altitude of the top and the bottom point were measured. It has to be taken into account that the analysis was done only on the GIS maps and it is possible that the terrain could have some obstacles which could make impossible the settlement of the cable yarding systems. Next it was calculated in (Annex 1 and Annex 2) the slope distance and the average slope of the cable yarding (columns 1 to 4). The slope distance is accounted as the length of the skyline. Afterwards there were introduced the descriptions of the plots: management unit, area, species composition, age, existing volume per ha, silvicutural treatments proposed and the volume proposed in the management plan to be harvested (columns 5 to 11).

Next step is to calculate the volume that can be extracted with the cable yarding systems. First, was calculated the corresponding volume proposed for harvesting per hectare (column 12). Then, was calculated the area that can be covered by the system (column 13), for which it was taken into account the horizontal distance and the lateral yarding distance of 20 m left and right. This means that for our purpose, was calculated the area of a rectangle with the long side equal with the horizontal distance of the cable yarding system and the short side equal with 40 m. The resulted area was divided for every plot crossed by the cable yarding system (column 14).

The volume that can be extracted by the system (column 15) was found by multiplying the area covered by the cable with the volume proposed per hectare. But this is the stocking volume which is including the branches, top, etc. So, for getting the harvesting volume will be deducted 10% from the gross one: 5% branches (GIURGIU et al., 2004) and 5% the top.

One specific case is the femel system (group tree selection). As it is known, this is a more intensive treatment than the plenter one. The problem is that cannot be determined how many gaps are crossed by the cable yarding system. So, to be conservative, the femel system was taken into account as the plenter one.

The next step for this specific case study is the calculation of the economical efficiency of the cable yarding systems established before. This represents the ratio between the volume that can be extracted (column 15) and the skyline length (column 3) and is shown in the column 16. According to the expert interview from the Institute of Forest Engineering the cable yarding systems are considered efficient if this ratio is between 1 and 0.3 m^3/m. In this master thesis 0.5 m^3/m was chosen as threshold. So, all the cable yarding systems that have this ratio higher or equal with 0.5 m^3/m are considered viable (STAMPFER, 2008).

As it was mentioned above, the most suitable situations were drawn. Additionally, more systems were designed for some plots but with more difficult conditions. So, a second scenario was developed whereby were analyzed again all the plots with at least one suitable cable yarding system from the previous scenario. In these plots were calculated the areas where can be located our systems and then multiplying them with the average harvestable volumes per hectare was found the possible volume that can be harvested in this new situation. These areas were found by designing regulated shapes on the slope and calculating their area. For some plots was difficult to calculate such areas and for them were considered the volumes calculated in the first scenario.

It has to be emphasized that only the similar cases were taken into consideration. If the new possible cable yarding system is crossing some other plots, this case and this area were not taken into consideration.

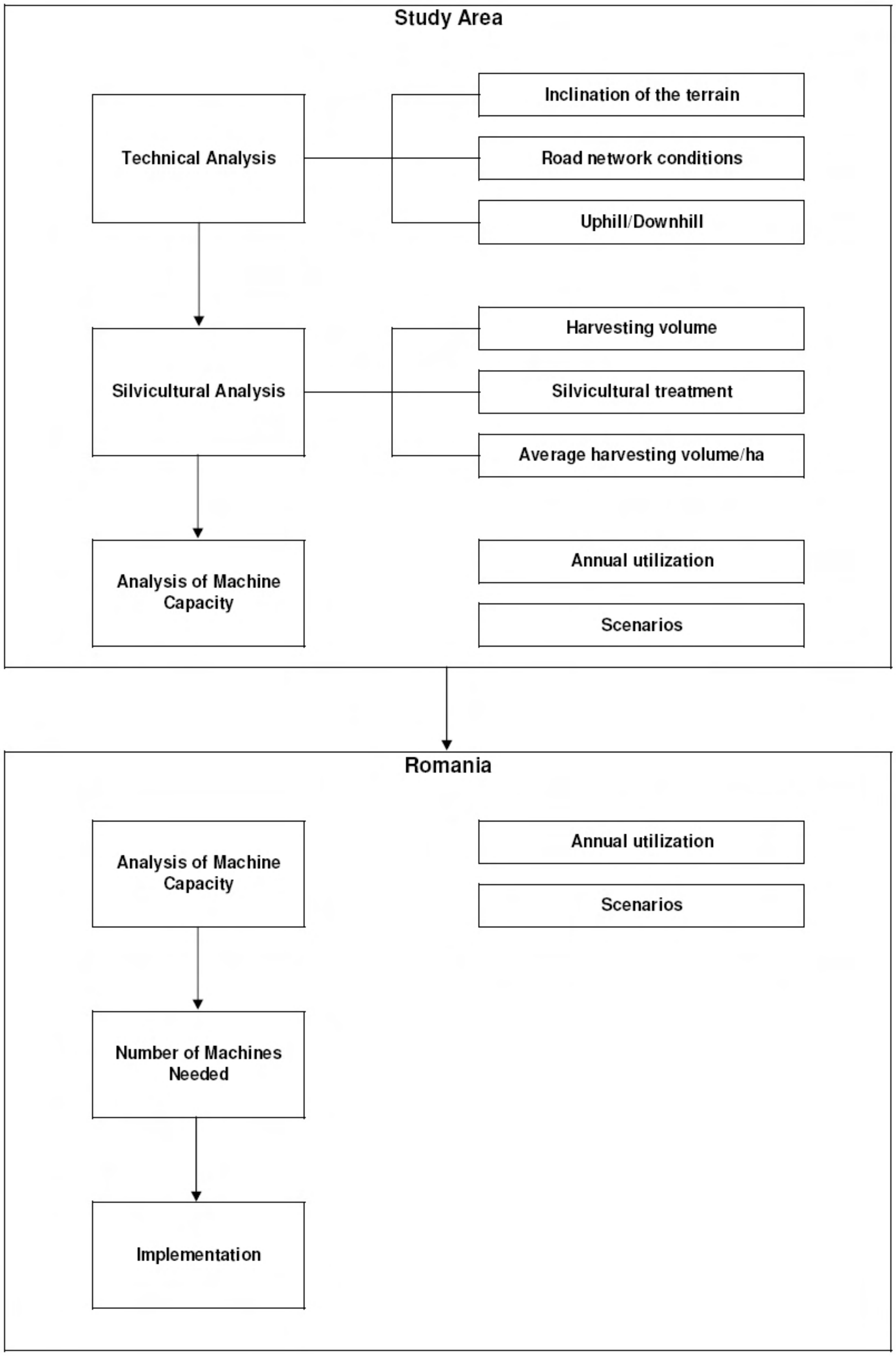
Another task of this study is to find out the share of the sledge winches and tower yarders. For this, was taken from the expert interview the threshold of 600 m. If the length of the skyline is lower or equal with 600 m, it is considered as being tower yarder and if higher it is considered the sledge winch case (STAMPFER, 2008).

Then the calculation was extrapolated for the whole forest area of Romania and, taking into account the productivity, was calculated the number of the machines necessary for extracting these volumes.

For the second scenario was taken the total volume and using the percentages from the first case, the total volume was split in volume harvestable with tower yarders, respective sledge winches. As in the first scenario, the results were then extrapolated and calculated the necessary number of the cable yarding systems.

The last step was to underline the conclusions and how to implement these systems in the Romanian forest harvesting.

Figure 19. Flow process chart



3.3 Description of Machinery

For this analysis will be used the tower yader Syncrofalke and the sledge winch Gantner HSW 80.

The tower yarder Syncrofalke is produced by the Austrian producer MM – Forsttechnik GmbH. It has been developed for yarding small or medium sized timber. This may be carried out either in uphill or downhill direction, as well as in flat terrain. The yarder can be mounted on any kind of carrier. The construction of the spar support allows a working range of 120° on both sides of the carrier. Furthermore, the raised spar may be tilted up to 12° in any direction, to compensate for the inclination of the terrain at the yarder's position. The power needed for operating the yarder is provided either from the carrier's engine or from a separate stationary engine. The power is transmitted to the winches by use of a hydraulic system.

Technical data

Power supply:	Carrier's engine, or an additional engine
Power transmission:	Hydraulic system
Diameter of Winch Drums:	1,000 mm
Maximum Pull:	3 or 4 to
Maximum cable speed:	Unloaded up to 10.0 m/sec Loaded up to 5.0 m/sec
Steel spar:	Height 10 or 12 m, hydraulically lifted. Working range 120° on both sides of the carrier.
Carriage:	"Sherpa-U 3 or 4 to", radio controlled clamping devices
Yarder's control:	Control handle (standard) Electronic control, including automatic distance and speed control. Additional radio control (optional).

(www.mm-forsttechnik.at)

Figure 20. The tower yarder Syncrofalke (www.mm-forsttechnik.at)

The sledge winch Gantner HSW 80 is produced by the Austrian producer Gantner Seilbahnbau GmbH. It is a fully hydrostatic sledge winch for efficient, economical and environment protecting operation

Versatile use: Up- and downhill transport, endless mainline systems, ground skidding, compatible with all carriage systems

Simple operation: One-handle operation with continuous regulation of line pull and line speed, electric starter, easy to view gauges

Allterrain: Sled design, closed bottom plate, roller fairlead, slope holding brakes, light weight, special lubrication system for steep terrain

Long life: Aluminum side parts, overload protection through pressure control valves, service friendly

Technical data

Type		HSW 80 NB
Max. line pull		
bare drum		60 KN / 6,000kp
full drum		30 KN / 3,000kp
Max. line speed		
bare drum		4.46 m/s
full drum		8.64 m/s
Line capacity*	Ø 10 mm	2,170 m
	Ø 12 mm	1,425 m
	Ø 14 mm	1,010 m
	Ø 16 mm	800 m
Weight with full tanks without lines		1,875 kg
Dimensions length x width x height		250 x 160 x 125 cm

Engine	Air cooled Hatz-Diesel engine with electric starter, approx. 58KW/80HP at 3,000 rpm, dry air filter, V-belt control
Power transmission	Linde variable displacement pump and motor for a large range o f torque and speed combinations
Brakes	Double shoe brake integrated in drum; downhill braking by wear-less hydraulic brake; multiple disk brake (safety brake - automatic stop)
Controls	Charging control, oil pressure control, temperature control, air filter pollution control, hour counter, high and low pressure gauges
Attachments	Sled frame, closed bottom plate, roller fairlead, slope holding brakes
Drum dimensions	Core Ø 31 cm, Flange Ø 60 cm, Width 1,000 mm

* The line capacity mentioned can be raised about 10 %.

(www.gantner-cableways.com)

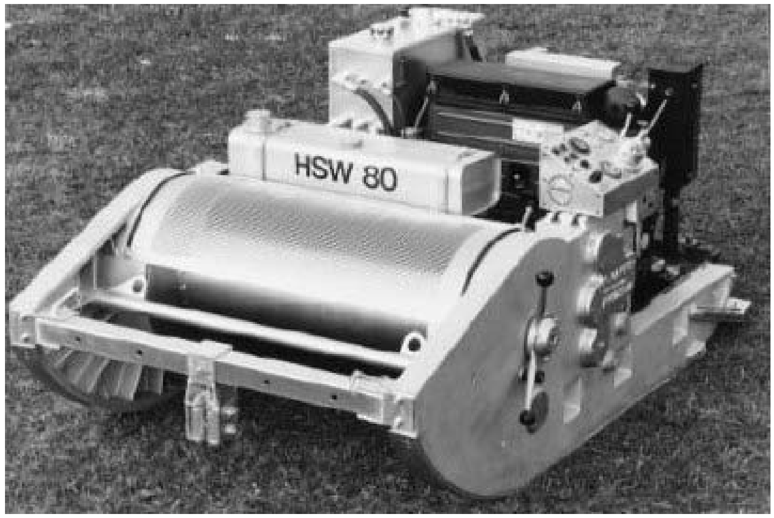
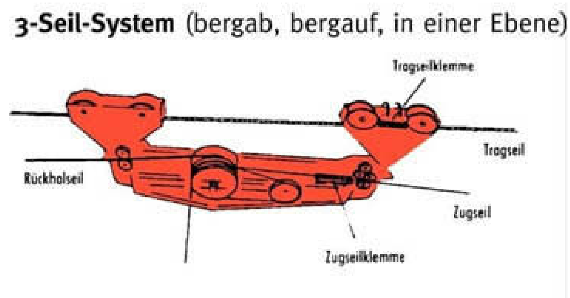


Figure 21. The sledge which Gantner HSW 80 (www.gantner-cableways.com)

Depending on the treatment where the cable yarding systems are used, they can be split in smaller than 3 tones used for the thinnings and bigger used for the final felling operations.

For both systems the carriages Sherpa U3 or U4 equipped with a skyline and mainline clamp will be used. The operation of the clamps is caused by remote control. When the skyline is clamped, the mainline clamp opens automatically and vice versa. The remote control has the advantage that the carriage can be fixed at any position of the skyline and that the load can be held at any height above ground. The kind of operation enables very efficient but gentle loading of timber on different stands, even while pulling the load to a line, as well as an exact loading on the storage.



Types

Type	Load-capacity	Skyline	Weight	Operation
SHERPA	1,5 to	14 – 20 mm	appr. 190 kg	gravity
SHERPA-U 1,5	1,5 to	14 – 20 mm	appr. 280 kg	allterrain
SHERPA-U 3	3,0 to	14 – 24 mm	appr. 410 kg	allterrain
SHERPA-U 4	4,0 to	18 – 26 mm	appr. 520 kg	allterrain
SHERPA Mot II	4,0 to	18 – 26 mm	appr. 610 kg	gravity

Figure 22. The carriage Sherpa (www.mm-forsttechnik.at)

3.4 Harvesting System Description

In this master thesis will be described the most widely-used system in Romania which is the stem system and can be considered somewhere between the whole tree and the cut to length system. This means that the felling, delimbing and toping will be done in the stand and then at the forest road the cross cutting and the sorting of the timber will be made.

One important thing is that the payload must not exceed 2 tones which means 2.5 m^3 of harvested timber.

3.5 Assumptions

As it was already emphasized, another task of this master thesis is to calculate the necessary number of tower yarders and sledge winches for the harvesting of the resulted volume from our analysis. For this is necessary productivity of the two cable yarding systems.

For the tower yarder will be used the formula:

$$prod_{Seil} = k * (-22.7713 + 41.8961 * baumvol^{0.15} - 0.0046 * dist - 0.0897 * neig)$$

baumvol	tree volume (m^3)
dist	extracting distance (m)
neig	slope gradient (%)
k	calculating factor from PSH_0 to PSH_{15} (0.8)
$prod_{Seil}$	system productivity (including break < 15 min) (m^3/PSH_{15} - h)

(LIMBECK-LILIENAU, 2002).

The volume of the tree without branches and top was found using dendrometric tables (GIURGIU et al., 2004) according to the average diameter at the breast height and the average height for each species and each plot. Then, according to the volume that can be harvested, it is calculated the weighted average of the stem volume for the plots harvested with the tower yarder which has a value of 2.83 m^3, but due to the limit of the payload of 2.5 m^3, this value will be used for the calculation. Even would be use the tree volume, which is higher than the stem volume, have to be used the maximum payload of 2.5 m^3.

The extracting distance is calculated as the weighted average, according to the volume that can be harvested and the slope distance of the cable yarding system divided to 2. This gives a value of 243.63 m.

The slope gradient is calculated as the weighted average of gradients and has a value of 37.3 %.

Substituting now all the values in the formula gives:

$$prod_{Seil} = 16.66 \text{ m}^3/PSH_{15}$$

The formula used above is used for the whole tree harvesting system. As it was shown, in this thesis it is used an intermediate system which is the stem volume. Considering the cut to length system the productivity can be calculated with the formula:

$prod_{Seil} = k * (-83.6676 + 140.7779 * stkvol^{0.15} + 1.0564 * distanz^{0.7} - 0.43 * zuzug - 3.0857 * KONSTR + 1.9835 * schling - 1.8559 * stkvol^{0.15} * distanz^{0.7} + 0.0019 * distanz^{0.7} * entpro)$

stkvol	average volume per piece (m^3)
distanz	extracting distance (m)
zuzug	lateral yarding distance (m)
schling	number of chokers
entpro	extraction percent (%)
KONSTR	factor: with (0) or without (1) pre-concentration
k	calculation factor from PSH_0 to PSH_{15} (0.92)

(STAMPFER, 2002)

For the calculation will be used the following values: average volume per piece 0.35 m^3, extracting distance 243.63 m, lateral yarding distance 20 m, 2 chokers, extraction percent 26%, 1 for the pre-concentration factor. The average volume per 4 m piece was calculated from the average height of the tree, 32.3 m divided to 4 gives 8 logs with a length of 4 m. Considering the average volume of 2.83 m^3 per stem, gives an average volume of 0.35 m^3 per piece. Substituting these values gives the result:

$prod_{Seil} = 6.07\ m^3/PSH_{15}$

Another important fact in the calculation of the productivity is the time used for the mounting and dismounting of the system.
For the tower yarder will be used the formula:

Installation time = Set-up + Take-down

*Set-up time = e ^ (*1.42 + 0.00229 ** corridor length* + 0.03 ** int. support height* + 0.256 ** corridor type* – 0.65 ** extraction direction* + 0.11 ** yarder size* + 0.491 ** extraction direction * yarder size)*

*Take-down = e ^ (*0.96 + 0.00233 ** corridor length* – 0.31 ** extraction direction* – 0.31 ** int support* + 0.33 ** yarder size)*
(STAMPFER et al.,2006)

For the calculation will be used the following values: corridor length 243.63 m, int. support height 12 m, corridor type 1 as first corridor, extraction direction downhill (0), yarder size small (0), one intermediate support. Substituting the values gives:

Set-up time = 13 h 20'

Take down time = 3 h 23'

which gives total:

Installation time = 16 h 43'

If would be considered a usual crew of 3 peoples gives a value of 5 h 34'.

The productivity of the sledge winch will be calculated with the formula:

$$L = V/Z * 60$$

L	system productivity (m^3/ PSH_{15})
V	volume extracted per cycle (m^3)
Z	cycle time (min.)

$$Z = (6.8 * 10^{-3} * RD + 8.0) + (0.187 * SZD - 0.9)$$

RD	extracting distance (m)
SZD	lateral yarding distance (m)

(HEINIMAN, 1986)

The average volume per tree without branches and top was calculated as it was shown above and in the sledge winch case this is 2.97 m^3. Considering an average weight of 800 kg/m^3, gives 2.4 to which is acceptable for our carriage. So, for our calculation this will be used as average volume per cycle.

The extracting distance was calculated as the weighted average slope distance of the cable yarding system divided to 2, resulting in a value of 472.95 m.

The lateral yarding distance, presented in the chapter 3.2, is 20 m.
Substituting now all the values in the formula, gives:

Z = 14.06 min.
L = 12.67 m^3/ PSH_{15}

For the time needed for mounting and dismounting the system will be used the formula:

$$MDA = 0.016 * SL + 0.026 * DUM1 * SL + 0.022 * DUM2 * SL + 19.2$$

MDA	time for mounting and dismounting (h)	
SL	skyline length (m)	
DUM1	Dummy – Variable	1 for “Alpen 2”
		0 for other regions
DUM2	Dummy – Variable	1 for “Voralpen”
		0 for other regions

(HEINIMAN, 1986)

The skyline length will be calculated as the weighted average of the individual skyline lengths for the tower yarders and has a value of 945.89 m.
The Dummy – Variable 1 is equal with “0” and the Dummy – Variable 2 is equal with “1”, because this region is closer to our subject area.

Substituting now all the values in the formula, gives:

MDA = 55 h
Considering, as above, a usual crew of 3 peoples, gives a value of 18 h 20’.

One important fact is that all the formulas were developed for uphill systems and as already emphasized all the systems from this master thesis are using the downhill yarding.

4 Results and Discussion

As it was shown previously 2 analyses were performed:

- the most suitable cases
- the potential volumes according to the suitable area

In the first one were analyzed the plots one by one and were determined the most suitable cable yarding systems and in the second one we considered the suitable areas from the first scenario.

For the first category of the most proper cable yarding systems, 79 cases in U.P. II and 22 cases in U.P. III were analyzed (Annex 1 and Annex 2).

In U.P. II from all 79 cases chosen due to the relief steepness and the scheduling of the harvests according to the decennial plan, only 48 were considered suitable with a total gross volume that can be extracted of 26,283 m^3, respective 23,655 m^3 real volumes. They are spread in 31 out of 686 management subunits.

Table 5. Number of cable yarding systems per management unit for U.P. II

Management unit	Number
8A	4
9A	2
13A	1
17A	2
18A	2
32	2
33A	1
43D	1
44C	1
46A	2
52A	3
53H	1
62A	1
63C	1
64A	1
65D	2

67A	3
68A	1
83A	2
83B	1
84A	1
85A	1
86A	1
86D	1
87A	2
88B	2
89A	1
96A	1
108F	2
117A	1
118A	1

Most of the cases, 32, have only one plot crossed by the cable yarding. This is normal because when the system crosses more plots, the area served, respectively the volume is lower. All these give a low efficiency ratio and then the unsuitability to use these harvesting technologies.

The slope distance, which was approximated with the skyline length, is varying from 347 to 1,480 m. Splitting now these cable yarding systems in the 2 categories, was found that 20 of them are tower yarders and 28 sledge winches with a volume of 6,877 m^3, respective 16,778 m^3.

Table 6. Distribution of the volumes that can be harvested with the cable yarding systems from U.P. II in the first scenario

Cable yarding type	**Volume [m^3]**	**Share [%]**
Tower yarder	6,877	29
Sledge winch	16,778	71
TOTAL	**23,655**	**7**
Volume proposed by the management plan	**337,487**	

An interesting fact is that for all the cases, the silvicultural treatment proposed is the femel cut. This is because in Romania the clear cuts are avoided as much as possible and in our specific case there are just a few plots with low volumes and high extraction distances. For thinnings and plenter system it is well known that the volumes proposed per ha are low and because of this and the high extracting distances, the cable yarding systems are not economically efficient.

In U.P. III from all 22 cases, only 11 are suitable. These 11 cable yarding systems can extract a total gross volume of 6,207 m^3, respective 5,586 m^3 real volume. They are spread in 8 out of 899 management units.

Table 7. Number of cable yarding systems per management unit for U.P. III

Management unit	Number
124A	1
152I	1
165A	2
167B	1
179A	1
301A	1
301F	1
329B	1

Most of the cases, 6, have only 1 plot crossed by the cable yarding systems and other 5 are crossing 2 plots. As it was shown also above, crossing more plots decreases the efficiency ratio because the skyline length which is crossing these plots is not used for the timber extracting.

The slope distances varies here from 440 till 1,701 m. Due to this distance, the cable yarding systems were split in 8 tower yarders and 3 sledge winches with a volume of 3,142 m^3, respective 2,444 m^3.

Table 8. Distribution of the volumes that can be harvested with the cable yarding systems from U.P. III in the first scenario

Cable yarding type	Volume [m^3]	Share [%]
Tower yarder	3,142	56
Sledge winch	2,444	44
TOTAL	**5,586**	**3**
Volume proposed by the management plan	**167,774**	

In U.P. III, even the area is lower with 1,241 ha, the volume proposed for harvesting is almost half of the volume proposed for U.P. II. This is because the area was very affected by the wind throws from 2002 and fragmented due to the forest ownership restitution process. As it was mentioned also in the chapter 3, in this area there are 4,157 ha private owned forests, comparable with the state owned forests of 6,038 ha. Like in U.P II the treatments proposed are mostly the femel ones; the novelty is that for 4 cases was found the clear cut system.
The cable yarding systems are developed from the valley to the top of the mountain, which means that the yarding is downhill.

In the second part of the analysis were analyzed some additional cases which are in fact some extensions of the first analyzed cases. The volume resulted from the calculations was reduced with 10% for getting the real volume and gives a volume of 22,231 m^3 for the tower yarder and 54,239 m^3 for the sledge winch in U.P. II.

Table 9. Distribution of the volumes that can be harvested with the cable yarding systems from U.P. II in the second scenario

Cable yarding type	Volume [m^3]	Share [%]
Tower yarder	22,231	29
Sledge winch	54,239	71
TOTAL	**76,470**	**23**
Volume proposed by the management plan	**337,487**	

In U.P. III results a volume of 9,023 m^3 for the tower yarder and 7,019 m^3 for the sledge winch.

Table 10. Distribution of the volumes that can be harvested with the cable yarding system from U.P. III in the second scenario

Cable yarding type	Volume [m^3]	Share [%]
Tower yarder	9,023	56
Sledge winch	7,019	44
TOTAL	**16,042**	**10**
Volume proposed by the management plan	**167,774**	

In this scenario the total volume for U.P. II is 76,470 m^3 and 16,042 m^3 for U.P. III. These represent about 3 times more then the previous case for each U.P. and maybe it looks not realistic. But, as it was shown before also, for all these plots the silvicultural treatment proposed is femel which can be considered a transition system from plenter to clear cut and it is well known that in this system the harvests are quite concentrated. Another important issue is that the whole volume proposed will not be harvested during a single year; the harvesting will be scheduled for 3 to 5 interventions during the whole period of 10 years, with some breaks in-between. Here comes the problem of concentrating the harvests to ensure the volume needed for the cable yarding systems to be efficient.

This scenario is in fact an extension of the specific case and all the systems found are using the downhill yarding. Summarizing, gives a total volume of 29,241 m^3 in the first scenario, representing 6% from the total volume proposed and 92,512 m^3 in the second scenario, representing 18% from the total volume proposed by the management plan.

Table 11. Distribution of the volumes that can be harvested with the cable yarding systems from the 2 scenarios

Cable yarding type	First scenario		Second scenario	
	Volume [m³]	Share [%]	Volume [m³]	Share [%]
Tower yarder	10,019	34	31,254	34
Sledge winch	19,222	66	61,258	66
TOTAL	**29,241**	**6**	**92,512**	**18**
Volume proposed by the management plan	**505,261**		**505,261**	

The next point is the extrapolation of the results from the specific case of the forestry subunit Brodina, to the whole forest area of Romania. For this, is necessary to have first of all the slope gradient of the analyzed area and the whole area.

The slope gradient shows that in U.P. II there are 2,620 ha (36%) steeper than 40% and in U.P. III 1,932 ha (32%) with the same characteristic. Comparing now the total area of both production units (13,317 ha) to the total area which has an inclination more than 40% (4,552 ha) gives an average percentage of 34% for these areas.

Unfortunately the analysis from the Brasov University doesn't show the proportion of forest area steeper than 40%, but steeper than 35%, which is 27%. Accordingly, onwards in our study will be considered for the calculation that 25% of the forest area is steeper than 40%.

Now the extrapolation should be done starting with the specific case where 6% of the harvestable volume that can be extracted with the cable yarding systems from a forest area which has 34% steeper than 40%, to the total area which has 25% steeper than 40%.

This is done simply as:

$$(25 \times 6) / 34 = 4.4$$

So, the share of the volume that can be extracted with the cable yarding systems for our first scenario is 4.4%, which represents 814,000 m^3/year from the total annual cut of 18.5 millions m^3.

Using now the percentages from the specific case and the productivity of the 2 cable yarding systems gives 276,760 m^3 for tower yarder and 537,240 m^3 for sledge winch.

Table 12. Volumes that can be harvested for the whole Romania in the first scenario

Cable yarding type	Volume [m^3]	Share [%]
Tower yarder	276,760	34
Sledge winch	537,240	66
TOTAL	**814,000**	

Following the same steps, was done the extrapolation of the results from the second scenario. Summarizing, the share of the volume that can be harvested with the cable yarding systems is 18%, split in 34% tower yarders and 66% sledge winches, with the same share of 34% of the area steeper than 40%.
Calculating now:

$$(25 \times 18) / 34 = 13.4$$

The share of the volume which can be extracted with the cable yarding systems is 13.4% which represents 2,479,000 m^3/year from the total annual cut of 18.5 millions m^3. Using the percentages from the specific case and the productivity of the 2 cable yarding systems gives a volume of 842,860 m^3 for tower yarder and 1,636,140 m^3 for sledge winch.

Table 13. Volumes that can be harvested for the whole Romania in the second scenario

Cable yarding type	Volume [m^3]	Share [%]
Tower yarder	842,860	34
Sledge winch	1,636,140	66
TOTAL	**2,479,000**	

The last step is the calculation of the number of cable yarding systems needed for harvesting the resulted volume from our analysis. For this will be considered the productivity and the time for mounting/dismounting of the systems from the chapter 3.4 with the assignation that for the tower yarder will be considered the lowest productivity value.

Most of the treatments applied are plenter ones. These treatments promote the natural regeneration and because of this the harvesting can be done only out of the vegetation period, between 15th of September and 30th of April. There are a few clear cuts, but they represent 5.6% from the whole volume, 10% from the volume extracted with tower yarders and 3% from the volume extracted with sledge winches. These cuttings can be done during the whole year, without restrictions.

So, for the calculation will be used the volume without the clear cuts and a period of 7 and half months which means 160 working days, 9 hours per day.

Another important task is the average volume that can be harvested with each system because in the calculation of the productivity have to be considered also the time needed for mounting/dismounting the system.

So, for harvesting the average volume of one plot, 408 m^3/plot in a period of:

408 m^3/plot / 17 m^3/PSH_{15} = 24 h.

To this have to be added the time for mounting/demounting of 5h 34' and gives a total time of 29 h 34'.

The period of 160 working days, 9 hours/day has a total of 1,440 hours, when one system can harvest 1,440 h / 29 h 34' = 48.70 plots with a total volume of

48.70 plots X 408 m^3/plot = 19,869.60 m^3.

Calculating now: 249,084 m^3 / 19,869.60 m^3 = 12.53 systems.

In the same way was done the calculation for sledge winch and gives a value of 39 systems.

Table 14. Volumes that can be harvested (excluding clear cut), productivity, time for mounting/demounting and the number of the cable yarding systems for the whole Romania in the first scenario

Cable yarding type	Volume [m^3]	Volume/system [m^3/plot]	Productivity [m^3/PSH_{15}]	MDT* [h]	System [number]
Tower yarder	249,084	408	17	5h 34'	13
Sledge winch	521,123	573	13	18h 20'	39
TOTAL	**770,207**				

** MDT – mounting/demounting time*

In the same manner will be made the calculation for the second scenario and results a total of 38 systems for tower yarder and 120 systems for sledge winch.

Table 15. Volumes that can be harvested (excluding clear cut), productivity, time for mounting/demounting and the number of the cable yarding systems for the whole Romania in the second scenario

Cable yarding type	Volume [m^3]	Volume/system [m^3/plot]	Productivity [m^3/ PSH_{15}]	MDT* [h]	System [number]
Tower yarder	758,574	408	17	5h 34’	38
Sledge winch	1,587,056	573	13	18h 20’	120
TOTAL	**2,345,630**				

** MDT – mounting/demounting time*

The calculations were done considering only the productivity and the mounting/demounting time. In practice can happen different breakdowns or transport issues which may make impossible the harvesting of the whole volume proposed.

Regarding the clear cuts, there is a small volume to be harvested during the remained period of 4 months and half.

So, the 13 systems can harvest a volume of 13 X 408 = 5,304 m^3 in a period of:

24 h + 5 h 34’ = 29 h 34’. This means that for harvesting the whole volume are needed:

27,676 m^3 / 5,304 m^3 = 5.22 times full systems and gives a period of:

5.22 X 29 h 34’ = 154 h 20’

In the same way results 45 h for the sledge winch.

Table 16. Clear cut situation for the whole Romania in the first scenario

Cable yarding type	Volume [m^3]	Volume/system [m^3/plot]	Productivity [m^3/PSH_{15}]	MDT* [h]	System [number]	Working time [h/system]
Tower yarder	27,676	408	17	5h 34’	13	154
Sledge winch	16,117	573	13	18h 20’	39	45
TOTAL	**43,793**					

** MDT – mounting/demounting time*

In the same manner will be made the calculation for the second scenario and results a total of 161 h for tower yarder and 45 h for the sledge winch.

Table 17. Clear cut situation for the whole Romania in the second scenario

Cable yarding type	Volume [m^3]	Volume/system [m^3/plot]	Productivity [m^3/PSH_{15}]	MDT* [h]	System [number]	Working time [h/system]
Tower yarder	84,286	408	17	5h 34'	38	161
Sledge winch	49,084	573	13	18h 20'	120	45
TOTAL	**133,370**					

** MDT – mounting/demounting time*

As can be seen, for the period 1st of May 15th of September the tower yarders have work for less than one month and the sledge winches for less than one week which is suboptimal from the economical point of view.

As it was already emphasized, Romanian forestry passes through a difficult period. This is due to a high demand of timber for the processing industry which is raising the prices, increase of the timber harvest and the non ecological harvesting technologies. These factors contribute to the environment degradation and due to the old technologies, to a low productivity and also a bad use of the timber resources.

In the mountainous regions where the harvesting conditions are the most difficult ones, all the consequences shown above are also worse than in the other regions. For the areas with steep slopes the cable yarding systems are the most suitable, being ecologically oriented and with a higher productivity comparing with the classical technologies.

Taking the actual situation of the Romanian forests, these systems can not be used in the same extent like in Austria, Switzerland or other countries with a rich experience in these harvesting technologies. The most important reasons are:

- the low road network density
- the silvicultural systems used and the treatments proposed

The implementation of these systems has to start firstly with good information in the educational level, forest administrators (private and state), state authorities responsible for forestry and harvesting firms. In the educational level, in the secondary, technical and high forestry schools, the lectures must be updated through different studies for trying to find solutions for the implementation of the cable yarding systems. Also very important is the practical training beside the theory. One solution could be the implementation of a national training system for forestry like Forstliche Ausbildungsstätte Ossiach. The forest administrators are mostly interested in the harvesting costs. Even though there are regulations for limiting the bad environmental effects of this activity, in hard harvesting conditions they are not respected almost at all. Most of these cases occur in the mountain areas, where are found usually the worth ones. For example, long distance skidding or crossing the water flows it is not allowed, but in a lot of the cases it is used. Here comes the role of the state authorities which should react in order to stop the environment degradation. The authorities have a double role: one is to try to stop the destructive harvesting practices and the second one is to find solutions to help the implementation of the modern harvesting technologies through financings, long term harvesting contracts, etc.

The most restrictive factors for the cable yarding systems use are the road network density and the silvicultural treatments. The road network is a problem of investments which can be improved by orienting the forestry strategy towards increasing the forest accessibility which has a lot of advantages such as: lower harvesting costs by decreasing the extracting distance, better conditions for performing the thinnings which means better conditions for the future forest, access in the case of fire, diseases and not the last, the tourism. The silvicultural treatments problem is the most sensible and maybe the most difficult one. The management plans which are regulating through the treatments proposed the harvesting techniques are oriented towards long regeneration periods with more interventions and low volumes. This is not bad if is thought only from the nature oriented point of view. In the case of steep slopes, where the only possibilities are the cable yarding, skidding or hand delivery, if the volumes proposed are low, taking into consideration, as it is mostly the case in Romania, a high extracting distance, brings the conclusion that the only economically efficient harvesting solutions are skidding or hand delivery. Now the topic of the evaluation is about what is better for the forest: extensive silvicultural treatments with bad environmental consequences which affect the forest soil, water flows, or intensive treatments which foster the use of the cable yarding systems with almost no significant damages to the forest soil, water flows. The problem is that in a lot of cases, following all the regulations regarding the silvicultural treatments, which are the most respected, and all the harvesting regulations, it is impossible or almost impossible to harvest the timber. So, the only possibility is to find a middle way for solving these problems.

As it was shown above, in the case of the treatments which are promoting the natural regeneration the harvesting can be done for a period of seven months and half. These treatments are the most used in the Romanian forestry. From an economical point of view this is suboptimal because for the rest of the year the systems have almost no work. This can be solved by increasing the intensity of the thinnings to make them efficient for the cable yarding systems. Another solution could be the increase of the clear cuts which can be harvested during the whole year. The strip clear cuts are the most suitable, but this can be done only on maximum 3 ha according to the Romanian forestry legislation. The harvesting in the case of the strip clear cuts is done mainly using the short distance cable yarding systems, respective tower yarders. But in the actual road network conditions of the Romanian forests it is very hard to implement these systems. So, this problem can be solved by increasing the road network density on the slopes.

Coming now to the harvesting companies, if they are created conditions for using modern technologies and also a legislative framework for restricting the destructive techniques, they are obliged to change their strategies towards the new technologies which are environmentally friendly. They can be also supported by the Romanian state or EU through subsidies or special conditions for financings.

5 Summary

The aim of the master thesis is to find the share of the harvestable volume from Romania which can be done using the cable yarding systems and the number of the machines needed.

Firstly was described the current situation of the forest and the harvesting systems used. Secondly, using 40% slope as the limit for ground based harvesting systems, the potential for cable yarding was analyzed for the wood harvesting from Suceava subunit of National Forestry Administration – Romsilva (RNP – Romsilva), subsidiary Brodina. From all the cases only the ones that have efficiency ratios higher than 0.5 m^3/m of the skyline were considered suitable. The cable yarding systems were split into tower yarders and sledge winches using the threshold length of the skyline of 600 m. The results were then extrapolated to the whole harvestable volume of Romanian forest for 2008, which is 18.5 millions m^3. For the extrapolation were used the shares of the area with a slope gradient higher than 40% for the analyzed area and total forest area of Romania. The volumes found were then used for the calculation of the necessary machines taking into consideration the tower yarder Syncrofalke with a productivity of 17 m^3/PSH_{15} and a mounting/demounting time of 16 hours and 43 minutes, 5 hours and 34' for a crew of 3 peoples, and the sledge winch Gantner HSW 80 with a productivity of 13 m^3/PSH_{15} and a mounting/demounting time of 55 hours, 18 hours and 20' for a crew of 3 peoples. In the calculation were considered the volumes extracted using the plenter system (90% for the tower yarders and 97% for the sledge winches) and a period of 7 months and half which means 160 working days, 9 hours per day.

Substituting the values shown above, results for the first scenario 13 tower yarders and 39 sledge winches and for the second scenario 38 tower yarders and 120 sledge winches.

This Master's thesis is a small step towards the implementing the cable yarding systems in the Romanian forestry. Going forward, the soil impacts of the skidding in the timber extraction must be studied in detail. It would be also very interesting to have an analysis about the share of the harvesting systems used in the Romanian wood harvesting.

It is also very important that the state authorities be more active to support the implementing of the harvesting systems which are ecological oriented.

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7 Appendix

7.1 Index of Figures

7.2 Index of Tables

7.3 Other

Annex 1

Calculations for U.P. II first scenario

Nr. crt.	Horizontal distance (m)	Height (m)	Slope distance (m)	Average slope (%)	Plots						Volume proposed per ha (m3/ha)	Total area (ha)	Area (ha)	Volume (m3)	Proportion of volume per skyline (m3/m)	Cable yarding system
					Managenet unit (nr.)	Area (ha)	Age (years)	Volume per ha (m3/ha)	Treatment proposed	Volume proposed (m3)						
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	615	265	670	43,09	7A	11,6	120	423	Femel	1530	131,90	2,46	0,78	102,88	0,15	sledge winch
					7B	23,1	120	410	Femel	2974	128,74		1,68	216,29	0,32	
2	645	255	694	39,53	7A	11,6	120	423	Femel	1530	131,90	2,58	0,58	76,50	0,11	sledge winch
					7B	23,1	120	410	Femel	2974	128,74		0,42	54,07	0,08	
					7C	1,9	35	241	Thinnings	73	38,42		0,58	22,28	0,03	
					7D	3,6	110	653	Sanitary	0	0,00		0,5	0,00	0,00	
					7E	2,4	115	412	Conservation cut	0	0,00		0,5	0,00	0,00	
3	510	235	562	46,08	8A	40,1	115	637	Femel	9311	232,19	2,04	2,04	473,68	0,84	tower yarder
4	500	210	542	42,00	8A	40,1	115	637	Femel	9311	232,19	2	2	464,39	0,86	tower yarder
5	545	210	584	38,53	8A	40,1	115	637	Femel	9311	232,19	2,18	2,18	506,18	0,87	tower yarder
6	460	205	504	44,57	8A	40,1	115	637	Femel	9311	232,19	1,84	1,84	427,24	0,85	tower yarder
7	490	195	527	39,80	9A	33,9	110	605	Femel	8598	253,63	1,96	1,96	497,11	0,94	tower yarder
8	830	220	859	26,51	9A	33,9	110	605	Femel	8598	253,63	3,32	3,32	842,05	0,98	sledge winch
9	990	215	1013	21,72	10B	27,4	20	59	Thinnings	407	14,85	3,96	3,96	58,82	0,06	sledge winch
10	390	115	407	29,49	11	51,8	20	56	Thinnings	749	14,46	1,56	1,56	22,56	0,06	tower yarder
11	305	130	332	42,62	12A	16,4	135	114	Femel	1870	114,02	1,22	1,22	139,11	0,42	tower yarder
12	435	145	459	33,33	12A	16,4	135	114	Femel	1870	114,02	1,74	1,74	198,40	0,43	tower yarder
13	380	120	398	31,58	13A	40,1	135	165	Femel	7659	191,00	1,52	1,52	290,32	0,73	tower yarder
14	670	180	694	26,87	17A	59	135	470	Femel	11494	194,81	2,68	2,68	522,10	0,75	sledge winch
15	620	185	647	29,84	17A	59	135	470	Femel	11494	194,81	2,48	2,48	483,14	0,75	sledge winch
16	570	240	618	42,11	18A	51,5	115	512	Femel	9248	179,57	2,28	2,28	409,43	0,66	sledge winch
17	690	250	734	36,23	18A	51,5	115	512	Femel	9248	179,57	2,76	2,76	495,62	0,68	sledge winch
18	600	270	658	45,00	21A	26,2	125	158	Femel	4284	163,51	2,4	1,54	251,81	0,38	sledge winch
					21C	1,8	60	441	Sanitary	0	0,00		0,62	0,00	0,00	
19	720	235	757	32,64	29A	40,3	50	421	Thinnings	1784	44,27	2,88	2,88	127,49	0,17	sledge winch
20	635	180	660	28,35	32	28,8	115	493	Femel	4455	154,69	2,54	2,54	392,91	0,60	sledge winch
21	830	185	850	22,29	32	28,8	115	493	Femel	4455	154,69	3,32	3,32	513,56	0,60	sledge winch
22	975	215	998	22,05	33A	27	115	450	Femel	3869	143,30	3,9	3,9	558,86	0,56	sledge winch
23	435	180	471	41,38	43A	17,5	70	512	Sanitary	0	0,00	1,74	0,5	0,00	0,00	tower yarder
					43C	7,4	70	20	Femel	148	20,00		0,5	10,00	0,02	
					43D	2,4	70	329	Femel	790	329,17		0,74	243,58	0,52	
24	785	265	829	33,76	44A	35,4	45	324	Thinnings	1386	39,15	3,14	2,42	94,75	0,11	sledge winch
					44B	8,6	85	559	Sanitary	0	0,00		0,72	0,00	0,00	

25	620	215	656	34,68	44C	8,7	115	309	Femel	2799	321,72	2,48	2,25	724,52	1,10	sledge winch
26	635	270	690	42,52	46A	19,5	125	390	Femel	3564	182,77	2,54	2,54	464,23	0,67	sledge winch
27	315	145	347	46,03	46A	19,5	125	390	Femel	3564	182,77	1,26	0,98	179,11	0,52	tower yarder
					46B	11,7	30	192	Thinnings	368	31,45		0,28	8,81	0,03	
28	1145	400	1213	34,93	47	48	35	287	Thinnings	2100	43,75	4,58	4,58	200,38	0,17	sledge winch
29	965	310	1014	32,12	52A	35,5	125	364	Femel	13458	379,10	2,44	2,44	925,00	0,91	sledge winch
30	400	165	433	41,25	52A	35,5	125	364	Femel	13458	379,10	1,6	1,6	606,56	1,40	tower yarder
31	520	185	552	35,58	52A	35,5	125	364	Femel	13458	379,10	2,08	2,08	788,53	1,43	tower yarder
32	690	185	714	26,81	53H	2,2	120	607	Femel	1386	630,00	2,76	1,68	1058,40	1,48	sledge winch
					53A	4,5	85	514	Sanitary	0	0,00		0,28	0,00	0,00	
					53D	13,9	110	520	Sanitary	0	0,00		0,8	0,00	0,00	
33	1140	325	1185	28,51	54C	6,5	35	297	Thinnings	291	44,77	4,56	3,4	152,22	0,13	sledge winch
34	1475	335	1513	22,71	62A	36,7	125	497	Femel	5763	157,03	5,9	5,2	816,56	0,54	sledge winch
					62B	3,9	125	143	Femel	557	142,82		0,7	99,97	0,07	
35	420	180	457	42,86	63A	25,1	125	482	Femel	3804	151,55	1,68	1,22	184,90	0,40	tower yarder
					63B	8,5	20	96	Thinning 4,25ha	0	0,00		0,46	0,00	0,00	
36	1430	380	1480	26,57	63C	46,9	125	516	Femel	7653	163,18	5,72	5,72	933,37	0,63	sledge winch
37	1260	360	1310	28,57	64A	27,4	135	449	Femel	3904	142,48	4,62	4,62	658,27	0,50	sledge winch
38	1120	355	1175	31,70	64C	32,9	135	443	Femel	4625	140,58	4,48	3,52	494,83	0,42	sledge winch
					64B	7	20	87	Thinnings		0,00		0,96	0,00	0,00	
39	440	145	463	32,95	65C	5,1	20	71	Thinnings	0	0,00	1,76	0,84	0,00	0,00	tower yarder
					65D	9,7	130	440	Femel	4443	458,04		0,92	421,40	0,91	
40	335	145	365	43,28	65C	5,1	20	71	Thinnings	0	0,00	1,34	0,32	0,00	0,00	tower yarder
					65D	9,7	130	440	Femel	4443	458,04		0,9	412,24	1,13	
41	410	175	446	42,68	67A	50,8	135	492	Femel	9066	178,46	1,64	1,64	292,68	0,66	tower yarder
42	525	200	562	38,10	67A	50,8	135	492	Femel	9066	178,46	2,1	2,1	374,78	0,67	tower yarder
43	580	220	620	37,93	67A	50,8	135	492	Femel	9066	178,46	2,32	2,32	414,04	0,67	sledge winch
44	580	215	619	37,07	68A	39,6	125	423	Femel	5235	132,20	2,32	2,32	306,70	0,50	sledge winch
45	585	220	625	37,61	81	50,4	50	447	Thinnings	2325	46,13	2,34	2,34	107,95	0,17	sledge winch
46	1160	300	1198	25,86	82B	51,4	45	460	Thinnings	2701	52,55	4,64	4,64	243,83	0,20	sledge winch
47	520	155	543	29,81	83A	30,7	125	532	Femel	5088	165,73	2,08	2,08	344,72	0,64	tower yarder
48	640	205	672	32,03	83A	30,7	125	532	Femel	5088	165,73	2,56	2,44	404,39	0,60	sledge winch
49	670	165	690	24,63	83B	12,3	90	596	Femel	2832	230,24	2,68	2,68	617,05	0,89	sledge winch
50	565	130	580	23,01	83F	13,1	115	353	Femel	1439	109,85	2,26	2,26	248,25	0,43	tower yarder
51	470	170	500	36,17	84A	24	135	493	Femel	3712	154,67	1,88	1,88	290,77	0,58	tower yarder
52	800	200	825	25,00	85A	52,2	125	415	Femel	7928	151,88	3,2	2,7	410,07	0,50	sledge winch
53	650	187	676	28,77	85A	52,2	125	415	Femel	7928	151,88	2,6	2,06	312,87	0,46	sledge winch
54	400	180	439	45,00	86A	16	130	418	Femel	2408	150,50	1,6	1,6	240,80	0,55	tower yarder
55	1405	275	1432	19,57	86A	16	130	418	Femel	2409	150,56	5,62	1,74	261,98	0,18	sledge winch
					86C	13,9	125	442	Femel	2258	162,45		1,22	198,18	0,14	
					86D	17,9	125	323	Femel	5782	323,02		2,66	859,22	0,60	
56	815	290	865	35,58	87A	62,8	125	460	Femel	10617	169,06	3,26	3,26	551,14	0,64	sledge winch
57	1130	325	1176	28,76	87A	62,8	125	460	Femel	10617	169,06	4,52	4,52	764,15	0,65	sledge winch
58	875	305	927	34,86	87A	62,8	125	460	Femel	10617	169,06	3,5	2,58	436,18	0,47	sledge winch
					87B	7,5	15	40	Thinnings	0	0,00		0,92	0,00	0,00	

59	335	160	371	47,76	87A	62,8	125	460	Femel	10617	169,06	1,34	0,86	145,39	0,39	tower yarder
					87B	7,5	15	40	Thinnings	0	0,00		0,48	0,00	0,00	
60	1160	345	1210	29,74	88B	17,9	125	351	Femel	6449	360,28	4,64	2,6	936,73	0,77	sledge winch
					88C	16,1	85	512	Sanitary	0	0,00		1,08	0,00	0,00	
					88D	6	10	45	Thinnings	0	0,00		0,96	0,00	0,00	
61	940	345	1001	36,70	88B	17,9	125	360	Femel	6449	360,00	3,76	3,38	1216,80	1,22	sledge winch
62	560	240	609	42,86	89A	14,5	125	328	Femel	4917	339,10	2,24	1,44	488,31	0,80	sledge winch
					89C	5,8	20	105	Thinnings	135	23,28		0,54	12,57	0,02	
					89D	3,1	90	335	Sanitary	0	0,00		0,2	0,00	0,00	
63	460	185	496	40,22	89A	14,5	125	328	Femel	4917	339,10	1,84	0,64	217,03	0,44	tower yarder
					89C	5,8	20	105	Thinnings	135	23,28		0,7	16,29	0,03	
					89D	3,1	90	335	Sanitary	0	0,00		0,42	0,00	0,00	
64	470	185	505	39,36	90A	25	55	494	Thinnings	1251	50,04	1,88	1,88	94,08	0,19	tower yarder
65	765	315	827	41,18	90B	27,9	50	393	Thinnings	1135	40,68	3,06	3,06	124,48	0,15	sledge winch
66	575	245	625	42,61	92B	24,4	55	496	Thinnings	1221	50,04	2,3	2,3	115,09	0,18	sledge winch
67	270	115	293	42,59	96A	9,9	115	626	Femel	2259	228,18	1,08	1,08	246,44	0,84	tower yarder
68	505	195	541	38,61	108C	8,6	20	93	Thinnings	207	24,07	2,02	0,28	6,74	0,01	
					108F	23,4	115	296	Femel	7266	310,51		1,74	540,29	1,00	tower yarder
69	620	220	658	35,48	108C	8,6	20	93	Thinnings	207	24,07	2,48	0,42	10,11	0,02	sledge winch
					108F	23,4	115	296	Femel	7266	310,51		1,42	440,93	0,67	
70	1005	240	1033	23,88	109A	32,1	40	346	Thinnings	1351	42,09	4,02	4,02	169,19	0,16	sledge winch
71	910	220	936	24,18	116F	8,9	135	290	Femel	2581	290,00	3,64	0,52	150,80	0,16	sledge winch
					117A	51,1	135	562	Femel	8991	175,95		3,12	548,96	0,59	
72	1140	245	1166	21,49	118A	31,1	125	531	Femel	6041	194,24	4,56	4,56	885,75	0,76	sledge winch
73	1350	235	1370	17,41	119A	34,3	125	566	Femel	6041	176,12	5,4	3,02	531,89	0,39	sledge winch
					119E	18,4	30	195	Thinnings	538	29,24		1,36	39,77	0,03	
74	980	215	1003	21,94	120A	18,6	125	619	Femel	4173	224,35	3,92	1,34	300,64	0,30	sledge winch
					120B	21,4	20	130	Thinnings	0	0,00		1,72	0,00	0,00	
75	820	240	854	29,27	120A	18,6	125	619	Femel	4173	224,35	3,28	1,24	278,20	0,33	sledge winch
					120B	21,4	20	130	Thinnings	0	0,00		1,38	0,00	0,00	
76	1065	285	1102	26,76	197A	59,7	20	125	Thinnings	1715	28,73	4,26	4,26	122,38	0,11	sledge winch
77	350	135	375	38,57	198A	50,1	30	257	Thinnings	1971	39,34	1,4	1,4	55,08	0,15	tower yarder
78	1185	310	1225	26,16	199A	32,1	125	484	Femel	5718	178,13	4,74	2,78	495,20	0,40	sledge winch
					199D	5	25	725	Thinnings	168	33,60		0,88	29,57	0,02	
					199F	6,1	25	916	Thinnings	213	34,92		1,08	37,71	0,03	
79	1600	420	1654	26,25	209B	28,3	115	502	Femel	5236	185,02	6,4	3,36	621,66	0,38	sledge winch
					209C	16,6	20	82	Thinnings	332	20,00		1,94	38,80	0,02	

Annex 2

Calculations for U.P. III first scenario

Nr. crt.	Horizontal distance (m)	Height (m)	Slope distance (m)	Average slope (%)	Plots: Managenet unit (nr.)	Area (ha)	Age (years)	Volume per ha (m3/ha)	Treatment proposed	Volume proposed (m3)	Volume proposed per ha (m3/ha)	Total area (ha)	Area (ha)	Volume (m3)	Proportion of volume per skyline (m3/m)	Cable yarding system
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1680	265	1701	15,77	123A	36,3	120	456	Femel	9412	259,28	6,72	2,18	565,24	0,33	sledge winch
					124A	37,7	115	557	Femel	13221	350,69		4,54	1592,13	0,94	
2	420	135	441	32,14	126	21,7	45	428	Thinnings 15,19ha	753	34,70	1,68	1,68	58,30	0,13	tower yarder
3	780	215	809	27,56	130B	33,1	40	299	Thinnings	1232	37,22	3,12	3,12	116,13	0,14	sledge winch
4	355	160	389	45,07	131A	35,9	45	343	Thinnings	1450	40,39	1,42	1,42	57,35	0,15	tower yarder
5	430	170	462	39,53	131B	17,6	60	410	Thinnings	653	37,10	1,72	1,72	63,82	0,14	tower yarder
6	515	205	554	39,81	136C	3,7	40	304	Thinnings	142	38,38	2,06	1,3	49,89	0,09	tower yarder
					136D	1,9	110	340	Femel	676	355,79		0,62	220,59	0,40	
7	515	175	544	33,98	137A	31,6	40	325	Thinnings	1283	40,60	2,06	2,06	83,64	0,15	tower yarder
8	410	160	440	39,02	152I	4,6	100	387	Clear cut	1782	387,39	1,64	1,64	635,32	1,44	tower yarder
9	525	185	557	35,24	154A	38	45	474	Thinnings	2144	56,42	2,1	2,1	118,48	0,21	tower yarder
10	480	125	496	26,04	165A	32,7	100	504	Femel	7815	238,99	1,92	1,48	353,71	0,71	tower yarder
11	430	120	446	27,91	165A	32,7	100	504	Femel	7815	238,99	1,72	1,72	411,06	0,92	tower yarder
12	470	155	495	32,98	167B	9,9	110	303	Femel	3140	317,17	1,88	1,88	596,28	1,20	tower yarder
13	605	175	630	28,93	167D	12,3	70	632	Sanitary	0	0,00	2,42	1,24	0,00	0,00	sledge winch
					167E	5,8	70	161	Clear cut	934	161,03		1,1	177,14	0,28	
14	505	110	517	21,78	179A	13,1	105	436	Femel	2703	206,34	2,02	2,02	416,80	0,81	tower yarder
15	465	115	479	24,73	179A	13,1	105	436	Femel	2703	206,34	1,86	1,86	383,78	0,80	tower yarder
16	1380	330	1419	23,91	182B	29,3	50	466	Thinnings	1425	48,63	5,52	2,88	140,07	0,10	sledge winch
17	580	185	609	31,90	301A	1,9	105	575	Clear cut	1143	601,58	2,32	0,8	481,26	0,79	sledge winch
					301B	4,9	65	530	Sanitary	0	0,00		1,2	0,00	0,00	
18	450	160	478	35,56	301A	1,9	105	575	Clear cut	1143	601,58	1,8	0,52	312,82	0,65	tower yarder
					301B	4,9	65	530	Sanitary	0	0,00		0,6	0,00	0,00	
19	420	160	449	38,10	301F	3,7	105	314	Clear cut	1217	328,92	1,68	1,16	381,55	0,85	tower yarder
20	1010	315	1058	31,19	328A	2,6	90	460	Clear cut	1281	492,69	4,04	0,94	463,13	0,44	sledge winch
21	950	215	974	22,63	329B	1,9	105	466	Femel	925	486,84	3,8	1,32	642,63	0,66	sledge winch
22	430	155	457	36,05	352C	7,6	25	145	Thinnings	0	0,00	1,72	0,64	0,00	0,00	tower yarder
					352D	5	100	240	Clear cut	1295	259,00		0,68	176,12	0,39	

Annex 3

Calculations for U.P. II second scenario

Nr. crt.	Plots						Volume proposed per ha	Area	Volume
	Managenet unit (nr.)	Area (ha)	Age (years)	Volume per ha (m3/ha)	Treatment proposed	Volume proposed (m3)	(m3/ha)	(ha)	(m3)
0	1	2	3	4	5	6	7	8	9
1	8A	40,1	115	637	Femel	9311	232,19	30,3	7035,49
2	9A	33,9	110	605	Femel	8598	253,63	26,3	6670,42
3	13A	40,1	135	165	Femel	7659	191,00	6,7	1279,68
4	17A	59	135	470	Femel	11494	194,81	19,2	3740,42
5	18A	51,5	115	512	Femel	9248	179,57	39,5	7093,13
6	32	28,8	115	493	Femel	4455	154,69	28,8	4455,00
7	33A	27	115	450	Femel	3869	143,30	3,9	558,86
8	43D	2,4	70	329	Femel	790	329,17	0,74	243,58
9	44C	8,7	115	309	Femel	2799	321,72	2,25	723,88
10	46A	19,5	125	390	Femel	3564	182,77	2,54	464,23
11	46A	19,5	125	390	Femel	3564	182,77	0,98	179,11
12	52A	35,5	125	364	Femel	13458	379,10	28,2	10690,58
13	53H	2,2	120	607	Femel	1386	630,00	1,68	1058,40
14	62A	36,7	125	497	Femel	5763	157,03	5,2	816,56
15	63C	46,9	125	516	Femel	7653	163,18	32,7	5335,89
16	64A	27,4	135	449	Femel	3904	142,48	4,62	658,27
17	65D	9,7	130	440	Femel	4443	458,04	3,8	1740,56
18	67A	50,8	135	492	Femel	9066	178,46	27,3	4872,08
19	68A	39,6	125	423	Femel	5235	132,20	18,9	2498,52
20	83A	30,7	125	532	Femel	5088	165,73	27,2	4507,93
21	83B	12,3	90	596	Femel	2832	230,24	2,68	617,05
22	84A	24	135	493	Femel	3712	154,67	8,5	1314,67
23	85A	52,2	125	415	Femel	7928	151,88	2,7	410,07
24	86A	16	130	418	Femel	2408	150,50	5,3	797,65
25	86D	17,9	125	323	Femel	5782	323,02	2,66	859,22
26	87A	62,8	125	460	Femel	10617	169,06	3,26	551,14
27	87A	62,8	125	460	Femel	10617	169,06	4,52	764,15
28	88B	17,9	125	351	Femel	6449	360,28	17,9	6449,00
29	89A	14,5	125	328	Femel	4917	339,10	8	2712,83
30	96A	9,9	115	626	Femel	2259	228,18	7,9	1802,64
31	108F	23,4	115	296	Femel	7266	310,51	1,74	540,29
32	117A	51,1	135	562	Femel	8991	175,95	15	2639,24
33	118A	31,1	125	531	Femel	6041	194,24	4,56	885,75

Annex 4

Calculations for U.P. III second scenario

Nr. crt.	Plots						Volume proposed per ha (m3/ha)	Area (ha)	Volume (m3)
	Managenet unit (nr.)	Area (ha)	Age (years)	Volume per ha (m3/ha)	Treatment proposed	Volume proposed (m3)			
0	1	2	3	4	5	6	7	8	9
1	124A	37,7	115	557	Femel	13221	350,69	20	7013,79
2	152I	4,6	100	387	Clear cut	1782	387,39	4,6	1782,00
3	165A	32,7	100	504	Femel	7815	238,99	7,8	1864,13
4	167B	9,9	110	303	Femel	3140	317,17	9,9	3140,00
5	179A	13,1	105	436	Femel	2703	206,34	9	1857,02
6	301A	1,9	105	575	Clear cut	1143	601,58	1,9	1143,00
7	301F	3,7	105	314	Clear cut	1217	328,92	1,16	381,55
8	329B	1,9	105	466	Femel	925	486,84	1,32	642,63