Interreg Alpine Space project - **NEWFOR**

Project number 2-3-2-FR

NEW technologies for a better mountain **FOR**est timber mobilization

Priority axis 2 - Accessibility and Connectivity

Workpackage: Forest accessibility

Harvesting technologies used in the Alpine Space according to topographic and forest network situation and data available.

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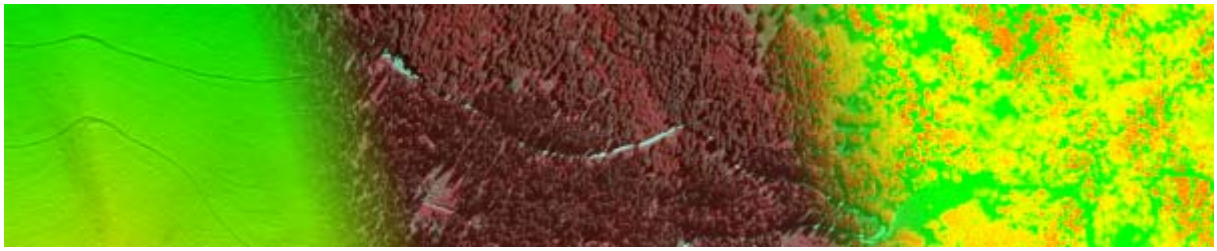
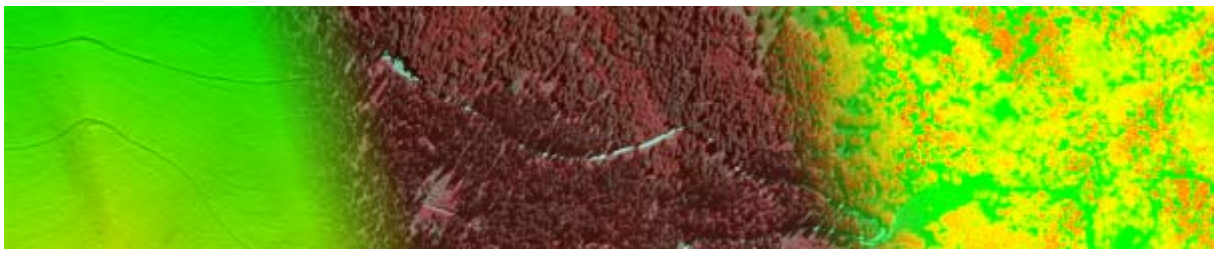


The consortium of the project Interreg Alpine Space NEWFOR

This project has been, co-funded by the European Regional Development Funds, and achieved under the third call of the European Territorial Cooperation Alpine Space Programme 2007-2013.



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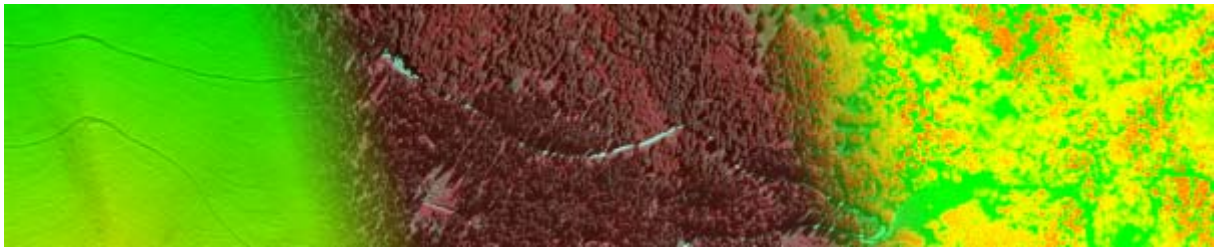
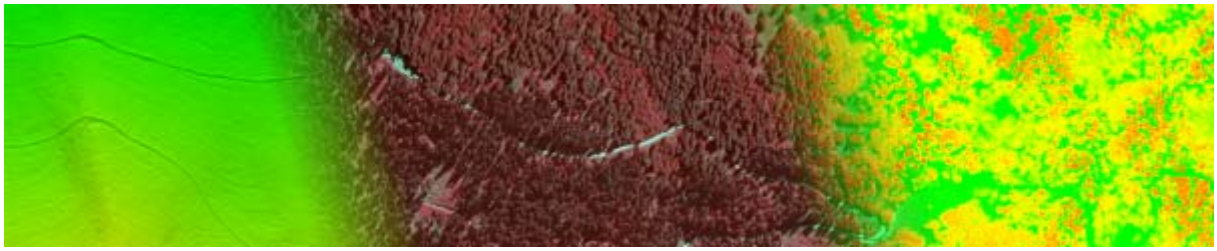
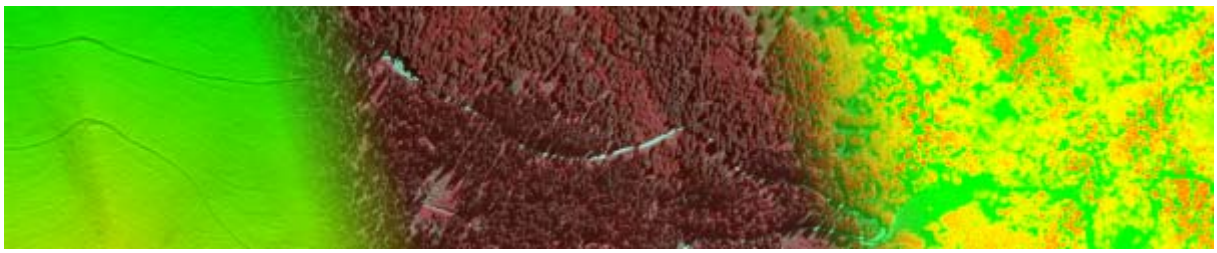
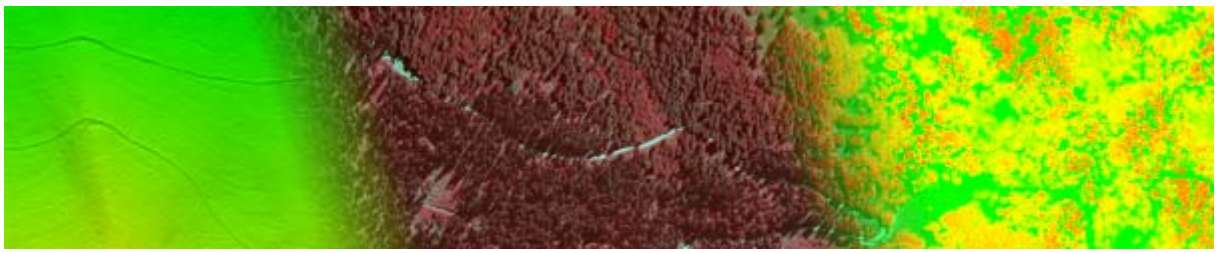


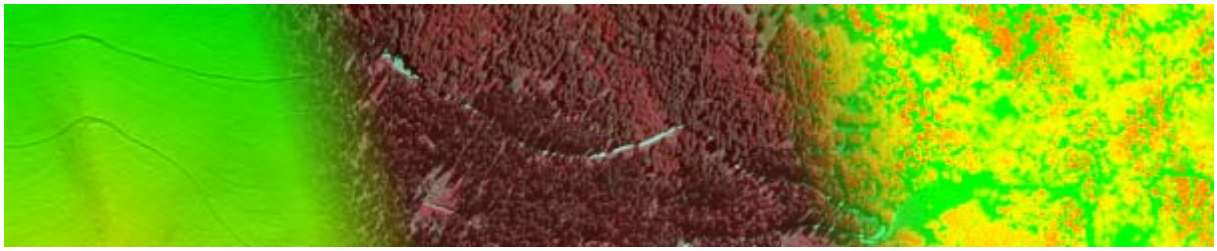






1 ABSTRACT

In high mountains, such as the Alps, timber harvesting takes place under difficult conditions. The slope and special off-road conditions, such as boulders or spring horizons, are special challenges for timber harvesting technology. After a synthetically presentation of the main techniques usable in mountain areas, this document presents the current state of the art in the pilot areas of the project NEWFOR. All the data have been gathered using a specific questionnaire.



2 A SYNTHETIC OVERVIEW OF THE INTERREG ALPINE SPACE PROJECT NEWFOR

2.1 THE CONTEXT

Although forests represent a key resource of mountain environments, their valorization is hampered by accessibility constraints that prevent an efficient mapping, management, harvesting and transport of wood products.

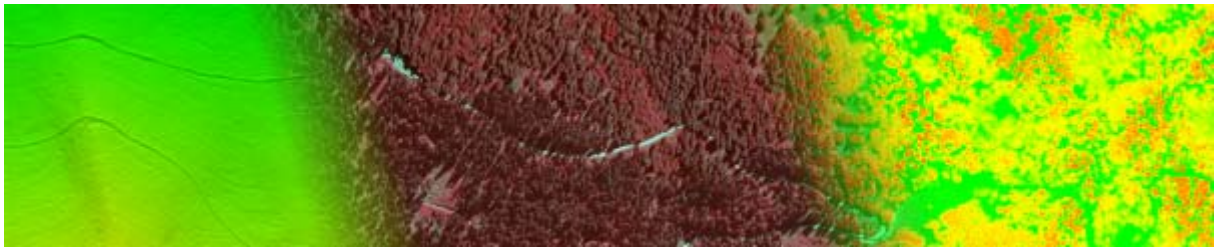
Forests fulfil multiple functions in mountainous areas. They have an ecological function as host of many habitats and species. They also are a leisure area for social activities such as hiking, skiing… From the economical perspective, the production of renewable resources like timber and fuelwood has positive effects both at global scale, with climate change mitigation, and local scale with rural employment and the development of a regional value chain. The objective of preserving and improving the development of mountain forests is a point of public interest. However, managing forests in mountain territories is a difficult task as topography and climate set strong constraints inside a complex socio-economical framework.

In particular, a precise mapping of forest biomass characteristics and mobilization conditions (harvesting and accessibility) is a prerequisite for the implementation of an efficient supply chain for the wood industry. The available information is currently insufficient to provide, at reasonable costs, the required guarantees on the wood supply and on its sustainability. With the recent development of new remote sensing technologies and modelling tools, major improvements regarding the evaluation of the forest growing stock and accessibility are now possible. Upon this highly valuable information, decision-making tools must be build to optimize the investments in forest infrastructures required for a cost-effective wood supply while securing the sustainable management of forests, and to support the implementation of an efficient European policy for mountain forest management.

2.2 OBJECTIVES OF THE PROJECT

According to this context and based on the use of new technologies (LiDAR: light detection and ranging, Unmanned Aerial Vehicle,...) for forest and topography characterization, the project NEWFOR is dedicated to enhance and develop tools and adapted policies for decision making in the field of a sustainable and adaptive mountain forest resources management facing the sustainability of mountain forest ecosystems services.

So, the main objective of the NEWFOR project is the improvement of mountain forest accessibility for a better economical efficiency of wood harvesting and transport in a context of sustainable forest management and wood industry in changing climate.



The 14 partners involved in the project consortium tackle this objective within five thematic workpackages (wp):

- Forest resources and LiDAR

Recent developments in LiDAR technology, combined to other available data sources (aerial photographs, aerial photo series by UAVs, …), are now allowing a precise and fine mountain forest resource quantification, qualification and mapping. Integrating this technology will provide an innovative response to the challenges of a precise and robust knowledge on the available growing stocks. The project aims at testing and developing tools that will help forestry end-users to benefit from this technological advance.

- Forest accessibility

After the identification of forest resources, the second step of an efficient forest management is to evaluate the accessibility to these resources. In mountain areas, topography is the main constraint to a technical and economically efficient exploitation. The project demonstrated how to use topographic LiDAR data coupled with geographic information systems (GIS) for an optimal planning of forest harvesting and logging while taking current and scheduled accessibility of forest resources into account.

- Forest and industry connectivity

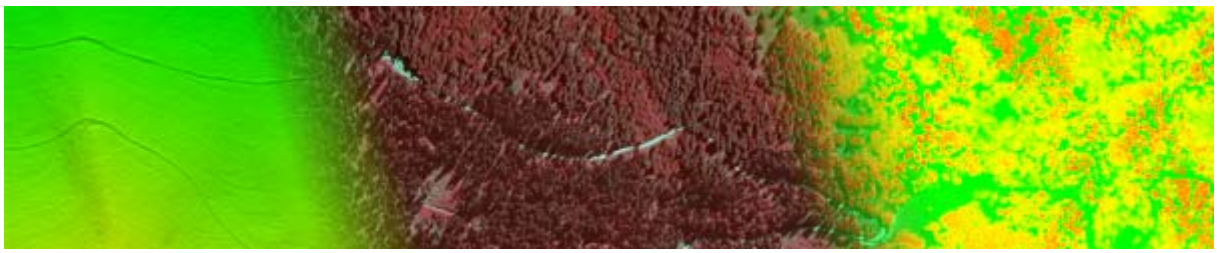
Once the forest resources and accessibility are characterized, then remains the issue of the connectivity between wood piles in the forests and wood yard of mills. This link is often neglected but is crucial for a comprehensive assessment of the wood supply efficiency.

- Costs and benefits evaluation

NEWFOR aims at developing decision-making tools dedicated to the definition of strategies for sustainable mountain wood supply chain. To fulfil this objective, tools for identifying forest resources, their accessibility and connectivity to the wood market are first considered separately. In order to achieve the demarche, and to choose the optimal strategy, it is necessary to evaluate the whole workflow from the economical aspect by comparing the costs and benefits of each possible strategy.

- Logistical planning strategy

There is a need to frequently adjust the planning of forest management to new economical evidence as well as to unforeseeable developments. Such an adaptive management needs to balance ecological, social and economic factors. The final objective was to provide forest managers and decision makers with reliable information for the evaluation of technical and economical conditions for their decision-making on timber supply chain logistical planning and land use strategies.



3 INTRODUCTION

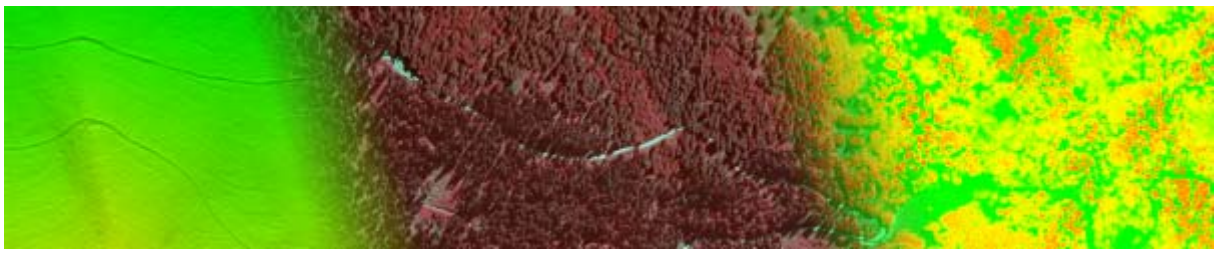
Maintenance and enhancement of protective functions of mountain forests in the Alpine Arc have gained in importance over the last decades. Protection forests can more or less greatly decrease the negative impacts of alpine hazards on the habitat in the Alpine region. This great advantage is achieved through protection forests management, which should guarantee the efficiency of forest protection permanently. At the same time, the forest secures jobs in rural Alpine region and provides an important contribution to wood supply.

Management of forests in the Alpine space is a particular challenge. In this sensitive area with its high importance for nature conservation – the Alps provide habitat for over 30.000 animal species and more than 13.000 plant species - and recreation, the applied treatment for silvicultural interventions has not only be appropriate to management requirements, but has also to respect its effects on the forest functions under the critical eyes of the public.

In high mountains, such as the Alps, timber harvesting takes place under difficult conditions. The slope and special off-road conditions, such as boulders or spring horizons, are special challenges for timber harvesting technology. Due to the special conditions, there are often problems with work place safety. It takes great effort and sophisticated technology to manage forest stands and use the wood.

Several procedures are used for mechanized harvesting in the Alpine space. Besides lowering of harvesting costs, the choice of the harvesting procedure is decisive for the conservation of soil and forest stand. For the economist, it is necessary to select the most favorable procedure dependant on the starting situation.

The aim of this report was to provide an overview of the most common work procedures for harvesting in the Alpine region of the partner countries and to present their application in these countries. In the following, the state-of-the-art in harvesting technologies, according to topographic conditions, will be given and exemplified with with data from the partner countries as far as possible.



4 METHODOLOGY

4.1 LITERATURE ANALYSIS

The analysis is based on personal interviews of forestry experts mainly of state institutions and by review of literature on harvesting technologies in high mountain regions.

4.2 QUESTIONAIRE

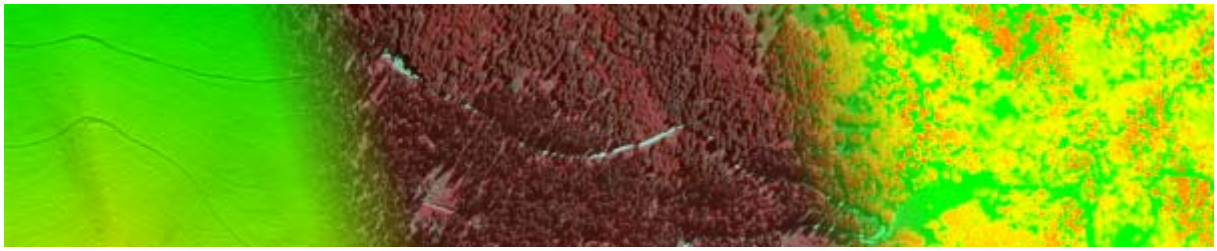
In order to get an overview about the state-of-the-art in harvesting techniques in the participating countries, a questionnaire was designed to ask for the procedures, which are used in the mountain forest.

The questionnaire is divided into two methodological sections:

- General questions
- Questions about the last three timber harvests of the forest enterprise

According to different selling practices in the different countries the questionnaire was modified by the partner countries. At the end, there were three different questionnaires (see appendix).

In France, for example, stumpage sale is a popular sales method. A private company pays the current owner of the land for the right to harvest timber. The company decides, which harvesting technology is used. The price is usually paid per solid cubic meter, meaning that only the company has detailed information about the applied harvesting technology. In the Bavarian Alps, the forest owner either assigns an enterprise to do the harvesting or does it by himself. The timber is sold by the owner. Therefore, the owner has good information about the applied harvest technology.

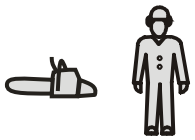


5 LOGGING SYSTEMS: FROM TREE TO LOGS – GENERAL OVERVIEW

5.1 LOGGING SYSTEMS: FROM TREE TO LOGS – GENERAL OVERVIEW

The most important established harvesting technologies for steep terrain are described in the following. The degree of mechanization increases from technology 1 to technology 7.

5.2 TECHNOLOGY 1: CHAIN SAW FELLING AND TREE PROCESSING, EXTRACTION BY A FORESTRY TRACTOR (HORSE, SKIDDING TRAILER, TIMBER SLIDE)

<table>
<tr><th></th><th>Forest stand</th><th>Skidding line</th><th>Forest road</th></tr>
<tr><td>cutting</td><td rowspan="2">  </td><td></td><td></td></tr>
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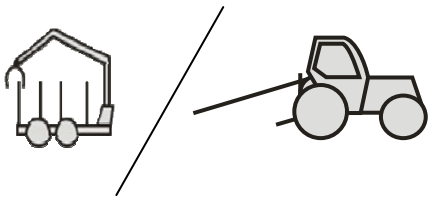
<tr><td>skidding</td><td></td><td colspan="2" rowspan="2">  </td></tr>
<tr><td>piling</td><td></td></tr>
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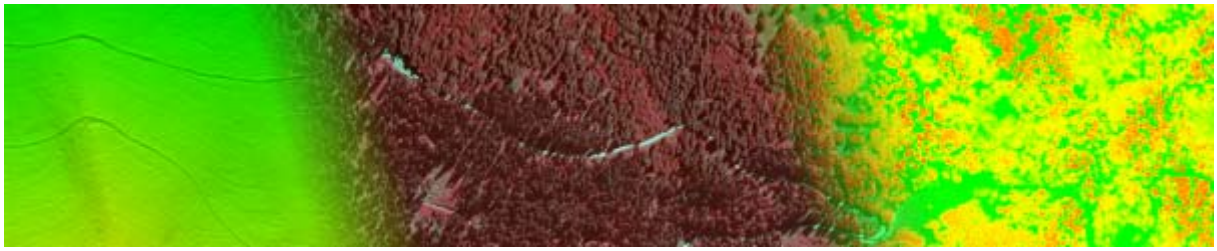
5.2.1 OPERATING RANGE/REQUIREMENTS

Hillslope: up to 35% on extraction lines

Opening up: extraction lines are necessary

Assortment: preferably logs (butts) and long logs

Felling volume: applicable by moderate felling volume



5.2.2 COURSE OF THE PROCEDURE

Felling and tree processing: chain saw felling in the stand. Skidding to the extraction lines normally follows after completion of the felling work in the stand.

Extraction: skidding is done by steel rope to the extraction lines, from there to the depots next to the forest roads.

5.2.3 RISK

Soil: Danger of emerging of lanes, especially on steep slopes

Stand: Damage to the trunk of the trees caused by skidding the logs. Long logs raise the probability of damages.

5.2.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: the forestry workers are endangered by ground driven logs; Slip hazard; the forestry tractor can tip over and skid down by exceeding the maximum hillslope (35%) and exceeding the cross slope.

Human engineering: hard work by felling, tree processing and pulling the steel rope from the winch.

5.2.5 PROFITABILITY

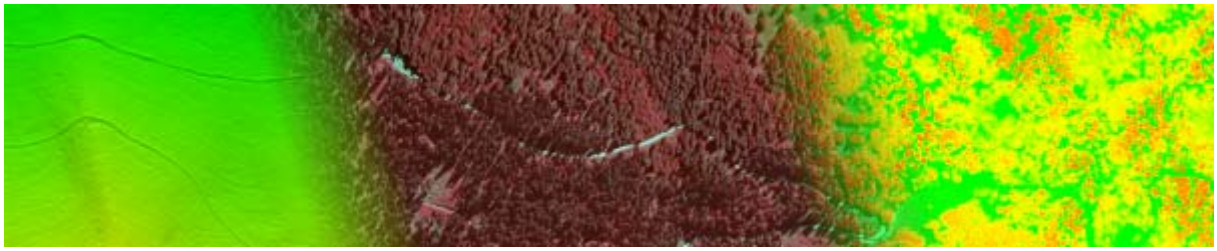
By adequate opening – up with extraction lines, the technology is affordable. It is especially applicable for small forest property.

Manpower requirement: felling and tree processing: two persons; extraction: one person.

Organizational work: low.

5.2.6 OTHER MATTERS

Extracting can also be done by timber slide or horse in case of a lack of extraction lines.



5.3 TECHNOLOGY 2: CHAIN SAW FELLING AND TREE PROCESSING, EXTRACTION BY A MOBILE CABLE CRANE

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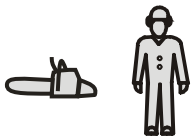
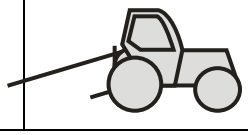
cutting			
logging			
skidding			
piling			

5.3.1 OPERATING RANGE/REQUIREMENTS

Hillslope: up to 100 (140) % depending on logging direction (uphill or downhill) and the total harvesting distance.

Opening up: Basis opening up by forest roads

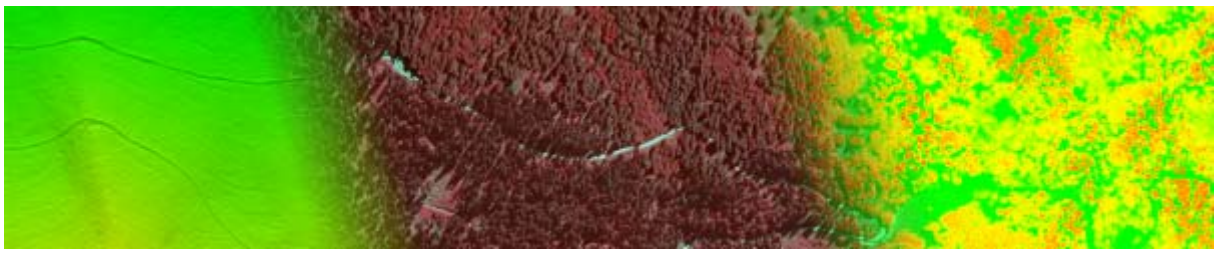
Assortment: logs (butts) and long logs

Felling volume: depending on the size of the cable crane at least 200m^3. In case of a short-distance cable crane (carrying cable length 400m) 500m^3. In case of a long-distance cable crane (carrying cable length at least 800m)

5.3.2 COURSE OF THE PROCEDURE

Felling and tree processing: chain saw felling in the stand

Adjustment of felling



- by uphill extraction: as a rule like a herring bone system,
- by downhill extraction: across to the rope path

Extraction: After completing the felling in the stand, skidding to the extraction lines is done by cable crane. Piling with a forestry tractor or/and with a skidding trailer

5.3.3 RISK

By adhering the guideline of felling carefully, the stand is treated with care.

Soil: no soil compaction, sander marks by attracting the logs

Stand: Damages to the trunk of trees are concentrated next to the rope path.

5.3.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: the forestry workers are endangered by ground driven logs; a radio control system on the cable crane raises the security during the work with the rope

Human engineering: hard work by felling, tree processing and setup of the cable crane plus hitching the logs at the ropes.

5.3.5 PROFITABILITY

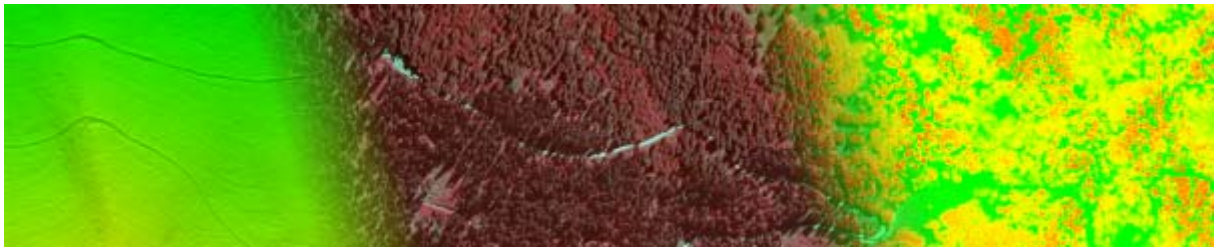
It is an efficient technology in case of sufficient workload of the cable crane. This means a minimum amount of timber is necessary.

Manpower requirement: felling and tree processing: two persons; working with the rope: two persons

Organizational work: medium

5.3.6 OTHER MATTERS

The workers responsible for the cable crane have to be well trained. Self driving cable crane trolleys reduce the effort of fitting the cable crane.



5.4 TECHNOLOGY 3: CHAIN SAW FELLING IN COMBINATION WITH MOBILE CABLE CRANE EXTRACTION (FULL TREE = STEM + CROWN) AND TREE PROCESSING WITH HARVESTER OR PROCESSOR

	Forest stand	Skidding line	Forest road
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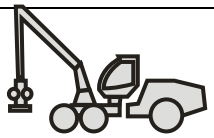
logging			
skidding			
piling			

5.4.1 OPERATING RANGE/REQUIREMENTS

Hillslope: up to 100 (140) % depending on logging direction (uphill or downhill)

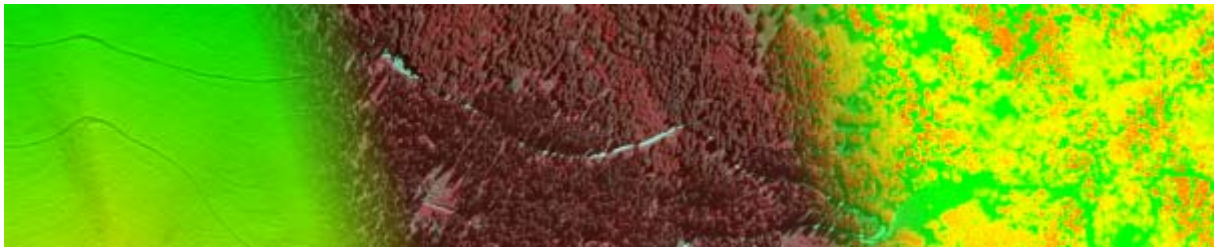
Opening up: Basis opening up by forest roads

Assortment: full tree

Felling volume: because of the high costs of the system, a big amount of timber is necessary. An approximate figure for uphill extraction is at least 0,35m^3 per running meter cable length (rmc) and 80m^3 per cable path. Downhill figures are quite higher: 0,5m^3/rmc and at least 130m^3 per cable path.

5.4.2 COURSE OF THE PROCEDURE

Felling: chain saw felling in the stand, adjustment of felling: exactly angled to the rope path.



Extraction: uphill with the mobile cable crane.

Tree processing: by harvester, according to the disposable space in the same time or later. Possibly piling with a forestry tractor or/and with a skidding trailer

5.4.3 RISK

Stand conservation is (quite) good.

Soil: no soil compaction, sander marks by dragging full trees

Stand: Damages to the trunk of the trees next to the rope path, caused by extraction with cable.

5.4.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: safe tree processing due to the use of harvester

Human engineering: hard work by setting up the cable crane.

5.4.5 PROFITABILITY

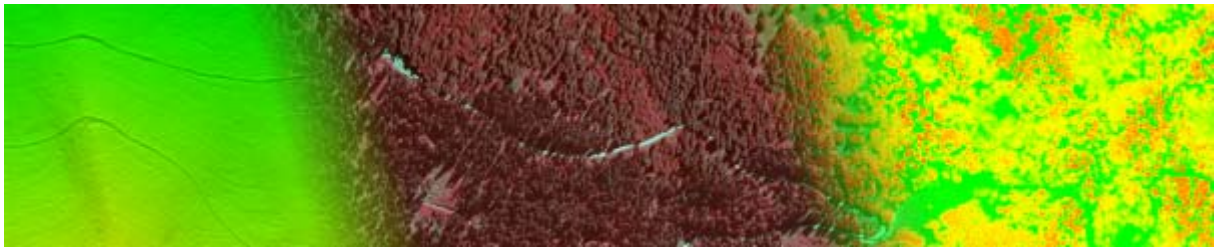
Profitability depends on piece-volume

Manpower requirement: felling and cable handling by two (three) persons; tree processing by one person.

Organizational work: high

5.4.6 OTHER MATTERS

Tree processing by processor is cheaper than by harvester



5.5 TECHNOLOGY 4: CHAIN SAW FELLING, EXTRACTION (FULL TREE = STEM + CROWN) AND TREE PROCESSING BY MOUNTAIN HARVESTER

	Forest stand	Skidding line	Forest road
cutting			
logging			
skidding			
piling			

5.5.1 OPERATING RANGE/REQUIREMENTS

Hillslope: up to 100 (140) % depending on logging direction (uphill or downhill)

Opening up: Basis opening up by forest roads

Assortment: full tree

Felling volume: because of the high costs of the system, a big amount of timber is necessary, at least 500m^3.

5.5.2 COURSE OF THE PROCEDURE

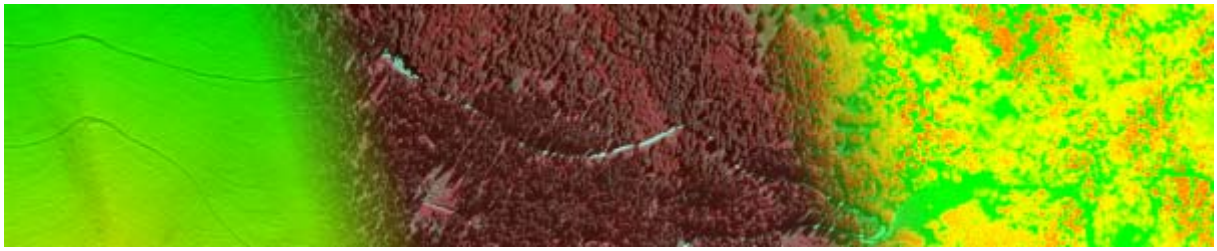
Felling: chain saw felling, possibly with the support of ropes

Extraction: full tree extraction by cable crane after or during the felling

Tree processing: by mountain harvester, possible piling with a forestry tractor or/and skidding trailer

5.5.3 RISK

The technology treats the stand with care



Soil: no soil compaction, sander marks by dragging full trees

Stand: Damages to the trunk of the trees next to the rope path, caused by extraction with cable.

5.5.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: safe tree processing due to the use of the mountain harvester

Human engineering: hard work by setting up the cable crane

5.5.5 PROFITABILITY

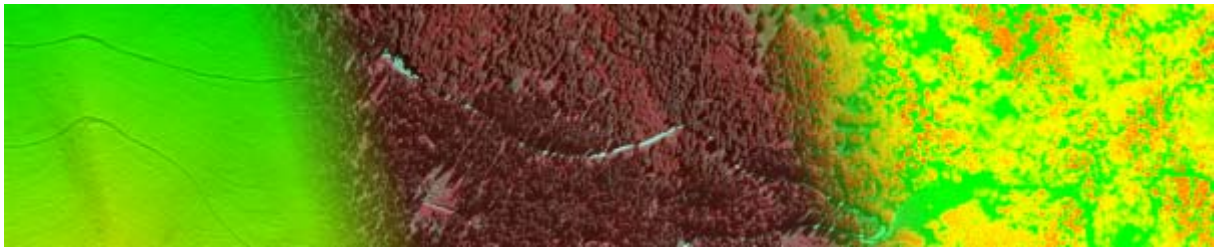
According to the workload, a high performance index is attainable.

Manpower requirement: felling and rope handling: three persons; tree processing: one person

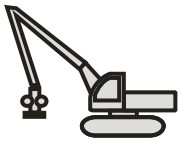
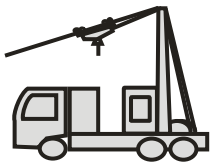
Organizational work: medium up to high

5.5.6 OTHER MATTERS

The activity place of the mountain harvester is on the forest road. Some mountain harvesters, such as the Mounty 4000 M6, are able to do uphill and downhill extraction from the same place. These harvesters can reduce unit costs, but there is a higher effort of arranging.



5.6 TECHNOLOGY 5: FELLING AND TREE PROCESSING BY A TRACKED HARVESTER, EXTRACTION BY CABLE CRANE

	Forest stand	Skidding line	Forest road
cutting			
logging			
skidding			
piling			

5.6.1 OPERATING RANGE/REQUIREMENTS

Hillslope: tracked harvester up to 65 %

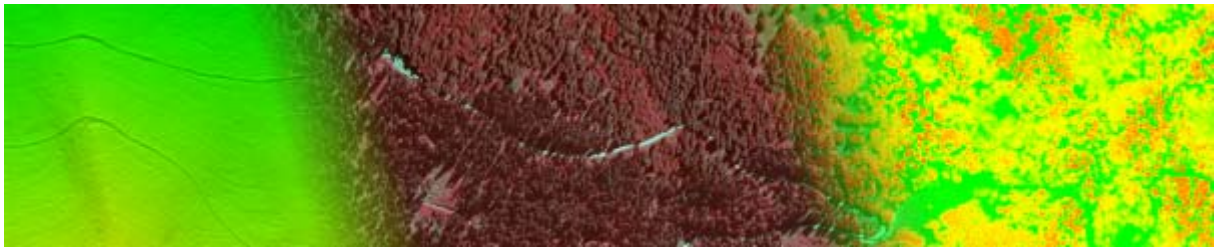
Opening up: extraction lines are necessary

Terrain: no overlay with boulders

Assortment: logs (butts) and long logs, heavy tree and small-sized trees

Felling volume: high

5.6.2 COURSE OF THE PROCEDURE



Felling and tree processing: by tracked harvester from the extraction lines, trees, which are out of the crane zone of the harvester, can be felled by workers with a chain saw, so that the harvester can grasp them.

Extraction: by cable crane during or after the felling. If the distance between the extraction lines is minor, a set-up of the cable crane at each second or third extraction line is enough. Trees in the intermediate zone have to be skidded within range of the cable crane; possible piling with a forestry tractor

5.6.3 RISK

The technology works partly with care

Soil: tracked harvesters cause less soil compaction than wheeled harvesters, soil damage by shear movements caused through steering movements. Roots may be damaged.

Stand: Damages of trunk of the trees next to the cable path, caused by extraction with cable. Possible attack of spruce bark beetles have to be taken into account.

5.6.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: Safe felling and tree processing due to the use of the harvester. Driver cabins, which can be leveled, improve the visual range and therewith the driving safety.

Human engineering: hard work by setup of the cable crane

5.6.5 PROFITABILITY

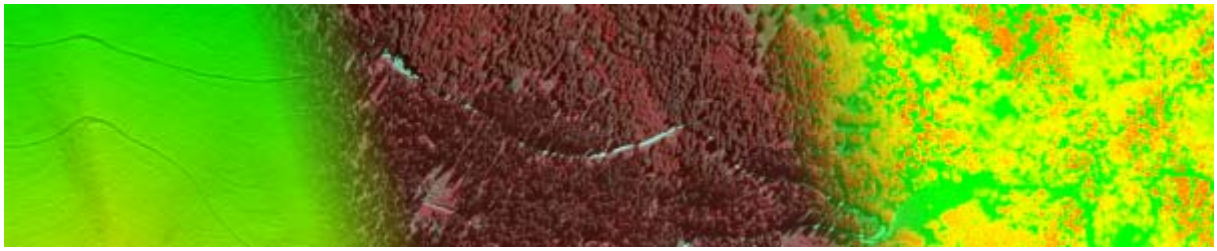
The harvester deposits the logs near the cable path. This increases the power of the cable crane. At present the most economic technology, in case the tracked harvester can be used.

Manpower requirement: felling and tree processing: one person; extraction: two to three persons

Organizational work: high

5.6.6 OTHER MATTERS

By working with a harvester, most of the nutrients remain in the stand. The technology is also suitable for thinning in small-sized stands. Up to a hillslope of 35%, wheeled harvesters and forwarders can be applied as a substitute for the cable crane (see Technology No. 6).



5.7 TECHNOLOGY 6: FELLING AND TREE PROCESSING BY A WHEELED HARVESTER AND EXTRACTION BY FORWARDER

<table>
<tr><th></th><th>Forest stand</th><th>Skidding line</th><th>Forest road</th></tr>
<tr><td>cutting</td><td rowspan="2">  </td><td></td><td></td></tr>
<tr><td>logging</td><td></td><td></td></tr>
<tr><td>skidding</td><td></td><td colspan="2" rowspan="2">  </td></tr>
<tr><td>piling</td><td></td></tr>
</table>

5.7.1 OPERATING RANGE/REQUIREMENTS

Hillslope: up to 35%up to 50% by using additional traction winches.

Opening up: extraction lines are necessary

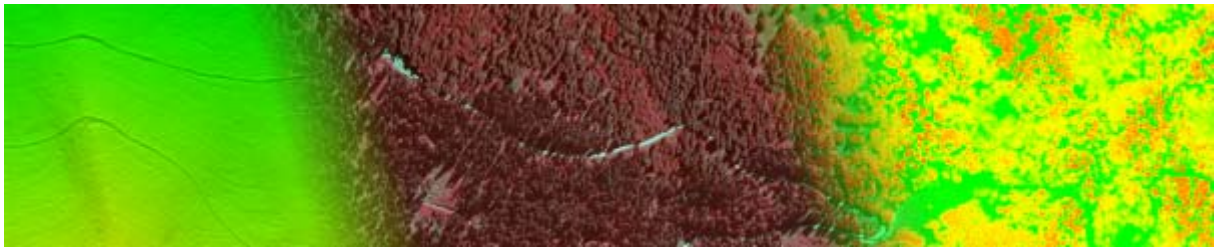
Terrain: no overlay with boulders

Assortment: logs (butts)

Felling volume: high

5.7.2 COURSE OF THE PROCEDURE

Felling and tree processing: by harvester from the extraction lines, trees out of the crane zone of the harvester can be felled manually by chain saw, further processing by harvester.



Extraction: by forwarder, also piling is done by forwarder (crane).

5.7.3 RISK

The technology works partly with care

Soil: tracked harvesters cause less soil compaction than wheeled harvesters, Repeated driving on skidding line by forwarder is required. Soil impact thereby is higher than by use of cable cranes.

Stand: Tree crowns and branches remain in the stands. Therefore, attention has to be payed on possible attack of the spruce bark beetle.

5.7.4 WORKING SAFETY AND HUMAN ENGINEERING

Working safety: Safe felling and tree processing due to the use of the harvester. Driver cabins, which can be leveled, improve the visual range and therewith the driving safety.

5.7.5 PROFITABILITY

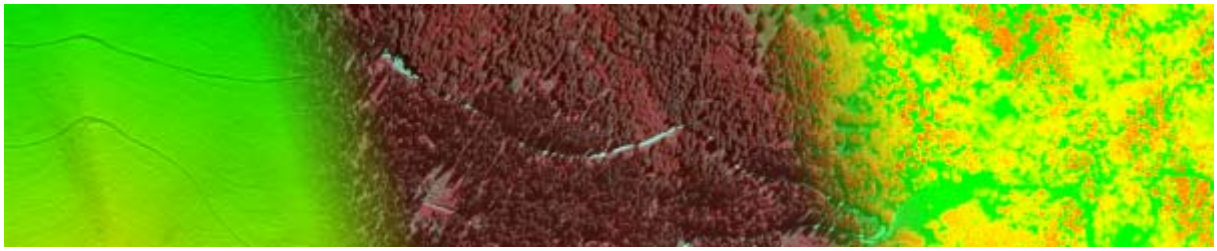
At first, logs are deposited nearby the cable path by the harvester, where they are picked up by the forwarder and transported to the next pile.

Manpower requirement: felling and tree processing: one person; extraction and piling: one person

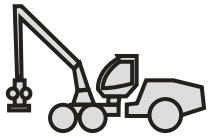
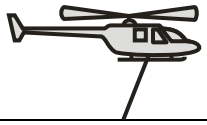
Organizational work: low/medium

5.7.6 OTHER MATTERS

Because of working with a harvester, most of the nutrients remain in the stand. The technology is also suitable for thinning in small-sized stands .



5.8 TECHNOLOGY 7: CHAIN SAW FELLING, EXTRACTION BY HELICOPTER, TREE PROCESSING WITH HARVESTER (PROCESSOR)

	Forest stand	Extraction	Forest road
cutting			
logging			
extraction			
piling			

5.8.1 OPERATING RANGE/REQUIREMENTS

Hillslope: no influence on extraction

Opening up: inaccessible terrain

Assortment: full trees

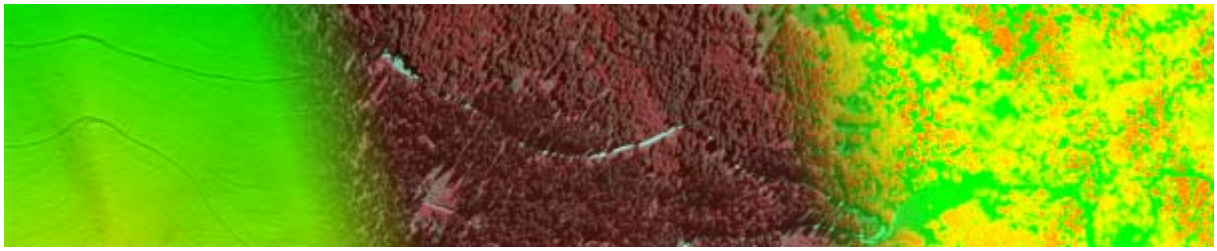
Felling volume: concentrated to small areas

5.8.2 COURSE OF THE PROCEDURE

Felling: by chain saw

Extraction: later on by helicopter

Tree processing: at the unloading point by harvester or processor, piling by forest tractor or/and by skidding trailer.



5.8.3 RISK

The technology works very careful related to the stand

Soil: no influence

Stand: normal damages, which are caused by felling the trees

5.8.4 WORKING SAFETY AND HUMAN ENGINEERING

Use of helicopter is only possible in case of stable weather conditions

Working safety: there is an accident risk while taking up and releasing the full tree with the helicopter cable;

Human engineering: hard work by felling the trees and catching the cable of the helicopter; high mental stress for the pilot

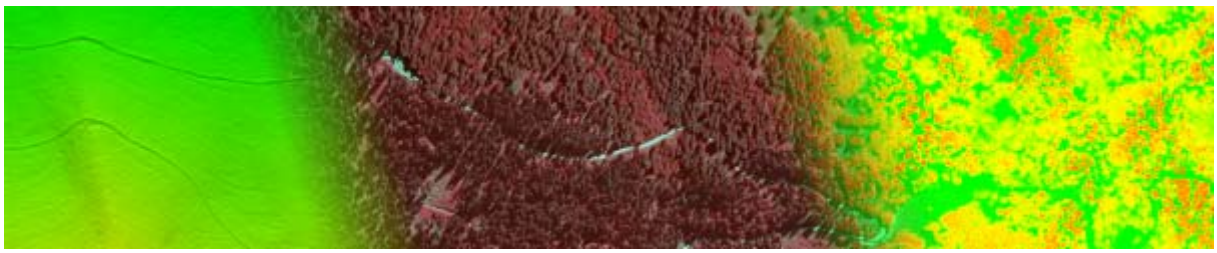
5.8.5 PROFITABILITY

Manpower requirement: felling and handling: 2 persons; extraction: 1 person, tree processing 1 person.

Organizational work: very high

5.8.6 OTHER MATTERS

In case of wind throw or in inaccessible stands attacked by spruce bark beetle it is often the only possible extraction technology.



6 LOGGING SYSTEMS: FROM TREE TO LOGS – OVERVIEW OF REGIONS OF THE PARTNER COUNTRIES

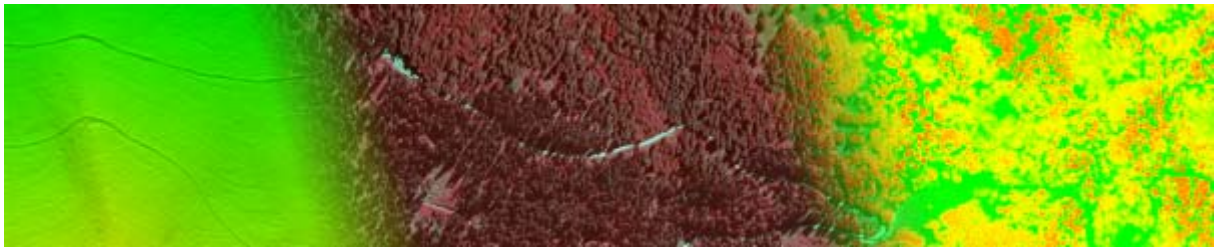
6.1 ITALY – VENETO REGION

6.1.1 THE DATABASE OF FOREST ENTERPRISES IN VENETO

In the Veneto Database 322 forest enterprises are registered, 99 thereof employing more than one single person.

Type of machine	Number
Farm Tractors	507
Crawler Tractors	128
Winches	411
Trailers	327
Loaders	40
Skidders	1
Forwarders	5
Yarders (sled)	45
Yarders (tower)	23
Processors	8
Chippers	36
Trucks	147

Table 1: Types of forest machines used in Veneto



Due to the large number of small sized enterprises (223 single person companies) and high investment costs for more enhanced systems, the usage of tractors is the most applied technology.

Three of the companies intend to purchase cable cranes within the next future.

Other key elements emerging from this study, regard the total workforce (3.563 workers in an Alpine Region basis, 689 in Veneto Region), the annual cut (1.919.766m^3 in an Alpine Region basis, 424.631 m^3 in Veneto Region), as well as the average productivity per company (1.830 m^3 in Veneto Region).

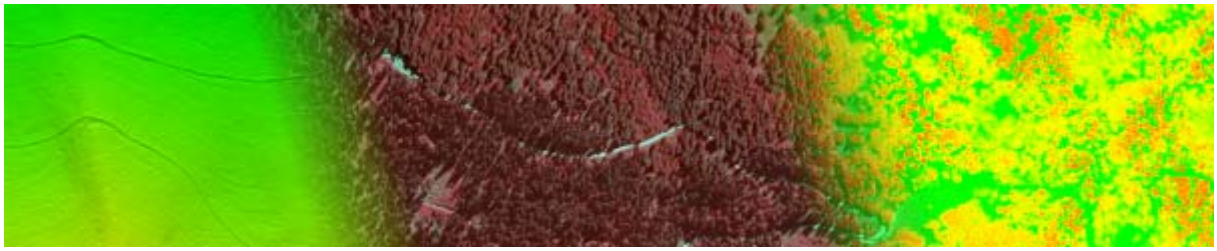
6.1.2 THE USE OF THE HARVESTING TECHNOLOGIES FOCUSING ON THE "ALTOPIANO DI ASIAGO" TEST- SITE

Eleven well structured forest enterprises are currently working in Asiago test-site, handling approximately 70.000m^3 per year. A series of enquiries have been conducted in the year 2013 in order to better understand the level of use and the problems these enterprises encounter during their activities.

The level of mechanization within the test-site is higher than the regional average. This is probably due to large public properties within this area. Thus, the supply of wood is better than in other regions.

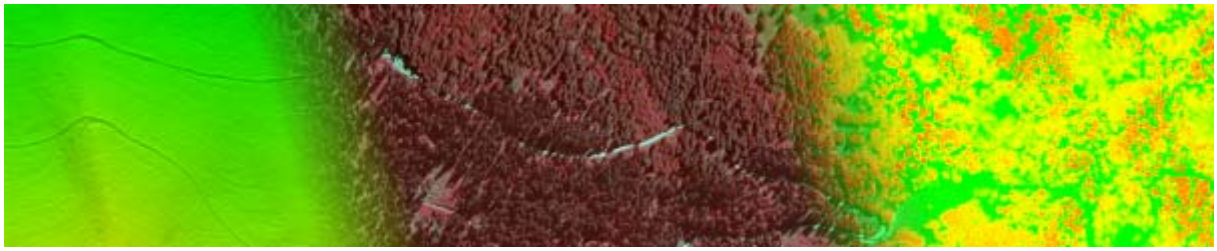
Four harvesters and seven forwarders are registered in the database; however, it has to be taken into consideration, that the database is not yet complete. Only four cable cranes are working in the area, while all the enterprises own at least one tractor equipped with winch. Two enterprises have a chipper.

The following table resumes the range of use of different technology and some problems in using different technologies arose from the forest enterprises. From this table one can derive that the technology 1 is still the most used technology in the test-site Asiago.



Operation	% use on the total	Maximum slope (%)	Average and Maximum extraction distance (m)	Major issue
Harvesting				
Harvester	23	38	/	**Tree dbh are often too big** for harvester and for this reason the two systems are often combined. The total volume felled by harvester is low in comparison with the number of machines. This is mainly due to a **lack of skilled operators**.
Manual felling	77	100	/	
Extraction				
Forwarder	50	38	250 / 850	The choice of the harvesting system as well as the length of the extraction route is often related to the **characteristic of the forest road**. The low standards of forest roads are the cause of long forwarder extraction routes to reach the closest landing site accessible for the trucks. Another element that often affects the efficiency of the harvesting operation is related with the **type of silvicultural intervention** (cutting intensity, tree distribution) that sometimes is not oriented to facilitate the work of the forest enterprise. One limit for the spreading of cable crane systems is the **lack of operators able to use this technology**.
Tractor and winch	42	40	70 / 120	
Cable crane	8	100	350 / 500	

Table 2: Use of different technology



Regional forest enterprises mainly work in public property (80% of the total). Most of them have a large activity radius (sometimes >200 km). 75% of the total harvested volume comes from coniferous stands while the remaining 25% relate to fire-wood production mainly from beech stands. Mostly the cut-to-length system is used.

6.2 ITALY – LOMBARDY

In total, 171 companies were inquired, 150 by one-on-one interviews, six by telephone call and 15 by email or fax.

40% of these enterprises are quite low mechanized only using small tractors for skidding and transporting purposes. Nearly half (49%) is equipped with tractors, tracked harvesters (on basis of excavators) and cable cranes for uphill pulling. 11% additionally use forwarders and cable crane techniques for uphill and downhill extraction.

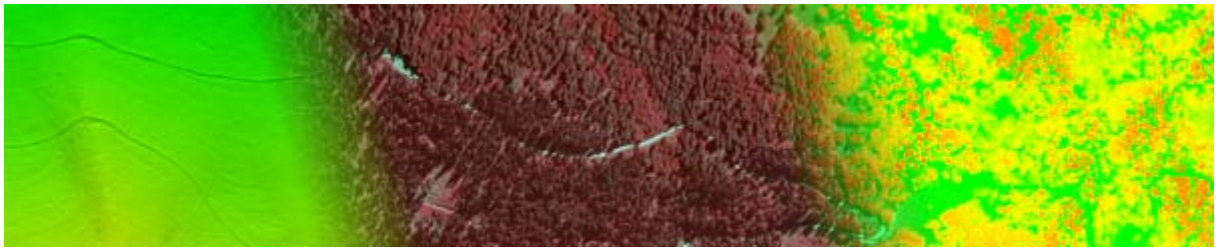
All the results are related to 2008-2009-2010.

6.3 SLOVENIA

In Slovenian Alpine space there are some companies which are well equipped and qualified for forest operations. Most of these companies are also granted the concession for the management in state forests, and therefore determine the applied forest production technologies in the region. A few years ago, companies began to reduce forest production costs by changing their organisation structure. New approaches have significantly changed forest technology practice. The number of employees in these companies decreased and more work has been done with modern technologies (harvesters etc.). Many of the former employees are now self-employed. Some now have their own small companies while others are subcontractors in the same companies where they were previously employed.

In the state forest, the trend of decreasing the share of outdated timber extraction methods, such as manual hauling, hauling with animals, a caterpillar etc. (figure 1), is noted. On the contrary, the share of hauling methodologies with four wheel drive tractors, cable cranes with processor heads and forwarders have been increasing.

Timber extraction techniques in private forests are slightly different. Similar as in the state forests the amount of four wheel drive tractors is increasing, as well as the sum of hauling with caterpillars and skidders. These methodologies are more suitable in small scale forests ownership. The shares of cable cranes and other expensive methodologies in private forests are lower. We have to emphasise, that smaller forestry entrepreneurs have been expanding their activities in private forest land.



Due to economic aspects, bigger companies are more oriented into more powerful and expensive technologies than smaller ones. Small entrepreneurs are more adapted to run forestry operations in small scale private forest property as they are equipped with cheaper and more suitable mechanization for such conditions.

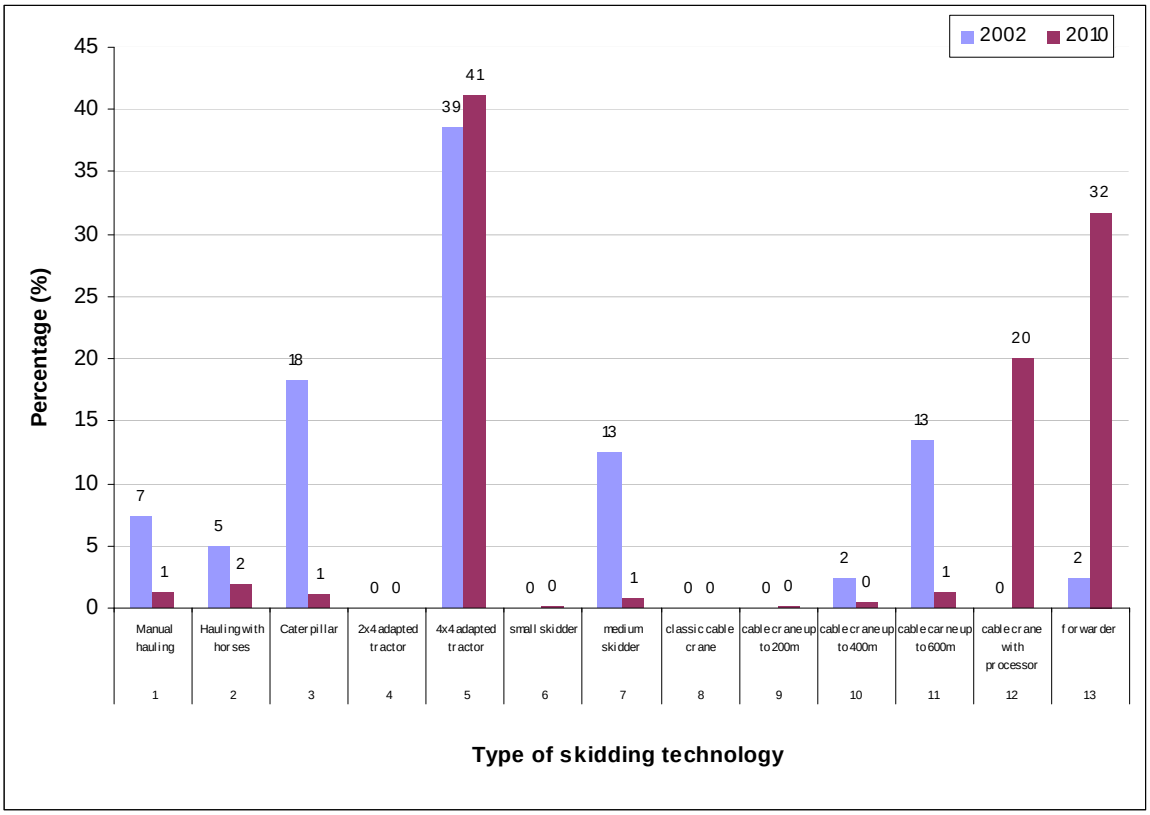
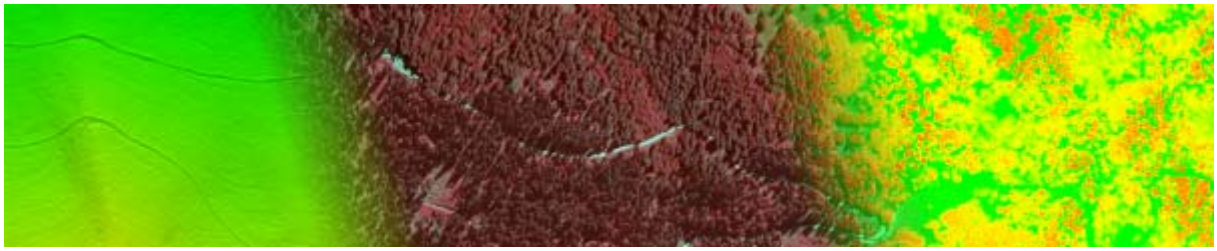


Figure 1: Number of used methodologies in state forests in the years 2002 and 2010

1-Manual hauling, 2-Hauling with horses, 3-Caterpillar,4-2x4 adapted tractor, 5-4x4 adapted tractor, 6-small skidder, 7-medium skidder, 8-large skidder, 9-cable crane up to 200m, 10-cable crane up to 400m, 11-cable carne up to 600m, 12, cable crane with processor, 13-forwarder.

6.4 AUSTRIA-MONTAFON

In the area of the Stand Montafon, the whole tree felling is done manually by chainsaw, mostly supported by hydraulic felling equipment. Larger trees are often pruned directly at the felling location, smaller trees by processor after extraction.



The following table gives an overview of methods of timber extraction in the Montafon test site:

Drift over ground	5,0%
Hauling by winch	14,7%
Extraction by horse	0,4%
Cable yarding up to 1000m downhill	10,2%
Cable yarding up to 1000m uphill	2,6%
Cable yarding up to 300m uphill	10,4%
Cable yarding up to 300m downhill	9,0%
Cable yarding up to 600m downhill	27,9%
Cable yarding up to 600m uphill	14,6%
Cable yarding >= 1000m downhill	2,3%
Helicopter	2,8%
	100,0%
Amount of cable yarding	77,1%

Table 3: Timber extraction in the Montafon test site

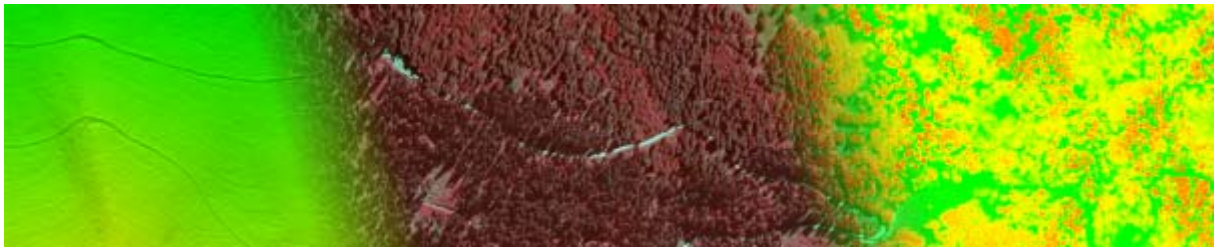
Most of the timber is extracted by cable crane or respectively cable yarding (up to about 80%). After extraction, the tree processing is done with a mountain harvester. The more complex uphill pulling technique is thereby used for nearly 23% of the volume. Approximately 15% is handled by tractor winch

6.5 AUSTRIA-TIROL

The Tyrolean database provides information about applied harvesting and extraction techniques for forest stands in the hand of non-governmental persons or organizations and covers therewith about 75% of the Tyrolean forest area.

6.5.1 HARVESTING TECHNIQUES

The topmost line indicates the development of the timber harvesting volume during the last decade up to the year 2012. The lines below give the ratio of the applied machinery during this time in the harvesting volume.



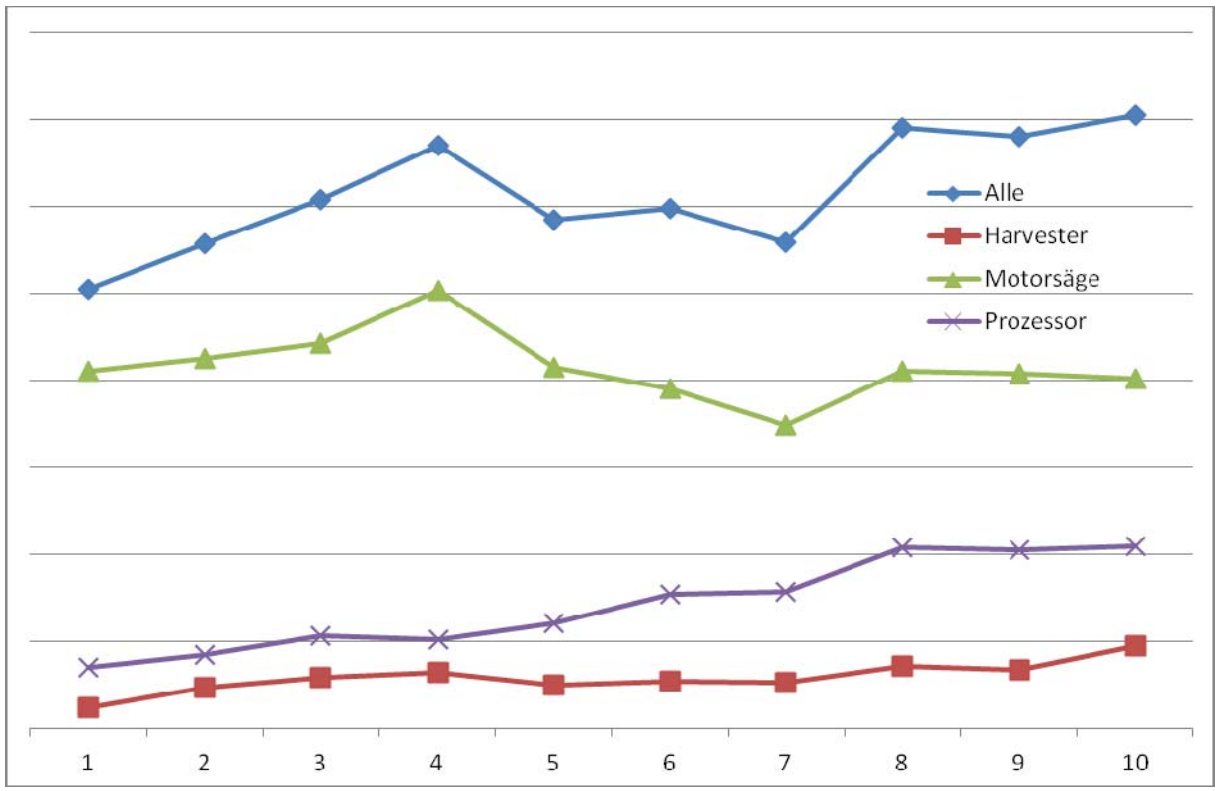


Figure 2: Development of timber harvesting volume during the last decade

The application curve of harvesters (lower most line) shows a slight but clearly recognizable increase of harvested timber volume. Compared to the indicator curve of processor usage, the increase is clearly steeper. Initially, cutting by chain saw reflects the same progression as the overall harvesting trend but then seems to decrease slightly during the last three to five years.

Note: Processors only complement the work done by chain saw and are not used for cutting, but for pruning and bucking. They can be used standalone or attached to a cable crane.

6.5.2 EXTRACTION TECHNIQUES

Hauling by winch and cable yarding are the far most used techniques for timber extraction. On ground hauling does not show any noticeable trend while cable crane application was clearly increasing over the same time. Even if not to the same extent, the use of forwarders was also rising during the last ten years. Other methods do not seem to be of major meaning. They keep relatively constant over the whole period.

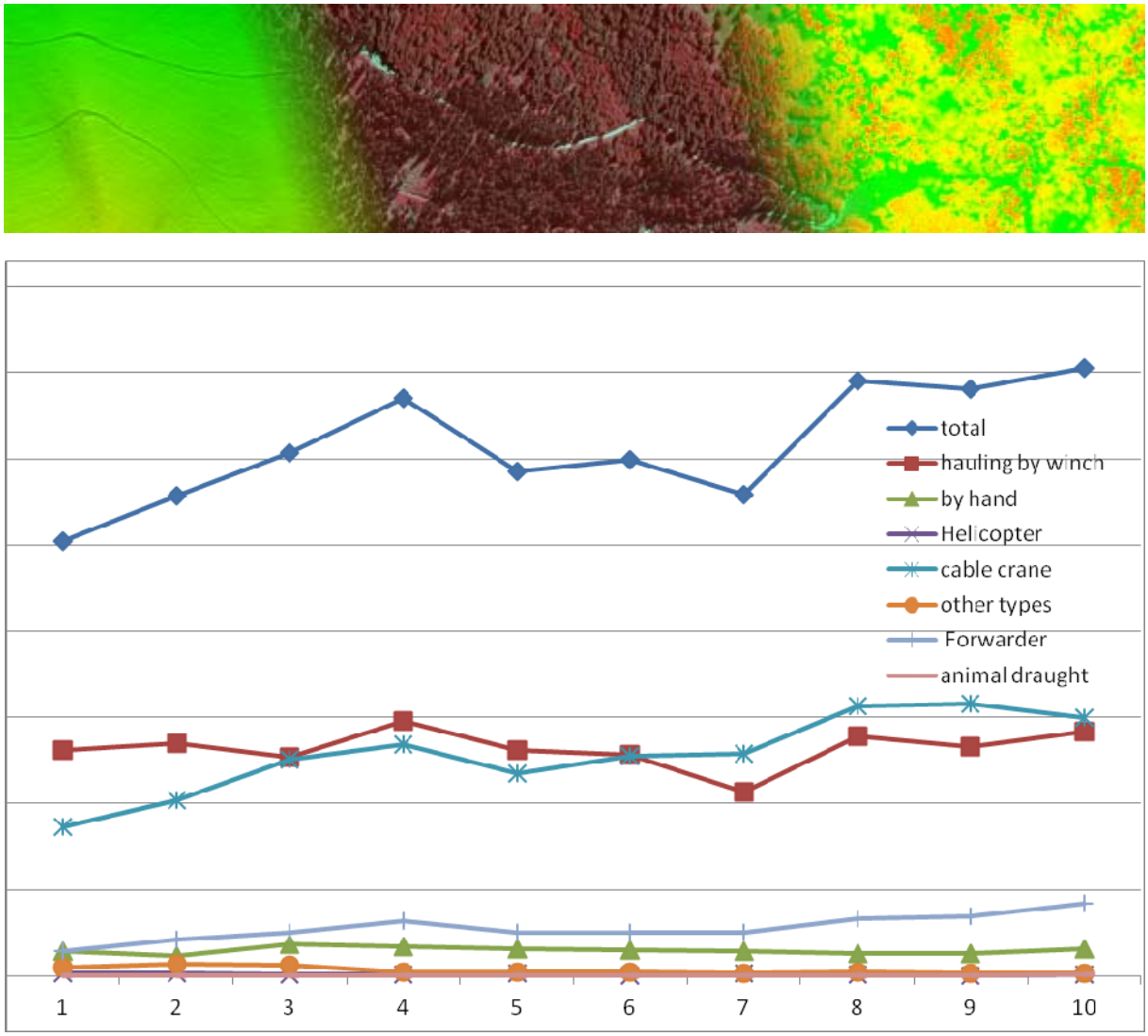
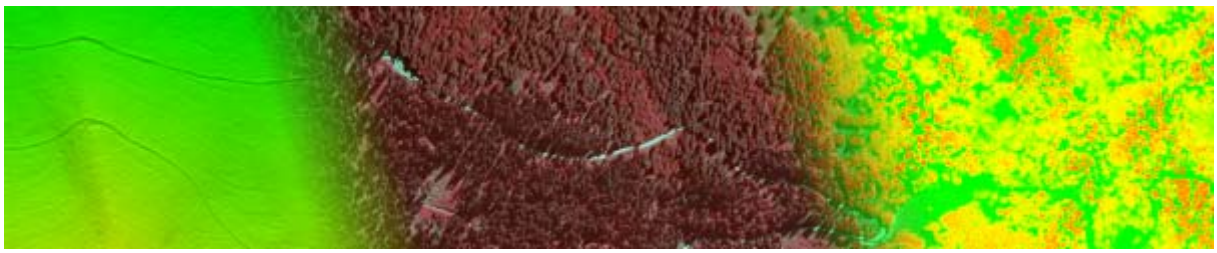


Figure 3: Used techniques for timber extraction during the last decade



6.6 FRANCE-FRENCH ALPS

Results of an inquiry on harvesting and extraction technology in the Northern and Southern Alps of France (dépts. 38, 73, 74 and depts. 04, 05, 06) are shown in the table below:

	Northern Alps	Southern Alps	total
Harvesters	15	15	30
Cable yarders	11	2	13
Forwarders	10	14	24
Skidders	67	19	86
Tractors	14	n.b.	

Table 4: Use of different technologies

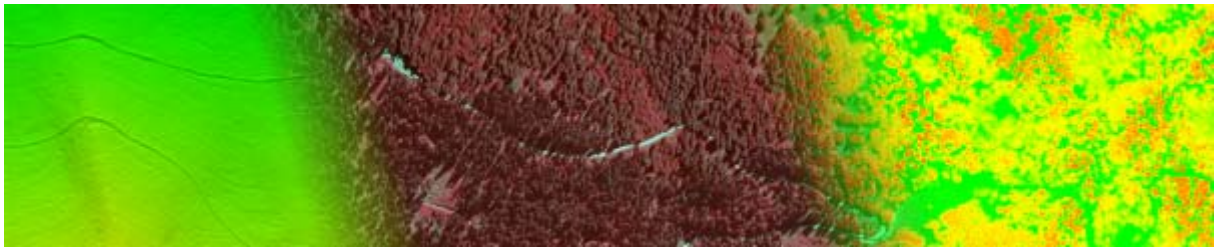
6.7 GERMANY-BAVARIAN ALPS - SATE FORESTS

The following data was provided by the BaySF, which is managing the state forests of Bavaria. They cover the whole alpine forest area wherein the Bavarian state holds a part of about 60%.

Because the data is stored with regard to working processes, not all the harvested timber can exactly be matched. Thus, curve points do not add up to 100%.

6.7.1 HARVESTING TECHNIQUES

Manual cutting lies more or less constantly at about 60% but is decreasing during the last four years while the rate of harvester activities is increasing, in particular over the last three years up to more than 30% in 2013.



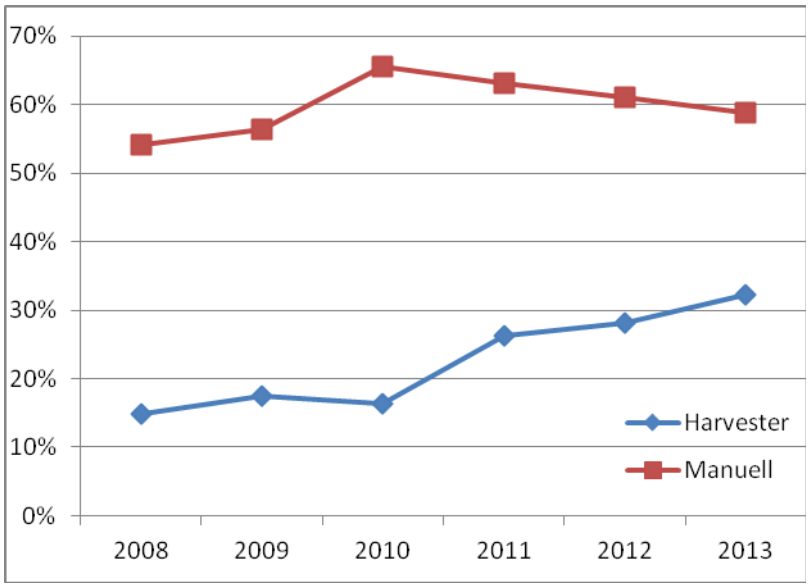


Figure 4: Rate of timber cut by hand and by harvester

6.7.2 EXTRACTION TECHNIQUES

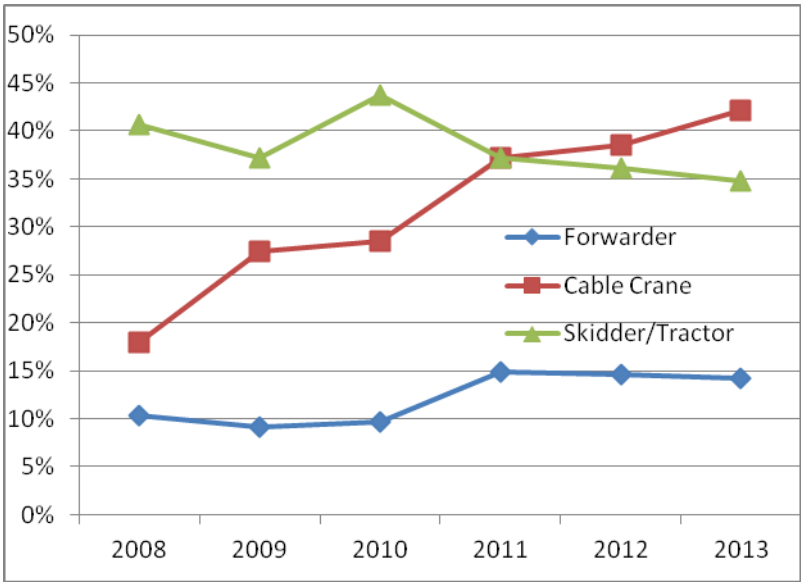
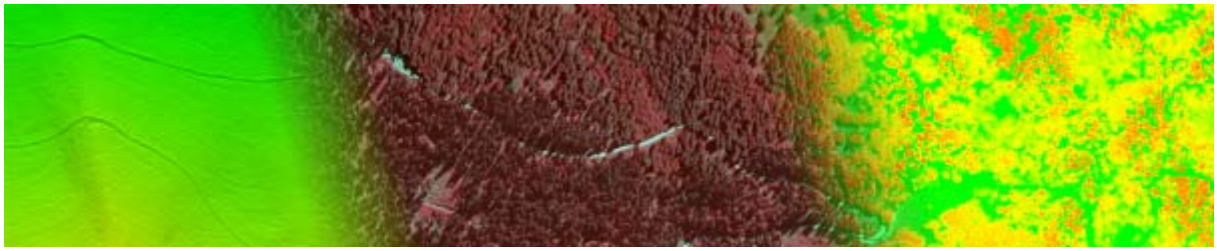


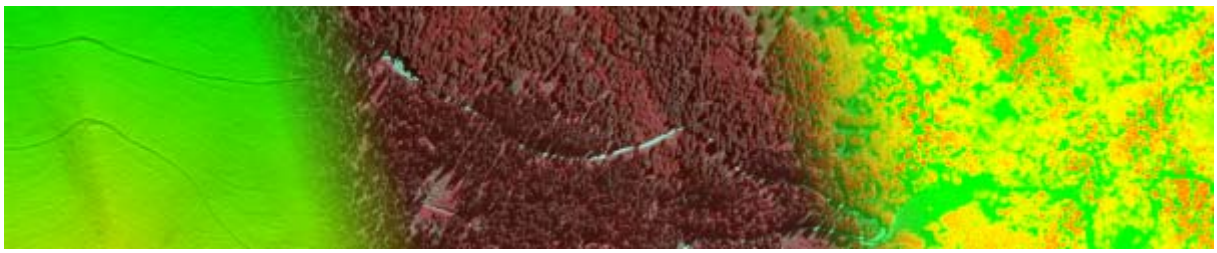
Figure 5: Rate of timber extracted by different techniques

Until the year 2011, skidders and tractors played the main role in timber extracting but were then exceeded by cable yarding.



The part of cable crane work shows a steep increase over the whole period. From 2010 to 2011 forwarders gained an extension from 10% to 15% but remained on the same level since then. Meanwhile, mountain harvesters play an ever greater part in extraction and pruning / bucking. About 50% to 60% of the arising timber from state forests is processed by mountain harvesters, and is of similar dimension in private forests.

For two years, tree crowns and branches and branches are to remain at the felling place to keep nutrients in the forest stand if possible. Using this method, damages to the remaining stand are also kept lower.



7 TENDANCIES AND ADVANCEMENTS

According to the intentions of forest enterprises and owners, productivity and efficiency of the applied machinery should be as high as possible and likewise of low impact to forest stands. However, as shown by an inquiry throughout Bavaria, there is a clear tendency to using heavier, more powerful machines. About a quarter of the harvesters were fitted with tracks, two thirds were found to have six wheels. Most of the forwarders (86%) were equipped with eight wheels, using mostly wide base tires between 600mm (40%) and 700mm (54%). These facts are to be seen very positively and indicate good preconditions for the demands of soil conservation. (Borchert and Kremer 2007).

In Austria, with a far higher ratio of mountainous regions, about 50% of the harvesters were already equipped with tracks in 2001 (Pröll 2001). In general, this indicates a broader use of this particular type of harvesters in alpine regions.

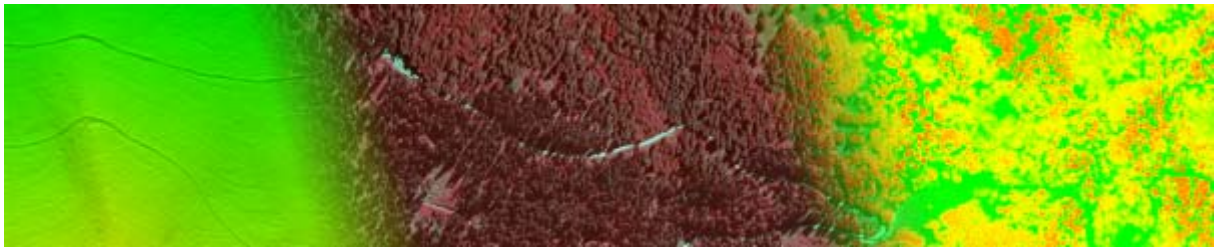
Physical and conservational conditions constitute the main restraints for the application of heavier machines in steep slopes. Better soil conservation can be attained by the use of tracked harvesters, which are also able to work in steeper terrain than wheeled machines. Tracked harvesters are often based on excavators used for construction purposes. In the simplest case, excavators are fitted with a processor head fixed at the excavator boom. In contrast to wheel based vehicles, they cause considerably more damage to the roots of nearby standing trees. Further restraints come up by moving on rough terrain with obstacles.

7.1 TRACKED HARVESTER WITH BOGIE LIKE WHEELS

One successful attempt to combine the advantages of wheel driven and tracked harvesters is the combination of a standard four-wheeled harvester by replaceing the wheels with tracked undercarriages. This leads to significantly better movement capabilities on rough terrain and improves climbing power up to a maximum of about 70% steepness. Unfortunately, root damages of nearby trees do not improve.

7.2 "WALKING" HARVESTER

An attempt to construct a walking harvester without wheels nor tracks but six legs has already been made during the nineties. At that time, however, technical difficulties were to high and expected selling prices overwhelming, leading to a stop of the project. Up to this time, no similar attempt was taken up again.



Since the late nineties, an excavator based harvester – especially built for difficult terrain situations – with four independently moving wheel carriers and an additional outrigger mounted onto the boom is on the market. Derived from a so called walking excavator, this type of machine is also often called walking harvester. Steep slopes up to 100% can be traversed.

Another harvester, sometimes also called walking harvester, exclusively for forestry purposes has been recently developed by an Austrian company. It combines movement by driving on wheels and by simultaneously pushing itself forwards by extending parts of its carriage (Step and drive movement). High maneuverability is attained by implementing crab steering technology.

7.3 SYNCHRONISED TRACTION WINCH

The development of an additional attached traction winch, synchronized with the wheel drive, is another huge improvement. As soon as the slippage of the wheels rises above the limit, the winch provides additional traction to keep the machine on the move. Thus, better soil conservation by wheel driven aggregates is also given in steeper terrain. As a result, this widens the operational area of the carrier machine considerably. Synchronized winches are available for harvesters and forwarders.

7.4 CABLE CRANE

Four of the seven described technologies work with cable crane. To be more profitable, the whole tree harvesting is/was common when applying this technology. During the last two years in Bavaria and Austria, a debate on harvesting full trees, especially on poor sites, is underway, with an advancement to leave the tree crowns in the stand. This is only possible in stands which are not endangered by spruce bark beetle. Otherwise, one has to take measure to prevent the increase of spruce bark beetle.

7.5 CABLE YARDER

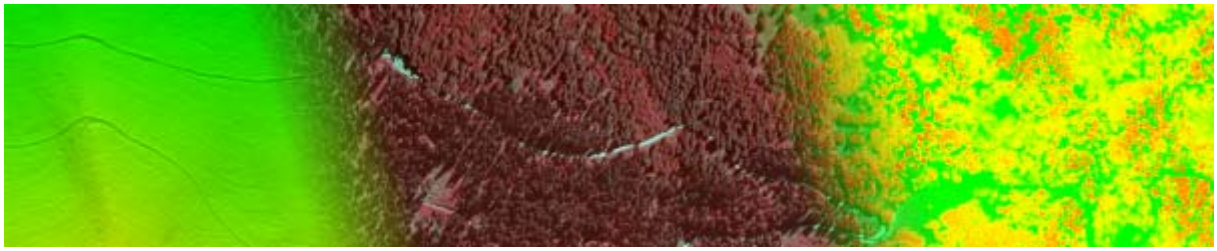
A crane pylon and the required winches are typically mounted on a standard crawler excavator. This means very short installation time of about two hours and less needs for operating space. Timber extraction is therewith possible up to 400m.

7.6 CABLE CARRIAGE

At the present time, extracting timber by specially constructed carriage systems (e.g. double carriages) to widely avoid soil impact is of growing importance, particularly in sensitive harvesting areas.

8 CONCLUSION

In some of the participating countries (e.g. Bavaria and Austria), the number of harvesters and forwarders appeared to strongly increase during the last two decades. The other countries point out the same tendency, but still on a lower level.

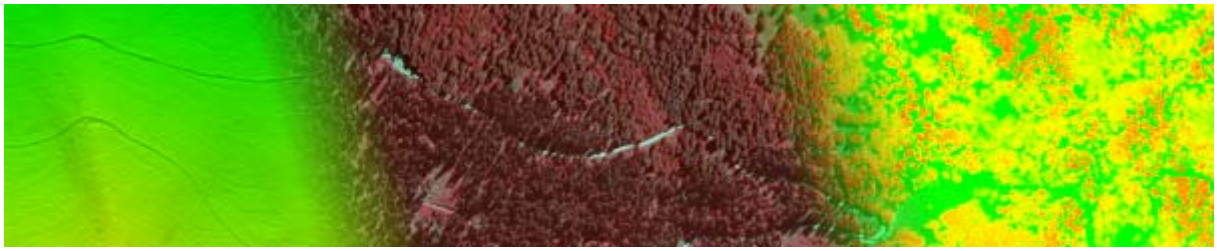


It seems that capabilities of working on steeper slopes by highly mechanized machines have now come to a physical limit. In the field of harvesting techniques we do not expect any revolutionary innovations in the foreseeable future.

Minor improvements probably will be made in the fields of ergonomics and conservation of soil and standings. Tendencies to develop more and more specialized equipment (according to terrain situation and character of the growing stock) will stay at a constant level or even decrease. On the part of the manufacturers of harvesters, development costs are extremely high and only low production numbers are to be expected. This means high investment and maintaining costs also for the customer. The threshold of amortization is hardly reachable. It is to be expected, that new investments will mainly be made in the course of replacing older machines.

Forestry machines usually operate in high sensitive and vulnerable ecosystems, particularly under mountainous conditions. Damaging / injurious effects in soil and standings mostly cause follow-up costs that quite often exceed the proceeds. Highly trained personnel with regard to machine operating and maintenance is therefore of high importance.

To increase revenues and, above all, gain better overall benefits, the consideration of complete working processes and the logistic chain instead of particular machinery becomes apparent. This is one of the main goals of the project NEWFOR.



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