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CHARACTERISTICS OF PROGRESSIVE TECHNOLOGIES OF SNOWBREAK PROCESSING AND THE PRODUCTION OF ENERGY WOODY BIOMASS IN YOUNG PINE STANDS

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Abstract: *Snowbreaks amounting to about 425 000 m^3 in young 40-year-old stands with the predominance of Scots pine occurred in southern Bohemia at the beginning of 2006. Operational and economic parameters of a new technological chain are characterized. A navigation instrument Geo Explorer XT with digital map data of stands and laid down gaps of affected pine stands and their access for a slash buncher and forwarder was used for the preparation of processing the part of snowbreaks. Directional felling of uprooted and broken trees in gaps using a power saw. Subsequently, a Timberjack 1490 D slash buncher was used and digital data for felling preparation were transferred to its navigation system Timber Navi^{TM}. The machine movement through a stand was optimized according to a digital map. Bundles of woody biomass (ca 15 in one load) were transported to a main forest road by a John Deere 810 D forwarder. A Volvo FM 12 semi-trailer unit carried out the transport of bundles from the forest to a consumer. At a consumer, bunches of woody biomass were unloaded and crushed by a hammer shaft to smaller fractions for energy purposes.*

1. Introduction

Extensive snowbreaks amounting to about 425 000 m^3, which affected young forest stands in the area of southern Bohemia at the beginning of 2006 are similar to “thinning” by their character. Thus, throughout the area of Forest District Trebon, particularly small-diameter trees, suppressed trees or trees with a one-side crown were affected and broken. It refers mainly to Scots pine (*Pinus sylvestris*) in age classes from 20 years. Trees of middle age were affected most, stands up to 40 years of age were broken on smaller or larger areas. Norway spruce trees (*Picea abies*) mostly survived snow load or only smaller parts of crowns were broken. By the end of July 2006, some 350 000 m^3 snowbreak wood were processed. The staff of the Department of Forest and Forest Products Technology, Mendel University of Agriculture and Forestry in Brno, participated in the development of optimum procedures of processing the disaster wood as well as in the explanation of its causes.

2. Objectives

To define causes of the extensive damage to stands by snow cover and particularly to determine optimum technological procedures, which would process broken young pine stands as friendly as possible within short time from September to the end of 2006. These stands occur mainly on forest type localities with waterlogged gleyed soils and peat pine woods.

3. Methods

Methodology consisted of several steps: localization of affected parts of stands by means of digital photos obtained using motor paragliding; the transfer of the photos to the map database atlas of Lesy CR Hradec Kralove (Forests of the CR Hradec Kralove); the preparation of stands for logging through a Geo Exproler XT navigation apparatus; mapping the affected gaps and their access for logging machines in such a way minimum damage to soil during logging operations to be guaranteed. Determination of the technological procedure of logging and transport operations bunching and the subsequent use of wood for energy purposes being selected as the most suitable method to process the woody biomass.

4. Processing and results obtained

4.1 Causes of snow damage to stands

In Forest District Trebon, snowbreaks totally affected pure stands of Scots pine at an age of 30 – 40 years. It concerned stands from artificial regeneration, which were established at a density of 10 000 trees per ha. In the given case, total disruption of pure pine stands was caused by the extreme amount of snow as well as by the insufficient tending of stands. Affected stands were virtually untended showing an unfavourable slenderness ratio, ie they were extremely "slender" showing insufficiently developed crowns, which could not carry considerable load of wet snow.

Thus, extreme snow conditions demonstrated a necessity to observe tending programmes also for pine. Models of tending tested by practice recommend the first tending measures to be carried out at reaching the upper stand height of 3 m, ie at an age of 6 – 10 years when wolf trees are removed and the stand density decreases to 9000 trees/ha. Next measures have to be carried out through removing subdominant unstable trees in the stand. In the management set of stands 13 (natural pine sites), the second tending measure has to be carried out at reaching the stand height of 8 m, ie at an age of 25 years and stand density is decreased to 6500 trees/ha. In the management set of stands 27 (pine management of gleyed sites), the second measure is carried out at reaching the upper stand height of 4 – 6 m at an age of 15 years and stand density is reduced to 6000 trees/ha. The third or the fourth measure has to be carried out at reaching the upper stand height of 12 – 15 m at an age of about 30 – 35 years. The number of trees must be reduced to 3000 – 4000 per ha.

This procedure is the only possible way of stand tending to reduce the potential danger of damage caused by wet snow in pure pine stands. Examples from Forest District Trebon document the markedly higher stability of pine stands with the sufficient admixture of broadleaved species and larch. At the regeneration of forest stands, it is necessary to observe the sufficient proportion of soil-improving and reinforcing species.

4.2 Preparatory operations of logging

Aerial photos of selected localities were carried out by means of motor paragliding. It concerns a parachute wing with a gliding characteristic of about 1: 6, which is equipped with a Simonini 200 cm^3 two stroke engine. This engine with a tuned exhaust stroke gives 28 HP, which provides climb capacity up to 3 m/s. Advantages for photography consist in the slow fly of a machine; its speed as against the air environment amounts to about 45 km/h.

To guarantee the exact localization of particular photos a GPS Garmin apparatus is used. The device is exactly time-synchronized with a Sony 2K 10.3M camera. Each of photos is equipped with EXIF printout making possible to allocate each of the photos to a locality accurate to ±7 m. The printout of the flight line is set up in GPS to store particular flight points every 5 s. The printout of points is supplied together with the set of digital photos. Each of the points is described by exact time, spatial coordinates, flying

speed, height and direction of fly, which makes possible to assign also the direction of photography in addition to exact localization to each of the photos.
Into the Geo Explorer XT navigation apparatus, which is controlled through satellites, map data were transferred of stands in the digital form from the LCR Hradec Králové database. Broken gaps of pine stands and their access were laid down into these map sources for a Timberjack 1490D slash buncher and forwarder. The preparation of these stands was transferred to the TimberNavi^{TM} navigation system in the slash buncher. The technological procedure of operations then occurred according to digital map data.

4.3 Logging procedure

A power saw directionally felled gaps of broken pine stands laid down in the operational digital stand map. Felled wood was then bundled by a slash buncher placed on a Timberjack 1490D forwarder. The tractor is carried on an eight-wheel chassis with tandem bogie axles. Low-pressure tyres 700 mm wide condition the machine width of 2930 mm. The total length of the machine is 11 110 mm, clearance height 605 mm and total weight 23 000 kg. John Deere six-cylinder engine, power 136 kW at 1900 rpm. The machine hydraulic crane has a range of 10 m and lifting moment 102 kNm. The bunching unit is 6.2 m long, 2.4 m wide, 1.9 m high and its weight is 7000 kg. The length of slash bundles ranges from 2.4 to 3.2 m, diameter 70 - 80 cm and weight 250 -700 kg according to the moisture and size of logging residues. The bunching unit has a mechanism for mounting 9 reels serving for spooling hemp cord of lighter colour ensuring good visibility. Binding the bundles begins already during pressing and thus, the logging slash bundle remains compact. The consumption of hemp cord is about 0.20 kg per one bundle. The logging slash bundle is automatically cut by a chain saw with a 1000 mm chain bar. The average output of a slash buncher under given conditions was 10 – 30 bundles per hour. Thus, about 70 bundles can be obtained from one hectare of felled area. The navigation system of John Deere Co. was used during these operations. The company developed a communication chain for mechanized logging in such a way to complete a gap between felled trees and their transport from the forest to a processing unit. This chain consists of the Timbermatic^{TM} 300 system, which is supplied with a harvester on a regular basis and of the Timbermatic^{TM} 300 system, which is optionally supplied with a forwarder. Communication between the two systems is provided by the TimberNavi^{TM} Professional Logistics system the principle of which is cooperation with the GPS system.

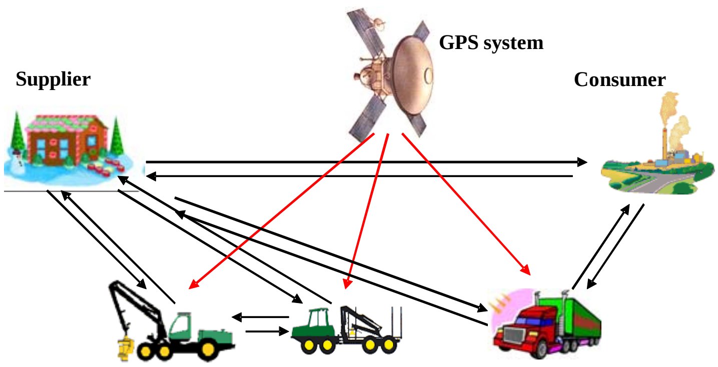

Figure 1: The scheme of a communication chain

The procedure of logging operations using the communication chain:

1. The machine owner receives a requirement for the production of assortments from a customer.
2. The machine owner enters necessary data to the harvester or slash buncher.
3. The harvester or slash buncher stores information in electronic form on produced assortments (in the given case on bunches of felling residues) including coordinates from the GPS system for every produced log (bundle).
4. The harvester (slash buncher) sends production data to the forwarder.
5. The forwarder accepts data from the harvester or slash buncher and on their basis plans an optimum forwarding plan.

6. Coordinates obtained from GPS and other data on particular piles are sent by the forwarder to the machine owner and the owner hands over the data to the consumer or hauler.
7. The machine owner or hauler organizes supplies of finished assortments to his consumer on the basis of the need of various assortments.

4.4 Basic advantages of the selected technological procedure and control system:

- During the operation, the machine is controlled according to information from GPS.
- The harvester (slash buncher) operator or forest manager lays out lines for a forwarder in the digital stand map with respect to the stand situation (gradient, watercourses, bogs etc.), which need not be marked in the stand. All lines are of the same direction and distance.
- The forwarder operator plans the forwarder line on the basis of data from the harvester (slash buncher) in order to prevent transport with half load or no-load.
- In winter in case of snow, the forwarder need not follow immediately the harvester (slash buncher) because even logs hidden under snow are visible being evident on a display; thus, no forgotten logs (bundles) remain in the forest.
- To provide an immediate view of the machine position in the stand and on the size of the already processed area.
- In case of a slash buncher, a way through the stand and the system of storing particular bundles are saved in the PC memory.
- The number of produced bundles serves for registration and conversion to m^3.
- Logging areas from which the bundles are produced are continuously handed over to the forest owner who records them to a forest management plan.

4.5 Forwarding bundles of felled wood

A Timberjack 810 D forwarder on an eight-wheeled chassis was used. The power of an electronically controlled turbodiesel engine John Deere amounts to 86 kW at 2000 rpm. The hydraulic crane shows a reach from 6.5 to 9.6 m according to the crane type. The tractor weight according to equipment is 10.4 – 11.5 t and effective carrying capacity amounts to 9 t. Low-pressure tyres are 700 mm wide, chassis clearance height is 595 mm. The Timbermatic 700 centralized digital control system facilitates communication between a harvester and a forwarder. In case of processing the snowbreak wood this digital control system Timbermatic 700 was installed into a slash buncher. The system enables to use the Windows environment with other groups of programs such as Timber Navi. The mean number of bundles on a forwarder is 15. In order to prevent bogging the logging machine wheel-tracks Eco Baltic 700/45x22 of a weight of 1402 kg manufactured by Olofsfors AB, Sweden were installed on both rear bogie axles of the forwarder. The wheel-tracks are suitable for waterlogged stands with the high level of groundwater, which is affected by ponds in the neighbourhood. On the basis of a proposal of the Department of Forest and Forest Products Technology, Faculty of Forestry and Wood Technology a modification of these wheel-tracks was concluded with this company consisting in the translocation of anti-skid spikes (studs) to centres of flange edges. It was achieved that passage with these modified wheel-tracks did not cause deep ruts into the bituminous surface of roads. It was possible to move along the roads without the necessary dismounting and subsequent mounting of these wheel-tracks. Thus, through the adequate preparation of stands, using suitable means of mechanization and wheel-tracks modified by the manufacturer nearly no-damage forwarding the slash bundles from broken pine stands was achieved.

4.6 The transport of bundles of felled broken pine trees

The transport of wood bundles suitably stored by a forwarder on landings was carried out using a logging truck-and-trailer unit created by a Volvo FM 12 semi-trailer truck equipped with a saddle and an Epsilon Z 165 hydraulic crane. Tyre pressure rating 900 kPa, speed limit 80 km/h. The semi-trailer frame consists of two weldments, viz. the main and the rear frame, which can be fixed in three positions (compound, half-extension and maximum extension). The semi-trailer is equipped (on a regular basis) with the EBS braking system with an information centre, which informs the machine operator on the actual condition of axle load. The highest permissible weight is 39 000 kg. The semi-trailer has two rear lifting axles (the first and the third). The semi-trailer sliding stakes make possible to transport long logs up to 14 m as well as short assortments at a length from 2 m. Before an exit to a public road the machine driver fastens the load from shift and the loss of branches by means of strap belts placed between stakes. During the transportation of bundled biomass smaller loading the road network occurs as compared with the transport of wood chips (Fig. 2) and, thus, bundles can be transported without any problems to a distance of 5 – 100 km. The bundles were transported to a power station based on the combustion of woody biomass.

Figure 2: Comparing the loads of transported forms of wood

4.7 Energy use of harvested woody biomass

Woody biomass obtained from stands affected by the snow disaster was mostly used for energy purposes. The importance of biomass to obtain renewable resources of energy steadily increases. It consists not only in the direct use of obtained energy but it is particularly important from ecological aspects. At the combustion of energy biomass the production of emissions significantly decreases. Through the combustion of fossil fuels these emissions considerably load the air. Another decisive importance of the production of biomass for energy purposes is associated with the greenhouse effect. This effect recently gradually increases with the increasing intensity of the combustion of fossil fuels. At the combustion, greenhouse gas (carbon dioxide) is released. In former times, the gas was bound by the vegetation of former plants, which served for the origin of fossil fuels. The greenhouse effect is a natural phenomenon and the present life on the Earth would not exist without it but the CO_2 cycle must not be disturbed. Nevertheless, the intensive combustion of fossil fuels in recent times results in too large amounts of carbon dioxide in the air and so its natural cycle begins to be disturbed, temperature on the Earth increases and increasing greenhouse effect begins to be a real threat of the global climate disturbance. At the biomass combustion, CO_2 is also released being, however, drawn from the atmosphere by plant vegetation and thus, its balance in the atmosphere is in principle stable. The more intensive stands of energy plants (plants used for heating etc.) are established the more CO_2 is consumed for their photosynthesis and the more CO_2 is drawn from the atmosphere.

Woody biomass is changed up to from 85% to combustible gases, which require another system of burning for their quality combustion than fossil fuels. Primary air has to be supplied into burning fuel, secondary air into burning gases and in larger combustion chambers even the tertiary air. Burning flames have to burn out in a ceramic extension chamber without cooling and after the total burn-up of the gases they transfer heat to the heat transfer medium. It is necessary to follow these principles of the effective combustion of biomass in all types of boilers burning biomass.
Heating using the woody biomass can be carried out in boiler plants of various size and type according to local conditions, eg as follows:

- Central boiler plants in villages and towns are suitable where there is compact concentrated housing estate.
- Block boiler plants can be established in villages with more centres, which are not near one another.
- Central or block boiler plants in combination with the individual heating of buildings distant of a public boiler plant, which are, as a rule, heated using chips or straw bales (bundles). Remote individual buildings are equipped with boilers heated with wood briquettes or pellets. These buildings can be included into the system of village industrial heating and the price of their fuel is advantaged and, thus, these peripheral buildings have comparable costs for heating as those, which are directly connected to a boiler plant.
- At present, the individual heating of single-family houses can be also carried out in modern stoves or fireplaces, which are characterized by the high effectiveness of combustion, viz. up to 90%.

A prospective objective is, on the basis of an advertising campaign, to create conditions for specific investment and commercial projects concerning the development of "phyto-energetics". With respect to the real threat of negative impacts of the increasing greenhouse effect it is necessary to reduce the use of fossil fuels as much as possible and thus to reduce the CO_2 release into the atmosphere. EU authorities are well aware of the real threat and, thus, they try to deal with the problem within the whole Europe. Therefore, an idea on "CO_2 emission trade" has originated. In practice it means that a country producing less CO_2 than is enabled by the Kyoto protocol can "sell" certain part of the amount to a country, which is not able to reduce effectively and in the given time its proportion of CO_2 emissions. In the CR, production of CO_2 has decreased at present (unfortunately, not due to the use of effective technologies but owing to the reduction of industrial production) and thus, it is below the given limit. Therefore, it is possible to sell to countries, which are above the given limit. Thus, a country buying a certain share of CO_2 should contribute to the selling country by the same financial amount for the use of energy biomass. However, in any case, it is necessary to support the development of phyto-energetics in our country and to use experience from abroad.

Table 1: Carbon dioxide emissions in the Czech Republic as compared with other countries

Country	CO_2 emissions (million t)	Population (million)	CO_2 emissions per capita (t)	Proportion in the world production of CO_2 (%)
Czech Republic	148.2	10.3	14.4	0.7
USA	5 228.5	263.1	19.9	23.7
China	3 006.8	1 200.2	2.5	13.6
Russia	1 547.9	148.2	10.4	7.0
Japan	1 150.9	125.6	9.2	5.2
Germany	884.4	81.7	10.8	4.0
India	803.0	929.4	0.9	3.6
Great Britain	564.8	58.6	9.6	2.6
Canada	470.8	29.6	15.9	2.1
Ukraine	430.6	51.6	8.4	2.0
Italy	423.8	57.3	7.4	1.9
France	362.0	58.1	6.2	1.6
South Korea	353.1	44.9	7.9	1.6
Poland	336.1	38.6	8.7	1.5
Mexico	327.5	94.8	3.5	1.5
South Africa	320.9	41.5	7.7	1.5
Brazil	287.5	159.2	1.8	1.3
Australia	285.9	18.1	15.8	1.3
Spain	246.9	39.2	6.3	1.1
Iran	232.9	64.1	3.6	1.1
Saudi Arabia	227.1	18.9	11.9	1.0
Indonesia	227.0	193.3	1.2	1.0
Kazakhstan	185.6	16.6	11.2	0.8
Netherlands	178.8	15.5	11.6	0.8
Taiwan	166.9	21.3	7.8	0.7
Turkey	160.5	61.6	2.6	0.7
World	**22 000.0**	**5 759.0**	**3.8**	**100.0**

At present, biomass is most often used for direct combustion. However, it is also a raw material for the production of biogas and fuels. In our country, energy biomass is used only in about 1.5% of the total primary sources of energy whereas in EU, it is about 6%. Until 2010, this proportion should be nearly double, roughly up to 12% of the total primary sources of energy

5. Recommendations resulting from the evaluation of the course of processing salvage felling in the given area

- Lower costs for the removal of felling debris after principal felling. Technologies used at present for slash disposal in the majority of forest owners require costs amounting to on average CZK 65 per m^3 harvested wood. Operational tests show that slash buncher can manage these work stages at the cost of CZK 30 – 40 per m^3, ie 50 – 60% costs of other technologies of slash disposal.
- The rate of a working procedure at the use of a slash buncher makes possible to remove slash immediately after felling. The slash buncher proceeds next to a harvester common (simultaneous) forwarding timber assortments and slash bundles being possible.
- The whole clear-felled area is available for subsequent reforestation. At commonly used methods of slash disposal (manually or by means of mechanization) slash remains mostly lie in rows on a clear-felled area. The buncher collects slash throughout the area and thus, reforestation is not limited at all.
- Prevention in forest protection. Through timely slash disposal conditions are limited for the development of cambioxylophagous insect and other pests on logging residues.
- Restriction of possibilities for the origin of fires. Slash burning on felled areas is prevented.

- Fast and more accurate measurement of the volume of removed biomass by means of bundles as against a relation between m^3 harvested wood and the converted volume of slash.
- Using GPS and a navigation system for the registration of areas in relation to primary records, clear-felled area balance, data for silvicultural projects and the renewal of a forest management plan.
- Effective preparation of workplaces makes possible the goal-directed minimization of damage to soil due to the operation of heavy machines.
- Possibilities of using the previously established unique potential of the LCR Hradec Kralove database (digital maps of stands), comparison of results obtained with foreign countries.
- Minimum requirements for storage area at a roadside landing, no requirements for continual and immediate transport to a consumer.
- Effective use of biomass for energy purposes – renewable source of energy. Performance of tasks of EU access protocols – proportion of the production of energy from renewable resources.
- Friendly approach to the environment thanks to lower energy consumption, road network loaded by the lower frequency of timber transport – at the transport of slash bundles "air" is not transported.

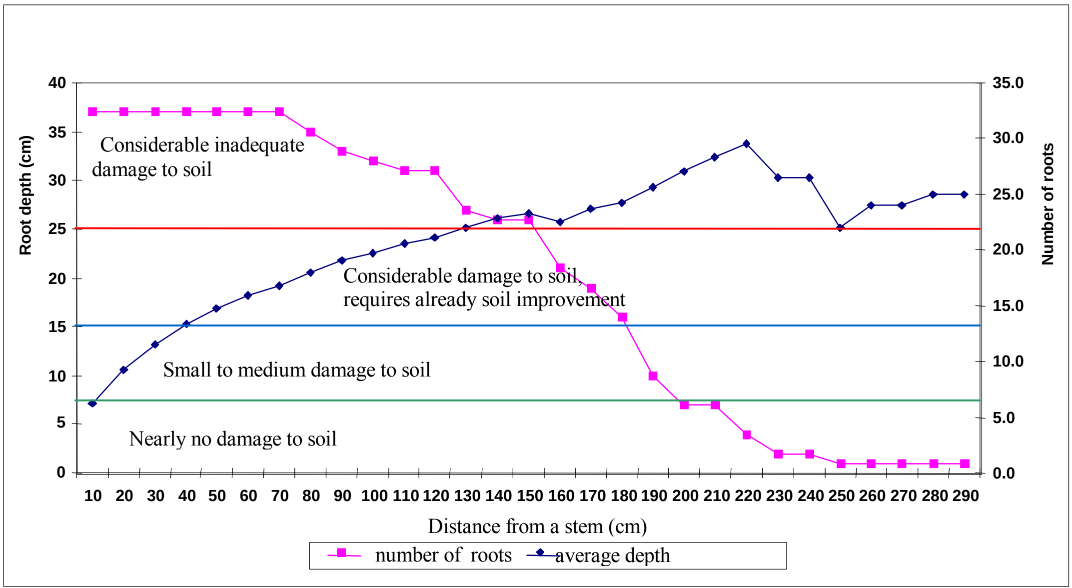

Figure 3: Relationship between the depth of soil damage and potential damage to spruce roots

6. Conclusion

For the preparation of production in stands affected by a snow disaster digital map sources of stands from the LCR Hradec Kralove database were used. Together with the map sources, a navigation system for optimum logistics was fully used. Modified wheel-tracks Eco Baltic were used on bogie axles. These wheel-tracks guaranteed nearly minimum damage to soil in an extremely waterlogged locality making possible logging machines to manage longer distance without damaging the surface of bituminous roads. In principle, the root system of stands was not disturbed. By means of the supersonic flow of air the root system of a spruce stand was uncovered (denuded) and a table was compiled on the depth of the spruce root system and limits of root damage were determined (Figure 3).

Under conditions of our country, sufficient awareness on practical benefits of “phyto-energetics” has not been ensured yet in the general public. Much useful information can be obtained from abroad, particularly through an international section, which is directly connected with the European association of AE – BIOM. At present, the association already includes 22 countries (including the CR). Information on the development of phyto-energetics in particular countries can be obtained continuously there. The highest proportion of energy from biomass is used, eg in Scandinavian countries, which have the high proportion with respect to primary sources of energy, namely Sweden about 18.5% and Finland about 20%. In the CR, we use energy from biomass only about 1%. Therefore, it is necessary to cooperate systematically with countries where there is long-time experience with this prospective field of energetics.

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