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RELATION BETWEEN MECHANIZATION AND BIOLOGICAL PRINCIPLES IN THE MANAGEMENT OF FORESTS

The forest is an irreplaceable natural community which alone may safeguard the conservation of natural values, animal and plant species, may eminently influence natural processes in the ecosystem and most efficiently neutralize and compensate the unfavourable influences of civilization. Indeed at present the negative effects of the activities of man already are reflected in the deteriorating sanitary condition and reduced resistance of forests against such influence. One of the most important factors are industrial fumes which impair the sanitary condition of forests and reduce their potential of resistance on wide areas.

In forest thus weakened, economic activities are going on which may top these negative influences.

*An important factor of the economic activities in the forest is mechanization used in silviculture, logging and timber transportation. It may operate as man's helper but it may become also an important cause of damage to the natural environment. Therefore ever more frequently a discussion goes on regarding the effects of mechanization on the natural environment, in search for effective measures in order to combine a high degree of mechanization with biological principles of forest management. The importance of solving this problem will increase ever more. This is the reason why the decision was made to devote a whole number of the journal *Lesnictví* to papers discussing the problems of the relation between mechanization and biological principles of the management of forests.*

The natural environment in the forest consists of several important components which may be affected by the negative influences of mechanization. They include the air, water, soil and the forest itself. It is necessary, of course, to investigate the negative influence of mechanization on the man who used it. The scope of the journal does not permit to discuss all these components. Therefore the papers are limited to the subject of damage caused to the soil which is the foundation of forest growth.

The quality of forest soil and the site conditions in the forest are created during long decades by the natural disintegration of rocks and the decomposition of organic matter produced by the forest. Nutrients taken from the soil are accumulated in trees and other plants. By logging these nutrients stored in the trees are withdrawn. A greater amount of nutrients is taken away if whole trees are logged because the accumulation of nutrients is larger in the tree crowns. On the other hand, nutrients are replenished by the weathering of soil and the decomposition of dead plants and shed leaves, needles, fruits and twigs. It is therefore necessary to identify the balance of the circulation of nutrients and according to this information to decide on the use of logging technology, mainly the technology of logging the whole biomass.

A no less important factor is mechanical damage caused to soil by the wheels of tractors resulting in erosion. This is especially important in mountain regions on clear cut areas. Therefore technologies used in such regions should be considered both from the point of view of performance and cost, and from the ecological viewpoint because erosion control measures on logged over areas may be more costly than more considerate methods of management. In this way should be considered both the proposed technological procedures and the various types of equipment used in the forest. It has to be borne in mind that such equipment may dig over the soil and damage the root systems, but also compact the soil and inhibit the growth

of roots in the compressed soil. In any case such technical solutions and equipment should be looked for which will avoid such damage. It is mainly necessary to reduce the weight of equipment and to use wide-profile low-pressure tyres. The most suitable solution is, of course, the use of aerial transportation of timber using cable systems, or to search for new solutions of aerial transportation, e. g. using balloon systems.

An important source of pollution of the forest soil is which gets into the soil from the lubrication systems of chain saws. Although the quantity of oil escaping during lubrication of the chain of one saw is relatively small, this source of pollution is very important because of the great number of chain saws operating in the forest. It is therefore important to identify the extent of infiltration of mineral oils into the soil and to develop objective methods of its detection. A solution would be the use of natural oil which quickly decompose in soil and water. In this respect it is necessary to develop such types of oil the properties of which at least match the oil used so far.

A great problem is also the leakage of oil from hydraulic systems of equipment used in the forest. Technical solutions which intercept oil leaked during the breakdown of hydraulic systems are only partially efficient and do not exclude the escape of oil products into the soil entirely. Therefore a more efficient way is to use in the hydraulic systems ecologically unobjectionable, synthetic or vegetable lubrication and pressure media.

Papers included in the thematic number of the journal cannot cover all the problems relating to forest mechanization and biological principles of forest management. Neither are equipment and technologies used in the forest the source of the largest extent of damage caused to them. But their incorrect use in forests disturbed by the activity of man, in the first place by industrial fumes, can contribute significantly to the general extent of damage. These problems should be addressed and solved by research much more intensively than has been done so far.

We hope that this monothematic number of the journal *Lesnictví* may contribute to this end.

Ing. Ján Ilavský, CSc.

VZŤAH MECHANIZÁCIE A BIOLOGICKÝCH PRINCÍPOV HOSPODÁRENIA V LESOCH

Les je nenahraditeľné prírodné spoločenstvo, ktoré jediné môže byť zárukou ochrany prírodných hodnôt, živočíšnych a rastlinných druhov, najvýznamnejšie môže ovplyvňovať prírodné procesy v ekosystéme a najúčinnnejšie tlmíť a kompenzovať nepriaznivé vplyvy civilizácie. Avšak v súčasnosti sa negatívne vplyvy činnosti človeka už prejavujú v zhoršenom zdravotnom stave a zníženej odolnosti lesov voči týmto vplyvom. Jedným z najvýznamnejších faktorov sú priemyselné imisie, ktoré zhoršujú zdravotný stav lesov a znižujú ich odolnostný potenciál na rozsiahlych územiach.

A v takto oslabených lesoch sa vykonáva hospodárska činnosť, ktorá môže negatívne vplyvy dovršiť.

Významným faktorom hospodárskej činnosti v lese je mechanizácia používaná pri pestovaní lesov, ťažbe a doprave dreva. Táto môže byť významným pomocníkom človeka, avšak aj významným zdrojom poškodzovania prírodného prostredia. Preto sa o pôsobení mechanizácie na prírodné prostredie hovorí stále častejšie a hľadajú sa účinné opatrenia na zladenie vysokého stupňa mechanizácie pri dodržaní biologických zásad hospodárenia v lesoch. Význam riešenia tejto problematiky bude stále väčší. Preto sme sa rozhodli venovať celé číslo časopisu Lesnictví príspevkom zameraným na problematiku vzťahu mechanizácie a biologických princípov hospodárenia v lesoch.

Prírodné prostredie v lesoch má viacero dôležitých zložiek, na ktorých sa môže prejavovať negatívny vplyv mechanizácie. Sú to vzduch, voda, pôda a samotný les. Samozrejme je potrebné sledovať aj negatívny vplyv mechanizácie na človeka, ktorý ju používa. Rozsah časopisu neumožňuje zaoberať sa všetkými týmito zložkami. Preto sú príspevky tematicky zamerané k poškodzovaniu pôdy, ktorá je základom pre rast lesa.

Kvalita lesnej pôdy a stanovištné pomery v lesoch sa vytvárajú po dlhé desaťročia prirodzeným rozkladom hornín, ako aj organických látok, ktoré produkujú lesy. Živiny odčerpávané z pôdy sa akumulujú v stromoch a ostatných rastlinách. Pri ťažbe dochádza k odoberaniu týchto živín, ktoré sú akumulované v stromoch. Viac živín sa odčerpáva pri ťažbe celých stromov, pretože v korunových častiach stromov je vyššia akumulácia živín. Na druhej strane sa živiny dopĺňajú zvetrávaním pôdy a rozkladom odumretých bylín a opadnutého lístia, ihličia, plodov a vetvičiek. Preto je potrebné poznať bilanciu kolobehu živín a podľa týchto poznatkov zvažovať používané technológie ťažby, hlavne technológiu ťažby celej biomasy.

Nemenej významným faktorom je mechanické poškodzovanie pôdy kolesami, alebo pásmi strojov, ktorého dôsledkom je erózia. Zvlášť veľký význam to má v horských oblastiach pri holoruboch. Preto používané technológie v týchto oblastiach je potrebné posudzovať nielen z hľadiska výkonnosti a nákladov, ale tiež z hľadiska ekologického, pretože protierózne opatrenia na vyťažených plochách môžu byť nákladnejšie ako jemnejšie spôsoby hospodárenia. Takto je potrebné posudzovať nielen navrhnuté technologické postupy, ale aj jednotlivé stroje používané v lese. Tie môžu pôdu buď rozrývať a poškodzovať koreňové systémy, alebo zhutňovať a zamedzovať rastu koreňov v príliš utlačenej pôde. V oboch prípadoch je potrebné hľadať také technické riešenie strojov, ktoré nebudú spôsobovať tieto poškodenia. Je potrebné predovšetkým znižovať hmotnosť strojov a používať nízkotlaké širokoprofilové

pneumatiky. Avšak najvhodnejším riešením je používať vzdušnú dopravu dreva lanovými systémami, alebo hľadať nové riešenia vzdušnej dopravy dreva, napr. balónovými systémami.

Významným zdrojom znečistenia lesnej pôdy je olej, ktorý sa do pôdy dostáva z mazacích sústav pilových reťazí. Aj keď množstvo oleja, ktoré unikne pri mazaní reťaze z jednej píly je pomerne malé, tento zdroj znečistenia je veľmi významný pre veľký počet pí, ktoré v lesoch pracujú. Preto je dôležité poznať rozsah vsakovania ropných olejov do pôdy, ako aj objektívne metódy jeho zisťovania. Riešením je však používanie prírodných olejov, ktoré sa v pôde a vo vode rýchlo rozkladajú. Tu je potrebné zamerať sa na vývoj takých olejov, ktorých vlastnosti sa aspoň vyrovnajú doteraz používaným olejom.

Úniky ropných olejov z hydraulických systémov strojov používaných v lese sú tiež veľkým problémom. Technické riešenia, ktoré zachytávajú oleje uniknuté pri poruchách hydraulických systémov sú len čiastočne účinné a úniku ropných produktov do pôdy celkom nezamedzujú. Preto účinnejšou cestou je používanie ekologicky nezávadných syntetických alebo rastlinných mazacích a tlakových médií v hydraulických systémoch.

Príspevky, zaradené do tematického čísla časopisu sa nemôžu zaoberať všetkými otázkami problematiky vzťahu mechanizácie lesov a biologických princípov hospodárenia v nich. Používané stroje a technológie nie sú ani zdrojom najväčšieho poškodenia lesov. Avšak ich nesprávne používanie v lesoch narušených činnosťou človeka, predovšetkým priemyselnými exhalátmi, môže významne prispieť k celkovému rozsahu škôd. Touto problematikou je potrebné sa vo výskume zaoberať oveľa intenzívnejšie ako doteraz.

Veríme, že k tomu prispeje aj toto monotematické číslo časopisu *Lesnictví*.

Ing. Ján Ilavský, CSc.

HARVESTING OF ABOVEGROUND BIOMASS OF TREES AND ITS EFFECT ON SITE CONDITIONS IN FORESTS

E. Bublinec, J. Ilavský

BUBLINEC, E. — ILAVSKÝ, J.: (Institute of Forest Ecology of SAS, Zvolen; Forest Research Institute, Zvolen): *Harvesting of aboveground biomass of trees and its effect on site conditions in forests*. *Lesnictví*, 36, 1990 (11): 887–894.

Whole-tree technology with chipping of whole trees, crowns of trees or branches brought an increase of work productivity and increase of volume of timber being harvested. At the same time it can mean negative effects on site conditions in forests due to depletion of nutrients with harvested biomass. Harvesting of whole aboveground biomass of trees results in increased depletion of N, P, K, Ca and Mg by 126–149 % for beech and by 176–231 % for spruce. Expressed in absolute values 589–638 kg of nitrogen, 476–775 kg of calcium, 268–312 kg of potassium, 268–312 kg of magnesium and 75–80 kg of phosphorus are depleted during 100 years in beech and spruce stands of mean site class by final cutting and intermediate cutting. These amounts are complemented by decay of fallen assimilation organs and mainly by intrasoil weathering which on fertile soils complements significantly stocks of accessible soil nutrients. Thus in average 1505 kg of potassium, 2385 kg of calcium and 225 kg of magnesium per ha is complemented in forest ecosystem during rotation. For given reasons whole-tree logging can be used in certain site conditions of Slovak Republic.

biomass; whole-tree technology; environmental impacts; nutrient depletion

In the past 15 years in countries with advanced forestry whole-tree technology with chipping of branches, crowns or whole trees has been used more and more. This technology brought an increase of work productivity and amount of timber harvested from square unit of forest. At the same time opinions about possible negative effects of this technology on site conditions in forests due to increased nutrients in harvested biomass appeared. Forest Research Institute in Zvolen and Institute of Forest Ecology in Zvolen started to work on these problems in complex way from proposal of optimal systems of machines and technologies for harvesting, transport and processing of whole aboveground biomass, economic questions associated with the introduction of new technologies, up to examination of the effect of whole aboveground biomass harvesting on nutrients drawn and site conditions. The paper deals with technological objectives with harvesting of whole biomass and ecological impacts resulting from them which were established on the basis of analyses of soil samples and samples of harvested biomass.

METHODS AND SOLUTION

With elaboration of proposals of technologies and systems of machines we used as a basis the natural conditions (mainly mountainous terrains), tree species composition, processing possibilities, economic calculations and other auxiliary criteria.

To judge the effect of whole aboveground biomass harvesting on site conditions of forest ecosystems beech and spruce were selected as model tree species. On the basis of nutrient contents (Bublinec, 1984) increased uptake of N, P, K, Ca and Mg with harvesting of slash, leaves and needles was calculated, as well as uptake for selected site classes. Stocks of available nutrients in soil were compared with their accumulation in separate parts of beech and spruce biomass. For chemical analyses of dendromass and soil, routine methods used at the Institute of Forest Ecology of Slovak Academy of Sciences in Zvolen were used. With calculations of nitrogen, phos-

phorus, potassium and magnesium depletion in forest ecosystem we used the data on biomass stocks in growth tables of main tree species in Czechoslovakia (Halaj et al., 1980), with calculation of slash and spruce needles from data by Petráš (Petráš et al., 1984). Calculations were made for three model height site classes (H-18, 28 and 38) which represent below-average, average and above-average productive conditions.

RESULTS

TECHNOLOGIES OF ABOVEGROUND BIOMASS HARVESTING

High costs and laborious collection and skidding of slash, and also problems with transport and processing of such raw material, have been main obstacles for the utilization of crowns of tree biomass up to now.

Since this is the raw material substantially differing by its shape, structure and other characters from timber harvested up to now a study of new technologies, development of systems of machines of new conception, making possible effective collection, homogenization and transport of raw material also from branches and tops of trees, was started. Problems are not only solved from standpoint gaining of new sources of raw material being wasted up to now with regard to industrial processing; at the same time developed technologies and machines must increase the degree of mechanization and improve laborious character of harvesting production process. At the same time new, non-traditional possibilities of utilization of timber to the top of 7 cm and below the top of 7 cm outside bark are searched for. The objective of new technologies is to make bucking in forest as simple as possible and to shift it to central log depots.

Besides improving the laborious character of work and increasing of its hygiene it is significant contribution to the increase of production of higher quality assortments due to improved bucking.

As to the new technologies, the use of whole-tree technology with skidding of whole above-ground parts of trees to landing is planned in stands with suitable terrain conditions and ecological aspects.

With elaboration of whole-tree technologies landing plays key role. Limbing and full or partial bucking are taking place there.

With deciduous tree species mechanization of limbing and bucking of crowns has not been solved up to now.

Mainly, most laborious stacked assortments are produced from crowns of trees. Pulp and paper mills and mills for manufacturing of agglomerated materials are the largest consumers of them.

With chipping at landing whole bucking can be simplified to one cut by power saw. Trees in stands are cut by power saws or by feller-bunchers. Whole trees are skidded to landings with tractors with winches or grapples. At landing logs which are suitable according to their quality for log assortments are cut off by power saw.

Crowns of trees remain at landing for chipping. In cases when stem part of trees is not suitable for log assortments (thin trees, rot, crook and other faults) whole trees are chipped. Chipped part of tree contains produced assortments of stacked timber for industrial use, fuelwood and slash which has remained in forest up to now. By chipping already at landing, production of stacked wood is eliminated and all complicated, laborious and costly bucking of stacked wood is eliminated too. This method is very advantageous in deciduous stands where in comparing with classical technologies through chipping of mentioned parts of trees an amount of raw material larger by 15–20% is gained. One productive chipper will save about 13 workers in logging and transport of wood.

Problems of the introduction of technology for chipping of coniferous tree species

is different from the viewpoint of shape of trees, mechanization of their harvesting, as also requirements of consumers for delivered assortments.

Mechanization of coniferous trees limbing is successfully solved by limbing machines. Also production of assortments is mechanized either by one-purpose machines for cutting, or more frequently by integrated machines for limbing and cutting, felling resp. With the use of these machines a problem of accumulation of great amount of branches and tops is arising, and therefore it is necessary to solve their processing or removal. This problem must be solved mainly during the operation of limbers at felling site due to necessary preparation of area for afforestation and during the operation of limbing machines at landings where already after limbing of several trees a pile of branches is formed which makes further work of machines more difficult.

These branches have been piled laboriously up to now or they were burned without any effect. A new source of raw material can be gained by their chipping.

Different from chipping in deciduous stands, chipping of branches of coniferous trees does not substitute the most laborious productional operation but it is a new operation. It results in increased costs, increased energy inputs and need of labour which must be more than offset by contributions from the processing of new source of raw material.

Chips from branches and tops of coniferous trees differ significantly from timber assortments being processed up to now by their high content of bark, needles and physical properties of wood. Therefore their utilization will be different. It is very interesting raw material for energy purposes, chemical industry and other purposes.

From the viewpoint of silviculture these technologies can be used only where border-cutting system or clear-cutting system is prescribed by forest management plan.

THE EFFECT OF ABOVE-GROUND BIOMASS HARVESTING ON SITE CONDITIONS

Harvesting of whole above-ground biomass of trees affects considerably site conditions of forest ecosystems, especially depletion of nutrients whose stocks decrease in forest soils. Increased nutrients uptake can have negative effect on the production of successive forest stand. Therefore harvesting of whole above-ground biomass must be carefully considered with regard to site conditions (Bublinec, 1982, 1984, 1985). For given reasons we calculated increased uptake of nutrients with whole-tree technology. Our calculations were made for two model tree species, namely for beech and spruce, the most frequent tree species in our forests, and they were based on knowledge about the content of biogenic elements in separate components of biomass and its weight.

Expressed in % (timber to the top of 7 cm outside bark = 100%) data about increased depletion of nutrients is in Table I. It is valid for fully stocked 100-years old beech or spruce model stand of mean site class, H = 24, 28 resp., of first for spruce of second stock level resp. The greatest increase with both tree species was recorded for phosphorus and nitrogen, with spruce also for potassium, since the content of phosphorus, nitrogen and potassium in slash, needles and leaves is considerably higher. But there is great difference between the two species. With harvesting of slash and biomass of leaves, and as usual with harvesting of both, uptake of nutrients from beech ecosystems is considerably lower than with harvesting of slash and needles of spruce.

In absolute figures overexport of macronutrients for whole aboveground harvesting of trees including biomass of leaves and needles represents, in comparison with harvesting of timber to the top of 7 cm outside bark with bark during rotation (both final cutting

I. Increased uptake of nutrients with harvesting of whole aboveground biomass of trees

Nutrient	Timber to the top of 7 cm outside bark with bark		Timber below the top of 7 cm outside bark		Leaves-Needles		Fogether	
	Beech	Spruce	Beech	Spruce	Beech	Spruce	Beech	Spruce
	[%]							
N	100	100	137	155	112	158	149	212
P	100	100	135	197	108	181	143	278
K	100	100	120	168	106	163	126	231
Ca	100	100	131	145	103	131	134	176
Mg	100	100	127	152	104	139	131	191

II. Nutrients uptake through harvesting of slash and foliage by harvest cutting and intermediate cutting in model 100-years old stands

Nutrient	Beech	Spruce
	[kg]	
Nitrogen	638	589
Phosphorus	75	80
Potassium	268	312
Calcium	775	476
Magnesium	100	79

and intermediate cutting), amounts to data in $\text{kg} \cdot \text{ha}^{-1}$ given in Table II. Values are valid for model 100-years old beech and spruce stand of mean site class ($H = 24$, $H = 28$ resp.).

Relations are similar for both tree species except calcium. If we take harvesting of timber to the top of 7 cm outside bark without bark as the basis, these values should be increased by about a half. Nutrients uptake is rising also with better site class as it is shown in Table III. (100% = beech, spruce stand resp. at the age of 100 years and with site class $H = 14$, $H = 18$ resp.). These data hold for depletion of nutrients by whole biomass. This is obvious since at better site classes the amount of biomass and also concentration of bioelements in it are increasing. Percentage was calculated for whole above-ground biomass of beech and spruce including leaves and needles. It is remarkable that with beech with increasing site class the increase is substantially greater than in spruce stands. From balance of available nutrients gained by comparing their stocks with accumulation in separate components of biomass of beech and spruce (Table IV) for particular examined stands it follows that only for formation of beech leaves 83 kg of N (28% from stocks in soil), 5 kg of P (5%), 34 kg of K (22%), 31 kg of Ca (2%), and 6 kg of Mg (3%) is used each year. In beech slash 139 kg of N (46% from soil), 32 kg of P (28%), 53 kg of K (36%), 124 kg of Ca (6%), and 22 kg of Mg (10%) was accumulated.

In spruce needles 129 kg of N (65% from stocks in soil), 12.5 kg of P (59%), 66 kg

III. Nutrient uptake by aboveground biomass for selected site classes

Nutrient	Spruce			Beech		
	Height site class					
	18	28	38	14	24	34
N	100	172	270	100	182	326
P	100	172	266	100	230	450
K	100	165	258	100	232	404
Ca	100	166	253	100	192	307
Mg	100	177	271	100	200	360

IV. Comparison of stocks of available nutrients in soil (= 100 %) with their accumulation in separate components of beech and spruce biomass in %

Nutrient	N	P	K	Ca	Mg
	[%]				
Leaves-beech	28	5	22	2	3
Needles-spruce	65	59	30	6	3
Slash-beech	46	28	36	6	10
Slash-spruce	67	70	20	5	5
Soil	100	100	100	100	100

of K (30%), 125 kg of Ca (6%), 9 kg of Mg (3% from stocks in soil) was accumulated. In spruce slash 132 kg of N (67%), 14 kg of P (70%), 52 kg of K (20%), 129 kg of Ca (5%), and 18 kg of Mg (5% from stocks in soils) was accumulated. Stocks of available nutrients, mainly of nitrogen, phosphorus and potassium, are in some soils so low that they can hardly cover needs of one generation of stands. In stands these values differ considerably in dependence on stocks of available nutrients in soil. Moreover these stocks are lost with whole-tree technology, contrary to harvesting of timber to the top of 7 cm outside bark.

DISCUSSION

At present when health state of whole forest biomass has been worsening due to bad immission situation ecologists have serious objections to harvesting of whole above-ground biomass. Uptake of nutrients by this method is compared with raking of litter from forest (Kreutzer, 1979) which was used as litter for cattle. Experience from past century has shown, as confirmed experimentally, that long-term, large-scale use of litter, slash, bark and in many cases also of pole wood resulted in drastical disturbance of productional relations. Even today, decades after, negative effects are still visible. According to Fiedler et al. (1962) even after single, complete but also partial removal of organic residues in 1912 from sand soil surface, effects were apparent still in 1962, it means after 50 years. Soil flora has changed in favour of great amount of heath and

lichen. Horizon of surface humus is thinner and it contains less N, P, and K. It results in significant differences in growth. We must stress that experimental plots with better site conditions were less disturbed than poorer soils. Kreutzer (1979) points out that such depletion of nutrients from forest had great effect also on other composition of forest stands. At protected sites more demanding spruce participated in the formation of stand while on plots poor in humus where forest waste was raked away spruce almost dropped out for lack of nutrients, abundance of heath and decreased ability of water accumulation. This fact is valid even more for many more demanding tree species which give way to spruce.

Such damages which are arising due to decrease of humus production can be hardly compensated. Escape of carbon as basic source for humus formation and biologic activity in soil decreases soil fertility mainly on weak, sandy and skeletal soil with poor sorption. Decrease of humus is reflected negatively in water regime and balance of nitrogen on sand sites.

It is necessary to realize that these data come from poor sandy soils where use of litter was combined with harvesting of whole, or substantial components of dendromass. Plain terrain of German plains with good access for transport made possible the use of thinner assortments and slash. Raking of litter worsened soil fertility usually only on sandy poor site, in surface humus where 20–50% of whole stocks of nitrogen, phosphorus, potassium, calcium and magnesium, included to annual circulation in soil, has accumulated.

On richer, structural, loamy soils with beech stands the production was not disturbed even during 30–40 years, it means after the litter was 5–7 times raked (Remezev and Pogrebnyak, 1965).

Moreover with hauling of whole trees which is exclusively used in our tractor terrains 20–50% of slash remains in stand (only 5–15% with tree skidding). Whole biomass can be completely harvested only in rare cases. Also industrially harvestible portion from secondary sources of biomass represents in Slovak forests only 1/7 to 1/8 of potential sources. At present 60–65% of tree biomass is used. The rest, of which 15–25% are branches with bark and foliage and 10–15% stumps and root remains in forest as so called post-harvest waste (Ilavský, 1986). Also stocks of nutrients in soil, and their complementing by intrasoil weathering and import of elements through precipitation and aerosols cannot be neglected. Since import of elements through precipitation and their leaching from soil have approximately the same range the key to the solution of harvesting of whole trees must be searched for in stock of nutrients in soil (including surface humus), in intensity of their circulation and their complementing from weathering of soil-forming substrate. We have only general information about gains of nutrients through the way mentioned last. Likens et al. state that at medium sites in humid climate of temperate zone, it means under conditions similar to the conditions of our beech and spruce forests, 7.1 kg of potassium, 21.1 kg of calcium and 3.5 kg of magnesium per ha was released through weathering. Cleyton (in Klimo, 1982) gives even higher values (23 kg of K, 26 kg of Ca, and 10 kg of Mg). But these values seem high. Yet even lower by a half do they still make during rotation a significant positive contribution to the balance of gains and losses of mineral nutrients (it means without nitrogen) in forest ecosystem (on average 1505 og of potassium, 2385 kg of calcium, and 225 kg of magnesium). We must say that these facts (stocks of nutrients in soil and their complementing by weathering) were insufficiently considered in otherwise exhaustive works of Kreutzer (1979) and Nebe (1979). On the other side acid rains are also threatening and they have the same effect as nutrients depletion through biomass harvesting. In our conditions we can add to these facts also a wide range of soils among which soils rich in nutrients prevail.

CONCLUSION

In our different site conditions we can with certain limits consider whole-tree technology reasonable. The limits apply to poor, strongly skeletal, debris, dry or waterlogged sites. Somewhere it can be used in vegetation period, at other sites out of vegetation period. We proposed detailed classification and key for determination of technology of wood harvesting from the viewpoint of nutrients uptake from forest ecosystems in guidelines (Bublinec, 1984, 1985) and in work of 1987 (Bublinec, 1987). We advise to perform detailed classification of forest land resources from the viewpoint of possibilities for harvesting of whole above-ground biomass of trees. Such a survey should be done by institutes for forest management with the assistance of basic and applied research.

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BUBLINEC, E. – ILAVSKÝ, J. (Ústav ekológie lesa SAV, Zvolen; Výskumný ústav lesného hospodárstva, Zvolen): *Ťažba nadzemnej biomasy stromov a jej vplyv na stanovištné pomery v lesoch*. Lesnictví, 36, 1990 (11): 887–894.

Stromová technológia so štiepkovaním celých stromov, korunových častí stromov alebo vetiev priniesla zvýšenie produktivity práce a zvýšenie množstva vyťaženého dreva. Zároveň však môže znamenať negatívne dôsledky na stanovištné pomery v lesoch v dôsledku odčerpávania živín vo vyťaženej biomase. Pri ťažbe celej nadzemnej biomasy stromov sa odoberanou tenčinou, listím a ihličím zvyšuje odčerpávanie živín N, P, K, Ca a Mg pri buku o 126–149 %, pri smreku o 176 až 231 %. V absolútnych hodnotách rubnou a predrubnou ťažbou v bukových a smrekových porastoch priemernej bonity sa za 100 rokov odčerpá 589–638 kg dusíka, 476–775 kg vápnika, 268–312 kg draslíka, 268–312 kg horčíka a 75–80 kg fosforu. Tieto množstvá sú dopĺňované rozkladom opadnutých asimilačných orgánov a predovšetkým vnútropôdnym zvetrávaním, ktoré na úrodných

pôdach významne doplnia zásoby pre dreviny prístupných živín v pôde. Počas rubnej doby sa v lesnom ekosystéme doplní takto v priemere 1505 kg draslíka, 2385 kg vápnika a 225 kg horčíka na hektár. Z uvedených dôvodov sa v určitých stanovištných podmienkach Slovenskej republiky môže používať stromová metóda ťažby dreva.

stromová metóda; odčerpávanie živín

BUBLINEC, E. – ILAVSKÝ, J. (Institut für Waldökologie der SAV, Zvolen; Forschungsinstitut für Forstwirtschaft, Zvolen): *Nutzung der oberirdischen Baumbiomasse und ihr Einfluss auf Standortverhältnisse in unseren Wäldern*. Lesnictví, 36, 1990 (11): 887–894.

Die Baumtechnologie mit Hackschnitzelherstellung von Ganzbäumen, Baumkronen oder -ästen brachte eine Steigerung der Arbeitsproduktivität und eine höhere Menge von gewonnenem Holz. Sie kann aber gleichzeitig negative Folgen für Standortverhältnisse im Wald infolge eines zu grossen Nährstoffentzugs durch die gewonnene Biomasse haben. Bei der Nutzung der gesamten oberirdischen Baumbiomasse wird mit dem gewonnenen Dünholz, Blatt und Nadeln der Entzug von N, P, K, Ca und Mg bei Buchen um 126 bis 149 %, bei Fichten um 176–231 % erhöht. In absoluten Werten ausgedrückt werden im Rahmen der Zwischen- und Endnutzung in Buchen- und Fichtenbeständen durchschnittlicher Bonität in 100 Jahren ungefähr 589 bis 638 kg N, 476 bis 775 kg Kalzium, 268 bis 213 kg Kalium, 268 bis 312 kg Magnesium und 75 bis 80 kg Phosphor entzogen. Diese Mengen werden durch die Zerlegung der abgefallenen Assimilationsorgane, vor allem durch die Bodenverwitterung ergänzt, die auf fruchtbaren Böden die Vorräte an den für Bäume verfügbaren Nährstoffen bedeutend ergänzen. Während der Nutzungsdauer werden im Waldökosystem im Durchschnitt 1505 kg Kalium, 2385 kg Kalzium und 225 kg Magnesium/ha ergänzt. Aus den erwähnten Gründen kann auf bestimmten Standorten in der SR die sog. Baum-methode zur Holznutzung benutzt werden.

Baummethode; Nährstoffentzug

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LOGGING SYSTEMS AND SOIL EROSION ON CLEARCUTS IN MOUNTAIN FORESTS

F. Šach

ŠACH, F. (Research Station, Opočno): *Logging systems and soil erosion on clearcuts in mountain forests*. Lesnictví, 36, 1990 (11): 895–910.

The management in mountain forests influences their soil conservation function. Besides the forest road network, a key role is played by logging systems. Following from the results of investigations on slopes 15–25° in the Beskids and Krkonoše Mts., tractor skid trails disturbed the soil surface on the greatest part of the cutover — 7.6 to 13.0 %, smaller disturbance of soil surface was caused by horse skid trails (6.6 %) and by high-lead yarding (1.0 to 1.7 %). This disturbance was related to the logging rill erosion: 62 to 195 m³ per ha, or 66 m³ per ha, or 11 m³ per ha, resp. Surface runoff depended on the extent and intensity of surface disturbance; the intensity of water erosion along skid trails after the end of skidding was related to the latter factors. The values of water erosion determined by the method of rain simulation on small runoff plots made in the same order 1.22 to 2.11, 0.04 and 0.07 to 0.09 m³·year⁻¹ in conversion per 1 ha cutover. The overgrowing of skid trails with grasses reduced only insignificantly the coefficient of surface runoff three years after cutting: on clearcut areas with tractor skidding from 6.4–11.3 % to 4.3–8.3 % of the yearly precipitation sum that has fallen onto the cutover surface, on the clearcut area with horse skidding from 2.2 to 1.4 % and on clearcut areas with high-lead yarding from 0.7–1.2 to 0.6–1.0 %. On the other hand, a decrease in water erosion was marked, from the above-mentioned values to 0.03–0.09, 0.01 and 0.01 m³ per ha/year in the same order. Water erosion on clearcut areas is reduced first of all by the use of suitable logging systems, and in specific cases by the restoration of the surface of skid trails.

mountain forests; clearcuts; logging systems; soil erosion

INTRODUCTION

Forest Act no. 61/1977 of the Statute-book lays down that the forest management will provide for the production of good-quality raw timber, and also for other- than-production functions of the forest. Soil conservation and water management belong to these important functions. The soil conservation function plays a key role in protection forests, as well as in regulated forests with an erosion-control ecological function, situated mainly in the areas of water resources. In these types of forests such forms of management must be practised that will reduce soil erosion to the minimum.

The factors influencing soil erosion can be divided into natural and anthropogenic (silvicultural, logging) ones. Natural factors are bedrock, soil, terrain geomorphology, climatic conditions and vegetation cover. Anthropogenic factors comprise first of all the construction and use of forest road network, regeneration methods, logging technology, skidding, removal of logging residues and soil preparation on areas to be afforested.

According to the natural factors reflected in groups of forest types, management groups and terrain types (Lesprojekt), and included in the Frevert-Zdražil equation of soil loss (Midriak, 1977), 5 to 10 % of the forest land fund in Bohemia and Moravia are exposed to above-average erosion, 11 to 47 % of the forest land fund are threatened by average erosion. The small range of forest plots with the above-average exposure to erosion indicates that these are extreme localities where the process of forest regeneration is weaker due to difficult terrain, especially to its steep slope. On the other hand the large range of forest plots with the average exposure to erosion shows that their definition is not so explicit. These are usually moderate slopes where the occurrence and evolution of erosion process will be influenced to a great extent by anthropogenic factors, mainly by the choice of logging systems.

I. The most important characteristics of experimental areas

Locality Forest enterprise	Regeneration cut	Logging system	Area ha	Volume of skidded wood [m ³ ·ha ⁻¹]	Height above sea level [m]	Yearly precipitation sum, mm
Beskids (flysch)	clearcut	tractor skid.	3.60	386	720–840	1150
Ostravice	clearcut	high-lead yarding	2.22	573	650–770	
Krkonoše (crystalline rocks)	clearcut	tractor skid.	8.40	469	1000–1100	
	clearcut	tractor skid. in terrain of lower bearing capacity	5.50	380	1050–1105	
Vrchlabí	clearcut	high-lead yarding	2.63	427	1025–1135	1300
	clearcut	horse skid.	0.70	469	980–1045	
Horní Maršov	clearcut	machine logging	4.88	272	1080–1120	

Forest type: 5F₂ – rather rich *Abieto-Fagetum* with ferns, on slopes, on very deep soils, 5Bg – rich *Abieto-Fagetum acerolum asperulosum mercurialosum*, 7K₃ – acid *Fageto-Piceetum* with *Calamagrostis*, on slopes to plateaux, 7N₄ – stony *Fageto-Piceetum* with *Dryopteris austriaca* on slopes, on stony soils, 8K₂ – acid *Piceetum* with *Calamagrostis* on slopes, 8V₂ – water-logged *Acereto-Piceetum* in damp valleys

Soil type: (B)mh – mesotrophic humus brown forest soil, Bhg – pseudogley mountain podzolic brown forest soil, Bh – humus podzol, Bhc – undeveloped humus podzol

The function of favourable soil-conservation and hygric effects of forest stands is threatened seriously mainly in mountain forests because air pollution must also be taken into consideration. The area of mountain forests (at heights above 600 m above sea level) makes about 1 235 000 ha (51 % of the forest resources in Bohemia and Moravia) and 18 % of forest area is exposed to air pollution. The forests at mountain localities exert their influence not only on the environment of the site where they are growing but also have distant effects. They are influencing the production landscape in view of erosion control, flood control and water supply in the region. This is the reason why mountain forests belong to the demarcated regions where the soil-conservation function of forests should be stressed (Midriak, 1977); the forests important as water resources were also set apart (Běle, 1981).

As for the soil erosion × forest regeneration process interaction, the effects of the construction and use of forest road network were investigated in mountain regions (Krešl, 1978; Jařabáč, Rybák, 1979; Buzek, 1981; Beneš, 1982). Other important management and technical factors, like logging systems, were investigated scarcely (Riedl, 1976). Exact data on the extent and intensity of erosion, which is conditioned by these factors, have been missing (Pobedinski, Krečmer, 1984). Only recently have these problems been solved and the first results have been presented: Škopek, Stránský, 1985; Midriak et al., 1985; Puklová-Krečmerová, 1987; Navrátil, 1988; Faiman, 1988; Křeček, Pretl, 1988.

In other countries, mainly in the Soviet Union and United States, great attention is paid to the effects of regeneration cuttings on soil erosion on slopes situated at mountain localities (Šach, 1988). But the results are of informative nature for this country because there are great differences in natural conditions and also in management and technical conditions (especially logging procedures and machines are quite different).

The above-mentioned reasons being taken into account, research on the quantification and

Exposure	Average slope %	Forest type	Bed-rock	Soil		Ground cover [%]		Tree species proportion in the original stand
				type	kind			
SE	30	5B ₆	sand-stone	(B)mh	ph, š	litter sod	25 75	sm 4, bk 6
NE	47 32-62	5F ₂		(B)mh	ph, š + k	litter sod	20 80	sm 6, bk 3, kl 1
W	31	7K ₃		Bh	hp, š	litter sod	20 80	sm 10
NW	27	8V ₂		Bhg	hp, š	litter sod	10 90	sm 10
W	33	8V ₂ 8K ₂	mica schist	Bhg Bh	hp, š hp, š	litter sod	55 45	sm 10
W	41	7N ₄		Bhc	k, b, (hp)	litter sod	50 50	sm 10
SW	27	8K ₂	ortho-gneiss	Bh	hp, š	litter sod	80 20	sm 10

Soil kind: hp — loamy sand, ph — sandy loam, (hp) — loamy-sand filling in stony soils, b — boulder, k — stony, š — gravel

Tree species proportion: spruce (sm) — *Picea excelsa* Link., beech (bk) — *Fagus sylvatica* L., sycamore maple (kl) — *Acer pseudoplatanus* L.

dynamics of erosion processes along forest roads must be orientated to other management and technical factors influencing these processes, especially to logging systems. The current development of the forest calamity induced by air pollution points to the centre of research: mountain regions exposed to the effects of air pollutants, not only their extremely steep slopes but also moderate ones (25 to 40 %) where alternative logging systems can be used. Concentrated fellings practised very often and the use of heavy-duty machines claim to find solutions to these urgent problems.

Felling and skidding influence the quantity and state of ground cover (forest floor and ground vegetation) and the hydrophysical properties of surface soil layer. At these localities logging erosion occurs which is defined as the amount of soil transported in the process of logging by the cumulated effects of machines, draught animals, transported logs, precipitation and running water. Water erosion can have additional effects (rainfall disturbance of soil surface and running water washing from the soil). The objectives of the present work were set on the basis of a detailed analysis of all these problems (Šach, 1988):

With respect to logging systems used in mountain terrains with different slopes, or different bearing capacity, it is necessary to

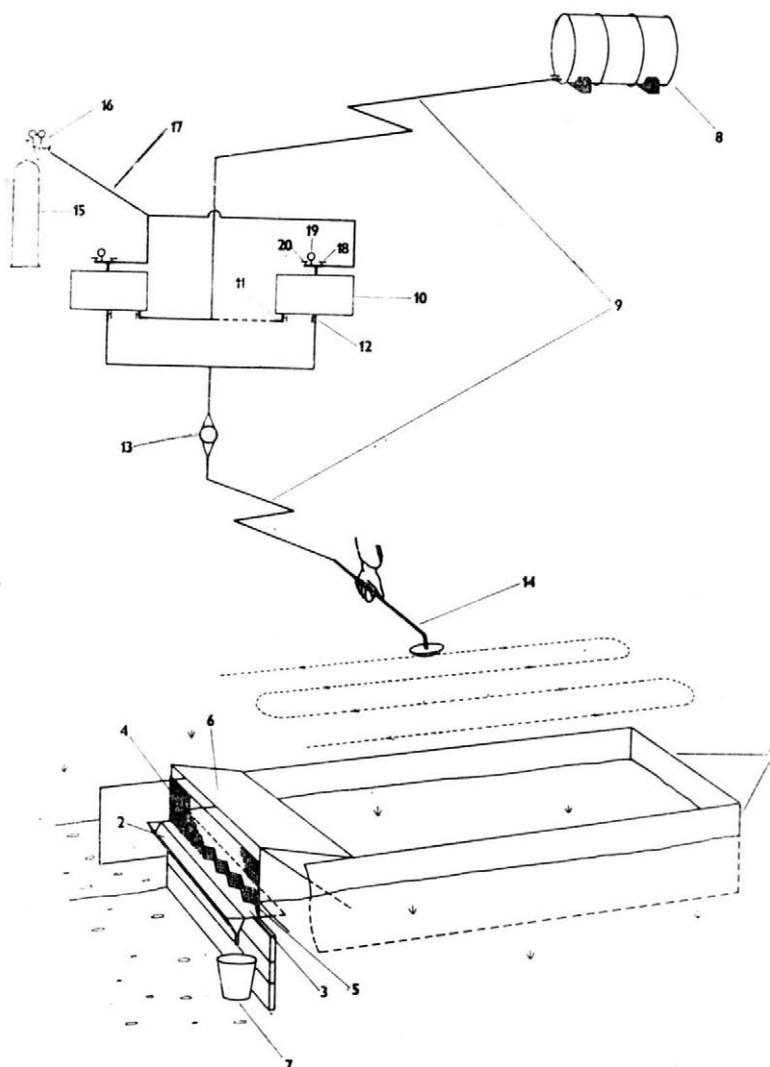
- determine the intensity and the extent of soil surface disturbance on logging areas,
- determine the intensity and dynamics of erosion processes,
- propose the principles of option of logging systems used in mountain forests so that erosion processes will be minimum if the forests are exploited in different ways.

METHODS

The effects of logging systems on soil-erosion processes were studied by means of ambulant investigations of experimental areas in the Beskids and Krkonoše Mts. Experimental areas represented two geological regions: Carpathian flysch in the Beskids and crystalline rocks of the Bohemian Massif in the Krkonoše Mts. The most important characteristics of experimental areas are presented in Tab. I.

Experimental areas in the Beskids were laid down at new clearcut sites in the perimeter of the Šance waterworks reservoir situated in the territory of the Ostravice Forest Enterprise. Uphill skidding with cable wheel tractor and uphill high-lead yarding were compared as two technologies. Experimental areas in the Krkonoše Mts. were laid down at new sites with large-area clearcuts due to salvage cuttings as a result of air pollution, in the watershed of two water-courses important as water sources: Klinový brook (Vrchlabí Forest Enterprise) and Malá Úpa (Horní Maršov Enterprise). In the territory of the Vrchlabí Forest Enterprise there were cut-overs with downhill skidding with cable wheel tractor in the terrain with good and worse bearing capacity (terrain with the bearing capacity smaller than 50 kPa), with uphill high-lead yarding and with downhill horse skidding. In the territory of the Horní Maršov Forest Enterprise there was a cut-over where various machines were working (felling machine and clambunk skidders were operating on the cutover, delimiting and bucking machines were working on the landing).

On the clearcut areas the characteristics as follows were investigated: intensity and extent of soil surface disturbance, logging erosion, surface runoff and water erosion.



1. Rain simulation experiment conducted on a runoff microplot 1 × 2 m; arrangement of the first type: 1 - metal frame, 2 - gutter, 3 - approaching sheet of gutter, 4 - wire screen, 5 - wire spillway, 6 - roof, 7 - gauging bucket, 8 - barrel with water supply, 9 - water hose, 10 - pressure tank, 11 - inlet valve, 12 - outlet valve, 13 - water meter, 14 - hand-operated sprinkler, 15 - air bomb, 16 - air reduction valve, 17 - air hose, 18 - compressed air feeding valve, 19 - air gauge, 20 - venting valve

II. Results of investigation of effects of logging systems on soil erosion on clearcuts in mountain forests

Logging system	Soil disturbance on clearcuts		Skid trails		Logging erosion		Age since logging	Presumed surface runoff		Presumed water erosion	
	class	percent of logged area	percent of logged area	density [m. ha ⁻¹]	m ³ per 1 ha of logged area	m ³ per 1 m ³ timber removed		depth mm per year	coef. percent of precipitation	[t. ha ⁻¹ . yr ⁻¹]	[m ³ . ha ⁻¹ . yr ⁻¹]
BESKYDY MTS.											
Cable wheel skidder	0	92.4					to 1 year	73	6.4	1.439	1.70
	1	4.4	7.6	280	62	0.16	3 years	50	4.3	0.068	0.09
	2	3.2									
High lead	0	99.0					to 1 year	8	0.7	0.045	0.07
	1	0.0	1.0	74	11	0.02	4 years	7	0.6	0.004	0.01
	2	1.0									
KRKONOŠE MTS.											
Cable wheel skidder	0	91.8					to 1 year	86	6.6	0.951	1.22
	1	2.1	8.2	274	131	0.28	3 years	65	5.0	0.014	0.03
	2	6.1									
Cable wheel skidder on terrain with reduced bearing capacity	0	87.0					to 1 year	147	11.3	1.655	2.11
	1	1.9	13.0	405	195	0.51	3 years	108	8.3	0.027	0.05
	2	11.1									
High - lead	0	98.3					to 1 year	16	1.2	0.031	0.09
	1	0.0	1.7	110	11	0.03	3 years	13	1.0	0.006	0.01
	2	1.7									
Horse	0	93.4					to 1 year	29	2.2	0.015	0.04
	1	6.6	6.6	471	66	0.14	3 years	18	1.4	0.004	0.01
	2	0.0									
System of logging machines	0	100.0					to 1 year	0	0	0.000	0.00
	1	0.0	0.0	0	0	0.00	3 years	—	—	—	—
	2	0.0									

Classes of soil disturbance: 0 — negligible (ground cover in place), 1 — severe (ground cover and mineral soil mixed, rill depth < 25 cm), 2 — very severe (ground cover removed, mineral soil exposed, rill depth > 25 cm)

Ground cover: low vegetation + forest floor

Terrain with reduced bearing capacity: bearing capacity < 50 kPa

The intensity of soil surface disturbance in the process of logging was evaluated according to a classification scale presented in Tab. II. The extent of soil surface disturbance was determined by mapping degrees of disturbance on the clearcut area, and it was expressed in relative values.

Mapping and volumetric methods were used to evaluate logging erosion on the clearcut area: rill volume in m^3 was calculated from the length, width, depth and shape of rills.

A modified method after Molchanov — rainfall simulation on elementary runoff microplots of the size 1×2 m (Molchanov, 1973; Figs. 1 and 2) — was used to investigate surface runoff and water erosion of soil. Artificial rain was applied to runoff plots by a rain simulator of our own design. As it is not possible to simulate perfectly the variability of atmospheric precipitation (including snow precipitation), the objective of the experiment was to develop such a kind of sprinkling that would simulate the process of surface runoff and mainly that of water erosion of soil corresponding to the average annual precipitation sum. A sprinkler application rate of 120 mm and sprinkling time of 60 min. were used. The final intensity 2 mm per min. is often used in various modifications of Molchanov method (e. g. Isaiev et al., 1973; Krasnoshchekov, 1977); this intensity was found to be sufficiently high for the simulation of surface runoff and water erosion.

Surface runoff from runoff plots with the undisturbed soil surface was measured at the boundary of organic and mineral horizon. To investigate surface runoff and soil wash on runoff areas with surface disturbance, the approaching sheet of gutter was put just under the ground level, instead of under the forest floor. Ten out of fifteen centimeters of the approaching sheet were planted into the soil. The approaching sheet was shaded by another sheet overreaching by 25 cm to eliminate vertical and lateral seepage. The earth hitting the approaching sheet was stopped by a triangular wire spillway and wire screen with meshes 2×2 mm. Besides stopping the earth, the spillway also prevented the deposition of drifted materials in front of the screen because it eliminated a reduction in water flow rate. The sedimentation of drifted materials in the gutter was prevented by its sufficiently great inclination in the direction of running water. Metal frames set into the mineral soil were used on runoff plots to prevent the undesirable lateral water flow.

Surface runoff was measured in the interval of five minutes. One litre samples of water were taken in the interval of ten minutes; in a laboratory the weight of drifted materials was determined by filtration and weighing. The values of surface runoff and soil wash were summarized over the whole period of experiment duration.

The soil wash on the whole clearcut areas was quantified on the basis of the results of measurements: expected yearly intensity of water erosion was calculated according to the adjusted equation after Lebedev (1979):

$$E = 10 H_r \sum_{j=1}^n K_j \cdot S_j \cdot P_j, \quad (1)$$

where: E — expected intensity of water erosion on a cutover area in kg/ha/annum,
 H_r — average yearly precipitation sum in mm,
 K_j — coefficient of surface runoff from j -th kind of soil surface on a cutover area,
 S_j — specific wash on a cutover area in g from $1 m^2$ per 1 mm surface runoff,
 P_j — ratio of the area of j -th kind of soil surface to the cutover area.

The kinds of soil surface were set apart as typical homogeneous areas in dependence on the degree of disturbance and ground cover. Runoff microplots were laid down for each kind of soil surface. On seven clearcut areas there were established nine runoff plots on a logged area with no serious disturbance, and eight runoff plots along skidding lines with significant and highly significant disturbance of soil surface.

The accuracy of the calculation of expected intensity of water erosion after Lebedev's adjusted equation was checked in a skid trail with tractor skidding and high-lead yarding in the Krkonoše Mts.; the accuracy of calculation was satisfactory.

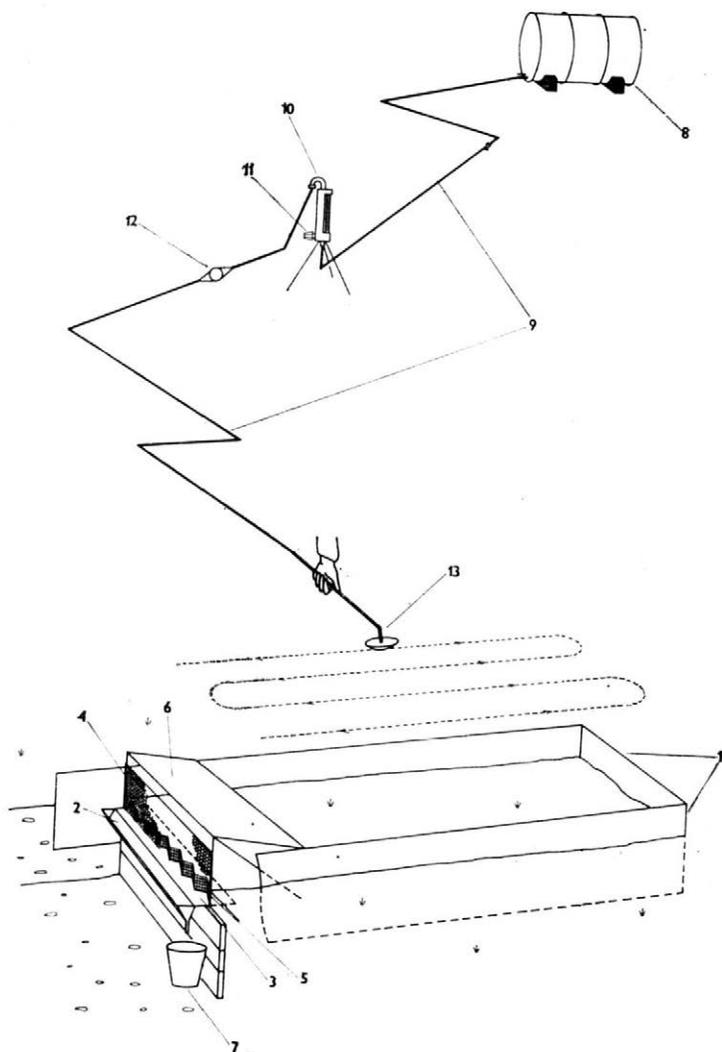
It was necessary to repeat after some time measurements performed to determine the dynamics of surface runoff and water erosion in regeneration cuttings. The repeated measurements were carried out on cutover areas in the Beskids and Krkonoše Mts., mostly in three-year intervals.

RESULTS

THE EFFECTS OF LOGGING SYSTEMS ON SOIL EROSION

Erosion processes on regeneration cuttings are a result of soil surface disturbance. The soil surface is disturbed when logging machines and tractors, or logs, get into contact with the terrain. The choice of the given kind of machine, or draught animals,

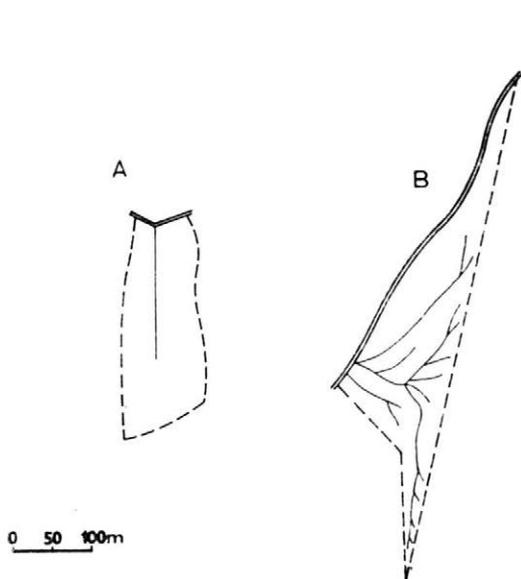
2. Rain simulation experiment conducted on a runoff microplot 1×2 m; arrangement of the second type: 1-9 see Fig. 1, 10 - flow meter, 11 - control valve, 12 - water meter, 13 - hand-operated sprinkler



and its use have a decisive influence on the intensity and extent of soil disturbance. The logging systems also influence the volume of earth which is transported from disturbed sites, especially in the process of skidding. Besides this so called logging erosion, subsequent water erosion is of great importance. A numerical expression of all these factors in the domestic natural, management and technical conditions was one of the main objectives of this study. The quantification of logging and water erosion was performed on the basis of investigations made on clearcut areas in the Beskids and Krkonoše Mts. in the course of years 1979 to 1987.

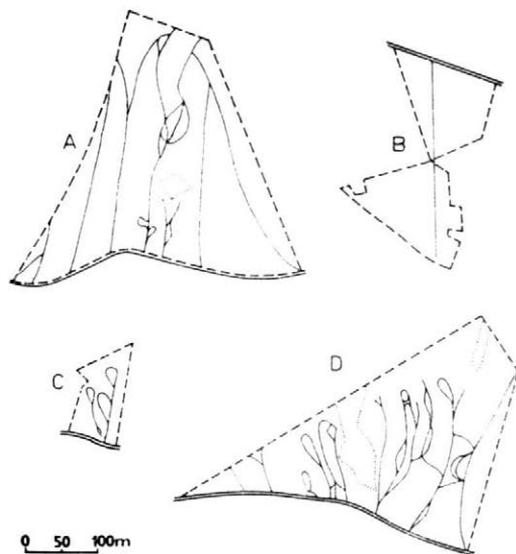
THE INTENSITY AND EXTENT OF SOIL SURFACE DISTURBANCE

The results of research on the intensity and extent of soil surface disturbance on seven clearcut areas (two in the Beskids and five in the Krkonoše) with the slope of $15-25^\circ$ where the factor of disturbance were skidding means, or logging machines, are presented in Tab. II. These data apply to linear disturbance because no great areal disturbance was observed. A comparison of the data in Tab. II indicates explicitly that the greatest disturbance of soil surface, as for the intensity and extent, occurred on the cutover areas in the Beskids and Krkonoše Mts. where forest wheel



1 2 3

3. Scheme of skid trails on cutover areas in the Beskids. A – cutover area with uphill high-lead yarding, B – cutover area with uphill skidding with cable wheel tractor; 1 – skid trail, 2 – logging road, 3 – cutover boundary



1 2 3 4 5

4. Scheme of skid trails on cutover areas in the Krkonoše Mts. A – cutover area with downhill skidding with cable wheel tractor, B – cutover area with uphill high-lead yarding, C – cutover area with downhill horse skidding, D – cutover area with downhill cable wheel tractor skidding in the terrain with lower bearing capacity; 1 – skid trail, 2 – skid road, 3 – logging road, 4 – boundary of young forests, 5 – cutover boundary

tractors were used. In view of soil erosion the denudation of mineral soil and appearance of deep rills were extremely dangerous; all this was manifest especially in the terrain with lower bearing capacity (water-logged soils) – up to 11 % of cutover area. On the other hand, high-lead yarding meant a small disturbance of soil surface only on the small cutover area, on 1 to 2 % of the area. Horse skidding induced a relatively large disturbance of soil surface (almost 7 % of the cutover area) but it was not so intensive – there appeared no deep rills like in the case of wheel tractors or high-lead yarding. Hardly any disturbance of soil surface was observed in logging machine systems. Felling machines and clambunk skidders which transported tree bundles caused a negligible disturbance of soil surface; they were operating all over the whole cutover area and extracting wood in a horizontal direction to the skid road.

Skid trails were places of a serious linear disturbance of soil surface. Their routes on the cutover areas where different skidding methods were used are represented in Fig. 3 (Beskids) and Fig. 4 (Krkonoše). The density and percent area of skid trails on individual clearcut areas are presented in Tab. II. At first glance the highest density of skid trails was observed in horse skidding – 471 m per ha. But these trails were narrow (average width of 1.4 m), that is why their percentage in the cutover area was smaller than that of tractor trails, the width of which was 2.5 to 3.3 m and the density of which was also high. The density and percent area of tractor trails were highest

in the terrain with lower bearing capacity — 405 m per ha and 13 % of the cutover area. The density and percent area of tractor trails in the terrain with good bearing capacity were practically identical on the clearcuts in the Beskids and in the Krkonoše (280, or 274 m per ha and 7.6, or 8.2 % clearcut area). The density of cableway tracks was explicitly lowest if compared with the other skidding methods, with the exception of machine logging. It was on an average 90 m per ha and the percent area made maximally 2 % of the cutover area, the track width being 1.3 to 1.5 m. No skidding tracks appeared on the cutover areas where machine logging were used.

LOGGING EROSION

On slopes the earth from rills in skidding trails which appeared in the skidding process was mostly transported away from the cutover area, a smaller amount of earth was compacted or swept to the sides (about 15 %). The volume of rills represented logging rill erosion: in the process of logging great amounts of earth were transported (wasted) at one sweep. The results of investigation are given in Tab. II.

The intensity of logging erosion in relation to the unit area of skid trail was highest in the Krkonoše Mts. in tractor tracks, in the Beskids in cableway tracks because there were great rills on the small area of disturbed surface. Similarly like the data on the intensity of logging erosion per 1 m of track, these data only inform about the extent of rill erosion in tracks (about the state of erosion of skidding tracks), they do not express the percent area of tracks out of the cutover area.

The data on rill erosion calculated per 1 ha of the cutover area help to illustrate the intensity of logging erosion on clearcut areas. The largest volume of earth eroded away in the process of tractor skidding in the terrain with lower bearing capacity on water-logged soils — 195 m³ per 1 ha of the cutover area. In the terrain with good bearing capacity logging erosion was higher in the process of tractor skidding on cutover areas in the Krkonoše Mts. (131 m³ per ha) than in the Beskids (62 m³ per ha). This difference was due to the higher volume of transported wood although the density and percent areas of tracks were roughly the same on both cutover areas; the volume of transported wood was 469 m³ per ha in the Krkonoše Mts. and 386 m³ per ha in the Beskids. The large volume of timber extracted on clearcut areas in the Krkonoše Mts. resulted in intensive logging erosion also in horse skidding tracks (1000 m³ per 1 ha of track). For the density of horse skidding tracks was high, the intensity of logging erosion per 1 ha cutover area was higher by even 4 m³ than that in the Beskids on the cutover with tractor skidding. A considerably smaller logging erosion was observed on cutover areas with high-lead yarding (11 m³ per 1 ha of cutover area).

The intensity of logging erosion when different logging systems are used, can be expressed by the value of rill erosion per 1 m³ of skidded wood. The order tractor (0.16—0.51 m³ per m³), horse (0.14 m³ per m³), high-lead yarding (0.02—0.03 m³ per m³) explicitly indicates that it is advantageous to use high-lead yarding and horses for skidding in the regions with a potential risk of erosion.

WATER EROSION AND SURFACE RUNOFF

Surface runoff of artificial rain and soil wash on elementary runoff microplots

As the ground cover on the soil surface of new areas was not practically disturbed (sod, less often forest-floor litter), the surface runoff outside skid trails was negligible. If the value of runoff coefficient on nine microplots made 0.0 to 6.5 % of artificial rain, the runoff water did not concentrate at any place to induce soil wash (Tab. III).

III. Surface runoff and specific soil wash from runoff microplots located on a clearcut area outside skid trails
 (artificial rain of 120 mm lasting one hour)

Location of runoff plots of the size 1 × 2 m	Time after logging	Slope [%]	Forest floor [cm]	Skeleton content in soil volume %	Surface runoff % of precipitation	Specific soil wash g·m ² per 1 mm surface runoff	
BESKIDS (FLYSCH)							
CLEARCUT WITH TRACTOR SKIDDING							
Plot with <i>Calamagrostis</i>	within 1 yr	27	7	25	5.0	There was no soil wash on any runoff microplot	
	3 years		6		0.0		
Plot with forest-floor litter	within 1 yr	27	3	35	6.5		
Plot with litter, overgrown with raspberry	3 years		2		11.1		
CLEARCUT WITH HIGH-LEAD YARDING							
Plot with <i>Calamagrostis</i>	within 1 yr	34	5	40	2.8		
	3 years		5		2.7		
KRKONOŠE (CRYSTALLINE ROCKS)							
CLEARCUT WITH TRACTOR SKIDDING							
Plot with <i>Calamagrostis</i>	within 1 yr	34	14	25	0.1		
	3 years				0.1		
Plot with litter	within 1 yr	39	13	25	0.1		
CLEARCUT WITH HIGH-LEAD YARDING							
Plot with <i>Calamagrostis</i>	within 1 yr	38	10	50	0.4		
CLEARCUT WITH HORSE SKIDDING							
Plot with <i>Deschampsia</i>	within 1 yr	46	16	85	0.0		
CLEARCUT WITH THE USE OF FELLING MACHINE AND CLAMBUNK SKIDDERS							
Plot with <i>Deschampsia</i>	within 1 yr	30	13	80	0.0		
Plot with litter	within 1 yr	23	6	80	0.5		

On the other hand the soakage on the surface of skid trails after the end of skidding was worse and the concentrated surface runoff with erosive effects was observed on this surface. The coefficients of surface runoff were determined in trials with rain simulation on eight runoff microplots (Tab. IV).

The results of investigation have indicated that there was great surface runoff on the area of skid trails after the end of skidding, and it reached as much as 95 % of water which fell onto the soil surface during rain simulation. The greatest runoff was observed in tractor skid trails, the lowest in horse skid trails.

The extremely great surface runoff in skid trails after the end of skidding was a factor causing the water erosion of soil. The values of specific wash of soil in g per m², related per 1 mm of surface runoff, which were determined in the process of artificial rain sprinkling on microplots of tractor, high-lead yarding and horse skid trails are presented in Tab. IV. The data in Tab. IV indicate that the greatest specific wash of soil occurred in tractor skid trails and the least in horse skid trails. The higher values of the specific wash of soil in skid trails in the Beskids, in comparison with the Krkonoše Mts., resulted from the higher content of silt particles (fractions I and II). This also underlies the higher erodibility of the soil surface of skid trails in the Beskids. The content of silt fraction in a five-centimeter surface layer of soil in skid trails on cutover areas in the Beskids was on an average 56 %, in the Krkonoše it was 40 %.

The rain simulation trials concluded on clearcut areas confirmed the great importance of ground cover: it prevents the appearance of rainfall surface runoff and soil wash. There was no great surface runoff on elementary runoff plots with well-preserved ground cover, neither was the soil wash recorded on any of runoff microplots. On the other hand, there was observed great surface runoff and soil wash on microplots without ground cover. This was related to an increase in bulk density and a decrease in porosity, and also to soil mixing on microplots with surface disturbance where the paths of original water soakage were interrupted.

The pattern of surface runoff and soil wash was determined in rain simulation trials repeated after three years. The time which elapsed from the end of operations in skid trails influenced a decrease in surface runoff to a smaller extent (Tab. IV) than it could have been expected according to weed overgrowing and better hydrophysical properties of soil on the microplot surface. In the main tractor skid trails the coefficient of surface runoff decreased after three years by 20 % in the Beskids, by 26 % in the Krkonoše, in secondary tractor skid trails the decrease was highly variable. In high-lead yarding trials the coefficient of runoff decreased by 9 % in the Beskids, by 15 % in the Krkonoše. In the horse skid trail in the Krkonoše a decrease made 14 %. In the rut of the main skid trail in the Krkonoše which became an occasional discharge gully, an increase by 7 % was recorded. A reduction in the specific soil wash was much more marked than the decrease in surface runoff. The absolute values of this decrease were higher in the Beskids, with regard to the initial values of soil wash the reduction was most marked in the Krkonoše Mts.

Determination of the expected intensity of rainfall surface runoff and intensity of water erosion of soil on cutover areas, including the checks of method accuracy

The objective of this study was not only to evaluate the surface runoff and soil wash on limited elementary microplots, but also to work out the method of determining the expected intensity of surface runoff and intensity of water erosion on the clearcut areas; another objective was to evaluate the accuracy of this method.

The surface runoff on new clearcut areas was concentrated only along skid trails, it was very small on the remaining clearcut areas, and it was changed into the subsurface runoff. This is the reason why only the runoff from skid trails was taken into consideration when the expected surface

IV. Surface runoff and specific soil wash from runoff microplots located along skid trails (artificial rain of 120 mm lasting one hour)

Location of runoff plots of the size 1 × 2 m	Time after logging	Slope [%]	Forest floor [cm]	Skeleton content in soil volume %	Surface runoff % of precipitation	Specific soil wash g.m ² per 1 mm surface runoff
BESKIDS (FLYSCH)						
TRACTOR SKID TRAILS						
Secondary skid trail	within 1 yr	27	0	25	76.6	1.2195
Ditto, overgrown with <i>Deschampsia</i>	3 years		2		44.9	0.0382
Main skid trail	within 1 yr	27	0	30	93.5	2.8062
Ditto, 70 % overgrown with <i>Deschampsia</i>	3 years		0		73.4	0.2202
HIGH-LEAD YARDING TRAILS						
Skid trail	within 1 yr	34	0	40	72.3	0.5390
Ditto, overgrown with <i>Calamagrostis</i>	4 years		2		63.1	0.0587
KRKONOŠE (CRYSTALLINE ROCKS)						
TRACTOR SKID TRAILS						
Secondary skid trail	within 1 yr	33	17	20	37.2	0.0152
Ditto, overgrown with <i>Calamagrostis</i>	3 years				36.0	0.0004
Centre of main skid trail	within 1 yr	27	0	30	98.7	0.6027
Ditto, overgrown with thin <i>Calamagrostis</i>	3 years				52.8	0.0418
Rut of main skid trail	within 1 yr	29	0	35	89.7	2.3691
Ditto, overgrown with mosses, <i>Calamagrostis</i> , stony bottom	3 years				96.4	0.0126
Entire main skid trail	within 1 yr	28	0	30	95.3	1.2714
	3 years				69.4	0.0307
HIGH-LEAD YARDING TRAILS						
Skid trail	within 1 yr	34	0	50	72.1	0.1964
Ditto, overgrown with <i>Calamagrostis</i>	3 years				56.8	0.0458
HORSE SKIDDING TRAILS						
Skid trail, stones form 10 % of surface	within 1 yr	34	0	50	34.2	0.0498
Ditto, overgrown with dense low <i>Deschampsia</i>	3 years				20.5	0.0202

runoff from 1 ha cutover was calculated (Tab. II). The expected surface runoff from 1 ha cutover was calculated according to reduced relation (1):

$$H = H_r \sum_{j=1}^n K_j \cdot P_j \quad (2),$$

where: H — expected surface runoff from 1 ha of cutover in mm per year,
 H_r — yearly average precipitation sum in mm,
 K_j — coefficient of surface runoff from the j -th kind of cutover soil surface,
 P_j — ratio of the area of the j -th kind of soil surface to the cutover area.

The surface runoff was in a direct dependence on the intensity and extent of cutover soil surface disturbance. On the cutover areas with the highest intensity and extent of disturbance, that means on tractor cutovers, the surface runoff meant an important component of water balance (6 to 11 % of the yearly precipitation sum). This amount (of 80 to 140 mm in absolute values) can influence on the areas with concentrated clear-cuts the level and time pattern of runoff in the hydrographic network. It must be mentioned that the drain age effects of skid trails with deep rills were not taken into consideration for this calculation; they would increase the calculated values of the expected surface runoff.

The expected intensity of water erosion along skid trails (erodibility of skid trails) and its values converted per 1 ha of cutover were expressed according to relation (1). The highest intensity of expected water erosion was recorded along tractor skid trails on the cutover area in the Beskids due to the high value of specific soil wash. Greater erodibility in the flysch zone was also observed along high-lead yarding trails. The expected water erosion converted per 1 ha (Tab. II), representing also the proportion of skid trail areas in the cutover area (the erosion is expressed in mass and volume values), was highest after tractor skidding performed in the terrain with lower bearing capacity — 1 655 kg per ha/year, or 2.11 m³ per ha/year. In the terrain with good bearing capacity, with respect to the higher erodibility of the soil surface of skid trails, the cutover area with tractor skidding in the Beskids had a higher water erosion than that in the Krkonoše Mts. (1 439, or 951 kg per ha/year). The same order (Beskids, Krkonoše) also applied to the considerably lower values recorded on the cutover areas with high-lead yarding (45, or 31 kg per ha/year). The lowest value was recorded on the cutover with horse skidding (15 kg per ha/year) due to the lower degree (intensity) of disturbance and consequently to the lower specific wash of soil along skid trails.

The development of the expected surface runoff and water erosion intensity on areas with regeneration cuts in the Beskids and Krkonoše was calculated from measurements repeated after three years (Tab. II). The disturbed surface on nutritive, but acidic or water-logged soils was overgrown quickly with ground vegetation, hydro-physical properties of the surface soil layer were also improving. Although there was a small decrease in the surface runoff (in the Beskids the expected runoff value on the cutover with tractor skidding made 68 %, with high-lead yarding 87 % of the original value, in the Krkonoše on the cutover with tractor skidding it was 76 %, with tractor skidding in the terrain with lower bearing capacity 73 %, with high-lead yarding 79 % and with horse skidding 60 % of the runoff level within the first year after felling), the expected intensity of water erosion decreased markedly (in the Beskids on the cutover with tractor skidding it decreased to 5 %, with high-lead yarding to 9 % of the original value, in the Krkonoše on the cutover with tractor skidding to 1 %, with tractor skidding in the terrain with lower bearing capacity to 2 %, high-lead yarding to 19 % and horse skidding to 27 % of the expected intensity of water erosion within one year after felling).

The accuracy of determining the expected intensity of water erosion on cutovers according to adjusted relation (1) Lebedev, Krasnoshchekov, 1979) was tested in high-lead yarding and tractor skid trails in the Krkonoše.

In the high-lead yarding skid a rain simulation trial was made in August in 1984, and applying relation (3) the water erosion E along the skid trail of the area 59.2 m^2 (slant length of trail 40 m , average width 1.48 m) was calculated from the recorded values over the period of 15 months (August 1984 – October 1985).

$$E = \frac{H \cdot K \cdot S \cdot P \cdot \cos \alpha}{1000} \quad (3)$$

$$E = \frac{1625 \cdot 0.7206 \cdot 0.1964 \cdot 59.2 \cdot 0.956}{1000} = 13.0 \text{ kg},$$

where: H – precipitation sum over the period of 15 months as mentioned in an Atlas of the Climate of the CSR (1958),

K – coefficient of surface runoff,

S – specific wash of soil in $\text{g per m}^2/\text{mm}$ of surface runoff,

P – area of skid trail in m^2 ,

α – angle of skid trail slope (17°).

Over the same period a sediment of the weight 38 kg and moisture content 66% was collected from a pit at the lower part of the skid trail. The weight of dried earth was 12.9 kg . A difference in these two values was negligible.

In the tractor skid trail of the slant length 195 m , the area of cross-section approximately in the same profiles was determined in October 1984 and 1985. Twenty-one profiles were measured every year. A difference in the cross-sections, tested by the method of paired samples, turned to be insignificant ($\bar{d} = -0.034 \text{ m}^2$, $s_d = 0.591$, $t = 0.257$, $t_{0.05, 20} = 2.086$). The volume of erosion rill made 295.2 m^3 in 1984, 297.5 m^3 in 1985, yearly soil wash made 2.3 m^3 . The water erosion over the same period of one year calculated by means of adjusted Lebedev's relation (3) was 1.673 t determined on the basis on the rain simulation test ($H = 1300 \text{ mm}$, $K = 0.953$, $S = 1.2724 \text{ g per m}^2/\text{mm}$, $P = 195 \cdot 3.2 = 624 \text{ m}^2$, $\cos 14^\circ = 0.97$); this represented 2.3 m^3 at the bulk density of earth on the skid trail surface of 0.72 t per m^3 . Difference in these two values was zero.

The accuracy of the method of determination of the expected intensity of water erosion can be considered as extraordinary with respect to the procedures used in the course of tests. Considering the procedure of determining the expected intensity of water erosion and the method of testing the accuracy of this procedure, even the 20% error would be very suitable.

A discussion about the findings acquired during the study of the effects of logging systems on soil erosion on areas with regeneration cuttings in mountain forests will be presented in a separate paper because the literature dealing with this problem is very ample.

CONCLUSION

The objective of the present paper was to quantify the soil disturbance and erosion in dependence on logging systems and to propose the principles of selecting such logging systems that will minimize erosion processes on areas with regeneration cuts in mountain forests.

The results of research on the effects of logging systems on soil erosion (experimental areas in the Beskids and Krkonoše Mts.) have pointed to an explicit conclusion that the intensity and extent of linear disturbance of soil surface are decisive factors of the origin and development of erosion processes and rainfall surface runoff on clearcut areas of the slope smaller than 25° in combination with different logging systems. The disturbance of soil surface was related to logging rill erosion, closely connected with the volume of skidded wood, and to surface runoff and water erosion linked to the erodibility of the soil surface of skid trails. The greatest and most intensive disturbance of soil surface was caused by tractors ($8-13 \%$ of the cutover area); this is the reason why the values of soil erosion and surface runoff were highest on clearcut areas with tractor skidding (logging erosion in the terrain of good bearing capacity 96 m^3 per ha, in the terrain of worse bearing capacity 195 m^3 per ha, expected surface runoff $6-11 \%$ of precipitation which has fallen onto 1 ha of cutover, expected intensity of water erosion $1.2-2.1 \text{ m}^3$ per ha/year). On the other hand, high-lead yarding or horse skidding meant the considerably smaller disturbance of soil surface as to its intensity and extent (deep rills 1 to 2% , or shallow rills on 6% of the cutover area), and in this way the smaller erosion and surface runoff (logging erosion 11 , or 66 m^3 per ha, expected surface runoff 1% , or 2% of precipitation that has fallen onto 1 ha of the cutover area, expected intensity of water erosion 0.09 or 0.04 m^3 per ha/year). The insignificant minimum disturbance

of soil surface when logging and skidding machines are operating on the whole cutover area did not cause any soil erosion and surface runoff at all. The overgrowing of skid trails with grasses on the nutritive soil in the Beskids, and acidic or waterlogged soils in the Krkonoše Mts., reduced the expected surface runoff three years after logging on cutover areas with tractor skidding to the value of 68 to 76 %, on cutover areas with high-lead yarding to the value of 79 to 87 %, and on those with horse skidding to 60 % of the original values. A decrease in the expected intensity of water erosion in the given time interval was much more expressive: to 3 % on cutover areas with tractor skidding, to 14 % on those with high-lead yarding and on cutover areas with horse skidding to 27 % of the expected intensity of water erosion within one year after skidding (the lower percent value in high-lead yarding and horse skidding, in comparison with tractor skidding, is due to the low initial values).

If the principles of selecting regeneration methods and logging systems in mountain forest are to be worked out, it is useful to divide the forest stands according to the ecological functions, by means of which management complexes are characterized (Plíva, 1981), into four functional groups (Peřina et al., 1977): 1. group with water-protection function, 2. group with erosion-control function, 3. group with draining function and 4. group with infiltration function. For these functional groups of forest stands, on the basis of the acquired knowledge, regeneration methods and logging systems were recommended with the aim to decrease soil erosion on areas with regeneration cuts in mountain forests with the multi-purpose management (Šach, 1986). The content of the proposed principles can be summarized in general in the following statement.

The regeneration method in itself does not influence very much the soil erosion on areas with regeneration cuts with the exception of localities with stony surface; therefore the erosion control will consist especially in the adequate use of logging systems. It means in practice that tractor skidding in the terrain with worse bearing capacity and at localities of steeper slope will be replaced by high-lead yarding and horse skidding. In the remaining terrain it is necessary to avoid water-logged sites, to reduce the number of one-trail passages on the area under logging, to minimize the density of skid trails, to use to the maximum extent the rope of tractor winch or to use horse skidding in some sections to reach the tractor skid trail. Shortening the time of logging operations (Weitzman, Trimble, 1955) and skidding operations in the winter period are favourable too. If there occurred a heavy disturbance of soil surface, heavy rill erosion and subsequent water erosion, it is necessary to restore the disturbed surface.

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Obhospodařování horských lesů ovlivňuje jejich půdoochrannou funkci. Vedle organizace lesní dopravní sítě jsou to především těžební dopravní technologie. Podle šetření na svazích 15—25° v Beskydech a Krkonoších největší část paseky poškodily přibližovací linky traktorové 7,6 až 13,0 % půdního povrchu, pak koňské 6,6 % a lanovkové 1,0 až 1,7 %. Tomu odpovídala velikost těžební dopravní eroze rýhového typu 62 až 195 m³.ha⁻¹, resp. 66 m³.ha⁻¹, resp. 11 m³.ha⁻¹. Na rozsahu a stupni poškození závisela velikost povrchového odtoku a na obojím pak intenzita vodní eroze na přibližovacích linkách po skončení soustředování. Její hodnoty zjištěné metodou zadržování malých odtokových ploch činily ve stejném pořadí 1,22 až 2,11, 0,04 a 0,07 až 0,09 m³.rok⁻¹ přepočteno na 1 ha paseky. Zarůstání přibližovacích linek travinami zmenšilo koeficient povrchového odtoku tři roky po těžbě jen nevýznamně: na holosečích s traktorovým soustředováním z 6,4 až 11,3 % na 4,3 až 8,3 % ročních srážek dopadlých na povrch pasek, na holoseči se soustředováním koňmi z 2,2 na 1,4 % a na holosečích s lanovkovým soustředováním z 0,7 až 1,2 na 0,6 až 1,0 %. Naopak snížení vodní eroze bylo výrazné, z výše uvedených hodnot na 0,03 až 0,09, 0,01 a 0,01 m³.ha⁻¹.rok⁻¹ v tomtéž pořadí. Erozi na holosečích zmenšil především vhodná aplikace těžební dopravní technologií a ve specifických případech také asanace přibližovacích linek.

horské lesy; holoseče; těžební dopravní technologie; eroze půdy

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ASSESSMENT OF THE LOKOMO MAKERI 34 T HARVESTER AS TO DAMAGE CAUSED TO THE FOREST ENVIRONMENT

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LASÁK, O.: (Institute of applied Ecology of the University of Agriculture, Kostelec nad Černými lesy): *Assessment of the LOKOMO MAKERI 34 T harvester as to damage caused to the forest environment*. *Lesnictví*, 36, 1990 (11): 911–920.

Investigating the influence of logging technology based on the LOKOMO MAKERI 34 T harvester and the LKT 81 special forest wheel tractor as to damage caused to trees and soil and making a comparison with classical technologies used in tending operations in conditions of this country, it has been established that damage to trees in spruce stands (22.5 %) shifted to roots (14.4 %) and butts (3.9 %). Damage to soil was limited to turning up the upper humus layer which occurred mainly while revolving the machine by more than 45° and did not exceed a depth of 50 mm. There was a difference also in the direction of felling and the storage of felled trees in the optimum angle (up to 45°) to the skidding line (88 % for the harvester and 56 % in classical technology).

forest technics; multioperational felling machines; logging; damage caused to stands and soil

INTRODUCTION

The mechanization of tending cuttings is much more difficult than the mechanization of regeneration cuttings because it requires usually the ability for selective intervention. The functional principles of machines must be chosen so as to avoid damage to trees of the tended stand by the working units of the equipment or to the forest soil by passing along. The observation of ecological viewpoints in the technics of logging and transportation in forestry requires, for further successful development, to study in detail the causes and consequences of damage caused in every work operation and stage of the production process so that damage can be gradually and systematically removed or significantly reduced.

Damage caused to forest trees in logging and skidding of wood in intermediate cuttings was analyzed lately mainly by the following authors: Butora and Schwager (1986), Douda (1981 and 1986), Meng (1978), Rotaru (1986), Soukup and Temlová (1977), Wojcik and Hakkila (1980). The results of their work show that the slightest damage to standing trees is done in logging operations, i. e. in felling, trimming and bucking (up to one third of all damage caused). The remainder (two thirds) is caused by timber skidding. Extraction of timber is responsible for the largest part of tree wounds causing about 90 % of all damage. It follows from the results that the share of damaged standing trees in timber skidding in stands not ripe for the harvest, using the stem method with manual extraction, represents 3.4 to 5.6 %, with manual gravitation skidding on slopes 38.0 %, with the use of a harvester and the MAKERI hauling equipment in pine stands 1.2 to 5.9 %, with using a horse team 1.9 to 17.7 %, with using a universal wheel tractor 5.7 to 25.0 %, with a combination of horse + universal wheel tractor 6.6 to 34 %, with the utilization of a radio operated winch 29 %, and with the use of a cableway 34 %. The extent of damage depends, in addition to the type of equipment, on the logging method and on the state of the tree (summer, winter), and also on terrain con-

ditions, on the qualification and care of the operating crew in skidding, on the age of the stand and on the intensity of the intervention.

Logging and skidding equipment may influence unfavourably, besides forest trees and undergrowth, also the forest soil, as is confirmed by the work of Bredberg and Wasterlund (1983), Dejmál (1983), Douda (1981 and 1986) and Lútočka (1988). As far as present and prospective types of logging and transportation equipment manufactured in this country are concerned, so far their construction did not contribute by any means to a significant reduction of damage caused to forest soil. Weight, traction force and transportation velocity are constantly on the increase. The construction of equipment reflects mainly the endeavour to obtain maximum work productivity and implicitly to overcome any obstacles on the road.

The greatest damage to forest soil occurs in skidding by both mobile equipment and transported timber. Soil damage consists mainly in the compressing, digging and tearing up of the upper humus layer with ensuing erosion. Soil destruction depends mainly on the type of soil and its humidity which influence the coherence of the various particles. Compression causes an increase of the volume weight, reduces the volume of coarse pores and this leads to the deterioration of the permeability of precipitation water and to water erosion. For the root system this implies increased mechanical resistance and a poorer supply of water with oxygen. This prevents root development and reduces increment. The extent of damage depends on the type of the driving mechanism, the frequency of passage, transportation velocity and the resulting specific pressure on the soil. Of great importance is also, besides the construction of the equipment, the chosen technology.

Since in professional forestry literature there are few investigations concerning multioperational logging and transportation equipment used in stands not yet ripe for cutting as to damage caused to the forest environment, this paper is concerned with the evaluation of the LOKOMO MAKERI 34 T harvester and the LKT 81 tractor with regard to the dependence of the damage caused to trees and soil on various factors and with the comparison of the results of this technology with values for classical technologies as described in literature or obtained from direct measurements.

MATERIAL AND METHOD

In order to evaluate the damage caused to the stand in fully mechanized intermediate cutting by the MAKERI 34 T harvester, direct observation was carried out on 14 experimental plots in May and June 1989. The age of the stand was 55 years, stocking 9, type of terrain 2, elevation above sea level 510 m. The subsoil was formed by calc. sandstone, greywacke, conglomerate and clayey slates. The soil was loamy-sandy to loamy, permeable, easily drying. Tree species representation: spruce 60 %, mean volume 0.42 m³, site class index 2, volume of timber 176 m³.ha⁻¹. Intermediate salvage cutting. The climatic conditions may be characterized as sunny weather. On the total surface of 1.01 ha 401 trees were felled, 893 trees together with the undergrowth remained on the plot. Intensity of intervention 31 %. The stand was divided by skidding lines into working fields 25 to 30 m wide and 30 to 80 m long. Between both lines distant 50 to 60 m the transportation limit was clearly marked for the orientation of the crew of the equipment.

Observation concerned the determination of the influence of the movement of the equipment around the stand, i. e. the length of passage to the felled tree and back and the number of revolutions of the equipment by 45, 90 and 180 %, on size of damage. Information was collected on the number of felled trees, the number of trees remaining on the experimental plot, the area of the experimental plot and the number of produced bundles. Observations referred also to the extent of damage to standing trees including the place (root, butt, lower part of stem – up to 1 m, stem), size of wound (up to 0.99 dm², from 1.00 to 9.99 dm², above 10.00 dm²) and the number of wounds on a tree. Also noted was the damage caused to the soil by the passage of the equipment and by logging operations and expressed by its area in m² and depth in mm. Similar observations were made on damage caused to trees and soil by the skidding of log bundles by the tractor to the landing.



1. The LOKOMO MAKERI 34 T harvester in felling



2. Damage caused to surface roots of spruce by steel bands of the harvester in turnings

All obtained data were processed by the various experimental plots using an ADT 4700.1 computer and a DGF 1208A digigraph and the method of multiple linear correlation including the calculation of the equation of regression equation $y = a + bx$ based on the regression coefficient. The number of the various revolutions was converted in this calculation to a passage in metres so that a revolution by 45° corresponded to a passage of 3 m, by 90° to a passage of 6 m and by 180° to 10 m.

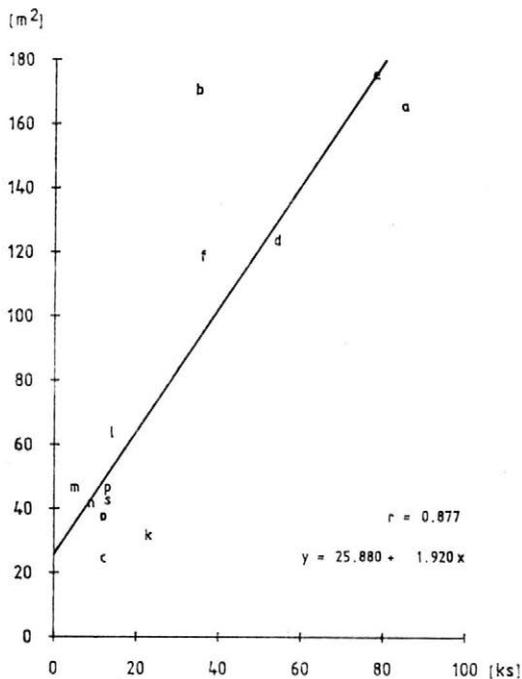
RESULTS

DESCRIPTION OF TECHNOLOGY

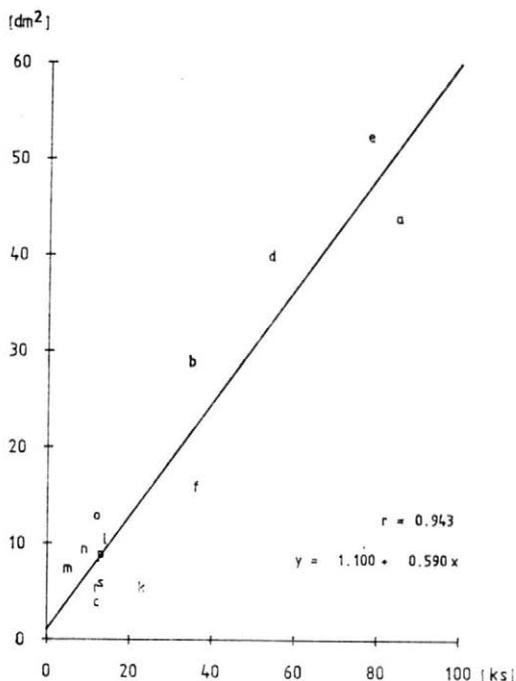
The operator of the harvester drove to the line and from its edge rode into the stand to a tree marked by paint (from both sides). Having separated the tree from its stump he carried it in a vertical position backing out of the stand to the skidding line. Turning the head of the harvester to the side and forward he placed the tree in a horizontal position, trimmed it (and bucked it, respectively) and deposited in piles (bundles) comprising 2 to 6 pieces (which corresponded to 2 to 4 felled trees), but also 11, exceptionally 16 pieces in a bundle. After trimming, during which the first 2 to 3 pieces having passed the trimming knives behind the centre of gravity slanted with the butt to the earth and digged the humus moderately by the butt ends, whereas the following pieces glided already over them, the operator evened out the butt ends of the pieces in the bundle by passing with the machine or shifting the piece in the head's cylinder. The prepared bundles were skidded by the LKT 81 with a double drum winch putting together the load. The skidding distance was up to 400 m. The crew of both the harvester and the LKT 81 was the same during the observation. The experimental plots were identical with the working fields.

DAMAGE CAUSED TO TREES BY THE MAKERI 34 T HARVESTER

Damage to standing trees by the MAKERI equipment is caused mainly by the driving mechanism because the steel belts, especially when turning around on the spot, tear off the upper layer of litter and lay the roots bare and break them. In narrow gaps between trees (2.0 to 2.5 m) root butts are directly damaged during riding. Trimming caused damage to the lower part of stems and to root butts of standing trees



3. Dependence of damage caused to soil by the MAKERI 34 T harvester on the number of felled trees



4. Dependence of the area of wounds of trees damaged by the MAKERI 34 T harvester on the number of felled trees

but this damage was slight and in most cases the operator was to be blamed for it. Damage caused to neighbouring trees during felling was limited to the breaking of dry branches.

The extent of damage caused to standing trees by the MAKERI 34 T harvester was as follows: From among 893 remaining trees a total of 155 (17.4 %) was damaged. One damaged tree had on the average 1.43 wounds. From the total number of 221 wounds (100 %) 165 (74.7 %) were on roots (!), 24 (10.8 %) on root butts, 25 (11.3 %) on the lower parts of the stem and 7 (3.2 %) on stems. A total of 57 % of wounds measured 0.99 dm², the remaining 43 % of wounds were larger than 1 dm². Wounds with a surface larger than 10 dm² were not recorded. In relation to the number of standing trees damage was caused in 13.0 % the cases to roots, in 1.9 % to root buttresses, in 2.0 % to the lower parts of the stem and in 0.5 % to stems. There were 3 trees damaged by a total of 5 wounds for every 8 felled trees. There were 2.49 damaged trees with 3.55 wounds and a total wound surface of 4.04 dm² for every processed cubic metre of felled trees.

SOIL DAMAGE CAUSED BY THE MAKERI 34 T HARVESTER

Damage to soil by the MAKERI 34 T harvester was caused by the driving mechanism, i. e. by steel belts. The most important damage to the soil surface occurred during the turning of the equipment. In direct passage damage arose in places with unevenness of the terrain. In turning, the size of the angle and the number of revolutions were decisive. The total surface of damaged soil depended also on the digging of the butt end of the first 2 to 3 trimmed pieces which formed the bottom layer of the bundle. The area of thus damaged soil varied around 1 m² per bundle. Soil damage consisted always in digging

up or tearing off the upper humus layer. Soil under this layer remained undisturbed, only when driving over terrain unevenness or in repeated turning on the same spot a minimum ploughing of the soil occurred. But such damage never exceeded the depth of 50 mm.

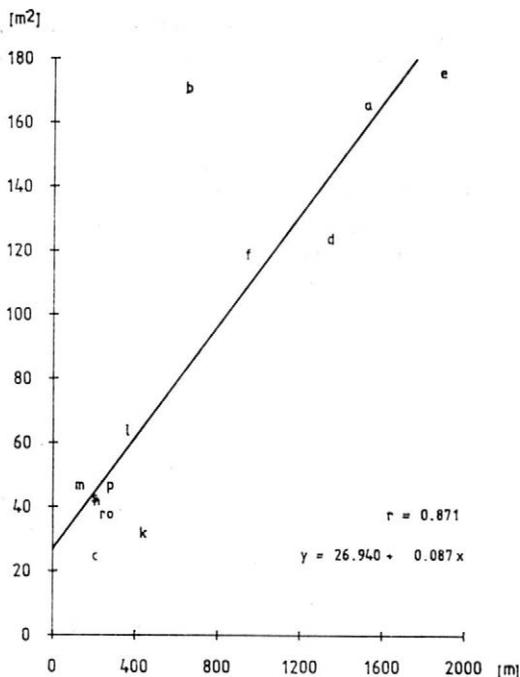
The extent of soil damage caused to the soil by the MAKERI 34 T harvester in felling, extraction, trimming, and bucking, respectively, was as follows: out of the total area of 10,100 m² 1,132 m² (11.2 %) of stand area was damaged, including 10.2 % by the passage of the harvester and 1.0 % of the soil surface by the butt ends of trimmed trees. 18.17 m² of soil was damaged per cubic metre of felled trees.

DEPENDENCE OF SOIL AND TREE DAMAGE ON VARIOUS FACTORS

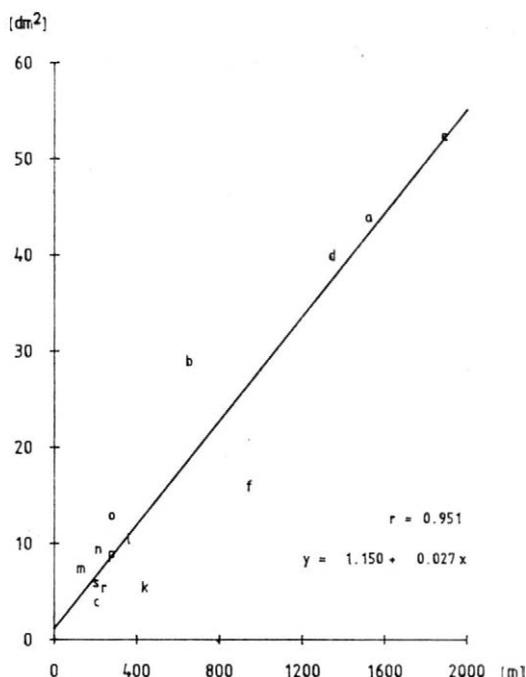
The following technological factors may influence the extent of damage caused to soil and trees: stocking, intensity of intervention, number of remaining trees, distance actually covered by the harvester, number of revolutions according to the size of angle, total covered road consisting of actually covered path and the distance converted from the revolutions, number of bundles on a certain cutting area, number of pieces in bundles and timber volume in the bundles. According to measured data, mainly the number of felled trees (intensity of intervention) and the total covered distance proved their influence on the extent of damage. The remaining factors were narrowly connected with these two factors. The influence of the number of felled trees and of the total covered path on the surface of damaged soil and the size of wounds on the trees was expressed graphically for the various experimental plots designed by the small letters a to s.

The number of felled trees is influenced by the age of the stand, the average tree volume and the number and intensity of previous interventions. The result is the intensity of intervention on the given area. The dependence of soil damage on the number of felled trees (Fig. 1) was close ($r = 0.877$). It was tightly connected with the size of the cutting area, with the covered distance, with the number of various types of revolution and with the number of processed trees in one bundle. The dependence of the area of wounds of damaged trees on the number of felled trees on a certain surface (Fig. 2) was also very close ($r = 0.943$). It was connected with the covered distance and the number of trees remaining after the intervention. The path covered by the harvester, together with the number of revolutions and the frequency of passage along the same route, increases with the growing intensity of intervention and consequently also with the number of trees extracted from a certain area.

The actual distance covered by the harvester influenced directly the area of damaged soil and the surface of wounds on trees. To accomplish the intervention on the area of one hectare the harvester needed to cover 3,620 m on the stand soil. On the average 9.12 m of actually covered path was thus required per one felled tree. Further it was necessary to distinguish the direct passage and the revolution of the equipment which influenced mainly root damage (Fig. 2). Though by lowering the front pair of bogie during the revolution the surface of contact of the belts with soil diminishes and so does the resulting area of soil damage, the specific pressure on the soil increase as well as on surface roots which, mainly in spruce, are by the belts either crushed, broken, or their bark is torn off. As for the MAKERI 34T harvester the specific pressure on the soil is 40 kPa for a belt width of 285 mm. While revolving on half of the belts thus pressure increases to about the double. During the intervention on an area of one hectare the harvester turned round 719 times (61.0 %) by 45°, 382 times (32.4 %) by 90° and 65 times (5.6 %) by 180°. The relation of the various revolutions in driving



5. Dependence of soil damage caused by the MAKERI 34 T harvester on the total covered passage



6. Dependence of the area of wounds of trees damaged by the MAKERI 34 T harvester on the total covered passage

there and back per one felled tree, on the average, was as follows: twice by 45° , once by 90° and 0.2 times by 180° . In order to express the influence of the revolution of the harvester within the covered distance on the size of damaged soil ($r = 0.871$) and on the surface of wounds on the trees, the actual distance covered by the equipment and the total path converted from the revolutions were added. The resulting total covered distance (Figs. 3 and 4) amounted to 8,723 m (100 %) for carrying out the intervention on the area of 1 ha, including 3,620 m (41.5 %) for direct driving and 5,103 m (58.5 %) for the distance from revolutions. Thus altogether one third of caused soil damage and surface of tree wounds originated in direct riding, and two thirds of the other damage arose in the revolutions of the harvester.

SOIL AND TREE DAMAGE IN THE MAKERI + LKT 81 TECHNOLOGY

The resulting damage caused to trees and soil in technology based on the MAKERI 34 T harvester (felling, extraction, trimming, bucking, bundling) and the LKT 81 tractor (skidding to the secondary landing) is given in Tables I and II.

Damage caused to trees (Tab. I) amounted to 22.5 % including 63.9 % of all caused damage falling on roots, 17.5 % on root butts, 15.0 % on lower parts of the stem and 3.6 % on stems.

Damage caused to soil (Tab. II) amounted to 14.9 %. It should be noted, with regard to further comparison with classical technologies, that damage consisted in digging up or tearing off the humus layer (14.0 %). The ploughing of soil by the harvester did not exceed the depth of 50 mm, and a depth of 100 mm by the tractor occurred only on 0.1 % of the damaged surface.

I. Damage caused to trees in the MAKERI + LKT 81 technology

Used equipment	Number of damaged trees												Number of wounds	Number of damaged trees	Number of remaining trees
	Roots [dm ²]			Butts [dm ²]			Lower part of stem [dm ²]			Stem [dm ²]					
	up to 0.9	1.0 9.9	above 10.0	up to 0.9	1.0 9.9	above 10.0	up to 0.9	1.0 9.9	above 10.0	up to 0.9	1.0 9.9	above 10.0			
MAKERI	97	68	0	10	14	0	15	10	0	5	2	0	221	155	893
LKT	6	4	0	12	12	0	6	9	1	0	2	1	53	46	x
Total	103	72	0	22	26	0	21	19	1	5	4	1	274	201	893
[%]	37.6	26.3	0	8.0	9.5	0	7.7	6.9	0.4	1.8	1.4	0.4	100	x	x
[%]	14.4			3.9			3.4			0.8			x	22.5	100

II. Damage to soil in MAKERI + LKT 81 technology

Used equipment	Area of operation [m ²]	Processed timber [m ³]	Damage to soil			Total [m ²]
			humus	up to 50 mm	up to 100 mm	
			[m ²]			
MAKERI	10 100	62.3	1132	0	0	1132
LKT-81	x	x	290	79	8	377
Total	10 100	62.3	1422	79	8	1509
[%]	100	x	14.0	0.8	0.1	14.9

DISCUSSION

If a comparison is made between the MAKERI + LKT 81 technology and the classical technologies used in the conditions of this country, at the first instance a marked shift in tree damage appears toward roots in spruce stands. In spruce, the surface root system is damaged much easier than the deeply rooted system of pine. In this connection the problem of caterpillar undercarriage comes to the fore, since caterpillar bands on the one side diminish pressure on the soil, but on the other side in turning points dig up fresh soil and denude and wound roots. Other parts of the tree (butts, lower and upper parts of the stem) are damaged in both spruce and pine to the same extent. If measured results and results from other technologies as listed in literature are compared, differences are found in the extent of damage in extraction, the reason being a difference in the direction of felling. In separated work of fellers not linked to extraction 56 % of trees were deposited at an angle of up to 45° to the skidding line, 30 % at an angle up to 90° and 14 % in an angle of above 90° (Lasák, 1988). The MAKERI harvester deposited 88 % of bundles at an angle of up to 45° to the skidding line and the remaining 12 % in at angle of up to 90°, thus the damage to trees resulting from skidding by the LKT 81 tractor, as compared to classical technologies, was markedly reduced to 5.1 % of the trees remaining in the stand.

The extent of damage caused in intermediate cuttings is substantially influenced by the inclination of the terrain. When using the MAKERI harvester the slope accessibility of which is said to be 25 %, it is of advantage, from the point of view of damage mainly to roots, to use it on slopes to a maximum degree of 10 %. On greater inclinations the harvester had to drive below the felled tree, the number of revolutions by 90 and 180° increased, extraction was slower and frequently slippage of bands occurred mainly in take-off runs uphill which affected unfavourably the extent of root damage.

If the various technologies are ranked from the point of view of damage caused to trees, the MAKERI + LKT 81 technology comes next to the stem technology and extraction by horse team and is equal to the combination horse + LKT 81 and horse + UKT and UKT doing also the extraction. But it surpasses them from the point of view of productivity because the daily output varied about 20 m³ with the harvester and 40 m³ with the LKT 81. When using the harvester in pine stands or in coniferous mixed stands with prevailing pine, the damage to surface roots is substantially reduced.

When comparing the MAKERI + LKT 81 technology from the point of view of soil damage with classical technologies, differences were evident between various

equipment as to the depth of damage caused to skidding and hauling roads. Among fully mechanized technologies the harvester produced the best results also from the point of view of soil compressing, acting favourably on the forest soil by its small weight (3700 kg), and the type of driving mechanism.

Certain technical, technological and organizational measures are a precondition for reducing damage caused to trees and soil by the MAKERI + LKT technology.

From the technical viewpoint a disadvantage of the harvester is the influence of the caterpillar undercarriage on the exposure and damage of surface roots. The minimization of revolutions of the equipment by 90 and 180°, mainly in spruce stands, may contribute to the reduction of damage. For spruce stands the solution of the problem could be some other technology which would exclude the driving of machines across the forest soil limiting them to the skidding lines. In choosing the equipment to skid the bundles prepared by the harvester, the width of this equipment should be based on the width of the skidding line. The wheel or caterpillar equipment with load should act on soil at a maximum pressure of 70 kPa (Rotaru, 1986). Another effective measure would be the removing of direct dragging in surface skidding which could be achieved by using suitable hauling equipment like the vehicle MAKERI, FMG 678 Mini Bruunett, Norcar 490.

From the technological viewpoint for the MAKERI harvester a 60 m spacing of skidding lines proved to be satisfactory, the transportation limit being marked in the middle to inform to which line the tree should be extracted. Likewise, the marking of trees for felling must be distinct, being visible from both sides and serving thus for a good orientation of the crew. Butora and Schwager (1986) recommended in thinning operations the marking of final crop trees (called C trees) in order to eliminate losses of the future mature stand. An advantage is the permanent knowledge of workers with regard to those trees which must not be damaged, and further the fact that damage caused is shifted on weakened trees under the crown canopy which will be removed in further tending interventions, this being in perfect agreement with silvicultural goals. When felling work is carried out carefully, the marking of C trees reduces damage by two thirds (i. e. by up to 15 %) which can be further reduced by using suitable buffers.

Organizational technical measures include the selection and classification of stands for felling which must be linked to climatic, soil (type, state, carrying capacity) and terrain conditions. All workers engaged in silvicultural activities should be systematically educated. They should be acquainted with the problems of damage and with new technologies which reduce damage caused to the forest environment. Connected with this is the suitable basic equipment according to used mechanical means, the chosen method and properties of the working site. A no less important measure is the permanent management and control by the technical and economic staff.

CONCLUSION

The use of multioperational logging equipment in tending operations is doubtless a way for solving problems of fellings in non-mature stands. But on no account is it the only way. Solutions equivalent from the technological viewpoint can be offered also by the system of one-purpose equipment. In making a decision several factors must be taken into account, among them regard for careful tending of the stand must not be absent.

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LASÁK, O. (Ústav aplikované ekologie VŠZ, Kostelec nad Černými lesy): *Posouzení harvestoru LOKOMO MAKERI 34 T z hlediska poškozování lesního prostředí*. Lesnictví, 36, 1990 (11): 911–920.

Předložená práce se zabývá vlivem těžební technologie založené na probirkovém harvestoru LOKOMO MAKERI 34 T a speciálním lesním kolovým přibližovacím traktoru LKT 81 na rozsah poškození stromů a půdy a jejím srovnáním s klasickými technologiemi používanými při výchovných zásadách v našich podmínkách. Pozorování bylo provedeno na 14 zkušných plochách o celkové výměře 1,01 ha a bylo zaměřeno na zjištění vlivu pohybu stroje po porostě na rozsah škod. Ve smrkovém porostě bylo poškozeno 22,5 % zůstalých stromů, přičemž se ve srovnání s klasickými technologiemi poškození výrazně přesunulo na kořeny (14,4 %) a kořenové náběhy (3,9 %) vlivem pásového pojezdového ústrojí. Povrchový kořenový systém smrku je poškozován daleko snadněji, než hluboko jdoucí kořenový systém borovice. Rozdíl byl i ve směrovosti kácení, kdy harvestorem bylo 88 % svazků uloženo v úhlu do 45° k přibližovací lince a zbylých 12 % v úhlu do 90°, což přispělo k tomu, že přibližování traktorem LKT 81 bylo poškozeno jen 5,1 % stojících stromů. Poškození půdy se omezilo na rozrytí vrchní humusové vrstvy, ke kterému docházelo zejména při opakovaném otáčení a při otáčení stroje o více než 45° a nepřesáhlo u harvestoru hloubku 50 mm. Pro zmírnění škod na stromech a půdě jsou uvedena některá technická, technologická a organizační technická opatření.

lesnická technika; víceoperační těžební stroje; těžba lesní; poškození porostů a půdy

LASÁK, O. (Institut für angewandte Ökologie der Landwirtschaftlichen Hochschule, Kostelec nad Černými lesy): *Beurteilung des Harvestors LOKOMO MAKERI 34 T aus der Sicht der Waldumweltbelastung*. Lesnictví, 36, 1990 (11): 911–920.

Die vorliegende Arbeit befasst sich mit dem Einfluss der auf dem Durchforstungsharvestor LOKOMO MAKERI 34 T und dem speziellen Waldtraktor für Holzrücken LKT 81 beruhenden Holzeinschlagstechnologie auf den Umfang der Baum- und Bodenbeschädigung und mit ihrem Vergleich mit klassischen, bei Erziehungseingriffen unter unseren Bedingungen angewendeten Technologien. Die Untersuchungen erfolgten auf 14 Versuchsparzellen mit einem Gesamtausmaß von 1,01 ha und wurden auf die Ermittlung des Einflusses der Bewegung der Maschine im Bestand auf den Umfang der Schäden gerichtet. Im Fichtenbestand wurden 22,5 % der restlichen Bäume beschädigt, wobei im Vergleich zu klassischen Technologien die Beschädigung vor allem auf den Wurzeln (14,4 %) und den Eissprossen (3,9 %) unter dem Einfluss des Raupenfahrwerks auftritt. Das Oberflächenwurzelsystem der Fichten wird viel leichter im Vergleich zum tiefliegenden Wurzelsystem der Kiefern beschädigt. Ein Unterschied bestand auch in der Fallrichtung, wo mit dem Harvestor 88 % der Bündel im Winkel von 45° zur Rückelinie und die restlichen 12 % im Winkel von 45° zur Rückelinie und die restlichen 12 % im Winkel von 90° gefällt werden, was dazu beiträgt, dass infolge des Rückens mittels LKT 81 nur 5,1 % der stehenden Bäume beschädigt wurden. Die Bodenbeschädigung begrenzte sich nur auf das Aufwühlen der oberen Humusschicht, zu dem es insbesondere beim wiederholten Wenden und beim Wenden der Maschine um mehr als 45° kommt. Es überstieg im Falle des Harvestors nicht 50 mm Tiefe. Zur Verminderung der an den Bäumen und am Boden auftretenden Schäden sind einige technische, technologische und organisationstechnische Massnahmen angeführt.

Waldtechnik; Mehrzweckholzeinschlagsmaschinen; Forstnutzung; Bestands- und Bodenbeschädigung

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COMPACTION OF FOREST SOIL BY SKIDDING DEVICES (THE SPECIAL FOREST WHEEL TRACTOR LKT-81)

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DEMKO, J. (Chair of Forest Logging and Mechanization, Forestry Faculty of the College of Forestry and Forest Industries, Zvolen): *Compacting of forest soil by skidding devices (The special forest wheel tractor LKT-81)*. *Lesnictví*, 36, 1990 (11): 921—930.

With the successive mechanization of logging operations in the forest the extent and degree of damage caused to forest soil increases. Damage caused to forest soil by its compacting and by the change of the water regime influence considerably the production capacity and the sanitary condition of the forest. Studying the influence of wheel technics (LKT-81) it has been established that the largest increment of volume weight of the soil occurs after the first drive of the tractor into the depth of 15 cm. After the second drive of the tractor still a moderate growth of the volume weight of soil is observed, after the third drive the increment of volume weight of the soil is minimal. As the zone of soil compacting also the space between the wheel tracks can be regarded, there the increment of volume weight (OH) of the soil is most pronounced after the first drive of the tractor in the depth of 20 to 30 cm. It has been also established that the compacting of soil does not cause an increase of the soil humidity, on the contrary, soil moisture decreases. The influence of the LKT tractor on soil changes proved to be ecologically dangerous since already the individually observed changes of the soil are grave and by their combination their unfavourable combination effect multiplies.

forest technics; forest logging; skidding; soil compacting; forest soils

A serious factor in the deterioration of the production capacity of soil is also its compacting, the extent and degree of which is unknown. The ecological, production and economic consequences of the compacting of forest soil are so far little known. The harmonious development of all partial disciplines of soil science integrated in the solution of concrete problems is lacking.

The state of the forest soil fund and thus also its fertility was in the past markedly influenced by the change of the long-term stand composition, the intensive utilization of the phytomass of the forest stands, and changing technologies of logging, transport and regeneration of forest stands (Klím, 1988).

The compacting of forest soil leads to the deterioration of conditions for the full development of the root system. According to certain authors (Bredberg and Wästerlung, 1983) increment studies established losses of increment ranging from 6 to 17% for a time period from 5 to 16 years. The combined effect of soil compacting and of contingent damage to the roots is far-reaching. The site class of land evidently influences the size of damage; it may be expected that on good site classes soil damage and consequently also ensuing increment losses will be smaller than on poor site classes.

Unfortunately, scientific information on the compacting of forest soil and its influence on forest production is in this country almost absent. The aim of this paper is to contribute to the explanation of certain partial problems.

METHOD

The compacting of forest soil has been studied in the School Forest Enterprise of the College of Forestry and Forest Industries in Zvolen which belongs mostly to the orographic unit of the Kremnické vrchy Mountains. These mountains have a stratovolcanic structure and are of the younger tertiary age.

Experiments have been carried out on brown forest soil (kambizem); this typical, humus-containing, mesotrophic soil is of medium depth.

The dependence of soil compacting on the number of LKT-81 passings has been established. Four basic soil characteristics were studied namely:

a) volume weight of "wet" earth (OH)	kg . m ⁻³
b) volume weight of "dry" earth (S-OH)	kg . m ⁻³
c) contents of water (OV)	kg . m ⁻³
d) moisture (W)	%

Experimental observations were performed on two places including the centre of the tyre track and a spot between the tyre tracks. Before the first passage of the LKT tractor with a load all mentioned values were observed in the natural setting of soil without previous loading. The experiment was carried out in a mixed stand (beech, oak, fir) of 55 year age, on the second site class, at a slope inclination of 20 %, during an intermediary cutting.

The tractor LKT-81 skidded logs in a semi-suspended position with the small end to the fore. The hardwood logs (beech, oak) had a volume of 4.76 m³.

The experiment was repeated after each further passage of the tractor. The respective values were measured at a depth of 0, 5, 10, 15, 20, 25 and 30 cm. Two comparative experiments were made. The mentioned basic characteristics were determined immediately after the passage of the tractor.

From the values obtained by regression analysis the regression equations for uncompacted soil and equations for each passage were computed. In addition to regression equations also other basic statistical values for all established experimental data were calculated.

RESULTS

Soil is an inorgano-organic system with a very wide range of possible composition. It is a fact that for broad-leaved tree species 60 to 70 % of the rhizomass is concentrated in the upper 300 mm of soil, and further 20 to 25 % in a depth of 0.3 to 0.5 m.

For coniferous tree species 80 to 90 % of the rhizomass is contained in the upper 0.3 m of soil, and 80 to 90 % of the sucking roots of forest trees (with a diameter up to 0.3 mm) is concentrated in the upper 10 cm of soil. The upper 0.4 m layer of soil may be considered to be the zone of intensive root occurrence. The root substance in the A horizon of forest soil represents 15 to 20 % of the total soil volume and 30 to 40 % of the porosity, i. e. all noncapillary pores, are practically occupied by roots. In deeper layers this correspond to 1 to 5 % of the volume and 2 to 10 % of the porosity (Šály, 1987).

The development of roots is limited, or entirely eliminated, by the lack of oxygen.

In timber skidding the contact with the soil in any form is unavoidable, be it through the wheels of the tractor, the pulled load, or the hoofs of the horse. In this process, the soil is loaded in the vertical direction, and first an elastic tension occurs; after the critical load is attained, plastic regions come into existence in which the shear strength of the soil is surpassed. By further increase of the load a limit occurs in which the soil is still able to keep the body, but this load being surpassed the wheel breaks through and the forced out earth advances by plastic flow obliquely upwards thus creating a track.

Data established with regard to non compacted soil are compensated by a regression equation (a parabola of the second degree) and given in Tab. I and II. The values are given for various depths. The compensation of values showed that the volume weight of soil increases with rising depth; where as in the first experiment OH in the horizon 0 to 30 cm amounts to 1,587.63 to 1,661.6 kg . m⁻³, in the second experiment OH ranges from 1,587.63 to 1,655.82 kg . m⁻³. After the first passage of the tractor along a strictly defined track the OH of earth in the middle of tyre tracks changed as shown in Tab. I and II.

The largest OH increase was recorded up to a soil depth of 15 cm, when the average OH increment in this layer represented 110 kg . m⁻³, whereas in the 20 to 30 cm layer only 40 kg . m⁻³ and the average increment of OH is 87 kg . m⁻³; in the second experiment

I. Soil characteristic before and after soil compacting by the LKT-81 tractor — centre of tyres, first experiment

Number of passages	Established characteristics	Depth [cm]	5	10	15	20	25	30
		0						
Non compacted soil	OH	1534	1558.8	1586.7	1610.8	1631.4	1648.3	1661.6
	S-OH	1072.1	1092.7	1115.7	1133.6	1152.6	1166.5	1177.2
	OV	461.7	466	470.9	475.1	478.7	481.6	483.9
	W	43.04	42.66	42.24	41.87	41.56	41.31	41.11
1-st passage	OH	1671.8	1673.1	1676.5	1681.7	1688.7	1697.7	1708.42
	S-OH	1176.8	1174.5	1175.9	1189.1	1192.9	1208.6	1288.9
	OV	495	498.6	500.5	499.5	495.6	488.7	478.9
	W	42.05	42.43	42.54	42.25	41.57	40.48	38.98
2-nd passage	OH	1688	1715.1	1741.6	1759.9	1770.3	1769	1766.5
	S-OH	1224.5	1256	1285.3	1303.8	1311.2	1307.7	1293.3
	OV	463	457.4	453.4	453.1	456.3	463.1	473.4
	W	37.48	36.52	35.72	35.36	35.44	35.97	36.94
3-rd passage	OH	1703.5	1714	1728.7	1745.1	1763.2	1783.1	1804.7
	S-OH	1219.8	1224.3	1223.1	1245.5	1261.5	1281.2	1304.5
	OV	491.5	494.1	495.6	498.2	498.8	498.6	497.5
	W	40.79	40.64	40.35	39.96	39.47	38.88	38.19

the average OH increment, compared to non compacted soil in a depth up to 15 cm, is 92 kg.m⁻³ and in the 20 to 30 cm depth only 59 kg.m⁻³, whereas the average OH increment was 97 kg.m⁻³.

After the second passage of the loaded tractor the OH increment of the soil was again measured in the depth up to 15 cm, it being in the depth of up to 15 cm on the average 46 kg.m⁻³ in the first experiment and 32 kg.m⁻³ in the second experiment.

After the third passage of the tractor with load the OH increment of the soil is not conspicuous, attaining only 3.75 kg.m⁻³ and almost zero in the second experiment.

After three passages of the loaded tractor the absolute OH of the soil increased in the depth of up to 15 cm on the average by 151 kg.m⁻³ in the first experiment and by 123 kg.m⁻³ in the second experiment. In the depth of 20 to 30 cm OH increased by 135 kg.m⁻³ in the first experiment and by 74 kg.m⁻³ in the second one.

The increment of the volume weight of the soil in the middle between the wheel tracks, as compared to the non compacted soil, is after the first passage in the depth of up to 15 cm 144.8 kg.m⁻³, whereas in the depth of 20 to 30 cm 170 kg.m⁻³. After the third passage of the tractor, soil compacting became minimal and in some layers even a lower soil OH was established after the second passage of the tractor, compared to the OH of the soil after the first passage, this being caused probably by the fact that after the passage a partial elasticity of the soil came into being. This same fact concerning soil change may be observed also after the third passage of the tractor, with

II. Soil characteristic before and after soil compacting by the LKT-81 tractor — centre of tyres, second experiment

Number of passages	Established characteristics	Depth [cm]	5	10	15	20	25	30
		0						
Non compacted soil	OH	1587.6	1592.3	1600.6	1611.5	1624.9	1641.1	1659.8
	S-OH	1054.1	1057.3	1064.5	1067.3	1089.5	1107.2	1128.3
	OV	533.6	535.2	536.3	536.4	535.3	533.1	529.9
	W	50.76	50.33	49.72	49.03	48.25	47.38	46.56
1-st passage	OH	1674.3	1684.4	1694.4	1701.5	1705.1	1707.1	1705.7
	S-OH	1103.3	1118.1	1132.2	1141.3	1145.6	1145.1	1139.6
	OV	575.8	568.9	563.4	561.4	562.7	567.5	575.6
	W	51.93	50.78	49.79	49.30	49.32	49.83	50.85
2-nd passage	OH	1680.77	1708.7	1733.2	1745.9	1747	1736.4	1714.1
	S-OH	1126.3	1152.5	1175.4	1187.4	1188.5	1178.7	1158.1
	OV	625.1	566.2	558.1	555.3	553.9	553.1	552.6
	W	61.52	49.54	47.89	47.34	47.06	46.89	46.78
3-rd passage	OH	1676.6	1707.6	1734.4	1747.7	1747.7	1734.3	1707.6
	S-OH	1115.7	1143	1166.9	1179.5	1180.7	1170.6	1149.2
	OV	525	558.6	563.3	564.9	565.6	566.1	566.4
	W	50.65	49.67	48.74	48.18	47.97	48.12	48.62

the only difference that in the 0 to 5 cm soil layer soil compacting increased by 78.5 kg.m⁻³, compared to the second passage. This increment of compactedness was caused by the pulled logs.

Data in Tab. IV to VI give the coefficients of equations, the form of compensation of the equations being $y = A + BX + CX^2$. The tables contain also selected basic statistical characteristics of compensated values. The indices of correlation indicate a suitable correlation dependence in the investigated population.

Established data correspond with the theory of the spreading of tension in the soil where in the field of radial shear one system of sliding surface has the form of rays whereas the second one appears in the system of logarithmic spirals (Svoboda, 1968). But the great variability of soil properties may cause that the mentioned results need not always be repeated nor confirmed by the compacting of soil between the wheel tracks.

In addition to the establishment of change in the volume weight of soil the state of soil humidity (W) was established. In this respect it can be stated that by the compacting of soil humidity does not increase; measurements carried out immediately after the passage of the tractor showed that soil humidity always diminished after the passage, although it could be expected to increase after compacting. This is caused probably by the fact that by loading the soil the orientation of pores changes in such a way that vertical pores become horizontal pores which serve practically as a drainage network for draining off the water after heavy loading of the soil.

III. Soil characteristic before and after soil compacting by the LKT-81 tractor — between the wheel tracks

Number of passages	Established characteristics	Depth [cm]						
		0	5	10	15	20	25	30
Non disturbed soil	OH	1568.8	1588	1610	1630	1648	1664	1678
	S-OH	1104.5	1122.1	1143.2	1163.4	1182.6	1200.8	1218.1
	OV	463.1	465	466.3	466.5	465.5	463.4	460
	W	41.92	41.41	40.75	40.05	39.33	38.59	37.82
1-st passage	OH	1688	1731.2	1775.2	1808.0	1829.9	1839.9	1839
	S-OH	1247.1	1284	1321.6	1350.3	1369.8	1380.3	1381.7
	OV	452.1	453.7	455.4	456.6	457.5	458	458.1
	W	36.35	35.42	34.5	33.80	33.36	33.16	33.20
2-nd passage	OH	1698.61	1740.76	1779.81	1803.71	1812.45	1806.04	1784.5
	S-OH	1183.9	1227.6	1271.7	1304.1	1324.8	1333.8	1331.1
	OV	515.3	514.2	509.5	501.1	489.1	473.5	453.4
	W	43.46	41.96	40.19	38.53	36.97	35.52	34.18
3-rd passage	OH	1803.55	1787.9	1777.6	1777.7	1788.1	1808.7	1839.7
	S-OH	1294.6	1284	1278.1	1280.3	1290.7	1309.3	1336.1
	OV	509.1	503.8	499.3	497.1	497.2	499.5	504.1
	W	39.34	39.26	39.08	38.84	38.53	38.16	37.72

DISCUSSION AND CONCLUSION

The volume weight of forest soil increases with growing depth of the soil and in the horizon from zero to 30 cm ranges approximately from 1,530 kg.m⁻³ at a zero depth to 1,680 kg.m⁻³ at the depth of 30 cm. The OH increase of forest soil is caused mainly by the first passage of the tractor when the OH increase is the largest. After further passage of the tractor OH increases only minimally, or does not change at all. The OH increment of soil can be registered both under the wheel track and in the active zone between the wheel tracks, or in the exterior zones of the track. The largest increment of soil compacting is observed to the depth of 15 cm in the centre under the tyres and between the wheel tracks in the depth of 20 to 30 cm.

If it is valid that for the OH of the soil exceeding 1.8 g.cm⁻³ root penetration ceases to exist, then the experimentally established values approach this limit, or even exceed it, consequently the compacting of the soil by the LKT 81 tractor is rather high and ecologically dangerous, especially when taking into account that to the compacting of soil itself root losses and root damage must be added; therefore the resulting combination effect of the various components of damage is very serious. In general, damage caused by soil compacting with the combination effect of damage to the root system depend mainly on site class, tree species, momentary state of the soil, parameters of machines, velocity of passage and technology applied. Certain authors (Campbel, 1973) report that a machine with an average soil pressure of 130 kPa may cause already at the first passage an OH increase from 1.34 to 1.41 g.cm⁻³.

IV. Selected statistical characteristics (centre of the tyre track, first experiment)

Number of passage	Established characteristics	Regression equation	Equation coefficients			Arithmetic mean		Standard deviation		Corelation index	Absolute mean error SYX
			A	B	C	X	Y	SX	SY		
Non disturbed soil	OH	$y = A + BX + CX^2$	1527.45	6.64779	-0.0725394	13.35	1596.25	9.83764	45.0028	0.9876	7.0603
	S-OH		1066.68	5.50549	-0.060662	13.35	1123.5	9.83764	36.6964	0.9985	2.00919
	OV		460.549	1.17124	-0.0130771	13.35	472.583	9.83764	10.3531	0.7482	6.86903
	W		43.1374	-0.101526	1.12581	13.35	42.0917	9.83764	0.932735	0.7225	0.644866
1-st passage	OH		1671.63	0.117112	0.369783	12.3308	1682.46	10.0856	16.4848	0.575	10.7714
	S-OH		1177.86	-1.14165	0.0947846	12.3308	1187.95	10.0986	21.8604	0.8452	11.6833
	OV		493.799	1.25409	-0.0583078	12.3308	494.462	10.0896	8.89786	0.80	5.45305
	W		41.9213	0.14276	-8.01863	12.3308	41.6462	10.0896	1.38641	0.8492	0.732121
2-nd passage	OH		1680.44	7.73686	-0.16233	13.35	1739.08	9.83764	33.8932	0.94	11.5728
	S-OH		1215.54	9.16937	-0.219199	13.35	1277.67	9.83764	34.5525	0.9403	11.7598
	OV		464.708	-1.84015	0.709994	13.35	459.667	9.83764	13.2565	0.55	11.1242
	W		37.7598	-0.292832	8.84682	13.35	36.2833	9.83764	1.45069	0.60	1.16649
3-rd passage	OH	1701.02	2.42428	0.034358	13.35	1742.83	9.83764	42.3497	0.8068	25.0213	
	S-OH	1219.1	0.670904	0.0725157	13.35	1248	9.83764	33.5578	0.8601	17.1187	
	OV	490.735	0.76777	-0.018115	13.35	496	9.83764	7.77315	0.5548	7.26745	
	W	40.8263	-0.0271222	-2.02142	13.35	35.5083	9.83764	0.894523	0.9898	0.127437	

V. Selected statistical characteristics (centre of the tyre track, second experiment)

Number of passage	Established characteristics	Regression equation	Equation coefficients			Arithmetic mean		Standard deviation		Corelation index	Absolute mean error SYX
			A	B	C	X	Y	SX	SY		
Non disturbed soil	OH	$y = A + BX + CX^2$	1586.71	0.863993	0.052431	13.35	1612.67	9.83764	29.7993	0.8226	16.9445
	S-OH		1053.61	0.395137	0.698588	13.35	1075.1	9.83764	28.8249	0.8815	13.6107
	OV		533.052	0.547488	-0.217162	13.35	534.389	9.83764	7.09533	0.6196	6.7232
	W		50.8578	-0.959632	-0.172652	13.35	49.0526	9.70745	2.69657	0.5341	2.27974
1-st passage	OH		1671.56	2.85218	-0.0571599	13.35	1693.92	9.83764	13.4257	0.9199	5.26494
	S-OH		1099.17	4.27369	-0.0974627	13.35	1129.42	9.83764	16.2942	0.9819	3.08612
	OV		577.836	-2.12245	0.068311	11.8071	565	9.90422	10.288	0.6199	8.07283
	W		52.2701	-0.348035	0.0100318	11.5615	50.6385	10.2369	1.39972	0.7539	0.919604
2-nd passage	OH		1672.6	8.39484	-0.233666	13.35	1720.42	9.83764	26.4906	0.9632	7.12029
	S-OH		1118.69	7.84709	-0.217755	13.35	1163.57	9.83764	26.3605	0.9068	11.1126
	OV		549.859	83.5116	-8.37975	13.02	555.6	10.7462	5.13612	0.7001	6.5236
	W		46.2148	16.9856	-1.67521	13.02	47.9091	10.2619	1.55011	0.63	1.20381
3-rd passage	OH		1667.55	9.35636	-0.267432	13.35	1718.92	9.83764	30.3727	0.9214	11.8033
	S-OH		1107.78	8.18193	-0.226683	13.35	1154.67	9.83764	29.1848	0.8549	15.1408
	OV		568.043	-47.9033	4.85984	13.2	565.727	10.2619	8.24621	0.6176	6.48558
	W		50.93	-0.289238	7.07862E-03	13.2	49.0909	10.2619	1.66654	0.605	1.32694

VI. Selected statistical characteristics (between the wheel tracks)

Number of passage	Established characteristics	Regression equation	Equation coefficients			Arithmetic mean		Standard deviation		Correlation index	Absolute mean error SYX
			A	B	C	X	Y	SX	SY		
Non disturbed soil	OH	$y = A + BX + CX^2$	1563.86	5.02030	-0.0407819	13.35	1619.67	9.83764	38.7134	0.9889	9.5798
	S-OH		1100.05	4.51308	-0.0192725	13.35	1155	9.83764	35.1216	0.9901	5.49125
	OV		462.558	0.607421	-0.0230316	13.35	464.333	9.83764	3.91112	0.5859	3.16551
	W		42.05	-0.124966	-5.3946504	13.35	40.2333	9.83764	1.39269	0.998	0.0880367
1-st passage	OH		1676	12.1592	-0.224203	13.35	1776.67	9.83764	59.9062	0.9545	17.8647
	S-OH		1237.04	10.2804	-0.181946	13.35	1324.25	9.83764	56.0469	0.8958	24.9104
	OV		461.106	-54.0832	5.31226	13.35	455.5	9.83764	8.95824	0.5761	8.33052
	W		36.6006	-0.259774	4.8812E-03	13.35	34.475	9.83764	1.74682	0.6868	1.26967
2-nd passage	OH		1686.56	12.3555	-0.303042	13.35	1768.17	9.83764	44.1022	0.9636	11.7906
	S-OH		1171.87	12.3264	-0.233957	13.35	1272.08	9.83764	58.3084	0.9667	14.9218
	OV		515.275	0.143097	-0.0724901	13.35	497.25	9.83764	24.5293	0.8622	12.4258
	W		43.8403	-0.385772	2.12623E-03	13.35	39.275	9.83764	3.43471	0.9235	1.31755
3-rd passage	OH		1808.5	-5.14364	0.206317	13.35	1796.5	9.83764	25.2488	0.8639	12.7167
	S-OH		1296.12	-3.64177	0.163626	13.35	1294.5	9.83764	23.5	0.8402	12.7435
	OV		510.629	-1.58536	0.455849	13.35	502	9.83764	12.0137	0.40	11.0434
	W		39.3638	-0.0143452	-1.35389	13.35	38.8	5.83764	1.3922	0.40	1.27616

The humidity of soil decreases with increasing depth of the forest soil and depends on the physical, biological and mechanic state of the soil. After soil compacting the humidity of soil does not increase nor does wetting occur, but when exceeding a certain limiting condition passages of the tractor may turn the soil into mud by creating tracks, because the soil is loaded, in addition to contact pressure, by shear tension.

As can be seen, the problem of establishing changes in forest soil, when loaded by skidding or logging machines, is rather complicated, extensive and little known. This paper does not claim to be comprehensive, since research should cover the different types of soil, various mechanical equipment and technological procedures, but it is hoped that even in the present form it may help to understand the relations between the soil and the machine in their mutual connexions.

SUMMARY

With the increasing mechanization of logging operations in the forest increases also the extent and degree of damage caused to forest soil. Special wheel forest tractors are widely responsible for the deteriorating state of forest soil. By compacting the soil, changing the water regime and affecting the micro-morphology of soil they have an important influence on the production capacity and the sanitary condition of forests. Studying the influence of wheel technics (LKT-81 tractor) it has been established that the largest increase of the volume weight of the soil occurs already after the first passage of the tractor to the depth of 15 cm. Also selected characteristics of the soil after further passages of the tractor were established. The results of the experiment showed that the influence of the LKT-81 tractor on changes in the soil are ecologically dangerous because already individually observed soil changes are serious and by their combination the unfavourable effect is combined and multiplied.

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DEMKO, J. (Vysoká škola lesnícka a drevárska, Zvolen): *Zhutňovanie lesných pôd sústreďovacími prostriedkami (Špeciálny lesný kolesový traktor LKT-81)*. Lesníctví, 36, 1990 (11): 921–930.

S postupnou mechanizáciou ťažbových prác v lese, vzrastá rozsah a stupeň poškodenia lesných pôd. Poškodenie lesných pôd vo forme zhutnenia a zmeny vodného režimu má významný vplyv na produkčnú schopnosť a zdravotný stav lesov. Pri zisťovaní vplyvu kolesovej techniky (LKT-81) sme zistili, že najväčší prírastok objemovej hmotnosti pôdy je po prvej jazde traktora do hĺbky 15 cm. Po druhej jazde traktora sledujeme ešte mierny nárast objemovej hmotnosti pôdy, po tretej jazde je nárast objemovej hmotnosti pôdy minimálny. Za zónu zhutňovania pôd môžeme považovať aj priestor medzi stopami kolies, kde sme zistili, že prírastok objemovej hmotnosti (OH) pôdy je najvýraznejší po prvej jazde traktora a to v hĺbke 20–30 cm. Ďalej bolo zistené, že zhutňovaním

pôd nedochádza k zvýšeniu vlhkosti pôdy, ale práve naopak jej poklesu. Vplyv LKT na zmeny v pôde sa ukázali ako ekologicky nebezpečné, nakoľko už jednotlivé sledované zmeny v pôde sú veľmi závažné a pri ich kombináciách sa znásobuje ich nepriaznivý kombinačný efekt.

lesná technika; lesná ťažba; sústreďovanie; zhutňovanie pôd; lesné pôdy

DEMKO, J. (Hochschule für Forst- und Holzwirtschaft, Zvolen): *Waldbodenverdichtung durch Einsatz von Rückungsmitteln (Spezieller Waldtraktor LKT-81)*. Lesnictví, 36, 1990 (11): 921–930.

Mit der fortschreitenden Mechanisierung der Holznutzungsarbeiten im Walde nehmen auch der Umfang und die Beschädigung der Waldböden zu. Die Beschädigung der Waldböden durch Verdichtung und das veränderte Wasserregime üben einen bedeutenden Einfluss auf das Produktionsvermögen und den Gesundheitszustand der Wälder aus. Bei der Auswertung des Einflusses der Radtraktoren (LKT-81) stellten wir fest, dass die grösste Bodenverdichtungszunahme nach der ersten Fahrt des Traktors in eine Tiefe von 15 cm zu verzeichnen ist. Nach dem zweiten Befahren stellen wir noch eine geringe Bodenverdichtungszunahme fest, nach dem dritten Befahren ist die Bodenverdichtungszunahme vernachlässigbar. Als Verdichtungszone können wir auch den Raum zwischen den Radspuren ansehen. Hier stellten wir fest, dass die Bodenverdichtungszunahme nach dem ersten Befahren des Traktors in einer Tiefe von 20 bis 30 cm am ausgeprägten ist. Ferner stellten wir fest, dass es infolge der Bodenverdichtung keinesfalls zur Steigerung der Bodenfeuchtigkeit sondern zu ihrer Senkung kommt. Der Einfluss von LKT auf Bodennumwandlungen ist ökologisch gefährlich, da schon die einzeln untersuchten Bodennumwandlungen sehr bedeutend und tiefgreifend sind und bei ihrer Kombination sich ihr ungünstiger Kombinationseinfluss wesentlich multipliziert.

Waldtechnik; Holzgewinnung; Rückung; Bodenverdichtung; Waldböden

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PROPOSED TECHNOLOGY OF AERIAL SKIDDING BY BALLOON SYSTEMS AND EXPERIMENTAL VERIFICATION ON MODELS

J. Astrab

ASTRAB, J. (Forest Research Institute, Košice): *Proposed technology of aerial skidding by balloon systems and experimental verification on models*. *Lesnictví*, 36, 1990 (11): 931–936.

Literature contains a number of findings concerning the adverse effects of the machines on the environment in forests. Seven technologies of aerial skidding, using the balloon rope systems, were proposed to contribute to solution of the problem. The proposed technologies were tested in models. The description of the technologies and findings concerning the behaviour of the balloon rope systems for skidding, operating when loaded and when exposed to atmospheric stresses, are summarized in this paper.

balloon aerial rope systems; skidding

Today's forestry is required not only to produce wood but also to fulfill some forest functions of overall societal importance. The possibility of using technological systems based on the lifting force of gases can be considered as a realistic approach to skidding operations. Though the use of aircraft lighter than air (balloons, airships) has had a long tradition, it is far from being common practice. Production of such aircraft declined in the 1930's. Nowadays a period of regeneration seems to begin.

Aerial skidding is of course better from the viewpoint of the biological requirements of forests, if compared with the ground systems used today, which have an adverse influence on the forest. A series of experiments was conducted with models of balloon rope systems and the first experience with their operation has already been gathered. The investigation had the following objectives: a) study of the behaviour of the balloon rope systems when carrying a load and under the influence of wind; b) determination of the percentage of exploitation of the maximum carrying capacity of the balloons.

METHODS

The experimental site was located near an aerological centre where the needed measurements of air temperature, air pressure and windspeed could be easily done and where the balloons could be safely filled. Angler's winches were anchored in a 50-metre work field and the ropes were simulated by 0.8-mm nylon threads, all depending on the requirements of the rope systems, and the behaviour of the balloon rope system was studied on this model.

The volume of the carrier gas in the balloon during filling and during the day was controlled by fixing known weights to the balloon. The filling of the balloon continued until the weight was lifted above the floor of the hall. The filled balloon was fixed to the prepared rope system. To prevent the balloon from tearing the "rope" (thread), exposed to excess dynamic stress, and flying away with the wind, a light parachute cord was used to anchor it.

The carrying capacity of the balloon rope systems was tested by shifting the balloon along the whole track. The used nylon threads, clamping aids and other materials for each system were weighed on the laboratory balance. The volume of the balloons was calculated on the basis of the uplift force of the carrier gas and the known weight of the control load.

CHARACTERISTICS OF THE SITE AND CLIMATIC CONDITIONS

Site: Meadow of the Aerological Centre of the Slovak Hydrometeorological Institute at Gánovce

Altitude above sea level: 706 m

Climatic conditions (values measured at 12.00 h Central European time):

Trial series 1: air temperature 1.2 °C
windspeed 2.0 m per s
barometric pressure 930.7 HPa
Overcast throughout the day

Trial series 2: air temperature 7.4 °C
windspeed 4.0 m per s
barometric pressure 920.0 HPa
Sunshine from 10.00 h.

Balloon used: Meteorological balloon, type 200

Carrier gas: Hydrogen.

RESULTS

a) THE HIGH-LEAD BALLOON ROPE SYSTEM

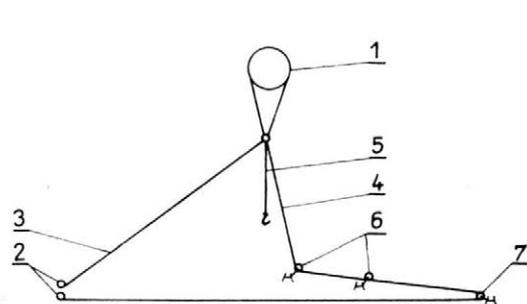
(Fig. 1)

The logs are transported fully suspended under the balloon, thus allowing for maximum utilization of the the balloon's lifting force. The balloon has a low stability when exposed to cross wind which carries it outside the direct track. When the load is drawn from a side the balloon moves to get above the load and does not pull the load towards the track until its lifting force is greater than the load's weight. The drawing of the balloon to the winch cannot be started sooner than the load leaves the ground. The theoretical lifting force of the balloon is utilized at 100 % (Tab. I).

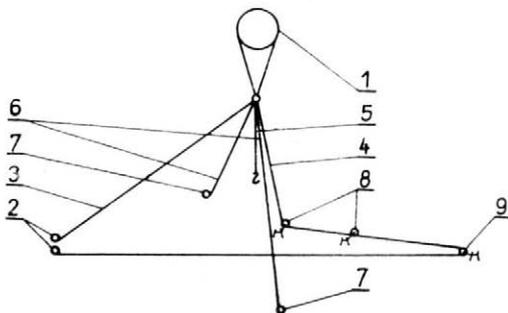
b) THE HIGH-LEAD BALLOON ROPE SYSTEM WITH SIDE ANCHORING

(Fig. 2)

Like in the preceding system, the load is transported in full suspension under the balloon with a maximum utilization of the balloon's lifting force. Side anchoring secures the stability of the system when it is exposed to cross wind, the anchors being controlled by means of winches and the ropes' length changing in dependence on the position of the balloon. Fixed anchors fail to fulfil their function along the whole length of the track, so they are useless. The carrying capacity is somewhat lower (Tab. II)



1. The high-lead balloon rope system (a):
1 - balloon, 2 - control winches, 3 - drag line,
4 - back line, 5 - fixing rope, 6 - descent
pulleys, 7 - return pulley



2. High-lead balloon rope system with side
anchoring (b): 1 - balloon, 2 - control winches,
3 - drag line, 4 - back line, 5 - fixing rope,
6 - anchoring ropes, 7 - winches of anchoring
ropes, 8 - descent pulleys, 9 - return pulley

I. Basic data on the balloon rope systems

System denoted as:	Length of work field	Carrier gas volume	MTCP of balloons	MTUCP of balloons	Weight of:				Actual useful carrying capacity	% utilization of MTUCP
					ropes	balloon fabric	carrier gas	total		
—	[m]	[m ³]	[kg]						—	
a	50	6.34	7.405	4.826	0.227	1.559	0.793	2.579	4.826	100
b	50	6.34	7.405	4.805	0.248	1.559	0.793	2.600	4.805	100
c	50	6.34	7.405	4.838	0.216	1.559	0.793	2.567	4.838	100
d	50	6.34	7.405	4.535	0.518	1.559	0.793	2.870	2.632	58
e	50	6.20	7.242	4.585	0.327	1.559	0.776	2.532	3.927	86
f	50	6.20	7.242	4.738	0.173	1.559	0.776	2.508	4.738	100
g	50	12.54	14.651	9.220	0.655	3.208	1.568	5.431	5.872	64

Explanatory notes: MTCP — maximum theoretical carrying capacity
 MTCUP — maximum theoretical useful carrying capacity

II. Comparison of the achieved useful carrying capacities of the balloon systems

Balloon system	a	b	c	d	e ⁺	f ⁺
Useful carrying capacity [kg]	4.826	4.805	4.832	2.632	4.009	4.880
Useful carrying capacity [%]	100.0	99.56	100.25	54.54	84.75	101.12

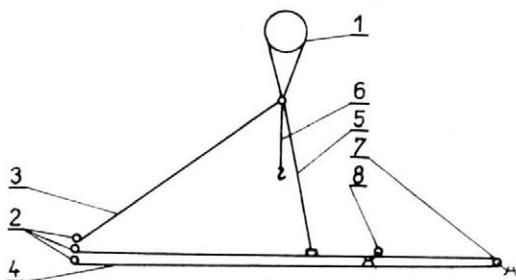
than in the system shown in Fig. 1, but this drawback is offset by good stability. The system is technically exacting.

c) BALLOON ROPE SYSTEM WITH LOOSENED BACK LINE (Fig. 3)

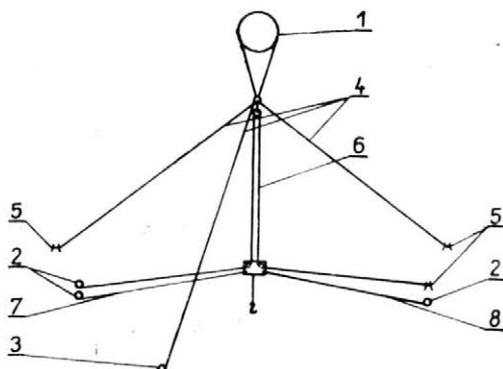
The load is carried in a similar way to the preceding system, with full suspension and with maximum use of the lifting force of the balloon. When it is pulled to the forest stand, the balloon's stability in cross wind is low but during the skidding of the load, when the back line is disengaged and the balloon remains connected only with the load and the drag line, cross wind is no longer a limiting factor. The balloon moves above the forest stand and stabilizes in its direction when the front resistance of the wind is the smallest. It has a somewhat higher carrying capacity than the preceding system (Tab. II). It is technically less exacting and is suitable mainly for improvement cutting.

d) THE PENDULUM-SWING BALLOON SYSTEM (Olsen, 1984) (Fig. 4)

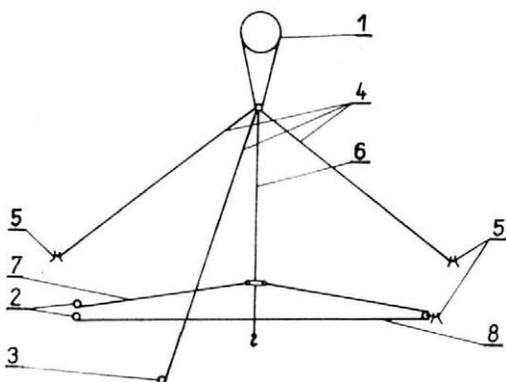
The load is carried in full suspension but is lifted by tightening the pendulum-swing line, drawn over a pulley under the balloon. The system is stable in relation to cross wind but the balloon must be high above the terrain. The maximum useful carrying capacity is achieved in the middle of the track but towards the ends the carrying capacity declines. In the case tested, the actual carrying capacity is 58 % of the maximum useful carrying capacity (Tab. I). The system is technically too sophisticated and the achieved stability does not offset the poor exploitation of the balloon's lifting force (Tab. II).



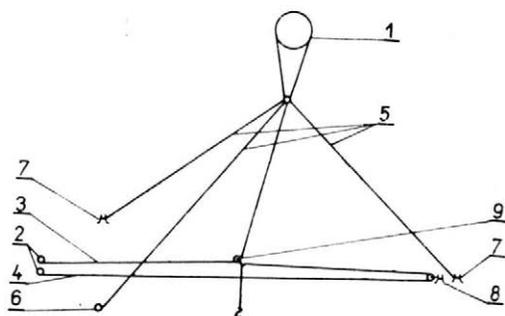
3. Balloon rope system with loose back line (c): 1 - balloon, 2 - control winches, 3 - drag line, 4 - back line, 5 - fixing rope, 6 - clamping pulley, 7 - return pulley, 8 - descent pulley



4. Pendulum-swing balloon system (d): 1 - balloon, 2 - control winches, 3 - anchoring rope winch, 4 - anchoring rope, 5 - fixed anchors, 6 - lifting cable, 7 - drag line, 8 - back line



5. Balloon rope system with vertical and partial horizontal balloon movement (3): 1 – balloon, 2 – control winches, 3 – anchoring rope winch, 4 – anchoring ropes, 5 – fixed anchors, 6 – clamping rope, 7 – drag line, 8 – back line



6. Balloon rope system with vertical movement of balloon (f): 1 – balloon, 2 – control winches, 3 – drag line, 4 – back line, 5 – anchoring rope, 6 – anchoring rope winch, 7 – fixed anchor, 8 – return pulley, 9 – skidding pulley

e) BALLOON SYSTEM WITH VERTICAL AND PARTIALLY HORIZONTAL BALLOON MOVEMENT (DERIVED FROM THE PENDULUM-SWING SYSTEM) (Fig. 5)

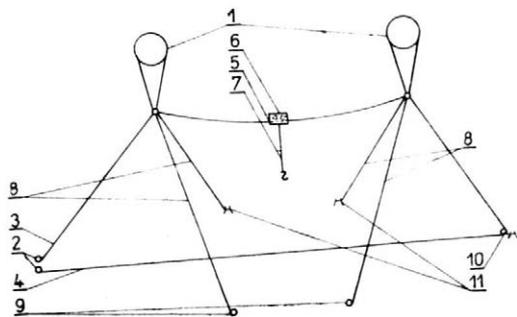
The load is carried in full suspension and is lifted by vertical movement of the balloon, the anchoring ropes being controlled by means of winches. Along the track the load is pulled by the drag line and the balloon moves horizontally at the same time: to let the balloon move, the most distant anchoring rope in the axis of the track slackens. The system is stable in wind and, compared with the shuttle balloon system, its carrying capacity is much greater (Tab. II). In the particular case tested the difference was about 30 %. However, the system is technically exacting.

f) BALLOON ROPE SYSTEM WITH VERTICAL MOVEMENT OF BALLOON AND WITH HALF-SUSPENSION SKIDDING (Smrčka, 1986) (Fig. 6)

The load is carried half-suspended with maximum exploitation of the balloon's lifting force. The height of the balloon above the terrain is directly proportional to the length of the skidding track in order to provide sufficient tension of the skidding line. Without further adjustment the system is suitable for terrains with slopes up to 20° in summer and up to 10° in winter to avoid the unprotected logs' gliding downhill by their own weight. If the system is to be used in terrains with steeper slopes the load has to be braked, otherwise it would become uncontrollable after lifting. The system is stable against cross wind and has a promising field of use in the clearcut systems of management.

g) TWO-BALLOON ROPE SYSTEM (Fig. 7)

The load is carried in full suspension and the lifting force of the balloons is utilized at 60 to 70 % along the whole track. At each end the effect of the other balloon is comparatively low, but it secures safe arrival of the logs at the yard. The load is braked by the carrying rope, so no special braking is needed. The length of the carrying rope between the two balloons should not be greater than 50 % of the length of the track, otherwise the rate of exploitation of the lifting force would decrease. The system is technically demanding.



7. Two-balloon rope system (g): 1 – balloon, 2 – control winches, 3 – drag line, 4 – back line, 5 – track line, 6 – carriage, 7 – clamping rope, 8 – anchoring ropes, 9 – winches of anchoring ropes, 10 – return pulley, 11 – fixed anchors

CONCLUSION

The trials with the models of balloon rope systems demonstrated the advantages and weak points of the tested systems. They also showed how complex and technically exacting each system is. It follows from the trials that the side anchoring of the balloons significantly increases their stability in relation to wind and prevents the balloon from drifting aside. Of course, side anchoring increases the technical complexity of the system.

The results confirm that further efforts have to be focused on developing balloon rope systems guaranteeing maximum utilization of the lifting force of the balloons and a high stability in wind with the use of side anchoring. Systems b), c), f) are suitable for border cutting, system c) for improvement cutting, and system g) for selection and shelterwood cutting.

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ASTRAB, J. Výskumná stanica VÚLH, Košice): *Návrh technológií približovania dreva balónovými systémami s experimentálnymi overeniami na modeloch*. Lesníctví, 36, 1990 (11): 931–936.

Lesné prostredie je v poslednom čase vystavené veľkému tlaku negatívnych vplyvov, vyvolaných činnosťou človeka. Jedným z nich je aj technizácia lesného hospodárstva. Pre zníženie jej negatívneho dopadu na les, bolo navrhnutých sedem technológií približovania dreva balónovými lanovými systémami a následne boli tieto experimentálne odskúšané na modeloch balónových lanových systémov. Zo získaných výsledkov vyplýva, že balónové systémy sú veľmi citlivé najmä na bočný vietor. Ich stabilitu proti vetru je možné preto zvýšiť použitím bočného kotvenia balónov. Okrem vplyvu vetra nás zaujímalo aj využitie maximálnej teoretickej užitočnej nosnosti balónov pozdĺž celej približovacej trasy. V tab. I vidíme, že túto možnosť maximálne využívajú balónové lanové systémy s pohybom balónu pozdĺž celej približovacej trasy. U ostatných systémov sú straty značné. Podobné výsledky sú i pri vzájomnom porovnaní dosiahnutých užitočných nosností (tab. II). Na základe získaných výsledkov sú pre ďalšie pokusy odporúčané modely b, c, f pre holohrubné a odrubné formy hospodárenia, model c pre výchovné ťažby a model g pre výberkové a podrastové formy hospodárenia.

balónové lanové systémy; približovanie dreva

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A CONTRIBUTION TO UNDERSTANDING OF OIL DISPERSION AT THE WORK WITH A CHAIN SAW BY MEANS OF THE RADIOTRACER METHOD

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SKOUPÝ, A. — PECHLÁK, B. — SEJKORA, P. (Faculty of Forestry, University of Agriculture, Brno; Institute for Development, Production and Utilization of Radioisotopes, Praha): *A contribution to understanding of oil dispersion at the work with a chain saw by means of the radiotracer method*. *Lesnictví*, 36, 1990 (11): 937–946.

A considerable part of oil used for lubrication of power saw chains is dispersed to the environment. To understand its dispersion a method was elaborated based on the use of radiotracers. The lubricating oil was labelled with radiotracers which facilitated its later quantification in the environment. The present paper provides verification of the radiotracers ^{113m}In and ^{82}Br . The latter was experienced to be more suitable. Experimental measurement evaluating the appropriateness of the proposed method revealed that 64.4 % of the oil used for chain lubrication was retained in sawdust, 21.9 % of it fell to the soil surface and 8.3 % stuck on the cut and its close vicinity. 5.4 % of the oil was not caught by the measurement, it got mostly to the air in the form of aerosol. The highest oil concentration on the soil surface was determined up to $1 \text{ ml} \cdot \text{m}^{-2}$, the average concentration amounted to $0.074 \text{ ml} \cdot \text{m}^{-2}$. The method can be used for quantification of oil dispersed in any place. It can also be used for measuring of aerosol escape, the amount of oil inhaled by the power saw operator, etc.

forest machinery; chain saws; lubricating oils; dispersion in the environment

During the recent years the questions concerning environmental pollution with oil and its derivatives have become a subject of interest in the professional and lay public. Considerable escapes of oil products to the environment are well-known and often discussed. They occur in oil transportation or in crashes of oil-product-storehouses.

In our country news very often appear in the press on large or small escapes of oil substances to watercourses or to underground waters. Conservationists caution emphatically against water and soil pollution with even small amounts of oils, for example when exchanging oil in a motor-car engine or when washing motor vehicles.

Moreover, it is well-known that using machines in forestry is responsible for continuous forest pollution caused by the escape of hydraulic, engine and gear-box oils due to untightness of oil charges and their refilling direct at the working place.

Nevertheless, these leahages can be prevented or limited considerably, at least, by taking suitable technical and organizational measures. We cannot avoid, however, escapes of oils used in lubrication of the chains of chain saws where the oil dispersion is given by the technical principle of operation of these machines. With regard to the fact that the cutting chains are the principal structural element of cutting components of petrol- and electric-powered saws and some other, especially cutting machines, the amount of oil consumed for their lubrication is considerable.

PROBLEMS

During its motion on the guide bar the cutting chain is exposed to a number of forces which are responsible for friction between the chain and the guide bar and between

individual links of the chain. The theory of forces originated in sawing was verified by Petříček (1973, 1978).

The velocity of the chain in sawing reaches the value of 16 to 18 m.s⁻¹, at maximum no-load engine overspeed it attains even more than 25 m.s⁻¹. Lubrication of the chain is thus necessary to remove solid friction which is responsible for excessive wear of the chain and of the guide bar and for considerable losses in engine power.

Lubrication of the chain is secured by an oil pump driven from a crankshaft which pumps the oil from the oil reservoir to the guide bar groove. Hence, the oil is distributed to all sliding surfaces by chain motion and spattered by centrifugal force (particularly in the terminal part of the guide bar) from the chain surface to the neighbourhood. The amount of oil pumped to the chain lubrication depends on type of the machine and on oil supply adjustment. It ranged most frequently from 12 to 25 ml per minute at surface cutting speed of the chain 18 m.s⁻¹.

When considering that power saws are among the most common forestry machines then it is no wonder that, for example within the framework of the South Moravian State Forests, the annual oil consumption for lubricating of power saw chains amounts to ca. 200,000 l.

The whole amount of oil used for chain lubrication does not get to the soil surface. A part of the oil is retained on both sides of the cut, i. e. on the cutting areas and on the sawed piece, a part is fixed in the sawdust falling to the ground cover, a part is caught on the logger's clothing and on the proper power saw and a part is sprayed into the air in the form of aerosol. A small amount of the oil is oxidized due to friction heat in the cutting part of the saw.

To recognize the actual condition it is necessary to quantify the amount of the oil dispersed to the environment. On the basis of this quantification it would be possible to draw conclusions about its concentration on the soil surface and thus about its harmfulness.

Quantification of environment-dispersed oil using classical methods is unfeasible. The method based on determination of the weight of the oil falling on the soil surface was quite inconvenient. Nor chemical analysis using leaching solutions was suitable because other organic substances were extracted with the oil. Other methods, for example chromatographic ones, are too slow and expensive for this purpose.

It was necessary to choose quite a different method of measurement. Therefore, a radiotracer method for quantification of small amount of substances was developed.

Similar methods are used e. g. in the so-called nuclear medicine to estimate the motion, absorption and liberation of various substances, especially of pharmaceuticals, in living organism. In rubber industry radionuclide methods are applied for measuring the course of tyre wear on road surface. Other examples can be mentioned from hydrology, hydraulics, gas manufacture and further branches.

Nevertheless, oil dispersion measuring in the environment differs from all the approaches used up to now so that it was necessary to establish quite new original methods which would be the only ones to answer the following questions effectively:

- how much of the oil consumed for chain lubrication gets to the surface of the cut and to its close vicinity;
- how much of the oil is bonded in the sawdust originated in sawing;
- how much of the oil gets direct to the soil surface.

METHODS

The method of the measurement of oil dispersion is based on the labelling of lubricating oil in the oil tank of the power saw with a suitable liquid radiotracer in such a way to detect and quantify

it in any place. For verification of the applicability of the method described by Skoupy et al. (1990) a model approach was designed, simulating transverse cutting of the stem placed on 15 cm high stands. The amount of oil was measured in sawdust, on the soil cover surface and on the faces of cut samples.

First the ^{113m}In radiotracer with radioactive transformation half-life $T_{1/2} \approx 105$ min. was used for labelling of lubricating oil. This tracer was emulsified into OA M6A lubricating oil by means of primary mixture with emulsifying oil (drilling oil). The ratio of tracer water solution with emulsifying oil to the proper lubricating oil was approximately 3 : 6 : 91. The total activity of all the oil filling of the saw, 100 ml of oil emulsion, was 9 mCi (333 MBq). This tracer was used for two experiments of orientation character, the aim of which was to verify the basic principles of the method suggested.

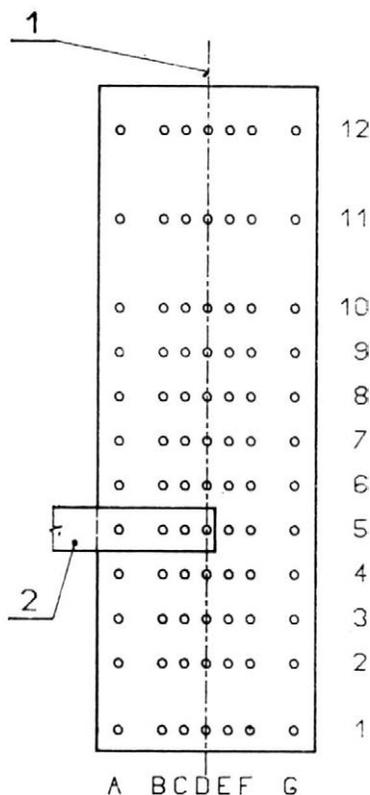
The third experiment, the results of which are reported in the present paper, was carried out with lubricating oil labelled with radionuclide ^{82}Br in the chemical form of $\text{C}_6\text{H}_5\text{Br}$ (bromobenzene) which is readily soluble in the OA M6A oil. The activity of filling of 100 ml in volume was 6 mCi (220 MBq), 0.5 ml $\text{C}_6\text{H}_5\text{Br}$ was used.

This tracer is less suitable from the hygienic point of view (active transformation half-life $T_{1/2} \approx 36$ hours), it allows no measurement within short time intervals (lapse of time) like with ^{113m}In , in which the measurement could be repeated in the same place as early as the second day. The advantage is the above-mentioned ideal solubility in OA M6A oil without changing its viscosity, higher energetical abundance of γ radiation, which is a precondition of higher accuracy of measurement. Furthermore, the advantage is that in short-term measurement, lasting tens of minutes, correction for radioactive transformation half-life need not be performed, which was necessary in the ^{113m}In .

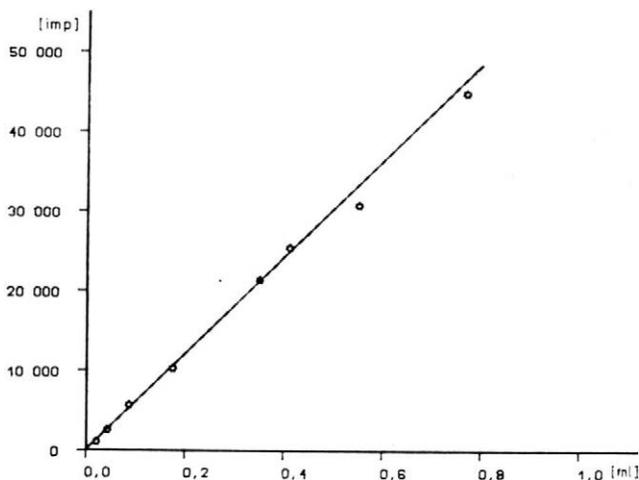
A ca. 4 cm disk was cut from a rough spruce stem sample 20 cm in diameter placed at 15 cm height above a 1×3 m pad using a chain power saw with lubricating oil labelled with the given radiotracer.

The exact location of the sample and the cut position are presented in Fig. 1, where the way of distribution of measuring points for determination of oil dispersion on the soil surface is indicated.

The proper measurement was carried out by the specialists from the Department of Radionuclide Methods of the Institute for Development, Production and Utilization of Radioisotopes, Praha.



1. Representation of measuring points and position of wood sample above the pad sized 1×3 m. 1 - cutting plane, 2 - test sample projection, A1 to G12 - measuring points for determination of oil dispersion on the soil surface. The sample is placed on stands at the height of 15 cm above the pad



2. Dependence of impulse frequency on the amount of oil labelled with ^{82}Br radiotracer. $N = 60797 \cdot M^{1.018}$; N - activity expressed as number of impulses (imp), M - oil amount (ml)

RESULTS

For the quantification of the oil amount it is necessary to express the dependence of the oil amount on the frequency of impulses originating by radioactive decay of the tracer during 20 seconds.

This dependence was estimated by spotting of different amount of oil labelled with the radiotracer on experimental pad and the measured value (impulse frequency) was recorded to Tab. I. The measurement was performed twice for each oil amount. The original activity of the pad without oil, i. e. the background activity, was then subtracted from the average of the both measurements. From these measurements the impulse frequency — oil amount curve was calculated (see Fig. 2).

The relationship computed for the determination of oil amount according to the impulse frequency is then

$$N = 60\,797 \cdot M^{1.018} \quad (\text{imp}) \quad (1)$$

where: N — the activity measured
 M — oil amount (ml)

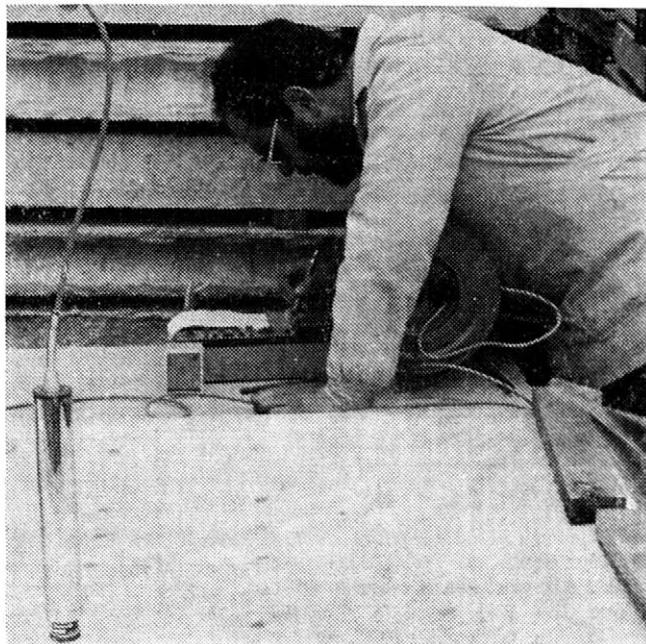
According to the activity of individual surfaces or materials in the proper measuring the absolute oil amount occurring on the object measured (and/or contained in it) can be calculated by the modified relationship

$$M = 1.99 \cdot 10^{-5} \cdot N^{0.9823} \quad (\text{ml}) \quad (2)$$

For the proper measurement the Husqvarna 180S chain saw was used, the oil pump of which was adjusted to supply 16 ml of oil per minute at the rated engine speed, i. e. 8500 min^{-1} . The air temperature during the measurement was $6.1 \text{ }^\circ\text{C}$,



3. Mode of saw holding and approach to sawing a wood sample with lubricating oil labelled with radiotracer



4. Measuring of oil concentration on a paper pad using the scintillation probe

I. Dependence of impulse frequency on oil amount labelled with ^{82}Br radiotracer. M — oil amount, N_v — measured sample activity, \bar{N}_v — average sample activity, \bar{N}_p — average background activity

Oil M [ml]	Sample activity N_v [imp]	Average \bar{N}_v [imp]	Average background activity \bar{N}_p [imp]	Pure sample activity $\bar{N}_v - \bar{N}_p$ [imp]
0.022	1 385 1 419	1 402	267	1 135
0.044	2 822 2 880	2 851	267	2 587
0.088	5 970 6 089	6 029	267	5 762
0.176	10 673 10 595	10 634	267	10 367
0.352	21 849 21 738	21 793	267	21 526
0.441	25 845 25 743	25 794	267	25 527
0.551	31 060 31 173	31 117	267	30 850
0.771	45 280 45 317	45 299	267	45 032

the relative air humidity attained 73 %. The wind speed did not exceed 1 m.s⁻¹. The cutting time with the ^{82}Br tracer was 3.8 sec. (Fig. 3).

Sawdust was dropped from the paper pad, the pad was covered with a polyethylene sheet and removed from the place of the measurement. Then a disk of about 4 cm in thickness was cut with another saw with pure unlabelled oil to measure the occurrence of oil on the cutting face.

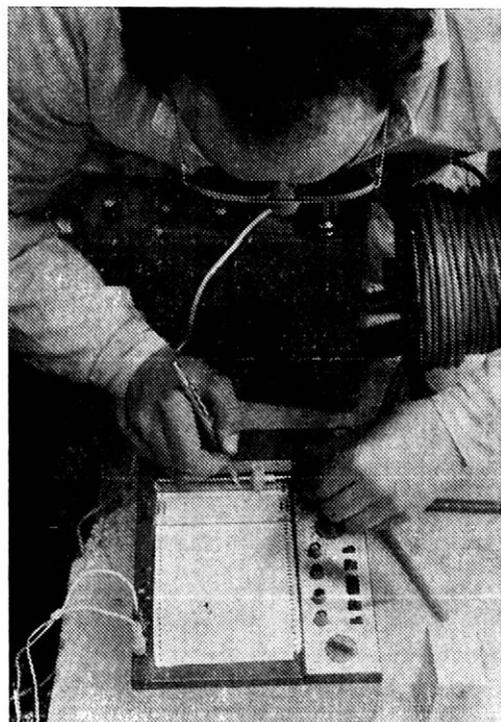
In the first part of oil dispersion measurement the oil falling to the pad was evaluated as far as its concentration in individual spots of the pad was concerned. The measurement was performed through a polyethylene sheet lest the measuring probe should contaminate with the labelled oil. The activity was measured on individual check points of the pad, for 10 seconds each. For the measurement the scintillation probe with TS-01 impulse counter and RE 501 — Miniger line compensation recorder were used. The scintillation probe was screened with a lead collimator (Figs. 4 and 5).

The results of this measurement are presented in Tab. II according to individual check points. The values of radioactivity at the individual points are expressed as percentages of the measuring level which was $3.3 \cdot 10^4$ (measurement range).

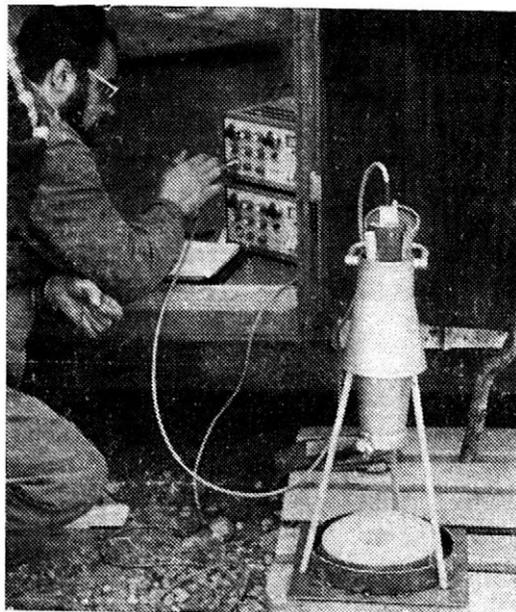
II. Oil concentration on the pad in individual measuring points. The upper part indicates percentages of measuring levels ($3 \cdot \bar{3} \cdot 10^4$), the lower part indicates corresponding oil concentration in $\text{ml} \cdot \text{m}^{-2}$

% of measurement level $\text{ml} \cdot \text{m}^{-2}$	A	B	C	D	E	F	G
12	7.0 0.016	9.0 0.021	11.0 0.025	13.0 0.030	11.0 0.026	10.0 0.023	8.0 0.010
11	9.0 0.021	12.0 0.028	15.0 0.035	16.0 0.038	11.0 0.026	11.0 0.026	10.0 0.023
10	12.0 0.028	19.0 0.045	24.0 0.056	25.0 0.059	18.0 0.042	15.0 0.035	12.0 0.028
9	20.0 0.047	35.0 0.082	55.0 0.129	68.0 0.162	34.0 0.080	25.0 0.059	16.0 0.038
8	29.0 0.068	54.0 0.127	83.0 0.195	115.0 0.270	57.0 0.134	35.0 0.082	19.0 0.045
7	32.0 0.075	67.0 0.157	120.0 0.281	258.0 0.604	89.0 0.209	47.0 0.110	20.0 0.047
6	30.0 0.070	70.0 0.164	138.0 0.323	423.0 0.992	121.0 0.284	58.0 0.136	20.0 0.047
5	23.0 0.054	49.0 0.115	89.0 0.209	206.0 0.483	80.0 0.188	43.0 0.101	22.0 0.052
4	19.0 0.045	36.0 0.084	52.0 0.122	76.0 0.178	48.0 0.113	30.0 0.070	19.0 0.045
3	14.0 0.033	24.0 0.056	37.0 0.087	94.0 0.220	41.0 0.096	26.0 0.061	16.0 0.038
2	14.0 0.033	18.0 0.042	26.0 0.061	32.0 0.075	26.0 0.061	20.0 0.047	15.0 0.035
1	9.5 0.022	12.0 0.028	16.0 0.038	19.0 0.045	17.0 0.040	12.0 0.028	10.0 0.023

The oil concentration, expressed in millimetres per square metre, was added to each such value. The oil distribution on the pad is presented graphically in Fig. 7 where curves demarcating areas of the same oil concentration are plotted in the scheme of the pad. The boundary values are chosen intentionally in such a way to record the second — lower — maximum of the occurrence of oil below the power saw, i.e. in the place of the fall of sawdust. For better illustration, longitudinal and transversal courses of oil distribution on the soil surface are drawn in this figure.



5. RE 501-Miniger compensation recorder



6. Measurement of absolute oil amount in the sample of material (cutting face) by the RFT 20046 single-channel spectrometer with TS-01 measuring probe in the foreground. The probe is screened with a lead collimator

After the measurement the paper pad and cover sheet were folded, their total activity being measured as well as the activity of the cut disk (cutting face) and the activity of the oil retained in sawdust. The approach to all these measurements is analogous in the same measuring geometry using the same instruments. The activity of individual materials was measured five times for 20 seconds each. The arithmetic mean was computed from the five measurements. In all measurements the background activity was subtracted from this average value. The results are presented in Tab. III.

To denote radioactivity of individual materials — to distinguish them — following symbols are used in the present paper:

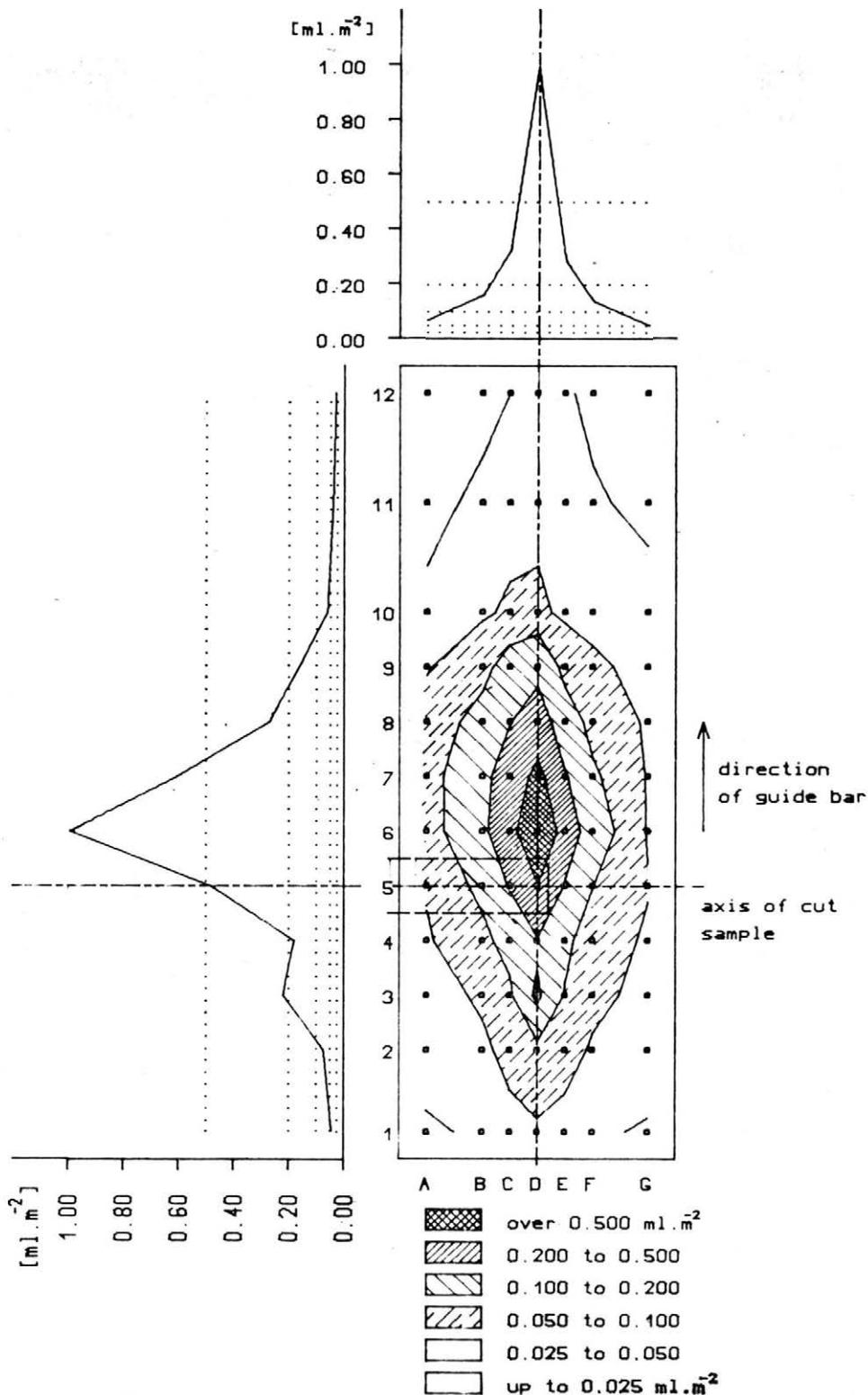
- N — the oil radioactivity measured in a given material or on its surface for twenty seconds — number of impulses
 \bar{N} — arithmetic mean of the values measured in impulses

- Indices: k — disk from the cutting face
 p — background (natural radioactivity)
 p_0 — paper pad 1×3 m
 f — covering polyethylene sheet
 p_i — sawdust formed in sawing with labelled oil
 v — sample for equipment calibration

The \bar{N}_{p_0} and \bar{N}_f values, thus the average paper pad and covering sheet activities (after subtraction of background activity) were summed and the total oil activity on the soil surface, i.e. 13 113 impulses per 20 seconds, was obtained.

From the relationship (2) the absolute oil amount for individual components was calculated. It was estimated that:

1. On the surface of one cutting face and in its close vicinity the average activity of 2 393 impulses was measured, which corresponds to 0.042 ml oil.



7. Graphical representation of lubricating oil concentration on the pad. The longitudinal profile is directed to the cutting plane in the points D, the cross profile is directed perpendicularly in the point of the maximum concentration — D6 point, where $0.992 \text{ ml} \cdot \text{m}^{-2}$ was measured

- In the sawdust the oil of $\bar{N}_{pi} = 39\ 344$ imp. activity was retained which corresponds to $M_{pi} = 0.652$ ml oil.
- On the pad, including the covering sheet, the total activity of 13 113 imp. was measured, i.e. $M_{po} = 0.222$ ml oil.

Analogously it was estimated that max. 0.002 ml oil was fixed to the logger's clothing. The total oil dispersion balance can be computed as follows:

$$M_c = m \cdot t = 2 \cdot M_k + M_{pi} + M_{po} + M_z \quad (3)$$

where: M_c – total oil supply for the time t (ml)
 m – average oil supply in cutting (ml. s⁻¹)
 t – cutting time (s)
 M_k – oil amount on cutting face and in its close vicinity (ml)
 M_{pi} – oil amount retained in sawdust (ml)
 M_{po} – oil amount on soil surface (ml)
 M_z – oil amount unretained by the measurement

Then:

$$M_c = m \cdot t = 0.267 \cdot 3.8 = 1.013 \text{ ml}$$

During one cutting 1.013 ml oil was consumed.

The unretained oil amount was then computed as follows:

$$M_z = M_c - 2M_k - M_{pi} - M_{po} = 1.013 - 2.0 \cdot 0.42 - 0.652 - 0.222 = 0.055 \text{ ml}$$

The measurement did not retain 0.055 ml oil, i.e. 5.4 % of the total supply. It is the oil which fell outside the pad, was retained on the surface of different parts of the power saw, on the logger's clothing, and/or it was dispersed in the form of aerosol, or it got oxidized by heat action on the guide bar surface when sawing.

CONCLUSION

The measurement of dispersion of the oil used for lubrication of cutting parts of power saws by means of radiotracer has confirmed the method to be simple, fast and relatively precise, which can be used not only for quantification of the amount of oil on individual surfaces and materials but also for determination of oil concentration in different points of the surface.

III. Activity N of individual materials and surfaces measured for 20 seconds. Denotation of individual indices: p – background, k – disk from cutting face ca. 4 cm thick, po – paper pad, f – polyethylene cover sheet, pi – sawdust

	Background activity N_p [imp]	Disk activity N_k [imp]	Pad activity N_{po} [imp]	Sheet activity N_f [imp]	Sawdust activity N_{pi} [imp]
1st measurement	240	2 639	11 304	2 282	39 670
2nd measurement	239	2 684	11 335	2 286	39 622
3rd measurement	238	2 606	11 538	2 175	39 613
4th measurement	240	2 670	11 120	2 219	39 461
5th measurement	248	2 570	11 557	2 158	39 539
N_x	1 205	13 169	56 854	11 120	197 925
\bar{N}_x	241	2 634	11 371	2 224	39 585
$\bar{N}_x - \bar{N}_p$	—	2 393	11 130	1 983	39 344

The measurement using ^{82}Br radiotracer showed that in transverse cutting of a lying spruce stem of 20 cm in diameter 1.013 ml of oil was consumed for 3.8 sec. cutting time, of which:

- 0.652 ml, i.e. 64.4 % was retained in sawdust;
- 0.084 ml, i.e. 8.3 % of oil was fixed to the cutting face and its close vicinity;
- 0.222 ml, i.e. 21 % of oil fell to the soil surface;
- the remaining oil, 0.055 ml in total, i.e. 5.4 % was dispersed outside these measured points, i.e. outside the pad, on the power saw surface, on the logger's clothing, etc. Its largest portion, however, remained probably in the atmosphere in the form of aerosol;
- the highest oil concentration determined on the soil surface was $0.992 \text{ ml} \cdot \text{m}^{-2}$, the average concentration amounted to $0.074 \text{ ml} \cdot \text{m}^{-2}$.

The above-mentioned method can be further modified and specified. Then it will enable direct measurement of the escape of oil aerosol to the atmosphere, detailed measuring of the contamination of the logger's clothing, the oil amount inhaled by the logger, etc. Likewise, the effects of air temperature, oil viscosity, oil type, oil pump dosing, etc. can be investigated. After modification this method can be used for measurement in all approaches to operation with the chain saw, i.e. in felling, trimming, etc. Furthermore, it can be used when determining oil concentrations even on larger areas, for example after total cutting treatment.

The results obtained in such a way can contribute to understanding the general harmfulness of oils in the natural environment, as far as pollution of soil, water, air and effects of oil on the health of loggers, etc., are concerned.

This method is probably the only possibility of oil dispersion measurement suitable for practical application with regard to its promptness and accuracy. The results obtained by this method, though the accuracy of measurement is estimated $\pm 10\%$, are quite sufficient for the given purpose.

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SKOUPÝ, A. — PECHLÁK, B. — SEJKORA, P. (Lesnická fakulta VŠZ, Brno; Ústav pro vývoj, výrobu a využití radioizotopů, Praha): *Příspěvek k poznání rozptylu olejů při práci s řetězovou pilou pomocí radioindikátorové metody*. *Lesnictví*, 36, 1990 (11): 937–946.

Olej používaný k mazání řetězů motorových pil je z velké části rozptylován do prostředí. K poznání jeho rozptylu byla vypracována metodika založená na použití radioindikátorů, kterými je mazací olej označen a které umožňují jeho pozdější kvantifikaci v prostředí. V práci je ověřeno použití indikátorů ^{113}mIn a ^{82}Br , z nichž druhý se jeví jako vhodnější. Při pokusném měření ověřujícím vhodnost navržené metody bylo zjištěno, že olej používaný k mazání řetězu je ze 64,4 % zachycen v pilinách, na půdní povrch dopadá 21,9 % a 8,3 % ulpí v řezné spáře a jejím blízkém okolí. 5,4 % oleje nebylo měřením zachyceno, z největší části se dostává do ovzduší ve formě aerosolu. Nejvyšší zjištěná koncentrace oleje na půdním povrchu byla do $1 \text{ ml} \cdot \text{m}^{-2}$, průměrná koncentrace byla $0,074 \text{ ml} \cdot \text{m}^{-2}$. Metoda může být využita ke kvantifikaci rozptýleného oleje na jakémkoliv místě. Lze jí měřit i úlet aerosolu, množství oleje vdechovaného obsluhou motorové pily apod.

lesnická technika; řetězové pily; mazací oleje; rozptyl v prostředí

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OIL INFILTRATION INTO THE SOIL AND ITS EFFECT ON ECOLOGICALLY IMPORTANT SOIL PROPERTIES

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GRUNDA, B. — ULRICH, R. (Faculty of Forestry, University of Agriculture, Brno): *Oil infiltration into the soil and its effect on ecologically important soil properties*. *Lesnictví*, 36, 1990 (11): 947–958.

An experiment was carried out to study the infiltration of the OTH-P-3 (Hydyn) oil into the soil in two localities. Differences were found in oil infiltration in relation to the physical properties of the soil. The soil containing oil exhibited lower moisture and air content, lower specific gravity and porosity. Volume weight was increased. Growth conditions deteriorated abruptly. The quality of ground water was seriously endangered by oil infiltration. The construction of catchpits was recommended where the risk of oil spills into the environment appeared. The study reveals the danger of health damage by hydraulic oils.

mineral oils; physical properties of soil; soil organisms; protection of soil and water

INTRODUCTION

The natural environment is increasingly endangered by the activity of man. Interventions into the balanced conditions of natural ecosystems are frequently caused by economic activities such as road building, mining operations, industrial air pollution, large-scale logging operations, etc. The natural environment can be also damaged by oil or diesel oil spills and their infiltration into the soil. These substances can particularly endanger water resources, viz water quality in watercourses or ground water quality. They also affect soil properties and living components of the ecosystem, i. e. plants and animals.

The effect of oils on ecological properties of soils has not yet been virtually studied in Czechoslovakia. The presented paper is a contribution to the topical problem and tries to study the effect of hydraulic oil which is used in various machines and mechanisms in forestry and in timber handling operations.

DESCRIPTION OF TRIAL PLOTS

Two trial plots of different soil conditions were used in the experiment.

The Útěchov plot represented a technically adapted place where the humus soil horizon was stripped and the soil surface was treated by a scraper. The plot serves as an example of technically prepared, nearly humus-free and slightly compacted soil which gradually passes into the granodiorite parent rock mantle of the Brno eruptive rock. As for the soil type, it is brown forest soil on the granodiorite waste, i.e. the typical cambic soil.

According to the field description of the soil and obtained data, it is sandy-loamy soil with a low content of small gravel, slightly porous, with small to moderate minimum air capacity (Tab. I). The soil is acid and exhibits moderate adsorption capacity. As for mineral nutrients available for plants there is a sufficient content of calcium, low supplies of potassium and nitrogen and moderate reserves of phosphorus. The soil exhibits a low content of organic substances reacting as oil hydrocarbons (part of humus) (Tab. II). Compacted soil of this type is quite frequent in places where mechanized operations are used. The plot is situated near the forest on a former forest land.

I. Physical properties of soil in the Útěchov locality

Depth [cm]	2–10	24–34	60–70
Particle-size fractions I [%]	15.1	13.6	15.2
II [%]	7.5	6.7	7.1
III [%]	10.9	7.3	6.9
IV [%]	66.4	72.4	70.8
Specific gravity [g.cm ⁻³]	2.62	2.63	2.67
Bulk density [g.cm ⁻³]	1.57	1.67	1.60
Porosity [%]	45.0	36.9	37.8
Actual moisture content [%]	7.1	16.9	13.4
Aeration [%]	37.9	20.0	24.4
Relative moisture content [%]	26.5	48.6	57.7
Maximum capillary moisture capacity [% in volume]	26.7	34.8	23.3
[% in weight]	18.4	20.9	13.9
Minimum air capacity [% in volume]	18.3	2.1	14.5

II. Chemical characteristics of soil in the Útěchov locality

Depth [cm]	2–10	24–34	60–70
Soil adsorption complex — T	14.3	17.0	23.0
[mval. 100 g ⁻¹] — S	13.9	15.4	19.8
— V	97.2	90.6	86.1
pH/H ₂ O	5.1	5.0	5.2
pH/nKCl	4.0	3.9	4.0
Available nutrients CaO	191.0	135.0	157.0
[mg. 100 g ⁻¹] K ₂ O	5.4	6.0	5.0
Na ₂ O	2.9	2.9	4.8
P ₂ O ₅	11.2	18.6	12.8
Humus [%]	0.49	0.22	0.28
C [%]	0.28	0.12	0.16
N [%]	0.03	0.03	0.04
C/N	9.3	4.0	4.0
Oil substances [mg.kg ⁻¹]	18.0	13.0	7.0

The Strážnice plot represents a forest soil supporting a Scots pine stand near a centralized log conversion depot. The soil belongs to the type of brown forest soils (arenaceous cambic soil). It serves as an example of a more or less loose and sandy soil with the

III. Physical properties of soil in the Strážnice locality

Depth [cm]	4-10	25-35	60-70
Particle-size fractions I [%]	3.5	3.5	2.5
II [%]	3.3	1.1	1.2
III [%]	6.2	2.8	2.7
IV [%]	87.0	92.6	93.6
Specific gravity [g.cm ⁻³]	2.58	2.64	2.66
Bulk density [g.cm ⁻³]	1.49	1.61	1.66
Porosity [%]	42.2	39.1	37.7
Actual moisture content [%]	2.5	2.2	4.1
Aeration [%]	39.7	36.9	33.6
Relative moisture content [%]	18.7	9.1	12.6
Maximum capillary moisture capacity [% in volume]	14.6	24.4	32.3
[% in weight]	9.9	15.1	19.5
Minimum air capacity [% in volume]	27.7	14.7	5.3

well-preserved soil profile formed by natural processes including the surface humus horizon.

Based on the soil profile and the described properties, the soil in question is a sandy soil, slightly porous, well-aerated in the upper and moderately in the lower horizon (Tab. III). The soil is also acid but of very low adsorption capacity. The content of available mineral nutrients (CaO, K₂O, Na₂O, P₂O₅) is very low and thus insufficient. The content of humus, nitrogen and „oil substances“ is also very low with the exception of the layer of surface humus soil (Tab. IV). According to the figures in Tab. V, the biological activity of the soils in the Útěchov plot is relatively low and in the Strážnice plot even lower.

METHODS

In each of the trial plots 3 squares of 1 m² were laid out and squares of 0.25 m² were marked in their centres. Into the centre of the squares 1, 2 and 3, 2.5 l, 5 l and 7.5 litres resp. of the OTH-P-3 (Hydyn) oil were poured. The oil was applied in July 1987. In both plots, the surface of the squares was cleared of herbs and fresh litter prior to the oil application.

In October of the same year, the areas of infiltrated oil were measured and plotted and the depth of oil infiltrated into the soil profile was found. Soil samples were also taken for analyses, the plots were again put to their original status and another dose of oil was applied in the squares 1 and 2, viz 2.5 l in each plot. Square 3 remained without any other treatment. The final (cumulative) dose of oil amounted to 5 (2 doses), 7.5 (2 doses) and 7.5 (1 dose only) litres in the squares 1, 2 and 3, respectively.

Eleven months later (Sep. 1988) the areas of oil spills were measured and plotted again, the soil profiles were opened within the central squares, depth and pattern of oil infiltration into the soil were measured and plotted and, finally, photodocumentation was carried out and soil samples were taken.

Soil texture fractions were determined using the method of Kopecký. The physical properties of soils were determined by the analysis of physical cylinders. Adsorption complex was determined using the Mehlich method, soil reaction values (both active and exchangeable) were

IV. Chemical characteristics of soil in the Strážnice locality

Depth [cm]	4-10	25-35	60-70
Soil adsorption complex — T	5.7	3.7	3.4
[mval. 100 g ⁻¹] — S	3.9	2.9	3.0
— V	69.3	78.1	89.0
pH/H ₂ O	4.5	4.8	5.2
pH/nKCl	4.0	4.1	4.3
Available nutrients CaO	7.2	5.5	18.0
[mg. 100 g ⁻¹] K ₂ O	1.9	1.2	1.2
Na ₂ O	0.6	0.5	0.6
P ₂ O ₅	0.6	2.1	1.6
Humus [%]	2.16	0.39	0.14
C [%]	1.25	0.22	0.08
N [%]	0.07	0.03	0.02
C/N	17.9	7.3	4.0
Oil substances [mg. kg ⁻¹]	39.5	4.5	4.0

V. Biological activity of soil in the Útěchov and Strážnice localities

Depth [cm]	2-10	24-34	60-70
<u>Útěchov</u>			
Respiration activity B	6.4	2.5	2.5
Respiration activity CN	31.8	23.4	23.2
CN/B ratio	5.0	9.4	9.3
Catalase	5.4	3.5	2.4
<u>Strážnice</u>			
Respiration activity B	7.2	2.7	2.1
Respiration activity CN	31.0	20.9	23.4
CN/B ratio	4.3	7.7	11.1
Catalase	2.2	1.4	0.6

Note: Basal (B) and potential (CN) respiration activity is given in mg CO₂. 100⁻¹ g. 24 hours⁻¹
Catalase activity in mg H₂O₂. 5 g⁻¹. 15 min⁻¹

determined in the water and nKCl soil suspension potentiometrically. Available mineral nutrients were determined in the extract of 1% citric acid. The content of humus was determined by burning in wet conditions using the Tjurin method and nitrogen content was assessed by the Kjeldahl's method.

The content of crude oil substances was determined by IR spectrophotometry from an extract using Freon 113 (Merck) in the laboratory of the Geotest Brno enterprise. CO₂ respiration from the soil was determined using titration and soil catalase activity was assessed by manganometry.

VI. Physical properties of soils after the application of oil at the Útěchov locality (Oct. 1987, Sep. 1988)

Depth [cm]		^o	^o	^o	^o	^o
		0-5	0-5	25-35	25-35	60-70
Soil texture fractions [%]	I	13.5	12.7	13.2	11.0	9.4
	II	7.3	8.0	7.6	5.6	4.9
	III	7.2	7.5	7.2	6.4	6.2
	IV	72.0	71.8	72.0	77.0	71.5
Specific gravity [g.cm ⁻³]		2.58	2.72		2.65	2.61
Volume weight [g.cm ⁻³]		1.60	1.63		1.61	1.68
Porosity [%]		37.9	39.9		39.4	35.6
Actual soil moisture [%]		9.9	13.5		16.7	15.3
Aeration [%]		28.0	26.4		22.6	20.2
Relative soil moisture content [%]		56.3	60.3		78.2	78.5
Maximum capillary water capacity – [% in volume]		17.1	22.4		21.5	19.6
[% in weight]		10.1	13.7		13.3	11.6
Minimum air capacity – [% in volume]		20.8	17.5		17.9	16.0

Note: Soil horizons containing oil are designated with "o"

RESULTS OF THE EXPERIMENTS

In the Útěchov plot with more compacted soil, oil penetrated after the first application only into the shallow layer of the soil, viz in the squares 1 and 2 about 3–5 cm below the soil surface, in square 3 a little deeper. After pouring the oil on the soil surface there was a tendency to spread all over the surface, oil infiltration into the lower horizons being slow. Infiltration in square 3 resulted in the formation of a funnel-shaped pocket whereas in the squares 1 and 2 a flat plate or disk was formed. Hatching denotes the oil areas and oil penetration after the first application (Fig. 1).

After the second application in squares 1 and 2 the oil did not spread so areally but penetrated more intensively into the soil forming deeper pockets, in square 2 even deeper than at the same oil dose in square 3. In the field, the area of oil spills was delimited with sticks.

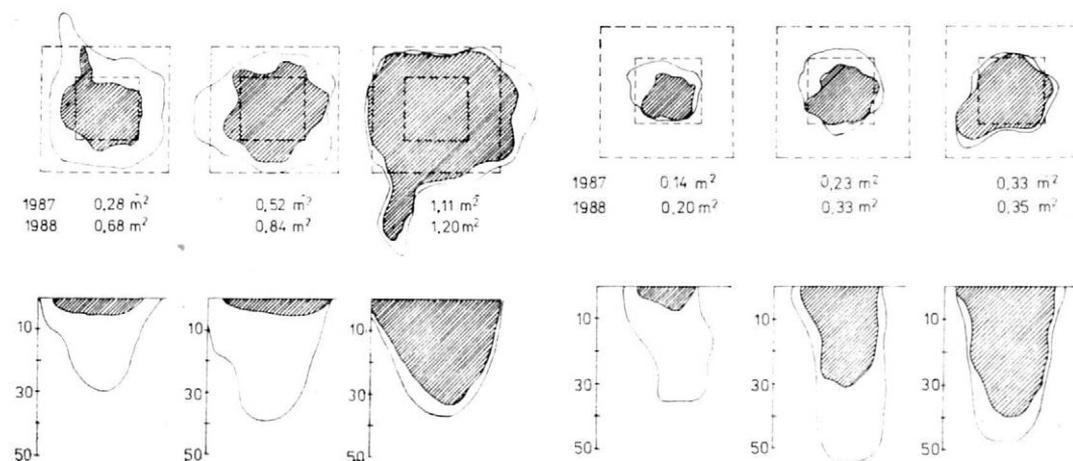
In the Strážnice plot with the loose surface soil layer the oil penetrated into the soil more quickly so that the spills were smaller and pockets in the soil profile were deeper. Further application only somewhat increased the affected area and deepened the oil pockets in the soil (Fig. 2). Oil penetration after the first application is marked by hatching. In the field, the area of oil spills was marked out with sticks.

When evaluating changes in physical properties of the soils under study resulting from the application of oil in both the plots, it can be found that soil texture did not change, specific gravity decreased but volume weight increased. These changes can be explained as the result of filling parts of the soil pores with oil. Decrease in actual soil moisture also appeared but not in all cases (see horizon A in Tab. VII) as well as in relative soil moisture content, aeration and minimum air capacity of horizons con-

VII. Physical properties of soils after the application of oil at the Strážnice locality (Oct. 1987, Sep. 1988)

Depth [cm]		o		o		o	
		0-4	0-4	4-10	4-10	25-35	25-35
Soil texture fractions [%]	I	9.5	7.5	5.0	4.7	4.7	5.0
	II	5.7	4.9	4.0	2.3	1.8	1.7
	III	6.1	6.9	3.3	4.9	3.1	3.8
	IV	79.2	80.8	87.8	88.2	90.5	89.5
Specific gravity [g.cm ⁻³]		1.83	2.47	2.49	2.61	2.62	2.67
Volume weight [g.cm ⁻³]		0.99	0.63	1.57	1.32	1.60	1.59
Porosity [%]		46.0	67.6	37.0	49.4	38.8	51.8
Actual soil moisture content [%]		15.8	7.3	6.8	3.3	6.6	12.4
Aeration [%]		30.3	60.4	30.2	46.1	32.3	39.4
Relative soil moisture content [%]		39.6	50.0	25.5	63.3	25.2	56.4
Maximum capillary water capacity —							
[% in volume]		37.7	16.6	27.3	5.2	25.5	24.4
[% in weight]		39.7	32.6	12.1	3.9	11.3	15.4
Minimum air capacity —							
[% in volume]		8.3	58.6	9.7	44.2	14.3	15.9

Note: Soil horizons containing oil are designated with "o"



1. Oil infiltration into the less permeable sandy-loamy soil at Útěchov

2. Oil infiltration into the permeable sandy soil at Strážnice

taining oil (Tab. VI., VII). Neither air nor water can penetrate into the soil pores filled with oil. Our results agree with those of foreign authors (Grummer, 1964; Skawina et al., 1970; Przedwojski et al., 1977, 1980).

VIII. Chemical characteristics of the soil after the application of oil at the Útěchov locality (Oct. 1987, Sep. 1988)

Depth [cm]	^o		^o			
	0-4	0-4	25-35	25-35	60-70	
Adsorption complex — T [mval. 100 g ⁻¹]	5.83	6.22	6.00	4.22	5.33	
	3.84	3.42	3.41	3.35	3.26	
	65.9	55.0	55.8	78.6	61.2	
pH/H ₂ O	5.9	6.2	6.4	5.4	5.0	
	pH/nKCl	5.3	5.6	5.7	4.7	4.1
Available nutrients [mg. 100 g ⁻¹]	CaO	220	218	362	194	167
	K ₂ O	6.7	9.2	9.2	8.9	5.9
	Na ₂ O	4.5	5.9	7.4	5.3	5.2
	P ₂ O ₅	11.1	17.9	14.0	19.7	16.1
Humus [%]	5.98	1.21	3.24	0.80	0.43	
Carbon [%]	3.47	0.70	1.88	0.46	0.25	
Nitrogen [%]	0.08	0.10	0.08	0.04	0.03	
C/N	48.7	7.2	23.5	12.1	9.8	
Oil substances [mg. kg ⁻¹]						
	Oct. 1987	57 900		6 790	160	183
	Sep. 1988	78 630	1 004	21 070	286	211

Note: Soil horizons containing oil are designated with "o"

Chemical properties of soils saturated with oil changed only slightly as concerns adsorption complex, soil reaction (pH) and the content of available mineral nutrients. A marked difference appeared in the content of carbon and „humus“. Only humus of the soil samples free of oil can be considered a real humus substance; oil markedly increased carbon content in the soil samples, the content of total nitrogen remained unchanged. Therefore, the C/N ratio in the samples containing oil is strikingly high (Tab. VIII and IX). Certain decrease in the content of oil substances appeared in both the plots between the first application and the end of the experiment. This was caused, on the one hand, by the fact that a partial infiltration of oil into the lower soil horizons occurred and, on the other hand, by the gradual biological oxidation of oil due to the soil microflora. Considerable attention has been paid to this process all over the world for a number of years. A review of the results was also published in our country (Grunda, 1983). Soil analyses have also shown that it is necessary to increase the values of analytical background which is formed by the extraction of humus substances in oil-free horizons by extraction agents for oil substances. In the surface humus soil horizon, it is possible to consider the values up to 1000 mg. kg⁻¹ as a background, in deeper horizons with the lower content of humus the values up to 300 mg. kg⁻¹ of soil.

Biological activity of the soil was assessed by three tests: using the basal respiration activity (wet soil only), potential respiration activity (soil + 0.5 % soya flour) and soil catalase activity (Tab. X and XI).

IX. Chemical characteristics of the soil after the application of oil at the Strážnice locality (Oct. 1987, Sep. 1988)

Depth [cm]	o		o		o		
	0-4	0-4	4-10	4-10	25-35	25-35	
Adsorption complex — T	6.77	7.84	1.89	3.00	4.53	2.00	
	— S	0.97	0.64	0.89	1.05	1.20	
	— V	16.3	8.1	46.3	50.0	31.7	60.0
pH/H ₂ O	4.6	4.3	4.3	4.1	4.5	4.6	
pH/nKCl	3.5	3.4	3.9	3.7	3.8	4.2	
Available nutrients [mg. 100 g ⁻¹]	CaO	38.0	43.0	4.0	4.0	3.0	3.0
	K ₂ O	3.7	5.5	1.7	1.4	1.6	1.1
	Na ₂ O	2.0	2.2	0.4	0.5	1.0	0.8
	P ₂ O ₅	2.9	3.0	2.1	1.9	1.9	1.6
Humus [%]	6.90	3.14	4.81	1.87	2.47	0.29	
Carbon [%]	4.00	1.82	2.79	1.08	1.43	0.16	
Nitrogen [%]	0.10	0.10	0.04	0.04	0.05	0.02	
C/N	40.1	18.2	64.8	23.0	35.7	9.4	
Oil substances [mg. kg ⁻¹]							
	Oct. 1987		49 070	273	28 150	108	
Sep. 1988	80 440	956			16 700	371	

Note: Soil horizons containing oil are designated with "o"

Basal respiration of CO₂ from the soil showed the predominantly depressive effect of oil in the soil 3 months after the start of the experiment. After 14 months from the start of the experiment, the situation changed. Soil, which contained oil, produced more CO₂ than a parallel (control) soil sample without oil. This proves the process of biological degradation of oil by the soil microflora. A similar trend was also found in potential respiration but only small differences appeared in the values. The CN/B ratio between the potential and basal respiration changed markedly. The values decreased considerably and indicated the decomposition of carbonaceous substances rich in energy so far not utilized.

Soil catalase activity showed markedly lower values in the samples with oil than in the samples without oil. Decrease in the activity can be related to the decrease in the soil moisture content which was caused by filling the part of soil pores with oil in place of water. A marked decrease in catalase activity appeared also in the natural ecosystem of a floodplain forest following the decrease in soil water content (Grunda and Šarman, 1985). The regeneration of the microflora enzymatic apparatus after the oil shock is probably slower than the formation of the oxidation type enzymes which are necessary for the biological degradation of oil. Gradual recovery of the soil catalase activity can be observed on the increasing values in samples taken after 14 months, compared with samples taken 3 months after the start of the experiment.

X. Biological activity of the soil after the application of oil at the Útěchov locality

Depth [cm]	^o 0-4	25-35	60-70
<u>3 months after the application of oil</u>			
Respiration activity B	9.5	6.5	7.1
Respiration activity CN	48.8	42.5	42.4
CN/B ratio	5.1	7.3	7.0
Catalase	2.4	3.4	4.8
Depth [cm]	^o 0-4	0-4	^o 25-35
<u>14 months after the application of oil</u>			
Respiration activity B	22.5	16.6	16.5
Respiration activity CN	49.2	45.6	40.5
CN/B ratio	2.2	2.8	2.5
Catalase	3.0	4.7	3.6

Note: Soil horizons containing oil are designated with "o".

Basal respiration activity (B) and potential respiration activity (CN) are in mg CO₂ · 100 g⁻¹ · 24 h⁻¹.

Catalase activity is given in mg H₂O₂ · 5 g⁻¹ · 15 min⁻¹

DISCUSSION

From the theoretical point of view, oil infiltration into the soil represents a special example of the sudden change in soil properties which return to their original status only slowly in accordance with the decrease of oil content due to the shift in the soil profile and gradual oxidation by the soil microflora. The oil fills primarily soil pores which put up smaller resistance, i.e. pores filled with air, but gradually the oil fills even the part of pores in which it replaces water so that the soil becomes drier having the lower water and air contents. These changes result also in the decrease of soil porosity because porosity is related to the specific gravity of soil which decreased and to the volume weight which, in turn, increased.

Chemical properties of soils changed primarily because of the marked increase in the content of carbonaceous substances due to the import of hardly degradable carbohydrates whereas the content of nitrogen and other mineral substances remains without any changes. Conditions for soil organisms changed also abruptly. The soil with oil is drier, the air content is lower, predominantly aerobic conditions change to anaerobic, potential hydrocarbon decomposers suffer from the shortage of available nitrogen and other mineral nutrients. Decomposition of hydrocarbons is dependent on the soil microflora adaptation to the new growing medium and will be taking place for a number of years.

The practical consequences of oil spills into the soil manifest themselves particularly in relation to plants. The plants similarly as the microflora suffer in the soil from the shortage of air, water and mineral nutrients. Not only the uptake of oxygen is reduced but also the exchange of gases in the root system. Oil comes into the plant also through the

XI. Biological activity of the soil after the application of oil at the Strážnice locality

Depth [cm]	^o 4-10	4-10	^o 25-35	25-35	69-70
3 months after the application of oil					
Respiration activity B	8.2	8.0	3.4	3.4	2.5
Respiration activity CN	36.3	40.7	35.4	37.7	42.0
CN/B ratio	4.4	5.1	10.4	11.1	16.8
Catalase	1.2	4.1	0.3	1.3	0.9
Depth [cm]	0-4	0-4	25-35		60-70
14 months after the application of oil					
Respiration activity B	23.4	17.9	4.9		5.0
Respiration activity CN	44.4	44.8	33.7		33.8
CN/B ratio	1.9	2.5	6.9		6.8
Catalase	2.2	5.2	0.9		0.8

Note: Soil horizons containing oil are designated with "o".

Basal respiration activity (B) and potential respiration activity (CN) are in $\text{mg CO}_2 \cdot 100 \text{ g}^{-1} \cdot 24 \text{ h}^{-1}$.

Catalase activity is given in $\text{mg H}_2\text{O}_2 \cdot 5 \text{ g}^{-1} \cdot 15 \text{ min}^{-1}$

surface of its aboveground parts and roots, disturbs chlorophyll in plant cells, inhibits transpiration and blocks vascular bundles. Conditions for plant growth can be adapted by the artificial loosening of the soil by ploughing and by the application of mineral fertilizers. Such a treatment can also improve conditions for the microbial oxidation of oil in the soil.

Natural degradation of oil progresses slowly and can last 15–20 years. These figures apply in the case of surface layers which exhibit the higher content of microflora and the permanent contact with the atmosphere. Loosening and fertilization can reduce the degradation period to about one half of the period given above. If the oil penetrates into the deeper layers of the soil it is possible to expect that the oil degradation will be 2–4 times slower.

Oil spills can of course directly endanger man. In our case, larger oil spills appeared on the soil surface in the more compacted soil of the Útěchov plot. This can result in the pollution of watercourses. In the soil with the loose surface layer of the Strážnice plot, the pollution affects a smaller area but oil infiltrates deeper so that more serious danger of ground water contamination appears. Drinking water resources are, therefore, endangered. In our case, oil penetrated into the depth of 40 cm (Útěchov) or 55 cm (Strážnice) but due to further infiltration the oil can reach gradually down to double depths. The experiment also showed that repeated pouring of oil on the same place resulted in easier infiltration into the soil so that oil reached deeper horizons. It is possible to imagine the extent of damage which could occur in case of large oil spills on the soil surface. The restoration (reclamation) of the soil would be very expensive and time consuming particularly because of the fact that oil oxidation in deeper soil horizons is extremely slow with respect to the shortage of both microbial decomposers and oxygen.

Because of the reasons given above the easiest way of how to prevent oil spills is the use of technical measures, i.e. construction of catchpits at places of oil spills danger. In case of the stationary machinery concrete catchpits could be used and in movable mechanisms portable catchpits (e.g. from plastics) are recommended. Such measures could prevent the environment contamination and the caught oil could be returned to further technical use.

In the last years, our researchers studied ground water pollution rather than soil pollution in relation to crude oil substances (Pelikán, 1983; Mašín and Pyšek, 1986; Muzikář, 1987; Bublínec and Šimek, 1989, etc.) which of course represents the problem of primary importance. Other investigators paid attention to the analytical problems of oil substance detection and determination in the waters (Svrčula, 1984; Homola, 1987).

The negative effect of oils on the environment can also occur at the direct contact of man with these oils. The effect of hydraulic oils on the human organism was studied in Sweden. About one quarter of the asked drivers and repairmen answered that they had health problems caused by oil. It has been proved that oils irritate skin due to various ingredients and cause frequent diseases. Particularly dangerous situation occurs when oil-soaked clothing comes into direct contact with the skin.

Based on the research results hygienic standards for work with oils were drawn up, protective clothing was prescribed and principles for washing the clothing were recommended as well as training of drivers and repairmen in the rules of proper handling with oils. Information was also prepared on the effect of oils on the human health.

SUMMARY

An experiment was carried out dealing with infiltration of the OTH-P-3 (Hydyn) oil into the soil in two trial plots. It was found that in the more compacted soil the oil has tendency to spread over the soil surface and penetrate more slowly into the lower horizons. In the loose soil, the oil forms a small infiltration area and penetrates quite easily into the lower horizons. Oil replaces air and water in soil pores so that the soil exhibits lower moisture and air contents, its specific gravity and porosity decrease and volume weight increases.

The carbon content in the soil and the C/N ratio markedly increase. Conditions for soil organisms and plants worsen abruptly. The gradual decomposition of oil depends on the adaptation of the soil microflora to this new growing medium. As a rule, the decomposition lasts usually 10–15 years. Oil infiltration into the lower horizons endangers the quality of ground and drinking waters.

Catchpit building is recommended at places where there is the danger of oil spills into the environment. The risk of health damage by hydraulic oils is pointed out in those workers who are in the direct contact with them.

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Na dvou lokalitách byl proveden pokus se zásakem oleje OTH-P-3 (Hydyn) do půdy. Byly zjištěny rozdíly v zásahu oleje v závislosti na fyzikálních vlastnostech půdy. Půda s olejem má nižší vlhkost i obsah vzduchu, nižší měrnou hmotnost a pórovitost. Zvyšuje se objemová hmotnost. Průdce se zhoršují podmínky pro půdní organismy i pro rostliny. Průsakem je ohrožena kvalita podzemních vod. Doporučuje se budování jímek tam, kde hrozí únik oleje do prostředí. Upozorňuje se na nebezpečí poškození zdraví hydraulickými oleji.

minerální oleje; fyzikální vlastnosti půd; půdní organismy; ochrana půdy a vody

GRUNDA, B. — ULRICH, R. (Forstwirtschaftliche Fakultät der VŠZ, Brno): *Eindringen des Öls in den Boden und sein Einfluss auf ökologisch bedeutende Bodeneigenschaften*. *Lesnictví*, 36, 1990 (11): 947–958.

Auf zwei Lokalitäten führten wir einen Versuch mit Eindringen des Öls OTH P 3 (Hydyn) in den Boden durch. Wir stellten bedeutende Unterschiede im Einfluss des Öls in Abhängigkeit von den bestehenden physikalischen Bodeneigenschaften fest. Der Boden mit Öl hat eine niedrigere Feuchtigkeit und einen niedrigeren Luftgehalt, ein niedrigeres spezifisches Gewicht und eine niedrigere spezifische Porosität. Das Volumengewicht nimmt zu. Die Lebensbedingungen für Bodenorganismen und Pflanzen verschlechtern sich jäh. Die Durchsickerung bedroht auch die Grundwasserqualität. Es kann der Aufbau von Behältern überall dort empfohlen werden, wo die Ölentweichung droht. Es wird auch auf die Gefahr der Gesundheitsbeschädigung durch hydraulische Öle hingewiesen.

Mineralöle; physikalische Bodeneigenschaften; Bodenorganismen; Boden- und Wasserschutz

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THE WEAR PATTERNS OF THE CUTTING PARTS OF CHAIN SAWS LUBRICATED WITH RAPESEED OIL, COMPARED WITH THE OA M6A OIL

A. Skoupý

SKOUPÝ, A. (Faculty of Forestry, University of Agriculture, Brno): *The wear patterns of the cutting parts of chain saws lubricated with rapeseed oil, compared with the OA M6A oil.* Lesnictví, 36, 1990 (11): 959–968.

The oil used to lubricate the cutting parts of chain saws is regarded as an important factor affecting the environment. Mineral oils, used for this purpose, have recently been often replaced by improved vegetable oils which are regarded as ecologically safe. On the basis of an order from the South Moravian State Forest Corporation, the Department of Forestry Mechanization of the Forestry Faculty at the Agricultural University, Brno, performed a laboratory comparison of the lubricating capabilities of raw food rapeseed oil with those of the OA M6A oil. A special device was used to measure the patterns of wear of the Stihl Oilomatic chains and Sandvik cutter bar; using this device, the conditions of the movement of the chain in the bar (speed and load) were simulated, including the dosage and temperature of the lubricating oil. It can be concluded from the results of the test that raw rapeseed oil cannot be recommended because of the much quicker wear of both the chain and the bar and a higher power needed to drive the chain. It will be necessary to develop new high-quality oil, based on vegetable oil, whose properties would match those of such oils produced in other countries and allow to fully replace the mineral oils used until now.

forestry machines; chain saws; lubricating oils

The increasing pollution of environment with petroleum and its derivatives arouses efforts to replace the mineral oils, used to lubricate chain saws, by other oils, safer to the environment.

One of the possibilities, most widespread at the present time, is to replace the mineral oils by oils produced on the basis of rapeseed oil. From the viewpoint of its action on the environment, rapeseed oil is considered to be safe. Its main advantage is that it decomposes in field conditions much more rapidly than do the mineral oils.

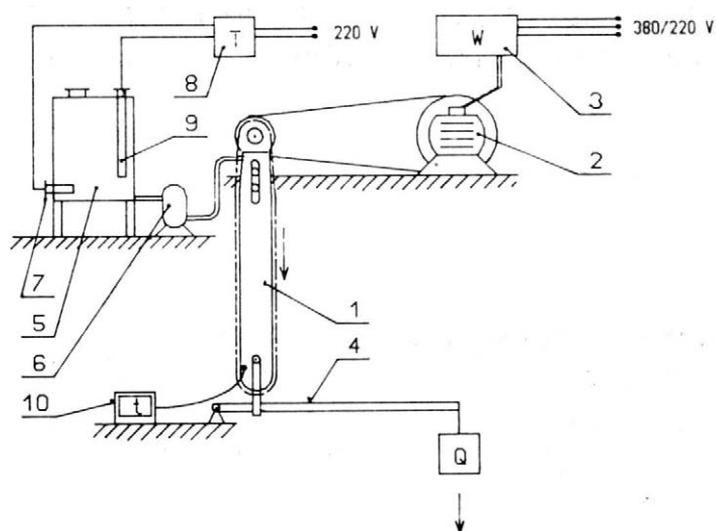
In some other countries, improved oils produced on the basis of rape seeds have been developed for at least ten years and are widely used at present, chiefly in Scandinavia, FRG and Austria.

In 1988, Ing. A. Pavlíček presented to the managers of the South Moravian Forest Corporation an improvement proposal given the title "Replacement of the Lubricating Oil of the One-man Chain Saw by an Ecologically Safe Oil". In this connection, the managers of the State Forest Corporation asked the Department of Forestry Mechanization to perform laboratory trials to evaluate the lubricating capabilities of rapeseed oil, in comparison with the OA M6A oil, used until now.

MATERIAL AND METHOD

The comparative tests were conducted on a full-scale model of the cutting part of the motor saw. Two Stihl Oilmatic Rapid Micro 3853 000 0056 35 chains (pitch of teeth 3/8") and two Sandvik 1 M 522-56 bars, long 15", were used for the measurement for each kind of oil used.

The rapeseed oil was produced from erucic-free rape without detailed determination of kind and purity. The producer is Milo Olomouc Corp. The OA M6A oil was used for comparison.



1. Diagram of the special measuring set

All the material to be tested was supplied from the headquarters of the South Moravian Forest Corporation, Brno.

A special measuring device was used for the comparative tests; the device allowed to simulate the load to which the cutting part of the chain saw is exposed at the rated speed without cutting but with continuous tensioning of the chain. This allowed to evaluate the wear of the bar and the base parts of the chain with elimination of any irregularity normally caused by cutting (effect of the kind and state of the wood being sawn, geometry of the teeth and the like).

The measuring device (Fig. 1) is so designed as to allow the testing of various kinds of chains and bars (1). The drive sprocket is driven via a belt by a three-phase electromotor (2), whose feed circuit includes a wattmeter (3) enabling current monitoring of the power input needed to drive the chain in the bar. The chain is continuously tensioned by means a one-armed lever (4) with weight Q. The oil for the loss lubrication of the chain is pumped from container (5) by oil pump (6) to the groove of the guide bar. The supply of oil is controllable. The oil is preheated in the container by means of a heating element (7) and its temperature is regulated by means of an automatic transistor controller (8) with a connecting mercury thermometer (9). A contact thermometer (10) is used for measuring the temperature of the end part of the bar. The measurements are taken in the place of the highest thermal stress to which the bar is exposed, i. e. at the spot where the chain falls onto the surface of the bar after leaving its end part.

The following criteria were used to compare the lubricating capability of the two oils: heat stress of the bar, power input needed to drive the chain in the bar, wear of the guide bar at three sites (Fig. 2), elongation of the chain as a whole, average clearance at the rivet, wear of the guide links (Fig. 3, š) and wear of the side links (Fig. 3, v).

The measurements were performed under the following conditions:

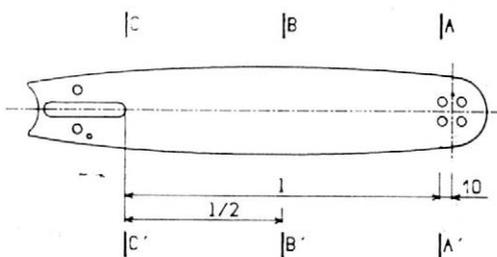
- circumferential velocity of the chain 18 m per second
- oil feed 10 cm³ per min (± 2)
- oil temperature when leaving the pump 50 °C
- chain tensioning force 200 N
- test duration 40 hours of operation for each chain and bar.

Throughout the whole time of the tests, the air temperature in the laboratory was between 15 and 17 °C.

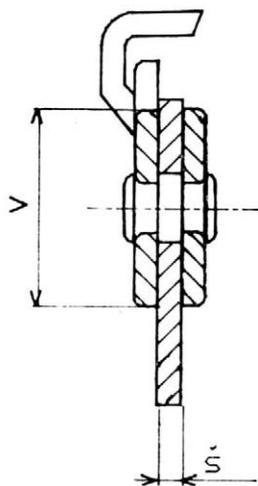
Wear of the cutting part of the saw was expressed with respect to the absolute starting dimensions of the chain, the measuring sites being permanently marked. Each measurement was taken after five hours of operation when temperature of the chain and bar was equalized with ambient temperature.

The power input and the temperature of the end part of the bar were measured in the middle of the five-hour interval of operation.

This method is based on similar earlier studies conducted at the same Department: Petříček (1970), Petříček et al. (1983), and Petříček (1984); it is similar also to the method described in Report No. 3156 of the Swedish State Testing Station at Umeå (1988); however, only the temperature of the end part of the bar and the elongation of the chain are measured in the last mentioned method.



2. Sites of wear measurement on the Sandvik bars



3. Sites of wear measurement of the leading and side links of the Stihl Oilmatic chains

RESULTS

The values of wear of the chain and bar are given in Tables I and II as deviations from the starting dimension which, irrespective of the absolute magnitude, is regarded to be zero wear. The only exception is the value of the average clearance in the rivet where the absolute average values are given as calculated for one rivet: otherwise the results would be difficult to survey. Where the negative values of wear occurred, the absolute dimension increased owing to the compacting of the material and the transfer and adherence of metal particles and oil deposits.

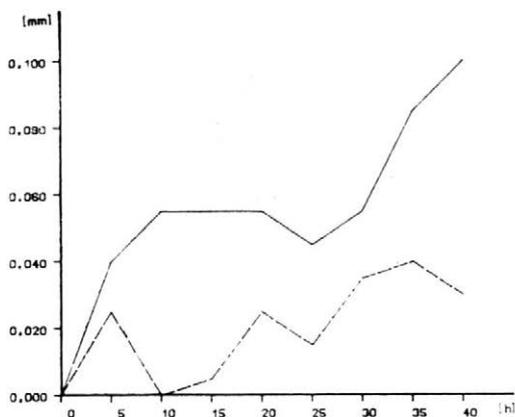
The temperature of the end part of the bar and the power input needed to drive the chain were expressed in absolute values.

All the length dimensions were expressed in millimeters, power input in kilowatts, and temperature in degrees Centigrade.

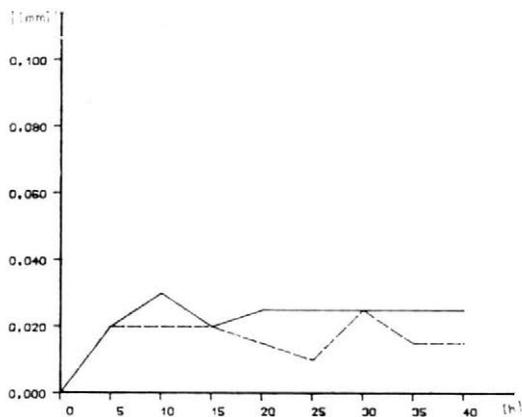
Diagrams were drawn to compare the values obtained for each kind of lubricating oil.

Figs. 4 to 6 show the wear patterns of the guide bars in planes A-A', B-B' and C-C'. With the use of the OA M6A oil, the wear was very low, so it is possible that the small particles of the material transported on the slide surface of the bar could adhere at some spots, thus causing a slight fluctuation of the value on the diagram (reaching up to three-hundredths of a millimetre). When rapeseed oil was used, there was a similar fluctuation of the values but in all the three planes the total wear of both bars was greater than with the OA M6A oil. The greatest wear was recorded during the last ten hours of the operation of the chain in plane A-A', i.e. 10 mm behind the axis of the guide sprocket, where the final value of wear reached one-tenth of a millimetre, which is 330 % of that recorded with the use of the OA M6A oil.

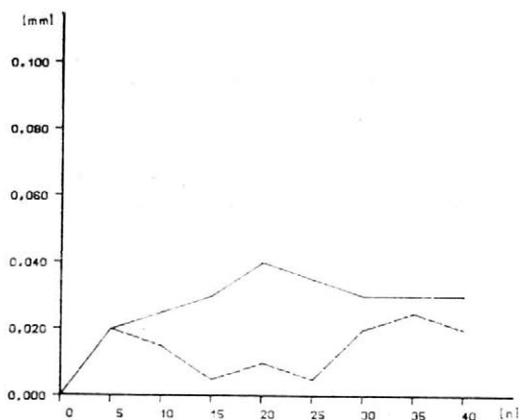
The values of chain elongation are shown in Fig. 7. With the use of the OA M6A oil the values increased steadily and the chain was elongated by 0.46 mm. With the use of rapeseed oil the elongation followed the same pattern until the 20th hour, but then the elongation stabilized at 0.28 mm, which is 61 % of that measured with the OA M6A oil. However, this course has to be considered in relation to the change of clearance in rivets, as shown in Fig. 8.: when the OA M6A oil was used, the clearance in rivets slightly increased but with the rapeseed oil the value stopped growing after 15 to 20 hours and declined again to one-third of the original level. This pattern can be ascribed to the de-



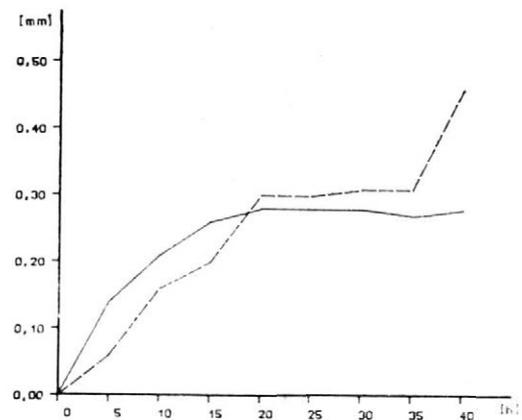
4. Wear of the bars in the A-A' plane (in the fig. 4-12 — rapeseed oil; ---- oil OA M6A)



5. Wear of the bars in the B-B' plane



6. Wear of the bars in the C-C' plane

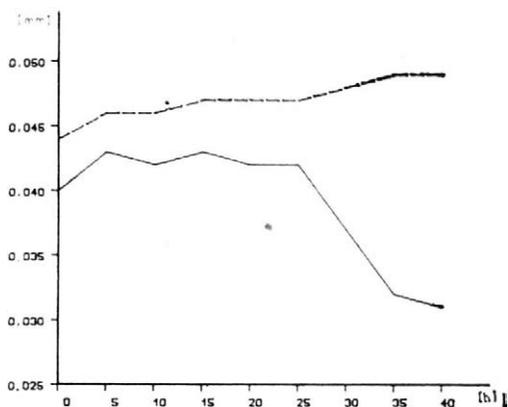


7. Total elongation of cutting chains

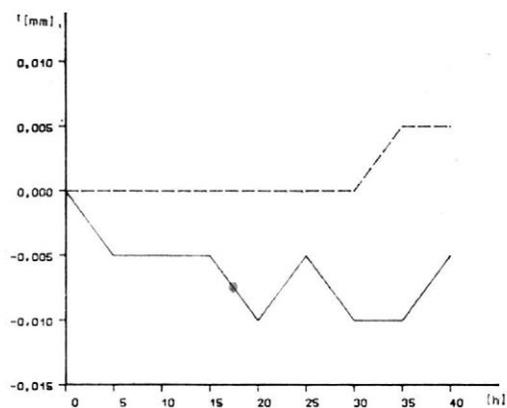
position of the solid products of rapeseed oil oxidation in the rivet joints. Owing to this, no greater elongation of the chain was recorded, although during the measurement the chain was exposed to a force of 50 N for determining clearance in the rivets. The depositions in the clearance of the rivets were so strong that even a toluen bath failed to dissolve them and when they were left in a benzene bath for 24 hours they even swelled and reduced the clearance from 0.031 to 0.023 mm. One of the chains was even broken in the 38th hour of exposure so that the whole cycle had to be repeated with another cutting part. All the data measured on the broken chain and its bar were eliminated.

The guide links of the chain also showed an unusual pattern of wear (Fig. 9). With the use of the OA M6A oil the width of the guide links showed almost no change. On the other hand, when the rapeseed oil was used the measured values increased. The explanation is similar to that in the case of clearance of the rivets.

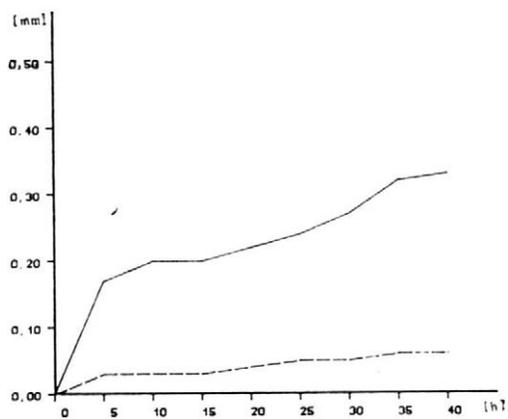
The largest differences in wear were recorded in the side links of the chain whose height was measured to have decreased as a result of friction against the surface of the bar (Fig. 10). This can be ascribed to the strong effect of chain speed and of the stretching



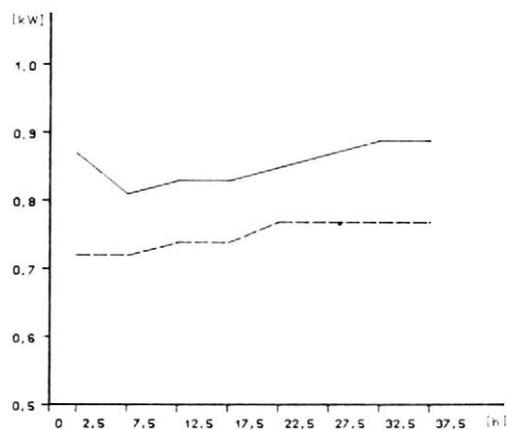
8. Changes in the clearance in the rivets



9. Wear of the guide links (the negative values of wear express the increase of their thickness)

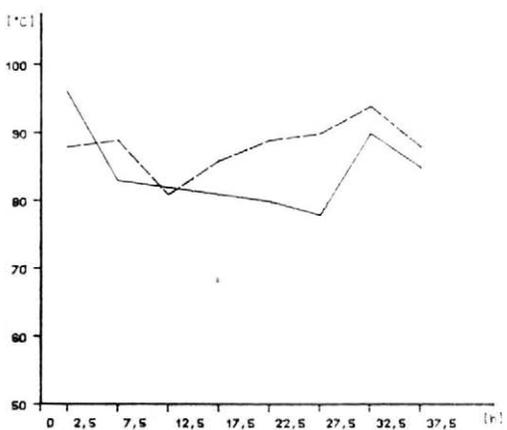


10. Wear of the side links of the cutting chains



11. Power input needed to drive the chains in the bars

12. The temperatures of the end parts of the bars



force. In the case of using the rapeseed oil the wear was much quicker and after 40 hours of the test the height of the side link decreased by 0.33 mm, on an average, whereas with the OA M6A oil it decreased by only 0.06 mm. Hence, the wear is greater by 550 % with the rapeseed oil.

The power input needed to drive the chain in the bar (Fig. 11) was greater by 0.09 to 0.15 kW, i.e. 10 to 20 %, in the case of rapeseed oil, compared with the momentary values of input with the use of the OA M6A oil, within the whole range of measurements.

With the use of rapeseed oil, the temperature of the end part of the bar (Fig. 12) was lower in the majority of measurements, only at the very beginning did it reach 96 °C. During the further course of measurement it declined to 18 °C. The relationships cannot be expressed in this case.

DISCUSSION

In comparison with the results of measurement of the suitability of rapeseed oils, as published in other countries, the method used in this study comprises a larger number of criteria, including those expressing abrasive wear of surfaces that move on each other. In the majority of the studies conducted abroad, chain elongation was used as the main criterion. Report No. 3156 of the Swedish State Testing Station at Umeå (1988) may be a good example: unlike many other papers, this report includes a description of the method; it presents the results of testing the characteristics of twelve kinds of oil used for the lubrication of chains in Sweden. Four of these oils, including the Karlshamns rapsolja, Huskvarna rapsolja, Svenska Omark and Swedcorn Rolja såg, are based on rapeseed. The following criteria are taken into account in the mentioned report: temperature of the end part of the bar, elongation of the chain, and viscosity of the oil at -26 °C. The temperature of the end part of the bar was always lower with the rapeseed oils than when other oils were used. These values cannot be compared with those of our study, because the Swedish testing station uses much smaller dosages of the oils (2.4 and 6.0 ml per minute) and does not specify accurately the site of measurement.

With the use of the vegetable oils, the elongation of the chain was smaller, ranging between 0.05 and 0.1 mm, whereas with e.g. the Shell sågkedjeolja mineral oil the elongation was as high as 0.38 mm and with BP 150 even 0.44 mm. However, there were some mineral oils whose results compared favourably with those recorded with rapeseed oils: for example, with the BP 4.4-0.1 oil the elongation was as low as 0.05 and with Texaco sågkedjeolja 68 Special it was 0.1 mm. However, it must be added that in the Swedish tests the chains are exposed only to a force of 50 to 180 N and the chains are left in operation for only 3 h.

Nevertheless, the results of the Swedish tests and those obtained in our study are not contradictory: both the temperature of the end part of the bar and the elongation of the chain as a whole were generally small with the use of the vegetable oils.

However, the Swedish testing station did not evaluate the wear of the bars and chains on surfaces in contact during operation, where the lubrication capacity of the oil should manifest itself most markedly. The reduction of the volume of the side links is so great that, with due and correct sharpening, maintenance and use of the chains, it may become the main reason for discarding the chain. Wear to the level of the heads of the rivets is regarded as the limit state. The wear of the bar is also often the reason why the whole cutting part of the chain saw is discarded.

The results of tests on the Timken instrument, published by Bublinc and Šimek (1989) and performed at the Research Institute of Fuels and Lubricants in 1987, cannot be used for comparison because they do not correspond to the physical conditions of the

I. Wear of the leading bar and the cutting chain when rapeseed oil is used

Hours	Cutter bar			Chain saw				Power input [kW]	Temperature [°C]	Hours
	A	B	C	chain elongation	backlash in rivet	wear of guide chain link	wear of lateral chain link			
0	0.000	0.000	0.000	0.00	0.040	0.000	0.00			
5	0.040	0.020	0.020	0.14	0.043	-0.005	0.17	0.87	96	2.5
10	0.055	0.030	0.025	0.21	0.042	-0.005	0.20	0.81	83	7.5
15	0.055	0.020	0.030	0.26	0.043	-0.005	0.20	0.83	82	12.5
20	0.055	0.025	0.040	0.28	0.042	-0.010	0.22	0.83	81	17.5
25	0.045	0.025	0.035	0.28	0.042	-0.005	0.24	0.85	80	22.5
30	0.055	0.025	0.030	0.28	0.037	-0.010	0.27	0.87	78	27.5
35	0.085	0.025	0.030	0.27	0.032	-0.010	0.32	0.89	90	32.5
40	0.100	0.025	0.030	0.28	0.031	-0.005	0.33	0.89	85	37.5

Dimensions in millimetres

II. Wear of the leading bar and the cutting chain when the OA M6A oil is used

Hours	Cutter bar			Chain saw				Power input [kW]	Temperature [°C]	Hours
	A	B	C	chain elongation	backlash in rivet	wear of guide chain link	wear of lateral chain link			
0	0.000	0.000	0.000	0.00	0.044	0.000	0.00			
								0.72	88	2.5
5	0.025	0.020	0.020	0.06	0.046	0.000	0.03			
								0.72	89	7.5
10	0.000	0.020	0.015	0.16	0.046	0.000	0.03			
								0.74	81	12.5
15	0.005	0.020	0.005	0.20	0.047	0.000	0.03			
								0.74	86	17.5
20	0.025	0.015	0.010	0.30	0.047	0.000	0.04			
								0.77	89	22.5
25	0.015	0.010	0.005	0.30	0.047	0.000	0.05			
								0.77	90	27.5
30	0.035	0.025	0.020	0.31	0.048	0.000	0.05			
								0.77	94	32.5
35	0.040	0.015	0.025	0.31	0.049	0.005	0.06			
								0.77	88	37.5
40	0.030	0.015	0.020	0.46	0.049	0.005	0.06			

Dimension in millimetres

movement of the chain in the bar. The test was performed at the speed of 800 r.p.m., though the rated speed of the driving sprocket of the chain saws is today between 8500 and 10 000 r.p.m. or higher. Knowing this, the workers of the mentioned research institute only expressed the assumption that the oil would be suitable. For the same reason they strongly recommended to perform further tests on a complete equipment such as the special measuring instrument described in the methodical part of this study. However, their assumption was not confirmed.

The Stihl chains, supplied from the South Moravian Forest Corporation and tested in our experiments, are much more resistant to wear than the chains produced by the Oregon Company, though the latter are used more frequently in forestry practice. It should also be stated that the properties of the rapeseed oil as a vegetable material are very variable. They depend on the rape variety, on plant nutrition, weather and other factors. The results of the tests to which only one oil was subjected cannot be fully generalized.

The differences between the results of measurement with the two types of oils compared are too large and do not allow to assume that a substantial change may occur if other kinds of cutting parts and other non-refined rapeseed oils are used.

CONCLUSIONS

A higher degree of wear of the bar occurs mainly in plane A-A', i.e. in the end part of the bar, when rapeseed oil is used for the lubrication of the saw chains.

The elongation of the chain with the use of rapeseed oil is rapid at the beginning but later it slows down and disappears. The average clearance in the rivets rapidly declines after 25 hours of operation owing to deposition of the products of oxidation of the rapeseed oil.

When rapeseed oil is used, the wear of the side links of the chain is much quicker than with the OA M6A oil.

Within the whole range of the performed laboratory measurements, rapeseed oil exhibits much higher values of power input needed to drive the chain in the bar, as compared with the use of the OA M6A oil.

The temperature of the end part of the bar is lower in the case of rapeseed oil than with the use of the OA M6A oil.

The general conclusion may be that unrefined raw food rapeseed oil cannot be used as a full-value replacer of the OA M6A oil and cannot be recommended for introduction in current operation without the risk of increased wear, leading to shorter service life of the cutting parts of the motor saws or other machines based on the same principle of cutting.

However, this conclusion cannot be generalized to apply to all rapeseed oils. The characteristics of the raw rapeseed oil which was the subject of this study cannot be compared with those of the oils used in other countries, because the latter contain various improving ingredients; in recent years some producers have been extracting from rapeseed oil only some esters which are then used as a basis for synthesizing high-quality oils, applicable in extreme conditions of operation.

It will be necessary to develop such oils in Czechoslovakia and to give up the view, abandoned long ago in many countries of the world, that raw rapeseed oil could be used to lubricate chain saws. The Department of Forestry Mechanization of the Forestry Faculty of the Agricultural University in Brno is ready to co-operate intensively with oil producers so as to introduce readily degradable oils in current logging practice as quickly as possible.

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SKOUPÝ, A. (Lesnická fakulta VŠZ, Brno): *Průběh opotřebení řezacích částí řetězových pil mazaných řepkovým olejem ve srovnání s olejem OA M6A*. *Lesnictví*, 36, 1990 (11): 959–968.

Olej používaný k mazání řezacích částí řetězových pil je považován za významný faktor zatěžující přírodní prostředí. Minerální oleje používané k tomuto účelu jsou v poslední době často nahrazovány zušlechťenými rostlinnými oleji, které jsou považovány za ekologicky neškodné. Na základě požadavku s. p. Jihomoravské státní lesy provedla katedra lesnické mechanizace lesnické fakulty VŠZ v Brně laboratorní porovnání mazacích schopností surového potravinářského řepkového oleje s olejem OA M6A. K měření průběhu opotřebení řetězů Stihl Oilomatic a list Sandvik bylo použito speciální aparatury, na které byly simulovány podmínky chodu řezacího řetězu v listě co do jeho rychlosti a zatížení, včetně dávkování a teploty mazacího oleje. Na základě výsledků zkoušky nelze surový řepkový olej doporučit k použití vzhledem k výrazně rychlejšímu opotřebení řetězu i listy a k vyššímu výkonu potřebnému k pohonu řetězu. Bude nutno vyvinout jakostní olej založený na rostlinném oleji, který by svými vlastnostmi odpovídal olejům zahraničním a který by plně nahradil dosud používané minerální oleje.

lesnická technika; řetězové pily; mazací oleje

SKOUPÝ, A. (Fakultät für Forstwirtschaft der Hochschule für Landwirtschaft, Brno): *Verschleiss von Schneidteilen der Kettensägen, die mit Rapsöl geschmiert werden — ein Vergleich mit dem OA M6A Öl*. *Lesnictví*, 36, 1990 (11): 959–968.

Das zum Schmierem von Schneidteilen der Kettensägen benutzte Öl wird für einen die Umwelt bedeutend belasteten Faktor gehalten. Die zu diesem Zweck benutzten Mineralöle werden in der letzten Zeit durch veredelte Pflanzenöle ersetzt, die für ökologisch unschädlich gehalten werden. Auf Grund einer Forderung des Staatsbetriebes „Südmährische Staatswälder“ wurde mit Hilfe des Lehrstuhls für Forstmechanisierung der Hochschule für Landwirtschaft in Brno ein Laborvergleich von Schmierfähigkeiten des rohen Lebensmittelrapsöl mit dem OA M6A Öl durchgeführt. Zur Messung des Verschleisses der Stihl Oilomatic-Ketten und der Sandvik-Schienen wurde eine Sonderapparatur benutzt, wo mit ihrer Hilfe die Bedingungen des Schneideketten-ganges in der Schiene, betreffs ihrer Geschwindigkeit und Belastung, Dosierung und Temperatur von Schmieröl eingerechnet, simuliert wurden. Auf Grund der Prüfungsergebnisse ist das rohe Rapsöl zur Nutzung nicht empfehlenswert, im Hinblick auf einen bedeutend schnelleren Ketten- und auch Schienenverschleiss und auf die zum Kettenantrieb verwendbare höhere Leistung. Es muss ein hochwertiges Pflanzöl entwickelt werden, das durch seine Eigenschaften den Auslandsölen entsprechen und das voll die bisher benutzten Mineralöle ersetzen würde.

Forsttechnik; Kettensägen; Schmieröle

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REPORT

USE OF ECOLOGICAL PRESSURE LIQUIDS IN MACHINES OPERATING IN A NATURAL ENVIRONMENT

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BARTOŠKA, J. — URBAN, C. (Research Station of the Forest Research Institute in Oravský Podzámok): *Use of ecological pressure liquids in machines operating in a natural environment*. *Lesnictví*, 36, 1990 (11): 969–977.

The leakage of petroleum (mineral) products from forest machines represents a source of permanent pollution of the natural environment. Their replacement by harmless, so called ecological oils represents the successful solution of this problem in accordance with ecological considerations in forestry and the requirements for nature conservation. The paper discusses the problem of replacing the mineral liquid HM 46 used in hydraulic arms in Czechoslovakia by some ecological pressure liquid developed abroad and inquires into the technical and ecological implications of this substitution.

crude oil products; ecological liquids; mineral liquid HM 46

INTRODUCTION

The twentieth century has brought the advancement of hydromechanics in forestry, too. The hydrostatic drive of machines penetrated this sphere in connection with the introduction of new heavy-duty mechanisms and found there permanent application. Its considerable advantage is based on its simplicity, economy and efficiency. On the other hand, in addition to such drawbacks such as the limited speed of flowing of the liquid in the hydraulic system, the change of viscosity of the hydraulic pressure liquid with the change of its working temperature, the need for precision in manufacturing the various components connected directly with the tightness of the hydraulic circuit, and the sensitivity as to the purity of the working liquid, there is also the disadvantage that the operating medium, the mineral oil, may cause by uncontrolled leakage an ecological catastrophe and the degradation of the living environment.

The leakage of hydraulic pressure liquid in hydraulic circuits because of their insufficient tightness or the rupture of hydraulic tubes causes the pollution of surface water and may even destroy its fauna. Seepage of leaked mineral pressure liquid into the soil may cause the pollution of subterranean water resources and watersheds which are important sources of drinking water. The pollution of subterranean water by such seepage represents a considerable danger mainly because in such a case the possibility of decontamination is much more limited as compared to surface water. Of great danger are in this respect mineral oils used in hydraulic mechanisms as a pressure medium, since they are insoluble in water, they cannot be broken down biologically, they are a permanent source of pollution of subterranean water, they change the conditions of life for fauna and flora and they change the biological balance in nature.

According to data published by Bublinec, Šimek (1989) the total leakage (loss) of oil products in forestry logging activities in Slovakia attains the value of 705.8 thousand l and represents the following load for the environment:

1. Transportation by surface runoff (30 %) — 211.700 l
2. Interception and retention in the soil (20 %) — 141.200 l
3. Transportation through the soil and subsurface runoff (20 %) — 141.200 l
4. Filtration into the bottom and underground water (30 %) — 211.700 l

Items 1 and 4 of this seepage represent a potential pollution of $423.4 \cdot 10^9 \text{ m}^3$ water annually.

In the last decennia efforts may be observed abroad to apply ecological thinking in construction, agriculture and forestry, to provide for legislation preventing the pollution of the natural environment, and to use experimentally ecological pressure liquids in mobile hydraulic mechanisms

operating mainly in regions important for water management, or near watercourses, in harbours and in the foodstuff industry. These pressure liquids should replace the present biologically indecomposable and in water insoluble mineral pressure liquids. Research into such liquids and their development aim at finding such pressure media for hydraulic mechanisms which would have suitable properties from the viewpoint of both technical and ecological requirements for a pressure liquid. In the following chapters it will be discussed in more detail what technical and ecological requirements should be met by pressure liquids used in modern heavy-duty machines with hydrostatic drive.

TECHNICAL REQUIREMENTS FOR HYDRAULIC PRESSURE LIQUIDS

The aim of hydraulic liquids is to convert the power of the driving engine to hydraulic power. The properties of pressure liquids are derived from the requirement for the fastest possible pressure transfer. The pressure liquids should be incompressible and of a suitable viscosity in order to display the smallest possible flow resistance and to eliminate internal loss because of seepage in the system. They must possess a lubrication capacity in a wide range of temperature and the ability to absorb and drain off local warming-up arising from overcoming flow resistance. What is important, they do not change their properties because of constant temperature differences, they are easily filtered and do not chemically cause mechanical changes in the packing.

Pressure liquids must not react with metals (copper, lead, bronze, brass) even during long-term contact. They must have a good ability to get rid of air, a low liquidizing temperature, a higher ignition temperature and a low volatility.

As can be seen, hydraulic pressure liquids must comply with a wide range of technical criteria. In the hydraulic systems of forest machines at present mineral hydraulic pressure liquids are used which are not subject to biological decomposition (biodegradation) and are insoluble in water and this may have grave consequences for Nature if there is a leakage from the hydraulic system because of untight joints or if an unexpected breakdown occurs. It is well-known what pollution can be caused by hydraulic liquids if they escape mainly in watersheds, near flowing water or reservoirs, destroying the living environment.

ECOLOGICAL REQUIREMENTS FOR HYDRAULIC PRESSURE LIQUIDS

From the point of view of harmless use of hydraulic liquids in machines operating in a natural environment (in the forest, near watercourses and reservoirs, on agricultural land, but mainly in regions important for water management) it is inevitable that they are biologically decomposable, irreplaceable for alimentation, non toxic for bacteria, fish and other aquatic animals, but also for humans. These criteria have not been proclaimed so far by legislation as binding, therefore hitherto they are more or less unknown.

As a consequence of an ever more profound understanding of the connections on our planet work has been directed, as far as hydraulics are concerned, to the search of alternative pressure liquids which — in contradistinction to the classical hydraulic pressure liquids used at present — would meet the above-mentioned criteria. The concept "Ecological pressure liquids" came into being, representing the result of research and development of several foreign firms.

CLASSIFICATION AND CHARACTERIZATION OF ECOLOGICAL PRESSURE LIQUIDS

In Czechoslovakia at present ecological pressure liquids are neither produced nor developed because customers did not show any interest in them.

Ecological pressure liquids developed and manufactured abroad may be classed as natural and synthetic ones (Tab. I). Natural liquids include those on the basis of vegetable oil, the synthetic liquids include polyglycols (polyalkenglycols) and esters. Table I includes only those liquids for which all necessary data were available.

Tab. II. illustrates how far these pressure liquids meet the mentioned ecological criteria.

a) VEGETABLE OILS

They include the rape-seed oil, the castor oil and the sunflower oil. They are aging quickly, at high temperatures they become dense and change their composition. Their operating temperature in the container should not exceed -20°C and $+80^{\circ}\text{C}$. Under the influence of water they tend to dissociate into glycerol and carboxylic acids.

Among them, rape-seed oil is the most suitable oil to be used in hydraulic systems. It can be mixed with mineral pressure liquids, certain manufacturers indicate that its disadvantage is its lower durability (quicker ageing), as compared to mineral oil, thus requiring shorter intervals of oil replacement, especially at higher loads of heat; but other manufacturers claim to have solved this problem. Rape-seed oil has a low point of conge-lation, the viscosity index is 200 (for mineral pressure liquid about 100), it provides for good lubrication and protects machines against wear and corrosion.

b) POLYGLYCOLS

Their ecological merits are documented in Tab. II. Especially their alimentary unexceptionable nature predetermines them for use in the food industry, cooling plants, stores and on watersheds. They include the polymer polyalkylenglycol (PAG) with decreasing solubility in water in dependence on rising temperature. In order to increase thermic stability and the ability of protection against corrosion, additives and polyethy-leneglycol (PEG), which is soluble in water completely and partially also in mineral pressure liquids, are added. In using this group of pressure liquids the recommendations of the producers should be strictly observed because they comprise a large number of polymers. So called HFC liquids are solutions of difficult inflammability of this group which are used in equipment endangered by fire up to a working temperature of 60°C and -20°C .

II. The comparison of the ecological properties of pressure liquids

Liquids	Properties					
	1	2	3	4	5	6
Mineral pressure liquids	-	-	+	+	+	++
Vegetable oil	+	-	+	+	-	0
Polyglycols	+	++	0	-	++	-
Synthetic esters	+	-	+/-	+/-	+/-	-

Legend: 1 - biological decomposability; 2 - solubility in water; 3 - general compatibility at normal temperature; 4 - compatibility with coatings; 5 - stability against ageing in heavy conditions of operation; 6 - price

++ very good; + good; 0 satisfactory; +/- various; - bad

I. Pressure liquids produced by certain well-known manufacturers

Manufacturer	Type and brand	Specific weight [kg . m ⁻³]	Index of viscosity	Flow point [°C]	Other properties
AGIP GmbH WÜRZBURG SRN	AUTOL BIO HVI 46 rape-seed oil	921	210	-33	insoluble in water, may be mixed with mineral oil
Parodiestrasse 14 8700 WÜRZBURG	ARNICA S 46 ester-based	921	187	-36	decomposable to 97 % in 21 days
ARAL AG BOCHUM ARAL AG Postfach 100450 46 BOCHUM 1	VITAM BAF 46 polyalkylenglycol	1125	140	-30	soluble in water non mixable with mineral oil
AVIA MINERALOEL AG Postfach 800 129 8000 MÜNCHEN 80	AVILUB Hydraulic Bio rape-seed oil — 32 — 46	922 922	215 217	-33 -33	insoluble in water, mixable with mineral oil, decomposable to 97 % in 21 days
BECEM GmbH HAGEN CARL BECEM GmbH Postbox 349, Weststrasse 120 D-5800 HAGEN	HYDROSTAR HEP 32 HEP 46 HEP 68 synthetic, ester	904 921 936	225 185 180	-42	insoluble in water, mixable with mineral oil, decomposable to 95 % in 21 days
BRENNTAG GmbH MÜLHEIM a. d. RUHR	Hydraulic V 32 vegetable oil	925	208	-21	insoluble in water, mixable with mineral oil
BRENNTAG MINERALOEL GmbH, Postfach 100 365 D - 4330 MÜLHEIM	HYDRAULIC TR 22 TR 32 TR 46 TR 68 TR 100 polyalkylenglycol	1016 1028 1040 1044 1050	185 210 215 220 224	-45 -39 -36 -30 -27	soluble in water, insoluble in mineral oil, dissolves coating with the exception of those with two components, unsuitable for paper filters
C + M GmbH ISSUM - SEVELEN C + M GmbH, Postfach 2103 D - 4174 ISSUM - SEVELEN	BA 32 rape-seed oil	918	217	-33	insoluble in water, mixable with mineral oil, decomposable to 97 % in 21 days, 8.45 DM per litre

DEA AG HAMBURG DEA MINERALOEL AG Überseering 40 D - 2000 HAMBURG 60	ECONA R HLP rape-seed oil	918	200	- 30	insoluble in water, may be mixed with mineral oil price 3.2 DM per kg
FUCHS GmbH MANNHEIM FUCHS INTEROIL GmbH D - 6800 MANNHEIM 1	PLATOHYD 40 rape-seed oil	925	210	- 30	insoluble in water, mixable with mineral oil, decomposable to 96 % in 21 days
MOBIL AG WIEN MOBIL OIL AUSTRIA Breitenlee Strasse 100 1222 WIEN	BIOFLUID HLP 22 HLP 32 HLP 46 polyalkylenglycol	1016 1035 1043	185 189 200	- 45 - 57 - 57	soluble in water, may be mixed with mineral oils, non compatible with coatings (with the exception of those with two components) and with paper filters, decomposable to 52 % in 30 days, compatible with packing - to be controlled
SHELL AG DEUTSCHE SHELL AG	FLUID BD 22 BD 32 polyalkylenglycol	1016 1028 1040	185 210 215	- 45 - 39 - 36	soluble in water, may be mixed with mineral oils, dissolves coating with the exception of those with two components, dissolves paper filters, price 2.75 USD per 1 kg
	NATURELLE HF rape-seed oil	920	215	- 33	insoluble in water, may be mixed with mineral oils, decomposable to 98 % in 21 days, price 4.45 USD per 1 kg
WINTERSHALL AG WINTERSHALL AG Postfach 5640	WIOLGAN HR 32 vegetable oil WIOLGAN 40 vegetable oil	920	210 240	- 30 - 33	insoluble in water, may be mixed with mineral oils, non compatible with lead (coating)
D - 4000 DÜSSELDORF	WIOLGAN HU 32 polyalkylenglycol WIOLGAN HU 46 polyalkylenglycol	1028 1040	210 215	- 39 - 36	soluble in water, may be mixed with mineral oils, compatible with packings - to be controlled

c) SYNTHETIC ESTERS

They have been marketed since 1983. They represent a wide range of compounds with properties widely changing according to the input. When using them, the stability of the packing elements against their unfavourable effects should be controlled. Synthetic esters are subject to further research.

EXPERIENCE WITH USING ECOLOGICAL PRESSURE LIQUIDS IN THE WORLD

a) RAPE-SEED OIL

It has been used already for some time as an oil for lubricating the bar of chain saws. According to information obtained from the firm Klöckner-Humboldt-Deutz (1990) in November 1989 in the FRG more than 300 000 KHD tractors were converted without major reconstruction from Diesel drive to rape-seed oil drive. Farmers are abroad the largest users of rape-seed oil as hydraulic pressure liquid. According to some experimental results rape-seed oil is not universally suitable and is not recommended mainly where a change of viscosity occurs as a consequence of high temperature of the medium (over 80 °C). The firm Kaelblegmeinder from the FRG (4) used a wheel loader of the 170 kW class operating over 2,500 working hours with a fill of rape-seed pressure oil and informs that this oil may be used also for longer replacement intervals than with mineral pressure liquid. The firm ORENSTEIN and KOPPEL from Dortmund (4) reports negative results in using rape-seed pressure medium. Besides insufficient durability also adverse properties in a cool environment, sediments of resin and mud in the oil were observed. The firm HANOMAG (4) tried rape-seed oil in five wheel loaders in Lüneburg and is systematically evaluating the results of testing. The firm FAUN from the FRG (4) is not interested very much in ecological pressure liquids with regard to their price. Rape-seed oil on the basis of esters is recommended.

Generally, opinions regarding the use of rape-seed oil differ most widely. Its quality has improved markedly in the last time, but problems are arising out of high and low temperature. Ageing is faster. Yet as to price it is more accessible than alternative ecological pressure liquids. Compared to mineral pressure liquid it is about twice as expensive.

b) POLYGLYCOLS

In the FRG, excavators with polyglycol fill are tested, but the experiments are not yet finalized. The firm LIEBHERR in Kirchdorf (4) has used polyglycols for over two years in 30 to 40 excavators operating in the protection belts of drinking water and near flowing water. The firm ORENSTEIN and KOPPEL from Dortmund (4) having preferred polyglycols for a number of years changed over to liquids based on esters. The firm ATLAS WEYHAUSEN in Delmenhorst (4) has been using in its equipment for over two years polyglycols and esters. No change in maintenance and replacement of the pressure medium has been recorded. No technical adaptation had to be made on valves, hydrogenerators and packings. Polyglycols are not compatible with mineral pressure liquids.

When changing over to the use of polyglycols it is necessary:

- to replace paper filters by filters made from glass fibre
- to eliminate the use of polyurethan packing
- to flush the whole system thoroughly because of the incompatibility of polyglycols and mineral pressure liquids
- to prevent water entering the system because polyglycols are soluble in water

- to control the medium continually (certain suppliers offer control free of charge)
- to use containers without internal lining since polyglycols dissolve most coatings (The firm DEMAG supplies containers without lining).

The duration of use in polyglycols is sufficiently long and so far information obtained on their use is only positive. The price of polyglycols is twice and a half and even six times as high as for mineral pressure liquids. Yet if their interval of replacement, as compared to that of mineral pressure liquids, were prolonged, this unfavourable fact could be eliminated.

c) ESTERS

In the FRG they are in the testing stage. They are thermally stable, durable and have a good lubrication capacity. In Switzerland they are preferred mainly in protected regions. About 2,000 construction machines are operating there with them. According to some information from abroad pressure liquids based on esters are most suitable for the immediate replacement of mineral liquids used in machines (4).

Those using machines abroad and being interested in the use of ecological pressure liquids observe the recommendations of the manufacturers. Enterprises using such liquids have different experience and this leads to accordingly different recommendations. In general, interest in ecological pressure liquids increases abroad and a steep rise in the use of ecological pressure liquids of all three types is to be expected, being stimulated by legislation and standards for ecological oil.

PROSPECTIVE APPLICATION OF ECOLOGICAL PRESSURE LIQUIDS IN FORESTRY IN CZECHOSLOVAKIA AND THE EXPECTED COSTS

Taking into account the proclaimed goals of nature conservation and the "ecologization" of forest management, the direction of future development in this respect can be derived for forestry in Czechoslovakia.

As the shortest way to achieving the use of ecological pressure liquids in the forest management of this country the author envisages the following steps to be taken:

- 1) Establishment of contacts with manufacturers of such liquids abroad and utilization of their experience, information and recommendation for finding out the most suitable liquids.

- 2) Identification of two to three brands of pressure liquids most suitable ecologically and as to price and their purchase for testing in machines in forestry in Czechoslovakia.

- 3) Research concerning technical, ecological and economic connections in the use of identified brands of liquid in cooperation with the manufacturer of hydraulic arms, state enterprise Slovenská L'upča and also with the manufacturers of imported hydraulic arms and their components. Preparation of a report containing the quantification of imports, with the necessary calculation and requirements for the development of domestic ecological pressure liquids in Czechoslovakia.

- 4) Presentation of a proposal for the purchase of the most suitable brand of foreign ecological pressure liquid for machines used in forestry in Czechoslovakia.

According to recorded data and information obtained from the manufacturer of domestic hydraulic arms there are at present in forestry operations in Czechoslovakia about 2,270 hydraulic arms of the HARA type and about 140 foreign arms of the FIS-KARS, HIAB and JONSEREDS types, thus together 2,410 arms.

Using information from foreign literature according to which the price of ecological pressure liquids is twice to six times higher than that of mineral liquids (2 to 8 DM per kg) (4), in case of the immediate replacement of the mineral medium HM 46 (new de-

signation of the former OT-H3) by ecological liquids in all used hydraulic arms (on the average 200 l in each hydraulic arm), it would become necessary to purchase at a time about 500 thousand litres of oil for replacement, this representing 1 to 1.5 million DM even for the cheapest oil.

The present cost of purchase of pressure liquids for hydraulic arms does not represent the cost that should be expended in order to ensure the trouble-free operation of the hydraulic system of hydraulic arms. Intervals of the replacement of pressure liquid are not observed, filters are not changed after the prescribed number of operating hours. Agents of foreign firms manufacturing hydraulic arms express, besides criticism, their astonishment that their machines are at all able to operate free of trouble. The consumption of filters is, namely, unbelievably low. This means that in calculating how much more expensive is the use of ecological pressure liquid than that of the mineral oil HM-46, it is necessary to consider the level of expenditure for such liquids and filters during the whole service life of the equipment according to the operational directions of the manufacturer.

Another circumstance which influences considerably the consumption and leakage of pressure liquids of hydraulic arms into the surrounding environment is their harsh handling in the replenishment of the system and also missing regard for the purity of the liquid (because of not observing the terms for replacement, or because of the penetration of impurities into the hydraulic circuit during repairs of hydraulic elements).

In order to lessen losses of the pressure liquid and improve its handling it is recommended to use for the repumping of liquid from barrels into machine containers, or back, the filtration equipment MOFIZ-E which is manufactured, at a price of 26,000 Kčs, by the state enterprise Stavební stroje, Praha 5 - Zličín, postcode 155 21.

CONCLUSION

The analysis of the problems referred to concerns mainly hydraulic arms and in future it should be expanded also to the use of ecological pressure liquids in other machinery used in forest management, like in tractors and mainly in construction equipment which represent, with their 300 to 400 l containers of pressure liquid, as to the danger of leakage, a still greater risk than hydraulic arms.

The application of ecological oil for the lubrication of chains of the power saw UPIL-R developed by the firm Petrochema Dubová in Slovakia in 1986 could be the first concrete step to take in the "ecologizing" of forest management which should be followed by the replacement of pressure liquids in all machines and equipment.

With regard to the high price of ecological pressure liquids their management and use should be improved, especially care should be taken to prevent losses by leakage caused by the bad technical condition of the equipment. Losses by dripping in the FRG are estimated at 3 to 8 million litres of oil annually. And how much is it in this country? It should be borne in mind that if 1 drop per second escapes from a certain machine or equipment, this represents 950 litres of oil per year. Such losses can be prevented by prescribed maintenance.

Pressure liquids based on polyglycols have a specific weight larger than 1. This means that the physical phenomenon used so far for the separation of water and pressure liquid will cease to exist. Polyglycols combine with water and it will not be possible to separate them in current separators based on the different specific weight of liquids.

For the utilization and disposal of ecological pressure liquids it will be necessary to adopt and introduce as soon as possible accepted and tested foreign prescriptions and directions which are often unknown in this country. This will be enforced by legislation and the need for the preservation of life on the planet Earth.

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BARTOŠKA, J. — URBAN, C. (Výskumná stanica VÚLH, Oravský Podzámok): *Použitie tlakových tekutín v strojoch používaných v prírodnom prostredí*. *Lesnictví*, 36, 1990 (11): 969–977.

Únik ropných (minerálnych) produktov z lesných strojov predstavuje zdroj trvalého znečisťovania prírodného prostredia. Ich zámena prírode neškodiacimi tzv. ekologickými olejmi, znamená úspešné vyriešenie tohto problému v súlade s ekonomizáciou práce v lesnom hospodárstve a požiadavkami ochrany prírody. Práca sa zameriava špeciálne na otázky náhrady minerálnej tekutiny HM 46, používanej v hydraulických rukách v ČSFR, niektorou z ekologických tlakových tekutín vyvinutých v zahraničí a technickými i ekologickými súvislosťami tejto náhrady.

ropné produkty; ekologické tekutiny; minerálna tekutina HM 46

BARTOŠKA, J. — URBAN, C. (Forschungsstation VÚLK, Oravský Podzámok): *Anwendung von Druckflüssigkeiten in den in der Natur eingesetzten Maschinen*. *Lesnictví*, 36, 1990 (11): 969–977.

Das Entweichen der Erdöl- und Mineralprodukte aus den im Wald zur Arbeit eingesetzten Maschinen stellt eine der Quellen der dauernden Umweltverunreinigung dar. Der Ersatz dieser Produkte durch naturschonende sog. ökologische Öle bedeutet eine erfolgreiche Lösung dieses Problems entsprechend der Ökologisierung der Arbeiten in der Forstwirtschaft und den Anforderungen des Naturschutzes. Die vorliegende Arbeit befasst sich speziell mit Fragen des Ersatzes der Mineralflüssigkeit HM 46, die in Hydraulikarmen in der Tschechischen Republik zum Einsatz kommt, durch eine im Ausland entwickelte ökologische Druckflüssigkeit und mit technischen und ökologischen Zusammenhängen eines solchen Ersatzes.

Erdölprodukte; ökologische Flüssigkeiten; Mineralflüssigkeit HM 46

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SCIENTIFIC JOURNALS
of the Czechoslovak Academy of Agriculture

present primary scientific studies on solved research projects from all fields of agriculture and forestry. There are also published scientific treatises, studies, and reviews of foreign literature dealing with scientific problems. Papers from different research workplaces concerning the same problem are edited in monothematic issues. The articles are written in Czech or Slovak with summaries in English.

In 1991 are published the following journals:

Rostlinná výroba (Plant Production)	12 issues a year
Živočišná výroba (Animal Production)	12 issues a year
Veterinární medicína (Veterinary Medicine)	12 issues a year
Zemědělská technika (Agricultural Engineering)	12 issues a year
Zemědělská ekonomika (Agricultural Economy)	12 issues a year
Lesnictví (Forestry)	12 issues a year

Sborník ÚVTIZ (Proceedings of the Institute of Scientific and Technical Information for Agriculture)

Genetika a šlechtění (Genetics and Plant Breeding)	4 issues a year
Ochrana rostlin (Plant Protection)	4 issues a year
Meliorace (Soil Improvement)	2 issues a year
Sociologie zemědělství (Sociology of Agriculture)	2 issues a year
Zahradnictví (Horticulture)	4 issues a year
Potravinářské vědy (Food Sciences)	4 issues a year

The scientific journal "Scientia agriculturae bohemoslovaca" serves to readers abroad. The scientific articles and studies which represent the Czechoslovak contribution to the world knowledge of agricultural sciences are published here. The articles are written in English journal is issued quarterly.

Věstník Československé akademie zemědělské ("Bulletin of the Czechoslovak Academy of Agriculture") is a periodical of the Czechoslovak Academy of Agriculture and research institutes. It provides information on problems relating to the agricultural science and research discussed on plenary sessions, on sessions of the presidium, departments and commissions of the Czechoslovak Academy of Agriculture, on conferences and symposia. It publishes proceedings from international congresses and reports from study journeys from abroad. In numerous columns it issues the materials about plans and results of activities in particular institutes and workplaces. "Věstník ČSAZ" is published monthly.

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