ODC 352:363:375.4

FOLIA FORESTALIA 433

METSÄNTUTKIMUSLAITOS·INSTITUTUM FORESTALE FENNIAE·HELSINKI 1980

PENTTI HAKKILA AND TOMASZ WÓJCIK

THINNING YOUNG PINE STANDS WITH THE MAKERI TRACTOR IN POLAND

MAKERI PIENTRAKTORI NUOREN MÄNNIKÖN HARVENNUKSESSA PUOLASSA

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FOLIA FORESTALIA 433

Metsäntutkimuslaitos. Institutum Forestale Fenniae. Helsinki 1980

Pentti Hakkila and Tomasz Wòjcik

THINNING YOUNG PINE STANDS WITH THE MAKERI TRACTOR IN POLAND

Makeri pientraktori nuoren männikön harvennuksessa Puolassa

Próba zastosowania ciągnika Makeri do pozyskiwania drewna w trzebieżach drzewostanów sosnowych w Polsce

ODC 352:363:375.4
ISBN 951-40-0446-9
ISSN 0015-5543

HAKKILA, P. & WÒJCIK, T. 1980. Thinning young pine stands with the Makeri tractor in Poland. Abstract: Makeri pientraktori nuoren männikön harvennuksessa Puolassa. Streszczenie: Próba zastosowania ciągnika Makeri do pozyskiwania drewna w trzebieżach drzewostanów sosnowych w Polsce. Folia For. 433:1—29.

A considerable proportion of Poland's forests are young Scots pine stands established after World War II, generally on flat ground easy of access. The dense spacing and small size of the trees are serious impediment to the mechanization of harvesting.

In May 1979, within the framework of the multilateral scientific-technical programme of the joint Commission for Cooperation between the CMEA member countries, experiments were conducted in Poland with the mechanization of thinnings of young pine stands by harvesting schedules based on the Finnish Makeri tractor. The same 2,0-ton prime mover can be equipped to serve as feller-buncher, harvester, forwarder or clam bunk skidder.

The investigation comprised combined corridor and selective thinning of a 30-year-old stand, selective thinning of a 32-year-old stand and selective thinning of a 55-year-old stand. The experimental series showed that the Makeri offers a new alternative for the mechanization of thinnings of young pine stands in the flat country of Central Europe. The results obtained concur well with experience gained in Finland.

Makeri's competitiveness compared with other alternative harvesting methods depends on the stand conditions, the timber to be prepared, the hauling distance and other factors. If the correct working technique is employed harvesting schedules based on the Makeri can significantly increase labour productivity in the thinning of young forests. The result is advantageous for the later growth of the stand for the width of the strip roads needed by the Makeri is only 2—3 m and damage to the growing stock is small.

Merkittävä osa Puolan metsistä on toisen maailmansodan jälkeen perustettuja nuoria männiköitä, jotka sijaitsevat yleensä helppokulkuisilla tasankomailla. Harventamisen koneistamista vaikeuttavat vakavasti suuri kasvatustiheys ja puitten pieni koko.

Suomen ja SEVin jäsenmaitten yhteistyökomission tieteellis-teknisen työryhmän ohjelman puitteissa kokeiltiin Puolassa toukokuussa 1979 nuorten männiköitten harvennushakkuitten koneistamista suomalaiseen Makeri traktoriin perustuvia korjuuketjuja käyttäen. Sama 2,0 tonnin peruskone voidaan varustaa kaato-kasauskoneeksi, harvesteriksi, kuormatraktoriksi tai pankkojuontotraktoriksi.

Tutkimuksen kohteina olivat 30-vuotiaan metsikön yhdistetty rivi- ja valikoiva harvennus, 32-vuotiaan metsikön valikoiva harvennus ja 55-vuotiaan metsikön valikoiva harvennus. Koesarja osoittaa, että Makeri traktori tarjoaa uuden vaihtoehdon nuorten männiköitten harvennushakkuitten koneistamiseen Keski-Euroopan tasankomailla. Tulokset vastaavat hyvin Suomessa aikaisemmin saatuja kokemuksia.

Makerin kilpailukyky muihin vaihtoehtoisiin korjuumenetelmiin verrattuna riippuu metsikköoloista, valmistettavasta puutavarasta, ajomatkasta ja muista tekijöistä. Oikeata työtekniikkaa käytettäessä Makeriin perustuva korjuutekniikka mahdollistaa miestyön tuottavuuden merkittävän kohottamisen Puolan nuoria metsiä harvennettaessa. Metsikön myöhemmän kasvun kannalta tulos on edullinen, sillä Makerin vaatimien ajourien leveys on vain 2—3 m, ja puitten vaurioituminen jää vähäiseksi.

Helsinki 1980. Valtion painatuskeskus

Znaczną część polskich lasów stanowią młode drzewostany sosnowe założone po II wojnie światowej, głównie na łatwo dostępnych terenach nizinnych. Duże zagęszczenie drzew oraz ich mała masa stwarzają poważne przeszkody dla mechanizacji pozyskiwania drewna w trzebieżach.

W maju 1979 roku, w ramach programu wielostronnej współpracy naukowo-technicznej Finlandii z krajami — członkami RWPG, przeprowadzono w Polsce badania kilku wariantów w pełni zmechanizowanego procesu technologicznego pozyskiwania drewna w trzebieżach młodych drzewostanów sosnowych, bazującego na fińskim ciągniku Makeri. Ciągnik ten, o masie 2000 kg, jest uniwersalną maszyną bazową i po zamontowaniu odpowiedniego osprzętu może służyć jako maszyna ścinkowo-układająca, ścinkowo-okrzesująco-przerzynająca, ciągnik zrywkowy typu forwarder lub klembank.

W trakcie badań przeprowadzono trzebież kombinowaną /schematyczno-selekcyjną/ drzewostanu w wieku 30 lat oraz trzebież selekcyjną drzewostanów w wieku 32 i 55 lat. Badania wykazały, że zestaw maszyn oparty na ciągniku Makeri oferuje nowe, interesujące możliwości rozwiązania problemu mechanizacji pozyskiwania drewna w trzebieżach młodych drzewostanów sosnowych na terenach nizinnych w Europie Środkowej. Otrzymane wyniki są zgodne z wynikami badań przeprowadzonych wcześniej w Finlandii.

Konkurencyjność ciągnika Makeri w stosunku do innych metod pozyskiwania drewna zależy od warunków drzewostanowych, rodzaju wyrabianych sortymentów, odległości zrywki i innych czynników. Przy prawidłowej technice pracy, w wyniku zastosowania metod pozyskiwania drewna bazujących na ciągniku Makeri, można uzyskać znaczny wzrost wydajności pracy. Równocześnie, przeprowadzenie zabiegów pielęgnacyjnych za pomocą ciągnika Makeri ma pozytywny wpływ na późniejszy przyrost drzewostanu, ponieważ wymagana szerokość szlaków zrywkowych wynosi tylko 2—3 m a uszkodzenia pozostających drzew są nieznaczne.

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PREFACE

Multilateral scientific-technical cooperation between the CMEA member countries and Finland in the sphere of timber harvesting and forest industry began in 1975. Several working teams were appointed within the programme, one of them for "Harvesting of Small-Sized Trees and Production of Whole-Tree Chips for Pulp and Board Industries". The working team prepared a proposal for a recommendation to the joint commision in May 1978 that a joint study be made on the "Use of Small Forest Tractors in the Harvesting of Small-Sized Softwoods in Young Stands in Flatland Conditions". The aim was to discover whether the Finnish Makeri Tractor is suitable for mechanization of the thinnings of young Scots pine stands in East-European forest conditions.

The final investigation plan was drawn up after the Finnish experts Paavo *Valonen* (The Finnish Forest Research Institute) and Aapo *Rahkjärvi* (Makeri Oy) had familiarized themselves in autumn 1978 with the harvesting problems of young softwood forests in Poland (Instytut Badawczy Leśnictwa, Warsaw), in Czechoslovakia (Výskumny Ústav Lesného Hospodarstva, Zvolen) and the German Democratic Republic (Institut für Forstwissenschaften, Eberswalde). The field experiments were performed in May 1979 in Poland and the German Democratic Republic by Finnish and local experts in cooperation. The feller-buncher, harvester, forwarder and clam bunk skidder versions of the Makeri were used in the experiments.

This report presents the results of the experiments at the research station of Janov Lubelski in Poland. Instytut Badawczy Leśnictwa (IBL) for Poland and the Finnish Forest Research Institute, Makeri Oy and Sponsor Oy for Finland were jointly responsible for the experimental series. The report was compiled by the undersigned.

Many experts from both countries participated in the experimental series. Of especially great value was the support of Professor Jozef *Stajniak* (IBL), Mr. Jacek *Komorowski* (IBL), Mr. Tomasz *Wòjcik* (IBL), Mr. Michał *Czereyski* (IBL), Mr. Jerzy *Przybyslawski* (IBL), Mr. Timo *Frilander* (The Finnish Forest Research Institute) and Mr. Kauko *Papunen* (Sponsor Oy) in the various phases of the project. Mr. Pentti *Jussila* was the operator of the Makeri tractors.

The black-and-white photographs were taken by Mr. Leszek *Kacki* and Mr. Michał *Chereyski*. The colour photograph page was donated by Makeri Oy. The drawings were made by Mrs. Pirkko *Hakkila*. The manuscript was typed by Miss Raija *Siekkinen* and translated into English by Miss Päivikki *Ojansuu*. Mr. L. A. *Keyworth* checked the translation.

We express our best thanks to all the Polish and Finnish institutes and private individuals who contributed to this interesting experimental series. We believe that the positive experience of the project will serve to strengthen cooperation between Poland and Finland in the sphere of forestry and forest research.

Helsinki and Warsaw in April 1980

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1. THE THINNING PROBLEM OF YOUNG PINE STANDS IN POLAND

The area covered by forests in Poland is 8,58 million hectares. The state owns 82 % of the forests. The remaining 18 % is owned by communes and private persons. The state-owned forests are managed by NZLP, the General Office for the Administration of State Forests. In 1978 the annual drain was 23,2 mill. m³. The distribution of timber assortments was as follows (Statystyka Polski . . . 1979):

	Mill. m³
Saw, veneer and match timber	11,8
Wood for the pulp and board industries	6,7
Pit-wood and pit props for coal mines	1,9
Fuel wood	1,5

The bolt length for pine pulpwood is generally 1 m, 2 m or 2,4 m and the minimum top diameter 5 cm. The length for pit-wood is 5—14 m at 0,5 m intervals, the minimum top diameter 5 cm and the maximum butt diameter 23 cm.

Timber is made by power saw with manual methods. Delimbing is carried out carefully. An accuracy of ± 2—4 cm is required of the fixed linear measure for pulpwood and ± 10 cm for pit-wood. The raw material for the particle board industry can have different lengths depending on transportation facilities and local factory. In case of log and stem form careful delimbing is required.

The average forest haulage distance is 400—500 m. Haulage is done mainly by horse, farm tractor and skidder. The number of forest tractors is growing and there is a shift from skidders to medium-sized forwarders.

The majority of the forests are on flat ground. The share of mountain forests in area is only ca 10 %. By far the most important tree species is Scots pine which accounts for 72 % of the forest area and 65 % of the growing stock.

The pine stands are usually on flat sandy soil. The rotation age is 100 years. The ratio of young age classes is high today for a significant part of Poland's forests was established after World War II.

To control the branchiness of the trees their spacing is kept fairly dense while the stand is young. Thinnings are moderate and repeated at short intervals. Logging of a flatland pine stand generally progresses according to the following timetable, depending on the fertility of the soil (Zasady hodowli lasu . . . 1979):

Age of the stand, a	Treatment
10—15	Precommercial thinning, no timber recovered
10—30	First commercial thinning, timber recovered partly
20—50	Thinning cuttings at 5—7 year intervals
40—90	Thinning cuttings at 10 year intervals
100	Final cutting

The role of selective thinning in timber production is decisive. About a third of all the timber is obtained from thinnings and the share of wood removed in thinnings will increase in the future because of the abundance of young forests.

The thinning of young pine stands is becoming a serious problem in Polish forestry. The area of young pine thinnings is large but the number of forest workers is decreasing. A part of the silvicultural thinnings may be neglected because of the manpower shortage unless it is possible to raise the degree of mechanization. The small size of the trees, the low areal yield and the dense spacing hamper mechanization. The following figures give an idea of the conditions in which mechanization will have to be implemented in pine stands of different ages.

Stand age, a	Dbh cm	Height m	Number of trees per ha after thinning
30	7—13	4—14	2150—4600
40	8—18	6—18	960—3000
50	9—23	7—22	600—2250
60	11—27	9—25	400—1700
70	13—31	10—27	300—1350
80	14—35	11—28	250—1150
90	15—38	12—30	200— 950

In Poland as in other countries the initial target of mechanization of harvesting has been clear cuttings which are easier to realize. But the shortage of labour will make it necessary in the near future to extend mechanization also to thinnings. To prevent the production capacity of the stand from diminishing the thinning must be selective despite mechanization. Systematic treatments mean yield losses in the later developmental phases of the stand.

The thinning problem of young pine stands in Poland closely resembles that in Finland. However, the spacing of trees is significantly denser in Poland. As encouraging experience has been gained in Finland of the suitability of the small-sized Makeri tractor for mechanization of harvesting young thinnings, a decision was made in 1978 to study this new machine in the flatlands of Poland and the German Democratic Republic within the multilateral scientific technical cooperation project of the CMEA member countries and Finland. This report, prepared by the Polish and Finnish forest research institutes jointly, summarizes the experimental series conducted in Poland in spring 1979.

2. THE STRUCTURE OF THE MAKERI TRACTOR

21. Prime mover

The Makeri tractor is made and marketed by Makeri Oy (address: Niittaajantie 7, 26820 Rauma 82, Finland). The number of Makeri tractors in use at the beginning of 1980 was 35. A new series of 35 machines will be completed in the course of 1980. A number of improvements will be made in the new machines, including an increase

Figure 1. Tipping the cabin aside to service the Makeri tractor.
Kuva 1. Makerin ohjaamo voidaan kääntää syrjään huollon ajaksi.
Fot 1. Przechylna kabina ułatwia obsługę ciągnika Makeri.

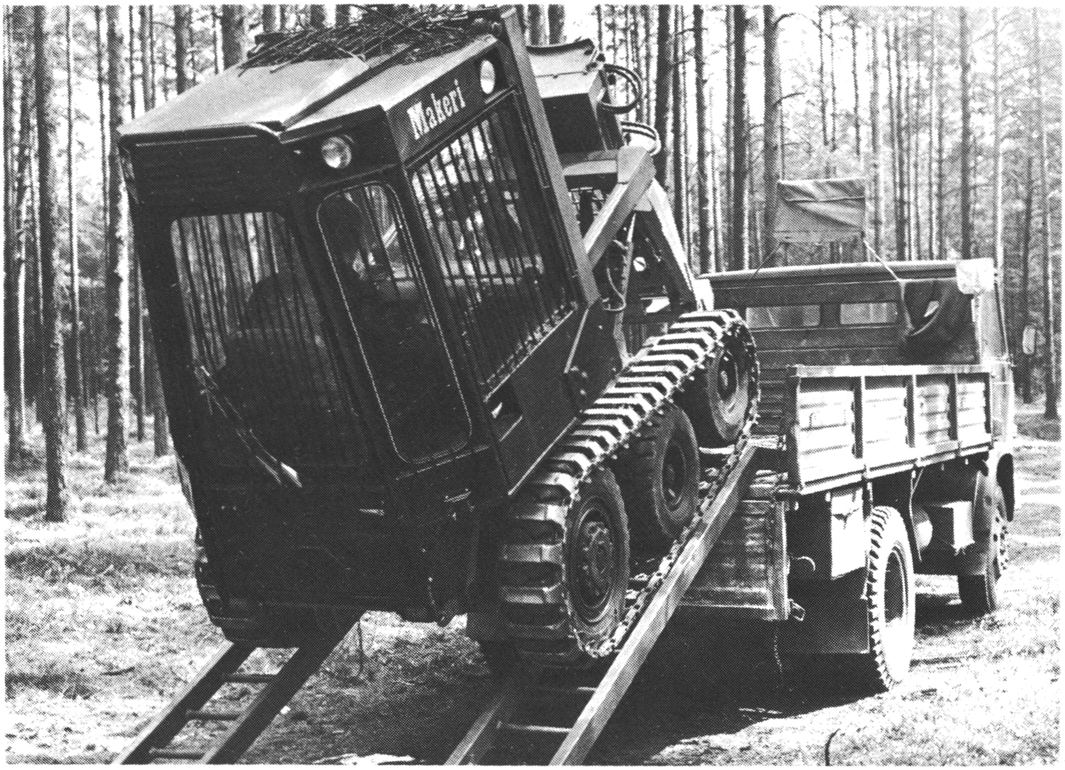

Figure 2. The Makeri tractor can be transported on a light truck.
Kuva 2. Makeria voidaan kuljettaa kevyellä kuorma-autolla.
Fot 2. Ciągnik Makeri może być przewożony samochodem średniotonażowym.

in the motor effect.

The tractor is designed for the special conditions of flatland thinnings. It is therefore essentially smaller than the earlier forest tractors. The dimensions of the prime mover without additional equipment are:

Length	2660 mm
Width	1580 mm
Height	2350 mm

Work in young thinnings requires a tractor that is not only small but also has a low ground pressure and good manoeuvrability. The Makeri has light weight, bogies, tracks and hydrostatic pover transmission to meet these requirements.

The metal tracks have three pairs of wheels. The two rear pairs form a hydraulically adjustable bogie. Power is transmitted hydrostatically to the foremost pair. The steering is rod-controlled by driving the two tracks at different speeds. When the tracks are driven in opposite directions the machine turns in its own length. Lowering the foremost pair of wheels of the bogie facilitates turning. The hydraulic system is the driving brake. The parking brake is mechanical.

Some of the important terrain properties are:

Weight	2000 kg
Track width	239 mm
Surface pressure	0,27 kp/cm^2
Ground clearance	450 mm
Driving speed	0—12 km/h

The tractor has a 2-cylinder, 4-stroke, injection-feed Hatz Z 790 diesel engine. The cylinder volume is 1,27 dm^3 and the maximum effect 22 kW (30 HP) DIN/3000 rpm. The engine is air-cooled. From the middle of 1980 the new tractors will be equipped with a stronger 26 kW engine.

The hydraulic system consists of two closed circuits for driving and one open circuit for the working machines. The tractor is fitted with the hydraulic valves required for the auxiliary devices. Hydraulic coupling is by bayonet catch.

The Makeri meets the high ergonomic requirements set by Finnish labour legislation. The operator's seat and the driving rods can be turned 360 degrees for loading and unloading. The maximum noise level in the safety cabin is 81 dB (A). Due to the tracks the low-frequency vibration is not essentially greater than in the heavier forwarders. This is also partly because the driver in a small tractor has a better view of the terrain and is therefore often able to avoid obstacles (cf. Sirén, Vuorinen and Sauvala 1979).

To reduce the number of technical breakdowns, special attention has been paid to fast and simple maintenance. The servicing points are easily accessible through inspection holes or by tipping the cabin or engine hood aside (Fig. 1). The components are exchangeable and can be replaced in the terrain. The machine can be transported on a light truck (Fig. 2).

22. The work machines

The object set for the Makeri development programme was a large selection of work machines for timber harvesting in young thinning stands. The following work machines are presently available. The felling-bunching device and the harvester device are inter-changeable. The coupling to the prime mover is by bayonet catch.

The felling-bunching device consists of a hydraulic shear and an accumulating grapple. The maximum butt diameter of the tree is 25 cm. Depending on the size and branchiness of the tree the grapple can store and carry simultaneously 1—6 trees. Equipped with the device, the total weight of the Makeri feller-buncher is 2400 kg, length 3090 mm and width 1600 mm.

The harvester device comprises a hydraulic shear for felling and bunching, one stationary and two moving delimbing knives, and two hydraulic feeding rolls to move the tree through the delimbing knives at a speed of 1,25 m/s. The machine used in the experiments in Poland was not equipped with a bolt length measurement system. However, an automatic bolt length measurement device will be optionally available for the new harvesters under construction in April 1980.

The compression power of the feeding rolls is dependent on the diameter and resistance of the tree. The maximum butt diameter is 25 cm. The total weight of the Makeri harvester is 2900 kg. When the harvester device is vertical the total length is 3500 mm. When the harvester device is lowered to the horizontal position for delimbing and bucking the length is 4500 mm. The maximum width is 2100 mm if the harvester device is turned to the side of the machine for delimbing, otherwise always 1600 mm.

The skidding equipment consists of a hydraulic clam bunk at the rear of the machine, a winch and a hydraulic grapple loader mounted on a special base right behind the cabin.

The closed clam has a cross-section area of 0,7 m^2 and a compression power of 1600 kp. The winch has a power of 1300 kp and a speed of 0,9 m/s. The maximum reach of the loader is 4,1 m, the turning radius 360°, net hoisting capacity 1000 kpm and the cross section area of the grapple 0,1 m^2. The total weight of Makeri skidder is 2400 kg, length 2900 mm and width 1600 mm.

The forwarding equipment is the grapple loader already mentioned and a drawing bogie trailer which can be equipped with tracks. The distance of the trailer bogie from the prime mover is adjustable to the length of the timber. The load space is 4—6 m^3 and carrying capacity 4000 kg. The upper end of the side posts of the load space curves inwards to avoid damage to standing trees. The total weight of the Makeri forwarder is 2500 kg, length 6150 mm and width 1600 mm.

3. WORKING TECHNIQUES

31. Thinning based on the Makeri feller-buncher

After severing the tree with shears the feller-buncher keeps the tree in vertical and moves to the next tree. Depending on the size and branchiness of the trees the Makeri can hold 1—6 trees at a time. If the stem volume is 30 dm^3 the load is generally 2—4 trees. The machine then takes the trees to the strip road at 15—30 m intervals, drops the bunch and starts collecting a new load.

The strip road is first opened for a distance of about 10—15 m. Thereafter, the stand is thinned selectively to a width of, say, 10—15 m on both sides of the strip road. The minimum width of the strip road depends on the hauling equipment.

It is customary in Poland that the trees to be removed are marked before the thinning starts. In Finland, the present preference is to leave the selection of the trees to the machine operator. This lowers the marking and planning costs and makes it easier for the operator to find the shortest and straightest driving routes. It may also improve the work motivation of the operator.

To prevent soil and root damage the feller-buncher should try to return to the strip road with the load by reversing. For flexible working, the number of trees left standing in the selective thinning should not exceed 1700—1800 trees per hectare. A better work result and performance are achieved if only 1000—1300 trees are left in the residual stand.

After the feller-buncher has bunched the whole trees, including the branches, alongside the strip road, several alternatives are

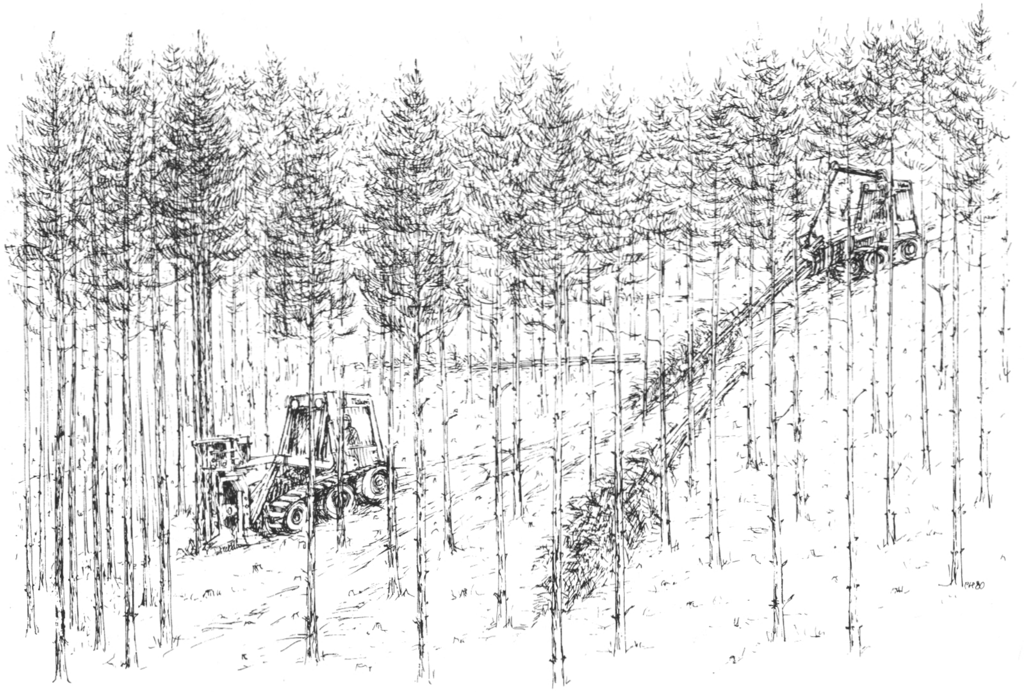

Figure 3. Mechanized selective thinning based on the Makeri feller-buncher and clam bunk skidder versions.
Kuva 3. Makerin kaato-kasauskoneeseen ja pankkojuontotraktoriin perustuva koneistettu korjuuketju.
Fot. 3. Mechanizacja trzebieży selekcyjnej przy użyciu maszyny ścinkowo-układającej i ciągnika klembank Makeri.

available for hauling the trees to the landing site. For the Makeri clam bunk skidder, a 2,0—3,0 m strip road is sufficient (Fig. 3). For an ordinary forest tractor, the minimum strip road width is 4,0 m.

The small-sized whole trees can also be chipped on the strip road with a farm or forest tractor-mounted terrain chipper. In that case the whole-tree raw material is hauled to the landing site in the form of chips. In the Federal Republic of Germany, the Makeri feller-buncher has been used for bunching whole trees for a multi-purpose machine working on the strip road. The Makeri increased the output of the processor by 20 % compared with the alternative methods (Der Makeri-Schlepper 1979).

32. Thinning based on the Makeri harvester

The machine operator first selects the tree to be removed. The tree is severed by the hydraulic shear and kept standing on the shear blades, supported by the delimbing knives. The machine takes one tree at a time in the vertical position to the strip road and drops it by turning the harvester device to the horizontal position. The feeding rolls pull the tree through the delimbing knives across or along the length of the machine. The stem is bucked into bolts of the desired length by the same shear blades that cut the stump cross-section. The bolts drop onto a stack beside of the machine or, if the narrow working space so requires, under the machine.

Many alternatives exist for hauling the timber to the landing site. Examples of the possibilities offered by the Makeri system are:

— The forest haulage is done by the Makeri forwarder (Fig. 4). The strip road width is 2,0—3,0 m and the road spacing 20—30 m. The minimum bolt length is 2 m. However, short bolts do not allow effective utilization of the load space of the forwarder as this study showed. A significantly higher output is achieved with 3 or 4 m bolt lengths.

— The forest haulage is done by the Makeri skidder. The strip road width and spacing are as above. From the output point of view, haulage by skidding is not recommended for bolt lengths of less than 4—5 m. If the harvester does not buck the trees whole stems are skidded to the landing site where the bucking is done by chain saw.

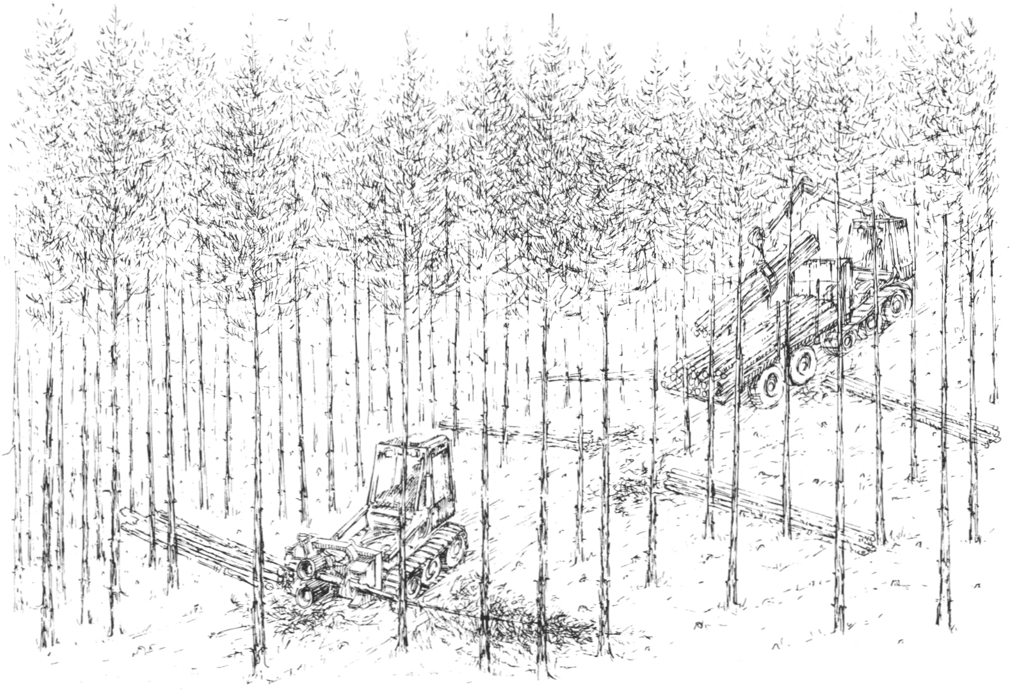

Figure 4. Mechanized selective thinning based on the Makeri harvester and forwarder versions.
Kuva 4. Makerin harvesteriin ja kuormatraktoriin perustuva koneistettu korjuuketju.
Fot. 4. Mechanizacja trzebieży selekcyjnej przy użyciu harwestera i ciagnika forwarder Makeri.

4. EXPERIMENTAL CONDITIONS AT JANOW LUBELSKI

The tests were carried out in the Experimental Forest of Instytut Badawczy Leśnictwa at Janov Lubelski in southern Poland in four pine stands in May 1979. The soil was sandy and the terrain flat in all these cases. Data on the experimental stands are presented in Table 1.

In stand 1 the treatment was a combination of systematic row thinning and selective thinning. Corridors were opened by removing every fifth row of trees in the plantation. In addition, light selective thinning was made between the rows. The average stem volume of the trees removed from the corridors was 65 dm^3 while the volume of the trees selected from between the rows was only 25 dm^3. In stands 2, 3 and 4 the treatment was purely selective. The trees to be cut were marked before thinning in all the stands.

The test series consisted of six mechanized logging schedules based entirely on the use of Makeri tractors. The alternatives studied were as follows (Fig. 5):

Test 1 was made in stand 1. The goal was to deliver whole pine trees, including the branches, to the upper landing site for whole-tree chipping. The majority of the raw material was recovered from the corridors. Only 27 % was taken from between the corridors. The 2,6 m wide corridors spaced 9 m apart acted as strip roads.

- — Felling and bunching first every fifth row with the feller-buncher.
- — Skidding the bunches of whole trees from the corridors to the road side with the clam bunk skidder.
- — Felling then every sixth tree on average from between the corridors and bunching the trees into corridors with the feller-buncher.
- — Skidding the bunches of whole trees to the upper landing with the clam bunk skidder.

Test 2 was made in stand 2. The goal was to produce raw material meeting the standards of the Polish pulp and board industries. The strip road width was partly 2—2,5 m and partly 4 m, which is actually wider than needed in logging based on the Makeri tractors. The distance between the strip roads was 40 m.

- — Severing the trees, moving them one by one in the upright position to the strip road, delimbing and bucking the stems by the harvester. The bolt length was 5,5 m for the butt part and 4,0—5,5 m for the upper part of the stem.
- — Hauling the bolts to the upper landing with the clam bunk skidder.

Test 3 was carried out in stand 2. The only difference from the second test was that no bucking was done after delimbing. The raw material gained met the standards of the Polish particle board industry.

Table 1. Data on the experimental stands at Janów Lubelski.
Taulukko 1. Tietoja Janow Lubelskin koealoista.
Tabela 1. Charakterystyka powierzchni doswiadczalnych w Janowie Lubelskim.

Stand *Metsikkö* *Powierzchnia*	Age, a *Ikä, a* *Wiek, lat*	Number of trees per ha *Runkoluku, kpl/ha* *Liczba drzew/ha*		Growing stock, m^3/ha *Puusto, m^3/ha* *Zasobność, m^3/ha*		Trees removed *Poistettu puusto* *Drzewa usuniete*	
		Before thinning *Ennen harv.* *Przed trzebieżą*	After thinning *Harv. jälkeen* *Po trzebieży*	Before thinning *Ennen harv.* *Przed trzebieżą*	After thinning *Harv. jälkeen* *Po trzebieży*	Average size *Keskikoko* *Śr. miąższość* dm^3	Volume *Tilavuus* *Miąższość* m^3/ha
1*)	30	3240	1940	211	150	47	61
2*)	32	2740	1725	252	206	46	46
3*)	32	4060	2325	267	204	36	63
4**)	55	1212	932	129	115	51	14

*) — solid volume of whole trees, including branches — *—m^3 kokopuuta oksineen — miąższość grub. brutto i drob.*
**) — solid volume of stem wood, excluding bark — *m^3 runkopuuta oksitta — miąższość grubizny netto*

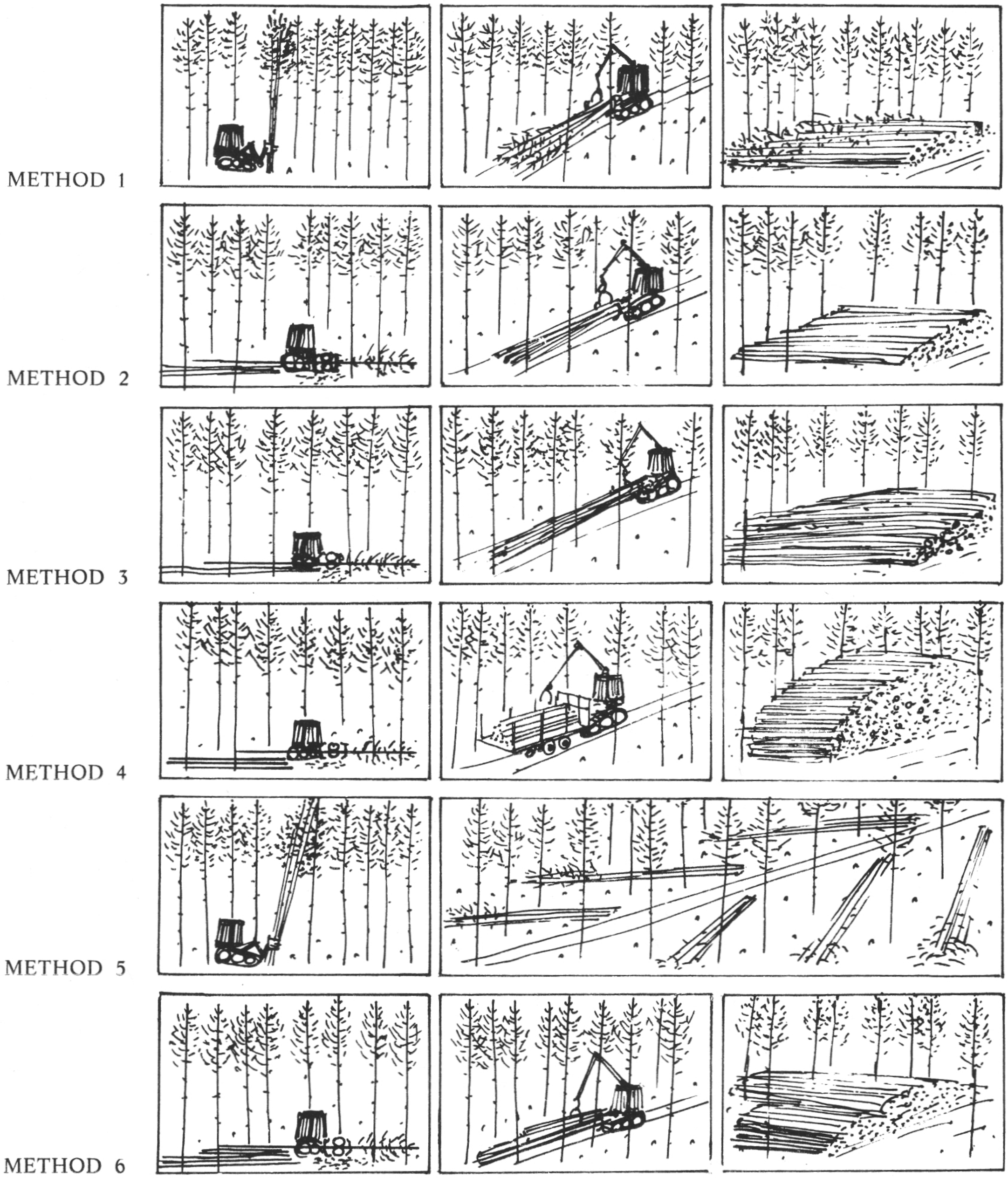

Figure 5. The logging schedules tested at Janów Lubelski.
Kuva 5. Janów Lubelskissä tutkitut korjuuketjut.
Rys. 5. Warianty procesu technologicznego pozyskiwania drewna, badane w Janowie Lubelskim.

Figure 6. Pulpwood alongside a narrow strip road, made by the Makeri harvester. Test 4 in stand 2.
Kuva 6. Makeri harvesterin tekemää kuitupuuta kapean ajouran varrella. Koe 4 metsikössä 2.
Fot. 6. Niewymiarowe stosy papierówki leżące przy wąskim szlaku zrywkowym, wyrobione za pomocą harwestera Makeri.

— Severing the trees, moving them one by one in the upright position to the strip road and delimbing by the harvester.
— Hauling the whole stems to the upper landing with the clam bunk skidder.

Test 4 was also in stand 2. The product was 2 m pulpwood meeting the Polish requirements (Fig. 6).

— Severing the trees, moving them one by one in the upright position to the strip road, delimbing and bucking to 2 m bolts by the harvester.
— Hauling the bolts to the upper landing with the forwarder.

Test 5 was carried out in stand 3. The purpose was to bunch whole trees alongside the strip roads for later chipping on the strip road. The strip road distance was 50 m and the width 4 m.

— Severing and accumalating the trees, moving them in bunches in the upright position to alongside the strip road and bunching perpendicularly to the strip road by the feller-buncher.

Test 6 took place in stand 4. The products made were 5,2 m pit wood from the butt and 2 m pulp wood from the top of the tree according to the Polish standards. The thinning was exceptionally light; only 14 m^3 of timber was gained per hectare. The strip road distance was 50 m and the width 4 m, which again was unnecessarily wide for skidding with the Makeri.

— Severing the trees, moving them one by one in the upright position to the strip road, delimbing and bucking to 5,2 and 2 m lengths by the harvester.
— Hauling the bolts to the upper landing with the clam bunk skidder.

The material collected in the time studies was rather restricted. However, the reliability of the comparisons is improved by the small variation in stand, terrain and weather conditions. The size of the material was:

Test					
1	2	3	4	5	6
Material, m³					
14,4	13,3	5,7	9,5	14,4	13,2

The driver of the Makeri tractors was experienced in working in Finnish forest conditions. He had no earlier experience of logging in Poland.

5. RESULTS

The terminology used in the present study is based on the work study nomenclature approved by the Nordic Forest Work Study Council (NSR) as a common Nordic standard (Skoglig arbeids . . . 1978). In reading the results of the experiments it is important to know the following terms:

m^3 = cubic meter of solid volume; either of stem wood including bark (tests 2, 3, 4 and 6) or whole trees including branches (tests 1 and 5)
performance indicates the quantity of timber harvested or hauled by a tractor in m^3 per operating hour (m^3/h)
labour productivity of a logging schedule indicates the volume of whole trees (incl. branches) or stem wood (excl. branches) in m^3 produced and hauled to the road side per man-hour
effective hour includes the work site time of the tractor excluding interruptions. Effective time is divided into main time and by-time
operating hour consists of effective time (90 %) and short interruptions (10 %).

51. Performance of the feller-buncher

The feller-buncher (Fig. 7) moves in the terrain at 40—50 m/min. A fourth of the

Figure 7. The Makeri feller-buncher in stand 3.
Kuva 7. Makeri kaato-kasauskone metsikössä 3.
Fot. 7. Maszyna ścinkowo-układająca Makeri na powierzchni 3.

Table 2. Results of the experiments with the Makeri feller-buncher.
Taulukko 2. Tuloksia Makeri kaato-kasauskoneella tehdyistä kokeista.
Tabela 2. Wyniki prób maszyny scinkowo-układającej Makeri.

Variable *Muuttuja* *Zmienne*	Test — *Koe* — *Wariant*			
	1	1	1	5
	From corridors *Uralta* *Trzeb. schem.*	From between corridors *Urien väliltä* *Trzeb. selekc.*	Average *Keskim.* *Średnio*	Average *Keskim.* *Średnio*
Tree volume incl. branches, dm^3 *Puun tilavuus oksineen, dm^3* *Miąższość drzewa /grub. i drobn./m^3*	65	25	43	36
Number of trees per bunch *Taakassa puita, kpl* *Liczba drzew w wiązce, szt.*	2,2	3,4	2,6	3,5
Volume of bunch, dm^3 *Taakan tilavuus, dm^3* *Miąższość wiązki, dm^3*	143	84	125	127
Distance to the first tree, m *Etäisyys ensimmäiselle puulle, m* *Odległość do pierwszego drzewa, m*	10,1	16,3	12,0	15,5
Return distance to strip road, m *Paluumatka ajouralle, m* *Odległość powrotna do szlaku zrywk., m*	5,8	13,2	8,1	15,1
Performance, trees per operating hour *Tuotos, puita/käyttötunti* *Wydajność, drzew/h operac. czasu pracy*	152	132	142	125
Performance, m^3 per operating hour *Tuotos, m^3/käyttötunti* *Wydajność, m^3/h operac. czasu pracy*	9,9	3,3	6,1	4,5

effective work site time goes to driving empty, a half is spent on collecting the bunch and the rest on transporting the bunch to alongside the strip road and dropping it onto the ground. The distribution of the effective work site time in the experiments in Poland concurs fully with earlier Finnish experience (cf. *Valonen* et al. 1978). The following figures show the distribution of effective time without by-time which accounted for 7 % of effective time.

Work element	Test results in Poland	Test results in Finland
	Distribution of effective time, %	
Moving to the first tree	24	26
Collecting the bunch	51	50
Carrying the bunch to the strip road	18	17
Unloading the trees	7	7
Effective time	100	100

Despite the accumulating grapple, tree size does not affect the time spent per tree very much. From 25 to 30 sec. on average is needed to handle a tree and the machine consequently fells and bunches 125—150 trees per hour (Table 2). Performance, measured in cubic metres, is thus sensitive to changes in tree size.

Performance was naturally best when trees were removed from the corridors. When small trees were selected from between the corridors in the same experimental stands the performance was essentially smaller because of the small size of the trees and the dense spacing of the growing trees. In combined systematic and selective thinning the performance of the feller-buncher averaged 6,0 m^3 per operating hour (tree volume incl. branches 47 dm^3). Performance was 4,5 m^3/h (tree volume incl. branches 36 dm^3) in selective thinning.

The following figures show the effect of the stem size on the performance of the feller-buncher according to earlier Finnish studies (*Valonen* et al. 1978). Allowing for the differences in stand conditions between Poland and Finland, the results of the present study concur fully with earlier experience.

Stem volume excl. branches, dm³	Performance of feller-buncher, m³/h
20	2,2
40	4,4
60	6,2
80	7,9
100	9,2

In addition to tree size, many other factors affect performance. The most important are the strip road spacing, number of trees left per hectare, areal yield of timber, and the terrain. From the mechanization point of view the spacing of the residual stands was left dense in all the tests, 1700—2300 trees per hectare.

52. Performance of the harvester

The harvester (Figure 8) works in the same way as the feller-buncher as regards severing the tree and moving it to the strip road. The harvester, however, carries only one tree at a time to the strip road, regardless of the stem size. The moving speed on even ground free from stones is 40—50 m/min. The carrying of a bunch hardly slows moving at all.

The time spent on severing and moving depends fairly little on tree size. On the other hand, delimbing the tree and bunching on the strip road require more time the larger the size of the trees.

The consumption of effective work time was distributed between the work elements in the following manner. The difference from the earlier Finnish study (cf. *Valonen* et al. 1978) arises partly from the different interpretation of the boundary between the second and third work phase and partly from the different strip road spacing.

Work element	Test results in Poland	Test results in Finland
	Distribution of effective time, %	
Moving to tree	28	27
Severing the tree	5	13
Carrying the tree to strip road	28	19
Delimbing and bucking	39	41
Effective time	100	100

Figure 8. The Makeri harvester in stand 4. Delimbing and bucking a tree.
Kuva 8. Makeri harvesteri metsikössä 4. Puun karsiminen ja katkominen.
Fot. 8. Harwester Makeri na powierzchni 4. Okrzesywanie i przerzynka drzewa.

Table 3. Results of the experiments with the Makeri harvester.
Taulukko 3. Tuloksia Makeri harvesterilla tehdyistä kokeista.
Tabela 3. Wyniki prób maszyny scinkowo-okrzesującoprzerzynającej (havester) Makeri.

Variable *Muuttuja* *Zmienne*	Test — *Koe* — *Wariant*			
	2	3	4	6
	cmin/tree — *cmin/puu* — *cmin/drzewo*			
Moving to tree *Siirtyminen puulle* *Jazda do drzewa*	27	24	20	28
Severing *Katkaisu* *Ścinka*	3	4	3	7
Carrying the tree to the strip road *Puun tuonti ajouralle* *Jazda z drzewem do szlaku zrywk.*	29	24	21	28
Processing of timber *Puutavaran teko* *Wyróbka sortymentów*	29	26	35	50
Additional operations *Aputyöt* *Czynności dodatkowe*	1	1	2	1
Effective time *Tehoaika yhteensä* *Efektywny czas pracy*	89	79	81	114
Interruptions, 10 % *Keskeytykset, 10 %* *Przerwy, 10 %*	10	9	9	13
Gross effective time *Käyttöaika yhteensä* *Efektywny czas pracy brutto*	99	88	90	127
Stem volume, dm³ *Rungon tilavuus, dm³* *Miąższość strzały, dm³*	36	34	29	90
Moving distance to tree, m *Siirtymismatka puulle, m* *Odległość dojazdu do drzewa, m*	13	14	9	15
Performance, trees/operating hour *Tuotos, puita kpl/käyttötunti* *Wydajność, drzew/h operacyjnego czasu pr.*	61	68	73	47
Performance, m³/operating hour *Tuotos, m³/käyttötunti* *Wydajność, m³/h operacyjnego czasu pracy*	2,2	2,3	1,9	4,2

Performance is influenced by the same factors that affect the feller-buncher: tree size and branchiness, strip road spacing, number of trees left per hectare, terrain, areal yield of timber, and also the timber assortment made.

In stand 2 the harvester handled 60—70 trees per hour in three tests. The performance was 1,9 m³ per operating hour when the stem size was 29 dm³ and the trees were bucked into 2 m bolts. When the stem size was a little larger and the trees were bucked into 5,5 m bolts (top bolts 4,0—5,5 m) the performance rose to 2,2 m³. When no bucking was made performance was 2,3 m³ of whole stems per hour.

Only 47 trees per hour were processed by the machine in experimental stand 6 on account of the sparse spacing and larger size of the trees. Tree size was nearly treble and performance rose to 4,3 m³ in spite of the low areal yield (Table 3).

The performances measured in Poland were slightly lower than those achieved in the Finnish experiments. The results concur all the same if allowance is made for the differences in stand conditions. The following examples from Finland are presented for the sake of comparison.

- — Performance for unbucked stems was 2,5 m^3/h in a pine stand in which the stem size was 27 dm^3 and strip road spacing 15 m *(Valonen* et al. 1978).
- — Performance for 3 m pulpwood was 2,9 m^3/h in a pine stand in which the stem size was 35 dm^3 and strip road spacing 15 m *(Valonen* et al. 1978).
- — Performance for 2 m pulpwood per operating hour with a strip road spacing of 30 m was 3,5 m^3 in a pine stand in which the average stem size was 63 dm^3. Performance rose to 4,3 m^3/h when the strip road spacing was only 15 m *(Melkko* 1979).
- — Performance for 2 m pulpwood per operating hour with a strip road spacing of 15 m was 2,5 m^3 in Sweden in a mixed pine-spruce stand in which the stem size was 60 dm^3 *Arvidsson* and *Spahr* 1980).

Strip road width was 4 m and spacing 40—50 m in Poland. As over a half of the harvester's time was spent on moving to the tree and carrying it to the strip road, it might have been more economical to use 2,5 m wide strip roads with a spacing of, say 20 m. This solution would probably have raised the harvester performance somewhat in Poland and may also improve the later yield of the forest. However, the narrow strip roads can be accepted only if the Makeri tractors are used also for hauling. Performance was reduced in Poland not only by the wide strip road spacing but also by the great number of residual trees, sometimes over 2000 per hectare.

The results of the experimental series conducted in the German Democratic Republic in summer 1979 also agreed with the experience gained in Poland and Finland after allowing for the differences in conditions. The following results were obtained in three experiments (Anlage zur . . . 1979).

- — Every 5th row was removed in the thinning of a young pine plantation and, in addition,

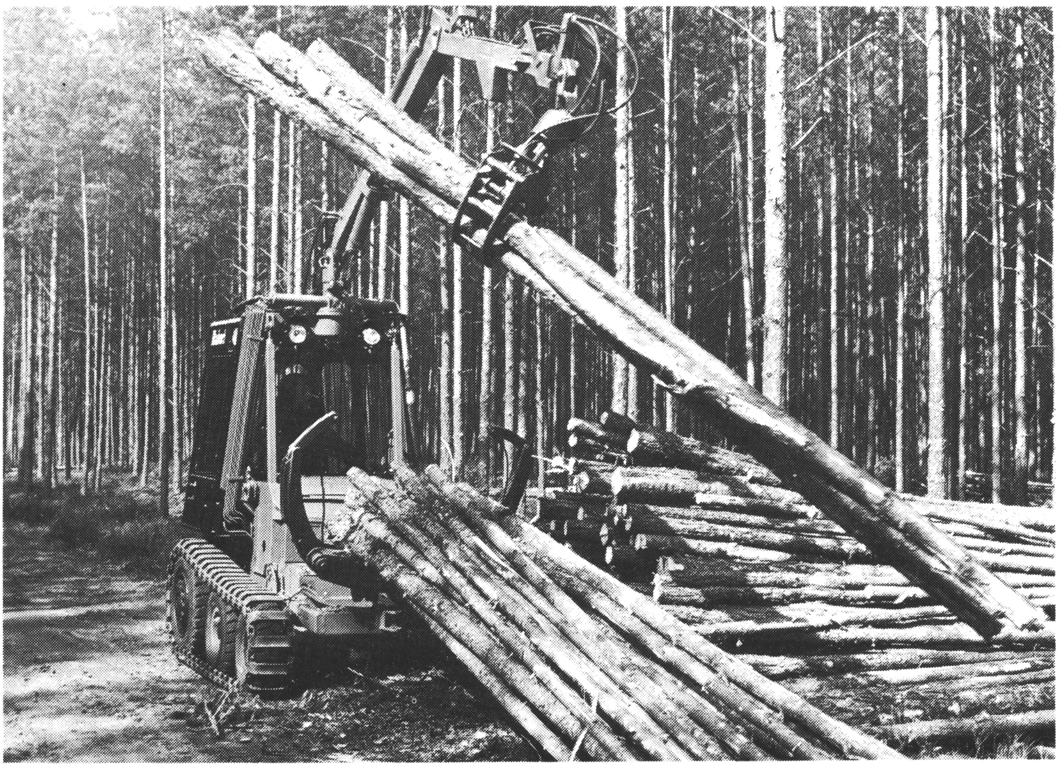

Figure 9. The Makeri clam bunk skidder unloading 5,5 m timber in stand 2.
Kuva 9. Makeri pankkojuontokone purkamassa 5,5 m puutavaraa metsikössä 2.
Fot 9. Zrywka 5,5 metrowych dłużyc ciągnikiem klembank Makeri na powierzchni 2.

the adjoining rows were treated selectively. The average stem size was only 20 dm³. The harvester processed alternatively unbucked stems or 3 m pulpwood. The performance was correspondingly 2,1 and 2,6 m³ per operating hour.

— In a stand with an average stem size of 122 dm³ and strip road spacing of 40 m the harvester processed unbucked stems. The performance was 7,0 m³/h.

53. Performance of the clam bunk skidder

The clam bunk skidder (Fig. 9) lends itself well to work on narrow strip roads. The strip road in the experiment, 4 m, was mostly unnecessarily wide for the Makeri. A width of 2—2,5 m was adequate and did not result in damage to the trees bordering the strip road.

When small-sized trees are hauled the load size of the clam bunk skidder is small. A load made of whole un-delimbed trees was decidedly insufficient in test 1. The following figures show the size of the knuckle boom loader bunch at the time the skidder was loaded and the load size in the different tests.

Test	Assortment	Bunch in loading, m³	Total load of skidder, m³
1	Whole trees	0,19	0,55
2	5,5 m bolts	0,15	0,81
3	Whole stems	0,19	0,62

The Makeri clam bunk skidder's high driving speed compensates to some extent for too small a load. When a load of small-sized timber weighs only 400—800 kg it does not slow the tractor movements essentially. The average speed of the clam bunk skidder in the total material was 88 m/min. when empty and 75 m/min. when loaded. It was distinctly faster than, say, a medium-sized forwarder in Finnish conditions. It must be emphasised, however, that the machine was operating on flat, sandy soil.

The distribution of work time phases depends on the driving distance. The following figures show the distribution for a distance of 200 m. The differences between the tests are due mainly to the organization of the work. In test 1, for instance, the skidder was unloaded by dropping the whole trees from the bunk and the skidder spent only a moment at the landing site. In test 2, on the other hand, long logs of 5,5 m were lifted by grapple into a pile and the skidder spent a significantly longer time at the landing site.

	Test 1	2	3	6
	%			
Driving unloaded	35	28	34	31
Collecting the load	17	23	24	19
Driving loaded	46	25	32	33
Unloading	2	24	10	17
Effective time	100	100	100	100

Although the clam bunk skidder moves at a high speed its performance depends greatly on the driving distance because of the small load size. Performance is calculated for three alternative driving distances in Table 4. When it is only 100 m the performance is 7—8 m³ per operating hour. Over a driving distance of 300 m the performance is halved.

The clam bunk skidder is thus suitable for short driving distances. When the distance lengthens it is more economic to use forwarders which have a significantly larger load capacity. If the timber size is larger than in the present experimental series the size of the skidder load increases and its competitiveness compared with the forwarder improves. For example, in an experiment in the German Democratic Re-

Table 4. Performance of the Makeri clam bunk skidder.
Taulukko 4. Makeri pankkojuontokoneen tuotos.
Tabela 4. Wydajność ciągnika klembank Makeri.

Hauling distance, m *Ajomatka, m* *Odległość zrywki, m*	Test — *Koe* — *Wariant* 1	2	3	4
	m³ per operating hour — *m³/käyttötunti* — *m³/h operacyjnego czasu pracy*			
100	7,0	6,6	7,4	8,4
200	4,2	4,8	4,9	5,9
300	3,0	3,8	3,6	4,6

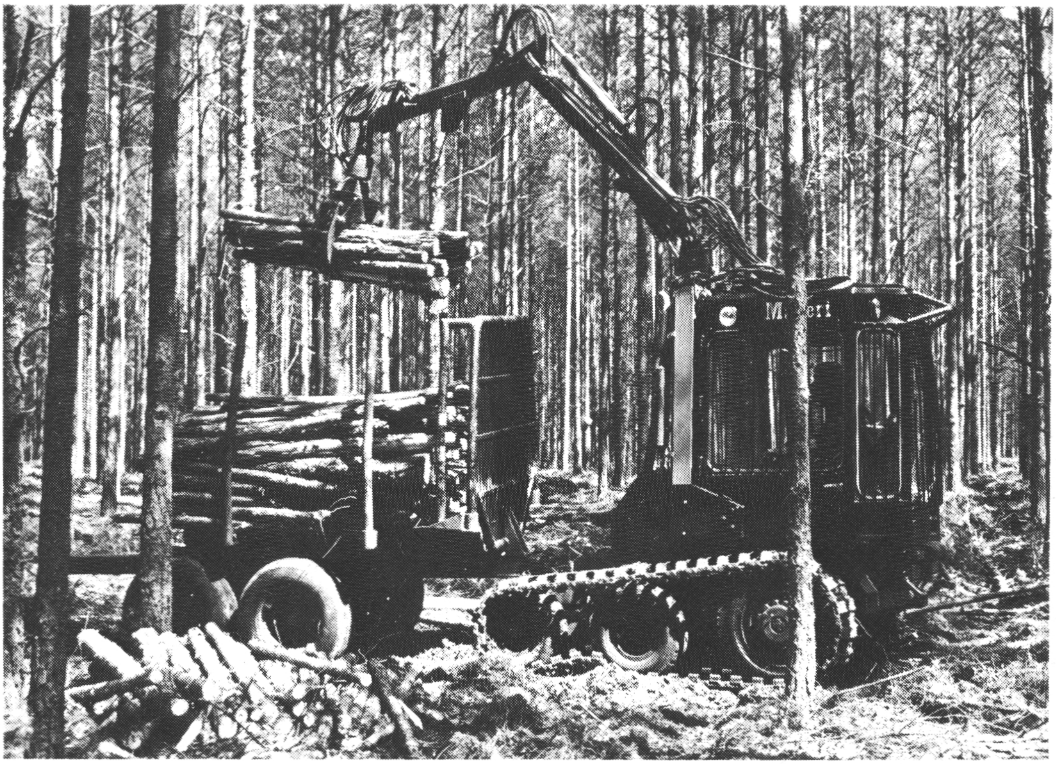

Figure 10. The Makeri forwarder, designed for 3—4 m timber, hauling 2 m pulpwood in stand 2. Because of the short bolt length the load size is small.
Kuva 10. Makeri kuormatraktori kuljettamassa 2 m kuitupuuta metsikössä 2. Lyhyen tavaran kuljetuksessa kuorman koko jää pieneksi, sillä kuormatila on suunniteltu 3—4 m puutavaralle.
Fot. 10. Zrywka papierówki długości 2 m ciągnikiem forwarder Makeri na powierzchni 2. Wskutek małej długości drewna ladunek ciągnika jest niewielki.

public the performance of the Makeri clam bunk skidder over a distance of 150 m was as high as 11,7 m^3 per operating hour when the average size of the delimbed boles was 122 dm^3 (Anlage zur . . . 1979).

The performances achieved in Poland were higher than those measured in Finnish experiments. An example of Finnish experience is a study in which 35 dm^3 unbucked boles were hauled by a Makeri clam bunk skidder. Performance was 5,6 m^3 per operating hour over a distance of 100 m and 4,1 m^3 over a distance of 200 m when the skidder was unloaded by dropping the timber at the landing site. Unloading by grapple loader into piles reduced the performance correspondingly to 4,5 and 3,5 m^3/h (*Valonen* et al. 1978).

The Makeri clam bunk skidder is at its best when narrow strip roads are desired for silvicultural reasons and the machine operates over short distances of under 150 m. The performance is better the longer the timber hauled. In contrast, the use of a clam bunk skidder is not practical over longer distances or when hauling short timber.

54. Performance of the forwarder

The Makeri's forwarder version (Fig. 10) is also capable of moving on a narrow 2—3 m strip road without causing serious damage to growing stock. The advantage of the forwarder over the skidder is its greater load. The cross section of the load space of Makeri forwarder is 2,0 m^2 and the length is adjustable between 3,0 and 3,5 m. The maximum size of the load depends on the length of the timber.

In this experiment 2 m timber was hauled by the Makeri forwarder. As the inadequate

Table 5. Performance of the Makeri forwarder. Test 4.
Taulukko 5. Makeri kuormatraktorin tuotos. Koe 4.
Tabela 5. Wydajność ciągnika forwarder Makeri. Wariant 4.

Hauling distance, m *Ajomatka, m* *Odległość zrywki, m*	2 m timber *2 m tavara* *drewno dług. 2 m*	3 m timber *3 m tavara* *drewno dług. 3 m*
	m^3 per operating hour — *m^3/käyttötunti* — *m^3/h operacyjnego czasu pracy*	
100	5,6	8,1
200	4,8	7,0
300	4,2	6,1

range of the loader makes it impossible to place two 2 m bolts end-to-end in the trailer the load size was unsatisfactory, only 1,9 m^3 on average. The load volume in the haulage of 3 m pulpwood in the Finnish studies has been 3,1 m^3 (cf. *Valonen* and *Kalaja* 1977) and 3,3 m^3 (cf. *Melkko* 1977), respectively, and for sawtimber even 5,6 m^3 (cf. *Valonen* et al. 1978). In a Swedish study, however, the load volume of 3 m pulpwood was only 2,1 m^3 *(Arvidsson* and *Spahr* 1980).

Short timber also slows the loading and unloading of the forwarder. In this experiment the bunch of the grapple loader was 46 dm^3 in loading and 156 dm^3 in unloading. The figures in the Finnish studies for 3 m timber were 200 and 290 dm^3, respectively. An inadequate bunch size naturally reduced the performance.

The driving speed of the Makeri forwarder is slightly higher than that of medium-sized forwarders. The speed when driving empty in Poland was 79 m/min. and when loaded at 56 m/min., thus of the same magnitude as in the Finnish studies. On the other hand, the speed of the Makeri forwarder, especially when loaded, was distinctly lower than that of the Makeri skidder.

The following figures show the distribution of the forwarder's work time in Poland and Finland over a driving distance of 200 m (test A: *Valonen* and *Kalaja* 1977, test B: *Mikkonen* and *Ylä-Hemmilä* 1977). Roughly a half of the work time is spent on making the load, a fourth on unloading it and a fourth on moving empty or loaded.

The performance of the forwarder is seen in Table 5 which is based on measurements

	Test results in Poland	Test results in Finland Test A	Test B
	Distribution of effective time, %		
Preparation of haul	2	—	5
Driving empty	15	11	15
Loading	51	49	47
Driving loaded	9	15	13
Unloading	23	25	20
Effective time	100	100	100

for 2 m timber only. The theoretical performance for 3 m timber was arrived at by raising the 2 m results by 45 %. This is based on the fact that the output of all haulage work phases increases with the Makeri forwarder in ratio to bolt length when changing from 2 m to 3 m timber.

The performance of the forwarder over a distance of 200 m with 2 m timber was 4,8 m^3 per operating hour. This was significantly smaller than in the Finnish experiments. The corresponding imputed performance for 3 m timber is 7,0 m^3/h. This concurs well with the Finnish experimental results in which the haulage performance for 3 m timber in different experiments has been 7,3 m^3/h *(Valonen* and *Kalaja* 1977), 6,6—7,2 m^3/h *(Valonen* et al. 1978), and 6,1—8,3 m^3/h *(Mikkonen* and *Ylä-Hemmilä* 1977). Thus, if the bolt length can be increased in Poland to 3 or 4 m the performance of the Makeri forwarder will increase highly significantly. A lower performance, 5,7 m^3 of 3 m pulpwood per hour, was achieved in a Swedish experiment over a hauling distance of 87 m *(Arvidsson* and *Spahr* 1980).

Despite the applications mentioned above, the Makeri forwarder can not reach as high output level as bigger forwarders. On the other hand, its purchase price is considerably cheaper. As it also permits the use of narrower strip roads, it seems to offer an attractive alternative for hauling timber in young thinning stands in flatland conditions.

55. Damage to standing trees

An inventory was taken of the damage caused by the tractor to standing trees. The results are accurate for stem damage, but root damage is difficult to asses and the extent of the damage is probably underestimated.

There are great differences in the susceptibility to damage between tree species. Damage to spruce mostly results in the onset of decay, whereas pine is highly resistant to decay. Moreover, the superficial root system of the spruce is hurt more easily. The root system of the pine goes deeper, especially on dry sites, and the problem is much smaller.

The share of wounded trees in the growing stock can be seen from the following figures. The differences between the tests vary irregularly because the experimental stands were small. Thus no conclusions are warranted on differences between the harvesting schedules. The incidence of damage was greatest in corridor thinning, but as this experiment was the first one the driver's lack of familiarity with local conditions may have been a part factor.

Test	Trees left per ha	Stem	Roots	Total
		Proportion of trees damaged, %		
1	1940	5,9	—	5,9
2	1725	—	2,7	2,7
4	1725	1,3	1,5	2,8
5	2325	1,4	0,3	1,7
6	932	1,2	—	1,2
Average	1730	2,0	0,9	2,9

Most of the damage is to trees bordering the strip road and less than half a metre from the track of the bogie. The stem damage is very close to the butt of the tree. Hardly any damage occurs higher up the stem.

Only 3 % of all the trees were damaged. The result must be regarded as very satisfactory even allowing for the fact that some root damage escapes detection at inventories. The Makeri has been found in Finnish studies to cause more root damage during the summer. The difference is explained by the fact that the root system of the pine in the sandy soils of Poland lies deeper than in Finland's colder soil. The damage caused by different forwarders and processors according to Swedish and Finnish studies has been greater than in the present work almost without exception (cf. *Kyttälä* 1980).

It must be emphasized that these results of the Polish experiments are valid only for Scots pine stands. It may be assumed that the incidence of root damage in a spruce stand would be much higher. Moreover, the damage to the residual trees is higher also in northern conditions where the trees have a more superficial root system (cf. *Arvidsson* and *Spahr* 1980).

6. CONCLUSIONS

The Makeri tractor is a modern basic machine. It can be equipped for many different operations. Its small size allows it to work in young thinning forests too dense for other machines. The strip road width can be as narrow as 2—3 m without leading to serious damage to standing trees. The ergonomic properties of the machine are good. The price is considerably lower than that of medium-sized or large forest machines with the same functions.

Manual delimbing of trees in bunches alongside the strip road is very difficult. Therefore, the application of the *Makeri feller-buncher* is feasible in mechanized logging schedules only. A multi-purpose machine or a whole-tree chipper adapted to processing whole trees on the strip road are proper alternatives to follow the feller-buncher in the harvesting schedule. At present, neither a suitable whole-tree chipper nor a method of processing whole-tree chips for the forest industries is in use in Poland. However, the terrain chipping system of whole trees will be developed further in Poland.

The manoeuvrability of the Makeri feller-buncher enables movement in relatively dense stands. The number of trees left standing may be up to 2000 per hectare without any serious damage occurring to the residual growing stock. However, the performance of the feller-buncher suffers from the dense spacing of the trees. On average, an output of 4—6 m^3 per operating hour can be excepted in selective thinning if the stem size is 30—60 dm^3.

The performance of the Makeri feller-buncher was highest in corridor thinning. The output was considerably lower in selective thinning due to the smaller tree volumes and longer distances between strip roads.

In systematic thinning the target of removing complete rows of trees is simply to make the forest accessible to machines and to shorten the carrying distance of timber. From the silvicultural point of view, systematic thinning is not recommended. The trials show that when a narrow machine like the Makeri is used for thinning the treatment can be selective.

Of the different alternatives tested in the joint project the *Makeri harvester* is at present the most useful for Polish conditions. It makes it possible to mechanize fully the heaviest operations of manual logging in selective thinnings of young pine stands at the age of 30—55 years, when the number of trees is reduced to 1700—1800 pieces per hectare or less. With this spacing the injuries to the residual growing stock do not limit the application of the machine, and compared with methods used presently in Poland a considerable labour productivity can still be achieved.

The performance of the Makeri harvester is greatly affected by the tree size. When the stem volume grows from 30 dm^3 to 100 dm^3 the output increases from 2 to 4—6 m^3 per operating hour, respectively. The output depends also on the timber assortment produced. It is higgest in the tree length system where no bucking is needed.

The labour productivity of the Makeri harvester relative to the small size of the trees is very satisfactory (Table 6). It was ca 6—8 times higher in stand 2 of the second age-class and ca 4—5 times higher in stand 4 of the third age-class than the labour productivity of the present manual methods used in Poland for felling, delimbing, crosscutting and winching or carrying to the strip road (cf. *Czereyski* 1967, *Millak* and *Wòjcik* 1977).

The quality of delimbing was good when the stems were straight and the branch diameter was no thicker than 3—4 cm.

Colour photograph. The new Makeri harvester coming on the market at the end of 1980.
Värikuva. Makerin uusi harvesteri, joka tulee markkinoille vuoden 1980 lopussa.
Kolorowa fotografia. Nowy Makeri harwester, który ukaże się na rynku pod koniec 1980 roku.


MAKERI
33T


MAKERI
33T

Table 6. The labour productivity of the mechanized harvesting methods based on the use of the Makeri tractors in thinning young pine stands.

Taulukko 6. Miestyön tuottavuus Makeri traktoreihin perustuvissa koneistetuissa korjuumenetelmissä nuorta männikköä harvennettaessa.

Tabela 6. Wydajność pracy ciągnika Makeri w wariantach zmechanizowanego procesu technologicznego pozyskiwania drewna w trzebieżach młodych drzewostanów sosnowych.

Harvesting method *Korjuumenetelmä* *Wariant procesu technologicznego*	Hauling distance, m *Kuljetusmatka, m* *Odległość zrywki, m*	Labour productivity m^3/man hour *Miestyön tuottavuus m^3/h* *Wydajność pracy m^3/roboczogodzinę*
1*)	100	3,96
	200	2,97
	300	2,38
2**)	100	1,62
	200	1,49
	300	1,38
3**)	100	1,76
	200	1,57
	300	1,42
4**)	100	1,42
	200	1,36
	300	1,31
5*)	—	4,49
6**)	100	2,79
	200	2,45
	300	2,19

*) m^3 of whole trees incl. branches
m^3 kokopuuta oksineen
m^3 grubizny brutto i drobnicy
**) m^3 of stem wood excl. branches
m^3 runkopuuta oksitta
m^3 grubizny brutto

Generally speaking, the delimbing result was fully satisfactory in the second age-class stand as well as in most of the third age-class stand. It was unsatisfactory only when the dimensions of the trees approached the limit of the machine's maximum capacity.

The small damage caused by the felling and bucking shear on the cross-cutting surface does not lower the quality of timber used for pulping or board manufacturing. However, the feed rollers cause regular, 3—6 mm deep wounds along the stem. This is not especially harmful for the raw material of the pulp and board industries, but it is of no small importance for pit props.

In Polish conditions bucking into exact length is required. To adapt the harvester better to Polish requirements and to extend the range of application, it must be equipped with an automatic and reliable length measurement system. Moreover, the minimum distance between the feed rollers should be decreased to 5 cm or less to ensure better recovery of thin tops, and the injuries caused by the rollers to the pit props should be reduced.

In the new Makeri harvesters, coming on the market at the end of 1980, an automatic length measurement device will be optionally available. It will also be possible to delimb the top to a minimum diameter of 4 cm.

The performance of the *Makeri clam bunk skidder* when hauling 5 m bolts, whole stems or whole trees is higher than that of agricultural tractors equipped with additional accessories as they are nowadays used in Poland. An output of ca 7 m^3 per operating hour can be expected if the hauling distance is 100 m.

As a result of the small load size of the skidder, the output decreases quickly with increasing driving distance. Because the average hauling distance in Poland is 450 m, forwarders are more economical in most cases.

On the other hand, a Makeri tractor is considerably cheaper than a medium-sized forest tractor. Moreover, the Makeri skidder's ability to work easily on narrow, 2—3 m strip roads is a noteworthy silvicultural advantage.

Neither does the *Makeri forwarder* require as wide strip roads as bigger tractors. For output alone, the Makeri forwarder is not competitive with medium-sized forwarders. On the other hand, lower investment and maintenance costs must also be taken into consideration. It must be emphasized that the 2 m pulpwood length used in the experiments was not the proper one for the load space of the forwarder, and this had a negative effect on the performance. The output in forwarding 2 m pulpwood was ca 5 m^3 per operating hour over a 200 m hauling distance. It can be calculated that the output in forwarding 3 m pulpwood would have been 7 m^3/h.

Due to the relatively long hauling distances, forest transport of timber will be carried out increasingly with forwarders in Poland in the future. The prevailing machine will probably be a medium-sized forwarder. However, in special conditions like young thinning stands where wide strip roads are undesirable, the use of the small-sized Makeri forwarder may very well be economical. It is important that the range of the loader, the length of the load space and the location of the side posts of the trailer match the length of the timber so that the capacity of the forwarder can be fully utilized.

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SELOSTE

MAKERI PIENTRAKTORI NUOREN MÄNNIKÖN HARVENNUKSESSA PUOLASSA

Metsien ikäluokkarakenteen ja odotettavissa olevan metsätyövoimapulan seurauksena nuorten männiköitten harvennuksista on kehittynyt vakava ongelma Puolan metsätaloudelle. Ellei työn tuottavuutta onnistuta kohottamaan koneistamisen avulla, metsänhoidollisesti välttämättömistä harvennushakkuista saatetaan joutua tinkimään.

Suomen ja SEV-maitten monenkeskisen tieteellis-teknisen yhteistyön puitteissa toteutettiin puun kokonaiskäytön asiantuntijoiden valmistelemana toukokuussa 1979 koesarja, jossa selvitettiin mahdollisuuksia koneistaa nuorten männiköitten harvennushakkuita Puolassa ja Saksan demokraattisessa tasavallassa suomalaiseen Makeri pientraktoriin perustuvia korjuuketjuja käyttäen. Puolassa tutkimuksen toteuttamisesta vastasivat yhteisesti Instytut Badawsczy Leśnictwa (IBL), Metsäntutkimuslaitos, Makeri Oy ja Sponsor Oy. Tässä julkaisussa selostetaan Janov Lubelskin tutkimusasemalla Puolassa tehtyjä kokeita. Paikoin viitataan lyhyesti myös Saksan demokraattisessa tasavallassa tehdyn vastaavan koesarjan tuloksiin.

Makeri on monipuolinen, korkeat ergonomiset vaatimukset täyttävä traktori, joka pienen kokonsa ansiosta kykenee työskentelemään tiheämmässä metsässä kuin muut toiminnoiltaan vastaavat metsätraktorit ja monitoimikoneet. Se voidaan varustaa kaato-kasauskoneeksi, harvesteriksi, pankkojuontotraktoriksi ja kuormatraktoriksi.

Makeri kaato-kasauskone soveltuu lähinnä vain koneistettuihin korjuuketjuihin, sillä ajouran varteen kerättyjen kokopuukasojen jatkokäsittely ei ole käsityönä mielekästä. Esimerkiksi ajouralla toimiva prosessori tai kokopuuhakkuri soveltuvat luontevasti samaan ketjuun Makeri kaato-kasauskoneen kanssa. Puolassa näitä koneita ei ole toistaiseksi käytössä, mutta tavoitteena on kehittää nimenomaan kokopuuhaketukseen perustuvia korjuuketjuja.

Makeri kaato-kasauskone kykenee liikkumaan verraten tiheässäkin metsikössä. Puolan männiköissä oli mahdollista jättää jopa 2 000 puuta hehtaarille ilman, että puustolle aiheutui vakavia juuri- tai runkovaurioita. Koneen tuotos kuitenkin alenee jäävän puuston tiheyden kasvaessa. Puun koon ollessa 30—60 dm^3 tuotos oli 4—6 m^3 käyttötuntia kohti. Tuotos kasvoi puun koon myötä.

Kaato-kasauskone ylti parhaaseen tulokseen istutusmännikön systemaattisessa riviharvennuksessa. Rivien välissä tehty valikoiva harvennus oli selvästi hitaampaa osaksi pitempien kulkumatkojen ja osaksi rungon pienemmän koon seurauksena. Systemaattinen harvennus ei ole kuitenkaan metsänhoidolliselta kannalta suositeltava vaihtoehto. Koesarja antoi toisaalta selvän osoituksen siitä, että kaato-kasauskone soveltuu tiheässäkin männikössä myös valikoivaan harvennukseen.

Koesarjassa tutkituista koneista näytti Puolan oloihin soveltuvan kaikkein parhaiten *Makeri harvesteri,* jolla voidaan koneistaa korjuutyön raskaimmat vaiheet iältään 35—55-vuotiaissa männiköissä, vaikka jäävän puuston tiheys on jopa 1700—1800 kpl/ha. Puolan perinteisiin menetelmiin verrattuna miestyön tuottavuus oli nuoremmassa metsikössä 6—8 kertainen ja vanhemmassa metsikössä 4—5 kertainen (vrt. taulukko 6).

Puun koko vaikuttaa harvesterilla tuotokseen jyrkemmin kuin kaato-kasauskoneella. Rungon tilavuuden kasvaessa 30 dm^3:stä 100 dm^3:iin harvesterin käyttötuntituotos kasvaa 2 m^3:stä 4—6 m^3:iin. Tuotokseen vaikuttaa lisäksi tehtävän pölkyn pituus. Parhaaseen tulokseen päästään luonnollisesti runkomenetelmässä, koska katkonta jätetään tekemättä.

Karsintatyön jälki oli täysin tyydyttävä lukuun ottamatta koneen kapasiteetin ylälaidan puita, joissa oksien paksuus ylitti 3—4 cm. Syöttörullat aiheuttivat pölkyn pinnalle 3—6 mm:n syvyisiä painautumia, jotka eivät ole erityisen vaarallisia massateollisuuden raaka-aineessa mutta joita ei hyväksytä Puolan oloissa tärkeässä kaivospuussa.

Suurempana heikkoutena oli kuitenkin pölkyn pituuden automaattisen mittausjärjestelmän puuttuminen. Katkaisukohta oli määritettävä silmävaraisesti, ja sen seurauksena pölkyn pituuden vaihtelu ylitti selvästi Puolassa noudatettavat ankarat mittatoleranssit. Kun tämä ongelma lienee jo ratkaistu vuoden 1980 lopulla valmistuvassa harvesterisarjassa, koneen soveltuvuus Keski-Euroopan metsätalouteen paranee edelleen.

Makeri pankkojuontokoneen tuotos ylitti selvästi Puolassa nykyisin yleisessä käytössä olevien lisävarusteisten maataloustraktorien tuotoksen laahusjuonnossa. Esimerkiksi 100 m:n ajomatkalla saavutetaan 7 m^3:n käyttötuntituotos, mutta pienen kuormakoon seurauksena tuotos supistuu nopeasti matkan kasvaessa. Kun keskimääräinen metsäkuljetusmatka on Puolassa 450 m, kuormatraktorit ovat useimmissa tapauksissa taloudellisempia. Makeri pankkojuontotraktorin halvempi hinta ja kyky liikkua kapeilla, 2—3 m:n ajourilla ovat kuitenkin merkittäviä etuja, joitten ansiosta se edellisestä huolimatta on nuorissa harvennusmetsissä lyhyillä ajomatkoilla huomionarvoinen vaihtoehto.

Myös *Makeri kuormatraktorin* merkittävin etu on mahdollisuus pienentää ajourien leveyttä. Pelkästään tuotoksen perusteella se ei ole kilpailukykyinen keskiraskaaseen kuormatraktoriin verrattuna. Puolan koesarjassa, jossa kuljetettiin Makerille heikosti soveltuvaa 2 m kuitupuuta, käyttötuntituotos jäi 200 m:n ajomatkalla vain 5 m^3:iin. Aikatutkimustulosten perusteella voidaan kuitenkin laskea, että 3 m kuitupuun kuljetustuotos olisi ollut vastaavasti 7 m^3/h.

Puolan puunkorjuutoiminnassa tullaan lähivuosina siirtymään enenevässä määrin laahustraktoreista kuormatraktoreihin. Jo tehtyjen ratkaisujen pohjalta on ilmeistä, että keskiraskaitten kuormatraktoreitten käyttö tulee kasvamaan nopeasti. Tästä huolimatta on ongelmallisten nuorten männiköitten harvennuksissa runsaasti kohteita, joissa Makeri kuormatraktori on pienen kokonsa ansiosta varsin kilpailukykyinen vaihtoehto, mikäli myös puuntuotannolliset näkökohdat otetaan huomioon. On kuitenkin välttämätöntä, että kuormaimen ulottuvuus, kuormatilan pituus ja pankkojen sijoittelu vastaavat korjattavan puutavaran pituutta.

Suomalais-puolalainen koesarja osoitti, että Makeri traktorien liikkuminen on nopeata ja vaivatonta Keski-Euroopan tasankomaitten kangasmetsissä. Puuston vahingoittuminen pysyi varsin kohtuullisena, sillä jäljelle jääneen metsän tiheydestä huolimatta vain 3 % puista sai runko- tai juurivaurioita. On kuitenkin huomattava, että kaikki kokeet tehtiin männiköissä, joissa juuristo on paljon syvemmällä kuin kuusikoissa.

STRESZCZENIE

PRÓBA ZASTOSOWANIA CIĄGNIKA MAKERI DO POZYSKIWANIA DREWNA W TRZEBIEŻACH DRZEWOSTANÓW SOSNOWYCH W POLSCE

Cięcia pielęgnacyjne w młodych drzewostanach sosnowych w Polsce należą do prac stosunkowo najmniej zmechanizowanych. Wskutek zmniejszających się stale zasobów siły roboczej w leśnictwie polskim wykonanie zadań z tego zakresu może napotykać na poważne trudności. Zapobiec im można jedynie poprzez zwiększenie stopnia mechanizacji tych prac.

W maju 1979 roku, w ramach programu wielostronnej współpracy naukowo-technicznej Finlandii z krajami — członkami RWPG, przeprowadzono w Polsce badania kilku wariantów zmechanizowanego procesu technologicznego pozyskiwania drewna w trzebieżach młodych drzewostanów sosnowych, bazującego na fińskim ciągniku Makeri.

W niniejszym sprawozdaniu przedstawiono wyniki prób przeprowadzonych w Lasach Doświadczalnych IBL w Janowie Lubelskim. Próby zostały przeprowadzone wspólnie przez Instytut Badawczy Leśnictwa ze strony polskiej i Fiński Instytut Badawczy Leśnictwa oraz firmy Makeri Oy i Sponsor Oy ze strony fińskiej.

Ciągnik Makeri jest nowoczesną maszyną bazową. Po wyposażeniu w odpowiedni osprzęt może on wykonywać wiele różnych operacji. Jego małe wymiary gabarytowe umożliwiają pracę wewnątrz młodych drzewostanów, zbyt gęstych dla innych maszyn. Szerokość szlaków zrywkowych może być zredukowana do 2—3 m. Maszyna charakteryzuje się wysokimi walorami ergonomicznymi. Cena ciągnika jest znacznie niższa niż cena maszyn średniej wielkości lub dużych, wykonujących te same operacje.

Ręczne okrzesywanie wiązek drzew ułożonych wzdłuż szlaku zrywkowego jest bardzo uciążliwe, dlatego też zastosowanie *maszyny scinkowo-ukladajacej Makeri* jest celowe jedynie w całkowicie zmechanizowanym procesie technologicznym. Następną maszyną w procesie technologicznym powinna być w tym przypadku maszyna okrzesująco-przerzynająca lub rębarka przystosowana do zrębkowania całych drzew na szlaku zrywkowym. Przewiduje się, że metoda zrębkowania całych drzew na szlaku zrywkowym będzie stosowana w pewnym zakresie w Polsce. Obecnie pgl nie posiada odpowiedniej rębarki, jak również nie została jeszcze opracowana metoda przemysłowego przerobu zrębków zielonych lub ich odzieleniania.

Duża manewrowość maszyny ścinkowo-układającej Makeri umożliwia jej poruszanie się w stosunkowo gęstych drzewostanach. Może ona operować przy zagęszczeniu nieco wyższym niż 2 000 drzew/ha bez powodowania znaczących uszkodzeń pozostających drzew. Wydajność maszyny obniża się wraz ze zmniejszaniem się średniej odległości między pozostającymi drzewami. Średnia wydajność wynosi 4—6 m^3 grubizny brutto i drobnicy na godzinę operacyjnego czasu pracy przy średniej miąższości 1 usuwanego drzewa wynoszącej 30—60 dm^3.

Wydajność maszyny ścinkowo-układającej Makeri była niższa w trzebieży selekcyjnej niż w trzebieży kombinowanej ze względu na mniejszą średnią miąższość usuwanych drzew i większą odległość między szlakami zrywkowymi.

Zasadniczym celem usuwania rzędów drzew w przypadku trzebieży kombinowanej jest udostępnienie drzewostanu dla maszyn i zmniejszenie odległości ręcznego donoszenia wyrobionych sortymentów. Z punktu widzenia hodowli lasu usuwanie rzędów drzew nie spełnia celów zabiegu pielęgnacyjnego. Przeprowadzone próby wykazały, że w przypadku zastosowania maszyn o tak małych wymiarach jak maszyna ścinkowo-układająca Makeri możliwe i celowe jest prowadzenie trzebieży selekcyjnych.

Spośród badanych maszyn Makeri za najbardziej przydatną w warunkach pgl należy uznać *maszynę scinkowo-okrzesujaco-przerzynajacą /harwester/*. Maszyna ta umożliwia pełną mechanizację najbardziej pracochłonnych operacji w trzebieżach drzewostanów sosnowych w wieku 30—55 lat, w których liczba drzew może być zredukowana do 1700—1800 sztuk/ha (lub mniej). Takie zagęszczenie nie ogranicza możliwości stosowania maszyny ze względu na uszkodzenia pozostających drzew, natomiast możliwe jest osiągnięcie znacznego wzrostu wydajności pracy w porównaniu z obecnie stosowanymi metodami ścinki, wyróbki i dociągania drzew do szlaku zrywkowego.

Największy wpływ na wydajność maszyny ma średnia miąższość usuwanych drzew. Przy wzroście średniej miąższości usuwanego drzewa od 30 dm^3 do 100 dm^3 wydajność harwestera wzrasta odpowiednio od 2 do 4—6 m^3 grubizny brutto na godzinę operacyjnego czasu pracy. Wydajność zależy także od rodzaju wyrabianych sortymentów i jest najwyższa w przypadku wyróbki strzał w całych długościach.

W wyniku zastosowania maszyny ścinkowo-okrzesująco-przerzynającej Makeri możliwe jest osiągnięcie znacznego wzrostu wydajności pracy w porównaniu z wydajnością pracy przy stosowanych obecnie metodach ścinki, wyróbki i przemieszczania drewna do szlaku zrywkowego — około 6—8-krotnego w trzebieżach drzewostanów II klasy wieku i 4—5-krotnego w trzebieżach drzewostanów III klasy wieku.

Jakość okrzesywania strzał prostych oraz o łagodnych krzywiznach, przy średnicy gałęzi u nasady do 3—4 cm jest dobra na całej strzale. Ogólnie można stwierdzić, że jakość okrzesywania drzew usuwanych w trzebieży selekcyjnej drzewostanów II klasy wieku jest dobra, podobnie jak w przypadku większości drzew usuwanych w trzebieżach drzewostanów III klasy wieku. Zła jakość okrzesywania występuje wtedy, kiedy wymiary okrzesywanych drzew zbliżone są do granicy możliwości maszyny.

Noże wykonujące ścinkę i przerzynkę nie powodują makroskopowych pęknięć drewna, natomiast walce przeciągające strzałę przez noże okrzesujące powodują nacięcia o głębokości 3—6 mm wzdłuż całej strzały. Uszkodzenia te nie mają wpływu na obniżenie jakości surowca dla przemysłu celulozowo-papierniczego i płyt wiórowych, mogą mieć praktyczne znaczenie w przypadku drewna kopalniakowego.

W warunkach polskich wymagana jest dokładna przerzynka strzał na żądane długości. Celem zwiększenia przydatności oraz zakresu stosowania maszyny należałoby ją wyposażyć w urządzenie do pomiaru długości drewna oraz w inny typ walców przeciągających, umożliwiających wyróbkę drewna do średnicy 5 cm i powodujących mniejsze jego uszkodzenia.

Nowe maszyny, które ukażą się na rynku w końcu 1980 roku, będą wyposażone w automatyczne urządzenie do pomiaru długości. Rozstaw walców przeciągających umożliwi okrzesywanie wierzchołków drzew do średnicy 4 cm.

Wydajność *ciagnika klembank Makeri* przy zrywce kłód, całych strzał lub całych drzew jest wyższa niż stosowanych obecnie w Polsce ciągników rolniczych. Przy odległości zrywki 100 m wydajność ciągnika wynosi około 7 m^3 grubizny brutto na godzinę operacyjnego czasu pracy.

W związku z niewielką ładownością ciągnika jego wydajność szybko spada wraz ze wzrostem odległości zrywki. Ponieważ średnia odległość zrywki w Polsce wynosi około 450 m, w wielu przypadkach bardziej ekonomiczne będzie zastosowanie ciągników typu forwarder średniej ładowności (6—8 ton).

Należy jednak zaznaczyć, że ciągnik ten jest znacznie tańszy niż ciągnik forwarder średniej ładowności. Ponadto może on poruszać się po stosunkowo wąskich szlakach zrywkowych (2—3 m), co jest godne uwagi z punktu widzenia hodowli lasu.

Również *ciagnik forwarder Makeri* nie wymaga tak szerokich szlaków zrywkowych jak większe maszyny tego typu. Pod względem wydajności nie jest on konkurencyjny z ciągnikami forwarder średniej ładowności. Należy jednak wziąć pod uwagę jego niższy koszt zakupu i eksploatacji. W czasie prób zrywano za pomocą tego ciągnika papierówkę długości 2 m, co nie pozwalało w pełni wykorzystać jego ładowności i miało negatywny wpływ na uzyskane rezultaty. Wydajność ciągnika wyniosła około 5 m^3 grubizny brutto na godzinę operacyjnego czasu pracy przy odległości zrywki 200 m. Z obliczeń wynika, że przy zrywce papierówki długości 3 m wydajność ciągnika wyniosłaby 7 m^3/h.

Ze względu (między innymi) na stosunkowo duże odległości zrywki w Polsce w przyszłości stosowane będą ciągniki forwarder średniej ładowności. Jednak w szczególnych warunkach, kiedy szerokie szlaki zrywkowe są niepożądane, zastosowanie ciągnika Makeri może być uzasadnione, również ze względów ekonomicznych, pod warunkiem pełnego wykorzystania jego ładowności.

ODC 352:363:375.4
ISBN 951-40-0446-9
ISSN 0015-5543

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ISBN 951-40-0446-9
ISSN 0015-5543

1280013637