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WHOLE-TREE HARVESTING IN THE
EARLY THINNING OF PINE

KOKOPUUNA KORJUU MÄNNIKÖN
ENSIHARVENNUKSESSA

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WHOLE-TREE HARVESTING IN THE EARLY THINNING OF PINE

Kokopuuna korjuu männikön ensiharvennuksessa

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Great attention has been paid in Finland since 1973 to the development of small-tree harvesting methods. The aims are more efficient raw material recovery, increased productivity, ergonomical easing of work, and lowered costs. The new harvesting methods which are based on the principle of whole-tree utilization have at the end of 1977 reached the stage where they meet the demands of practical forestry. It is no longer technical harvesting considerations that are the obstacle to the generalization of whole-tree harvesting, but rather the slackened global demand for forest industry products and, the undeveloped state of mill-sorting of whole-tree chips.

The report describes the newest Finnish small-tree harvesting machines and alternative harvesting schedules in the conditions of early thinning of Scots pine stands. The emphasis is on harvesting technology, especially felling and bunching methods, the chipping of whole trees, forest haulage and long-distance transport. Information is given on the composition of the biomass of a young pine stand and on the measurement of whole tree raw material.

In the early thinning of a pine stand the trees harvested have an average stem size of only 25—35 dm³. The new methods make it possible in these difficult conditions to recover over 90 % of the biomass of the trees. Compared with the traditional short-wood method, labour productivity increases 2—5-fold. Cost savings can be achieved by using the correct alternatives. It is evident that whole-tree harvesting will become general as the forest industry market recovers.

Suomessa on vuodesta 1973 lähtien kiinnitetty suurta huomiota pienpuun korjuumenetelmien kehittämiseen. Tavoitteena on raaka-aineen talteenoton tehostaminen, tuottavuuden kohottaminen, työn ergonominen keventäminen sekä kustannusten alentaminen. Uudet korjuumenetelmät, jotka rakentuvat kokopuunkäytön periaatteelle, ovat vuoden 1977 päättyessä kehittyneet käytännön metsätalouden vaatimuksia vastaaviksi. Kokopuuna korjuun yleistymisen esteenä eivät ole enää korjuutekniset seikat vaan pikemminkin metsäteollisuuden tuotteiden heikentynyt kysyntä maailmanmarkkinoilla sekä toisaalta tehtaalla tapahtuvan kokopuuhakkeen lajitelun kehittymättömyys.

Raportti kuvaa uusimpia suomalaisia pienpuun korjuukoneita ja niiden varaan rakentuvia vaihtoehtoisia korjuuketjuja männikön ensiharvennuksessa. Pääpaino on korjuutekniikassa, erityisesti erilaisissa kaato- ja kasausten menetelmissä, kokonaisten puitten hakettamisessa sekä metsä- ja kaukokuljetuksessa. Lisäksi annetaan tietoja nuoren männikön biomassan koostumuksesta sekä kokopuuraaka-aineen mittauksesta.

Männikön ensimmäisessä harvennuksessa korjataan puita, joiden rungon keskikoko on vain 25—35 dm³. Uusilla menetelmillä saadaan näissä vaikeissa oloissa yli 90 % kaadettavien puitten biomassasta talteen. Perinteiseen tavara-lajimenetelmään verrattuna miestyön tuottavuus kasvaa 2—5 kertaiseksi. Oikeita vaihtoehtoja käyttämällä voidaan saavuttaa myös kustannussäästöjä. On ilmeistä, että kokopuuna korjuu tulee yleistymään metsäteollisuuden markkinatilanteen elpymisen myötä.

Helsinki 1978. Valtion painatuskeskus

Lisäpainos

PREFACE

In 1973, the Finnish Forest Research Institute, financed by the Finnish National Fund for Research and Development, SITRA, began to develop on the principle of whole-tree harvesting methods for the improved recovery and utilization of small-sized trees.

The work has made fast progress as a result of the cooperation between the engineering and forest industries and researchers. The principle of whole-tree utilization has been accepted as an alternative to traditional wood utilization. New harvesting schedules for small-sized timber are being shaped to the requirements of forestry. It is believed that whole-tree harvesting will become generalized as soon as the international demand for forest industry products revives.

The first intermediate report of the project contained preliminary results of the work done in 1973 and 1974 (Hakkila et al. 1975). The present report describes the situation reached at the end of 1977. It is confined to early thinning of Scots pine in which the work studies have progressed furthest. As the thinning of young pine stands is a universal problem the report is published in English.

Many members of the staffs of various companies and research institutes have par-

ticipated in the development work the results of which are reported here. The following persons have played a leading role: Mr. Martin Lillandt and Mr. Kauko Papunen, Oy W. Rosenlew Ab; Mr. Ilkka Kallio and Mr. Yrjö Schildt, Enso-Gutzeit Osakeyhtiö; Mr. Juhani Mutru and Mr. Matti Ruotsalainen, Työväline Oy; Mr. Muisto Laine, Ky. M. Laine; Mr. Klaus Rantapuu, Valmet Oy; Mr. Pertti Szepaniak, private contractor; Mr. Martti Issakainen, SITRA; and Mrs. Kaija Kanninen, Professor Kullervo Kuusela, Mr. Eero Lehtonen, Mr. Tapio Nevalainen, Mr. Paavo Simola, Mr. Sauli Takalo, Finnish Forest Research Institute. The report was translated into English by Miss Päiviikki Ojansuu and checked by Mr. L. A. Keyworth.

The work was made possible by the disinterested support of SITRA. The research project was assisted in the final phase by the Academy of Finland.

We extend our sincere thanks to all persons, institutes and companies participating in the project.

Helsinki, October 1977

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EXPLANATIONS

Some terms are used in the report which may lead to difficulties of interpretation. To prevent misunderstandings, the following explanations are offered:

Whole tree means the part of the tree inclusive of needles that is above the stump cross-section. The transport or chipping of whole trees often applies in fact to non-delimbed trees which have been bucked into two or three parts.

m^3 refers always to a solid cubic metre, including bark, unless otherwise stated. This is valid also for chips. The output of machines or harvesting schedules is expressed as whole-tree m^3 including the volume of branches (wood, bark and needles). A solid cubic metre can be converted to a loose m^3 of chips by using the coefficient 2,33.

Merchantable stem wood means the part of the stem that meets the minimum measurements of traditional pulpwood; bolt length 2 m and minimum top diameter under bark 6 cm.

Unmerchantable stem wood means the part of the stem that does not meet the requirements of merchantable timber.

Upper landing site means the place at each logging site to which the whole-tree material is transported by forest tractor or terrain chipper. Onward transport is then done by trucks.

Lower landing site is a centralized timber handling yard between the upper landing sites and the mill. Chipping at lower landing is not practised in Finland and is not included in the present report.

The landing chipper works at the upper or lower landing site.

The terrain chipper chips the raw material at the stump or on the strip road and hauls the chips to the upper landing site.

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1. INTRODUCTION

Mechanization of timber harvesting has been concerned so far mainly with large-sized trees of clear cuttings. The number of machine components, machines and man-machine systems developed for thinnings, especially early thinnings, is very limited (Brenøe 1976). However, a situation will gradually arise in which because of the manpower shortage it will be necessary to extend mechanization also to thinnings and small-sized trees.

The concept small-sized timber is defined differently in different countries, but the problems of harvesting small-sized trees are universal. Typical small-sized tree stands in Finnish forestry are first and foremost the following:

- unproductive hardwood stands
- young Norway spruce stands in early thinning
- young Scots pine stands in early thinning
- (short-rotation plantations of fast-growing hardwoods in the future).

The basic harvesting problem is the same in each case. Handling small-sized trees singly strictly limits the capacity of the machine and the proportion of unmerchantable biomass tends to reach unacceptably high levels.

The traditional practice is to deliver small-sized timber to the mill in bolt form, but successful mechanization of this procedure has not proved feasible. The following continue to be characteristic features of the harvesting of small-sized timber:

- low productivity of work
- high logging costs
- unsatisfactory recovery of raw material

When the Finnish National Fund for Research and Development in 1973 commissioned the research project Production and Utilization of Short-Rotation Wood, a salient part of the work came to be the development of new harvesting methods for small-sized wood. Encouraged by the results achieved in the United States, development work

was started on whole-tree utilization and the requirement of bolt form was abandoned.

The present report illustrates the stage reached at the close of 1977. For the sake of clarity, the report is limited to the thinning of young Scots pine stands (*Pinus silvestris* L.). The same machines can, of course, be used for the harvesting of hardwoods and spruce, but it is expressly in the thinning of pine stands that the methods may be applicable almost as such even beyond the frontiers of Finland.

Outside North Europe, pine is cultivated in extensive areas of Central, East and South Europe, the USA and Canada, New Zealand, Australia and many African, Asian and

Central and South American countries. The thinning problem is topical in many European countries where the stands established since World War II are reaching the stage of early thinning. Moreover, in wide areas of North America and the Soviet Union there are natural softwood forests which have not been thinned (cf. Chase and Young 1976).

Although several species of pine are at issue, the logging technical conditions and limitation of early thinnings are actually often similar in different parts of the world, mountainous districts excepted. But it must be remembered, of course, that the biological, economic and social premisses of mechanization are by no means the same everywhere.

2. OBJECT OF THINNING YOUNG SCOTS PINE STANDS

Contrary to what is sometimes assumed, the basic aim of thinnings is not to increase the total yield of the stand. Finnish forestry has, however, long been based on the practice of selective thinning as this makes it possible to increase the financial return of the forest. The following advantages are gained.

1. Naturally dying trees are recovered
2. Growth is concentrated on desired species and high-grade trees
3. Growth is concentrated on fewer trees and the proportion of saw timber in the total yield is increased
4. The forest owner obtains an earlier income.

The emphasis in the thinning programmes is on wood production targets. It is good for the biology of the stand if the treatments are moderate and repeated frequently. The decrease in the forest labour force and cost factors force a compromise, however, and logging technical considerations are increasingly influencing the intensity and timetable of thinnings.

The thinning practice depends on the tree species, site, rotation age, timber demand and prices, logging costs, etc. Thinnings of a South Finnish pine stand may be repeated before the ultimate final cutting in conformity with, e.g., this approximate timetable.



Figure 1. A Scots pine stand before the first commercial thinning.
Kuva 1. Männikkö ennen ensibarvennusta.

	Stand age, years
Uncommercial thinning	15
First commercial thinning	30
Second commercial thinning	50
Third commercial thinning	70

In southern countries where pine grows faster and the rotation age is shorter, the number of thinnings is smaller and they are performed at a much younger age. However, the technical basic problems of early thinnings are almost the same everywhere.

1. Danger of damage to remaining trees restricts the moving of machines.
2. Trees to be cut are small, often partly unmerchantable.
3. Timber yield per unit area is low.

A pine stand must be thinned in Finnish conditions for the first time at the age of 10—20 years. The trees are too small for industrial use at this juncture and are left as waste in the forest. As the treatment is uncommercial it is often omitted, which seriously retards the later development of the stand. It may prove possible in the future by reducing the seedling stand establishment density, slowing the thinning timetable and developing the logging technique to combine the first two treatments to improve the recovery of forest biomass from young stands.

The logging technical conditions of the first commercial thinnings are difficult. Depending on the site and other factors, there generally remains a stand of the following type (Fig. 1):

— dominant height, m	10—14
— average Dbh, cm	8—13
— basal area, m ² /ha	10—20
— number of trees/ha	1 000—1 500
— distance between strip roads, m	25—35
— strip road width, m	4—4,5

The trees to be removed are very small in size, which inevitably means a great proportion of waste wood and high costs. The yield is often so small that early thinning tends to be postponed indefinitely

3. LIMITATIONS OF THE PRESENT SHORT-WOOD METHOD

Thinning is a selective procedure in Finland. Systematic thinning methods are not used as they are considered to result in a lower wood yield.

The timber of thinnings is harvested in Finland and Sweden traditionally by the short-wood method. The stem method has not gained a foothold because of the risk of damage to growing trees. In addition, when small-sized trees are harvested the skidding of whole stems is expensive as it is difficult to achieve an adequate load size. The stem method is naturally more competitive in countries in which the principle of systematic thinning is applied and larger-sized trees are harvested.

In the conventional short-wood method good delimiting is required, and bucking is done into exact bolt lengths of generally 2, 3 or 4 metres on the basis

until more profitable logging is possible. However, this short-sighted attitude is soon penalised by retardation of the later development of the stand. Using traditional methods, the following crop is harvested from an average pine site (cf. Vuokila 1976):

— average stem volume of removed trees, dm ³	20—25
— total drain of stem wood, m ³ /ha ...	30—40
— recovered yield of merchantable wood, m ³ /ha	20—30
— per cent of stem wood wasted	25—35

Mechanisation of thinnings is always difficult on account of the risk of damage to the growing forest and the small size of the trees. The problem is aggravated in early thinning.

According to an unpublished calculation by Professor Kullervo Kuusela, the structure of the annual drain from Finland's forests develops as follows. The figures cover both pine and other tree species, chiefly spruce.

	1980	1990	2000
	Per cent of the potential drain		
Southern Finland			
From uncommercial thinnings	3,5	3,4	3,0
From first commercial thinnings	2,4	4,5	9,0
Northern Finland			
From uncommercial thinnings	4,0	3,9	3,5
From first commercial thinnings	3,0	3,4	6,0

The share of early-thinnings will be 2—3 times bigger in the future when the age class composition of Finnish forests changes. As the forest labour force will contract concomitantly, a serious factor of friction will arise in Finnish forestry. If the thinning targets are impossible to meet, the foundation of the wood production programmes will collapse.

This background and the scarcity of wood raw material face forest research with the necessity of seeking new solutions to the problems of the mechanisation of early-thinning harvesting.

of measuring. Three-fourths of pulpwood is harvested in Finland in this way. However, the new short-wood method, where rougher delimiting and bucking by eye are allowed, is gaining due to the increased productivity of the work.

The minimum diameter of pine pulpwood inside the bark is 6 cm. Smaller trees and tops are not utilized and there is occasional pressure to raise the minimum diameter to 7 cm. The proportion of stem waste wood in early thinning is today 25—35%, sometimes even more (Vuokila 1976). The current practice is extravagant from the point of view of industry that suffers from a shortage of wood.

An even more serious problem is the low productivity of the work. The method by which the bolts are taken in selective thinning to alongside the strip road

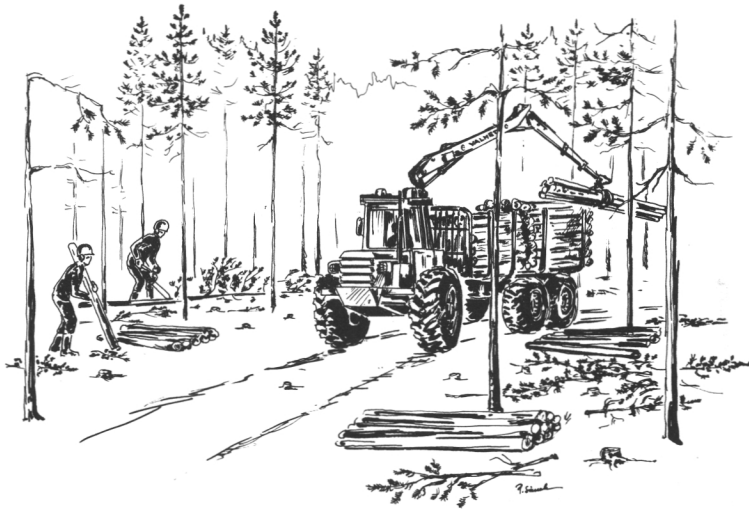


Figure 2. The present short-wood method.
 Kuva 2. Nykyinen taveralajimenetelmä.

within the range of the hauling tractor is especially unsatisfactory. The prevailing practice is to carry them alongside the strip road (Fig. 2). It has recently been possible with the new SCAPE method, it is true, to reduce carrying by using the slide or telescope boom of the forwarder (Harstela 1977, Harstela et al. 1977).

The output of the worker in the present short-wood method is strongly dependent on the tree size. When the volume of merchantable stem drops from 300 dm³ to 25 dm³ the time consumption is doubled (Table 1).

For forest haulage, on the other hand, the output of the method is satisfactory. When the strip road spacing is 30 m, timber yield 30 m³ per hectare and hauling distance 200 m, the output of a medium-sized forwarder is 13,0 m³ per effective work hour. If the distance increases to 500 m the output is 8,8 m³ (cf. Kahala 1974).

The following table gives an idea of the harvesting costs of a thinning according to tree size in South Finland at the end of 1977 in average conditions (Metsä ja uittoalan... 1977, Tavoitetaksaan perustuvat... 1977). The method in question is the new short-wood method with rough delimiting and bucking by eye.

	Volume of merchantable part of stem, dm ³					
	12	25	50	75	100	300
Cutting wages	27,70	22,70	18,70	16,70	15,70	10,20
Social security costs, 42 %	11,60	9,50	7,90	7,00	6,60	4,30
Forwarding, 300 m	11,50	11,00	10,50	10,00	10,00	10,00
Planning, measuring	13,00	11,50	10,00	8,00	6,00	3,50
Total	63,80	54,70	47,10	41,70	38,30	28,00

The harvesting costs for early thinnings are so high that, important as it is for the later development of the stand, this treatment is neglected in many countries. Finland has so far performed early thinnings, but the price of the timber harvested may actually be higher than industry can afford to pay. This has been accepted

Table 1. The productivity of work in the conventional short-wood method as a function of tree size. Making 2 m pine pulpwood (cf. Kahala 1969).

Taulukko 1. Tekomiehen työn tuottavuus tehtäessä 2 m mäntykuitupuuta ajouran varteen (vrt. Kahala 1969).

Merchantable volume of stem, dm ³ Rungon käyttöosa, dm ³	Time consumption per m ³ Ajanmenekki m ³ kohti		Output m ³ /manday *) Tuotos m ³ /mies-päivä *)
	Minutes Minuuttia	Man-days *) Miespäivää *)	
12	106	0,272	3,7
25	85	0,217	4,6
50	69	0,176	5,7
75	62	0,159	6,3
100	58	0,149	6,7
150	53	0,136	7,4
325	42	0,108	9,2

*) One man-day is 6 1/2 man-hours of work.
 Miestyöpäivässä on 6 1/2 työtuntia.

as the wood production programme requires thinnings performed in time. The problem will become critical in the future when the share of young forests grows and the forest labour force decreases. New small-sized timber harvesting methods are needed.

4. THE BASIS OF WHOLE-TREE HARVESTING

The first aim in the development of harvesting methods for small-sized timber is more thorough recovery of raw material than is achieved at present. Even thin stem wood, under 6 cm in diameter, must be utilized.

Another absolute requirement is improved productivity and lowered costs. The output and economicalness of the present-day multipurpose machines are satisfactory only for the harvesting of large-sized trees. An example is the effect of tree size on the output of the Pika 75 harvester in clear-cutting conditions. When the stem volume is 800 dm³ the output per hour is 48 m³. When the size drops to 200 and further to 50 dm³ the output is only 13 and 2,5 m³/h, respectively (Peltola 1976a).

A further aim is ergonomic development of methods to reduce the strain of the work and to improve work safety. The uncommercial and first commercial thinnings of young stands are less popular jobs from the workers' point of view and it is already becoming difficult to find the manpower for them.

The development of the harvesting of small-sized timber has collided with the traditional practice in which the processing technology is based on timber of bole form. Scaling and debarking, in particular, have required retention of the bole form as far as the mill yard. But when the product is bolts that have to be handled singly, rationalisation as a whole is difficult to implement.

If it is possible, on the other hand, to handle small-sized wood raw material as a mass article, there is better scope for intensification of recovery and logging work. One alternative then, though not necessarily the only one, is the principle of whole-tree utilization and the chipping method. The new harvesting schedules are based as far as possible on the following solutions.

1. The aim is to recover the whole above-ground portion of the tree. In practice, however, a small proportion of the biomass is left in the forest.
2. The tendency is to lighten or even to abandon delimiting and bucking. Simplification of the work increases the output of both manual and mechanized methods.

For example, presently the share of delimiting and bucking is about 55 % of the worker's cutting wage in the conventional short-wood method, depending on the conditions, and about 40 % in the new short-wood method. When delimiting is necessary for raw material quality requirements, it must be based on multiple-tree treatment.

3. Treating small-sized trees singly is abandoned and the raw material is given the form of a mass article in the earliest possible phase. Work is transferred from the forest to the mill yard.
4. Scaling is adapted to the requirements of the new raw material. Alternative methods that come into question are measurement of the standing trees before felling, measurement of the pile volume of whole-tree stacks, or measurement of chips. Each case requires information on the distribution of biomass between the stem and branches.
5. The processing technology is adapted to whole-tree chips. Either the present quality requirements for chips are modified or the mill is equipped with machinery for the separation and segregation of the main part of the bark and green matter for fuel or other purposes.

Economic recovery of the very smallest bush-type trees requires that the raw material is treated as a mass article on the multiple-tree principle already when the trees are felled. A continuous operation multipurpose machine is needed. Its output will be determined not by the treatment time of an individual tree but, rather, in accordance with the basal area and volume of the growing stock along its route and the speed at which it can travel. One such machine, the prototype of the Pallari Busharvester (cf. Hakkiila and Mäkelä 1975) is, however, suitable only for clear-cutting or corridor thinning of very small trees and bushes.

The busharvester principle cannot be used in selective thinning of young pine stands. The felling phase at least must be based therefore on single tree handling. As a result there is an economic minimum size for the trees to be recovered and it is not worth

going below it. However, in whole-tree harvesting the line can be drawn essentially lower than in the traditional methods in which treatment singly continues longer.

When developing the methods, care must naturally be taken not to damage the growing stock. This applies to the stem, crown and

root system. On the other hand, to avoid reduction of the future growth of the remaining trees, the strip road network may not be excessively dense. The machines should have low ground pressure, easy manoeuvrability and small size.

5. THE BIOMASS OF YOUNG SCOTS PINE TREES

Whole-tree harvesting means an epochal change in the traditional forestry practice. In addition to the work technology, the reform is reflected also in the pricing of raw material, wages, scaling, the biological consequences, etc. These factors require that the distribution between stem and branches of the biomass of the above ground portion of the growing stock is known.

Tables 2 and 3 illustrate the growing stock of a young Scots pine stand in the phase of

development when the first commercial thinning of the stand is topical. They represent chiefly dry, firm forest land of *Vaccinium* site type in South Finland.

Excluding the branches, the volume tables are based on the following regression equations. An exception is the branches which are calculated as the difference between whole tree and stem. According to the equation the weight of the branches should be a little greater, but the difference is small.

Green weight, kg:

		100 · R ²	s, %
Stem:	$y_1 = 0,098 \cdot x_1^{1,8851} \cdot x_2^{0,7178}$	97,5	6,4
Branches:	$y_1 = 0,210 \cdot x_1^{2,9553} \cdot x_2^{-1,1884}$	92,6	16,3
Whole tree:	$y_1 = 0,218 \cdot x_1^{2,1917} \cdot x_2^{0,1852}$	97,2	6,0

Volume, dm³:

Stem:	$y_2 = 0,095 \cdot x_1^{1,9185} \cdot x_2^{0,7381}$	98,9	4,2
Branches:	$y_2 = 0,218 \cdot x_1^{2,9712} \cdot x_2^{-1,1760}$	92,8	15,5
Whole tree:	$y_2 = 0,224 \cdot x_1^{2,2067} \cdot x_2^{0,1991}$	98,2	4,7

y_1 = Green weight, kg

y_2 = Volume, dm³

x_1 = Dbh, cm

x_2 = Tree height, m

s = standard deviation from regression line in the mean tree of the material, %

The tree biomass increases when height and breast height diameter grow. However, the biomass of branches is smaller in a certain breast height diameter class the taller the trees. This concurs with earlier studies which report that the biomass of branches is greatest in sharply tapering trees (cf. Hakikila 1969, 1971).

It is possible with the help of Tables 2 and 3 to calculate the green weight and the volume of the above-ground biomass of a typical early-thinning pine stand. The breast height diameter must be measured for each tree to be felled, for the sample trees also height. A corresponding scaling method, measurement of standing trees before cutting,

Table 2. The green weight of the above-ground biomass of young Scots pine trees in Southern Finland.
Taulukko 2. Nuoren männyn maanpäällisen osan tuorepaino Etelä-Suomessa.

Dbh, cm <i>D_{1.3}, cm</i>	Height, m — <i>Pituus, m</i>																
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Stem, kg — <i>Runko, kg</i>																
2	0,6	0,8	1,0	1,2	1,3												
3	1,3	1,7	2,1	2,5	2,8	3,1											
4		2,9	3,6	4,3	4,8	5,4	6,0										
5		4,5	5,5	6,5	7,4	8,2	9,1	9,9									
6			7,8	9,1	10,4	11,6	12,8	13,9	15,0	16,1							
7			10,4	12,2	13,9	15,5	17,1	18,6	20,1	21,5							
8				15,7	17,9	20,0	21,0	23,9	25,8	27,6	29,4						
9				19,6	22,3	24,9	27,4	29,9	32,2	34,5	36,7						
10					27,2	30,4	33,5	36,4	39,3	42,1	44,8	47,4					
11					32,6	36,4	40,1	43,6	47,0	50,3	53,6	56,8	59,9				
12						42,9	47,2	51,4	55,4	59,3	63,1	66,9	70,5	74,1			
13							54,9	59,7	64,4	69,0	73,4	77,8	82,0	86,2	90,3		
14							63,1	68,7	74,1	79,3	84,4	89,4	94,3	99,1	103,8	108,4	
15							71,9	78,2	84,4	90,3	96,1	101,8	107,4	112,8	118,2	123,5	
16								88,3	95,3	102,0	108,6	115,0	121,3	127,4	133,5	139,4	
17								99,0	106,8	114,4	121,7	128,9	136,0	142,9	149,6	156,3	162,8
18								110,3	118,9	127,4	135,6	143,6	151,4	159,1	166,7	174,1	181,4
	Branches, kg — <i>Oksat, kg</i>																
2	0,5	0,4	0,3	0,2	0,1												
3	1,5	1,3	1,0	0,8	0,6	0,4											
4		2,7	2,3	1,8	1,5	1,1	0,7										
5		4,6	4,1	3,5	2,9	2,4	1,8	1,3									
6			6,5	5,8	5,0	4,3	3,5	2,7	2,0	1,2							
7			9,7	8,7	7,7	6,7	5,7	4,7	3,7	2,7							
8				12,3	11,1	9,8	9,6	7,3	6,0	4,8	3,5						
9				16,7	15,2	13,7	12,2	10,5	9,0	7,5	5,9						
10					20,0	18,2	16,3	14,5	12,6	10,7	8,9	7,1					
11					25,6	23,5	21,3	19,1	17,1	14,8	12,6	10,4	8,2				
12						29,6	27,1	24,5	22,0	19,5	17,0	14,4	11,9	9,4			
13							33,6	30,8	27,9	24,9	22,0	19,1	16,2	13,3	10,4		
14							41,1	37,7	34,4	31,2	27,9	24,0	21,2	17,9	14,6	11,4	
15							49,3	45,6	41,9	38,2	34,5	30,8	27,0	23,3	19,5	15,8	
16								54,3	50,1	46,0	41,8	37,7	33,5	29,4	25,2	21,1	
17								63,9	59,3	54,7	50,1	45,5	40,8	36,2	31,6	27,0	22,4
18								74,3	69,4	64,2	62,2	54,1	49,0	43,9	38,7	33,6	28,5
	Stem and branches, kg — <i>Runko ja oksat, kg</i>																
2	1,1	1,2	1,3	1,3	1,4												
3	2,5	3,0	3,1	3,3	3,4	3,5											
4		5,6	5,9	6,1	6,3	6,5	6,7										
5		9,1	9,6	10,0	10,3	10,6	10,9	11,2									
6			14,3	14,9	15,4	15,9	16,3	16,6	17,0	17,3							
7			20,1	20,9	21,6	22,2	22,8	23,3	23,8	24,2							
8				28,0	29,0	29,8	30,6	31,2	31,8	32,4	32,9						
9				36,3	37,5	38,6	39,6	40,4	41,2	42,0	42,6						
10					47,2	48,6	49,8	50,9	51,9	52,8	53,7	54,5					
11					58,2	59,9	61,4	62,7	64,0	65,1	66,2	67,2	68,1				
12						72,5	74,3	75,9	77,4	78,8	80,1	81,3	82,4	83,5			
13							88,5	90,5	92,3	93,9	95,4	96,9	98,2	99,5	100,7		
14							104,2	106,4	108,5	110,5	112,3	113,4	115,5	117,0	118,4	119,8	
15							121,2	123,8	126,3	128,5	130,6	132,6	134,4	136,1	137,7	139,3	
16								142,6	145,4	148,0	150,4	152,7	154,8	156,8	158,7	160,5	
17								162,9	166,1	169,1	171,8	174,4	176,8	179,1	181,2	183,3	185,2
18								184,6	188,3	191,6	194,8	197,7	200,4	203,0	205,4	207,7	209,9

Table 3. The volume of the above-ground biomass of young Scots pine in Southern Finland.
 Taulukko 3. Nuoren männyn maanpäällisen osan tilavuus Etelä-Suomessa.

Dbh, cm <i>D</i> _{1.3} , cm	Height, m — <i>Pituus</i> , m																
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Stem, dm ³ — <i>Runko</i> , dm ³																
2	0,6	0,8	1,0	1,2	1,4												
3	1,3	1,8	2,2	2,6	2,9	3,3											
4		3,1	3,8	4,5	5,1	5,7	6,3										
5		4,7	5,8	6,8	7,8	8,8	9,7	10,6									
6			8,2	9,7	11,1	12,4	13,7	15,0	16,2	17,4							
7			11,1	13,0	14,9	16,7	18,4	20,1	21,7	23,3							
8				16,8	19,3	21,6	23,8	26,0	28,1	30,1	32,1						
9				21,0	24,1	27,1	29,9	32,6	35,2	37,8	40,3						
10					29,6	33,1	36,5	39,9	43,1	46,2	49,3	52,3					
11					35,5	39,8	43,9	47,9	51,7	55,5	59,2	62,8	66,3				
12						47,0	51,9	56,6	61,1	65,6	69,9	74,2	78,4	82,5			
13							60,5	65,9	71,3	76,5	81,6	86,5	91,4	96,2	100,8		
14							69,7	76,0	82,2	88,2	94,0	99,7	105,3	110,8	116,2	121,6	
15							79,6	86,8	93,8	100,6	107,3	113,8	120,2	126,5	132,7	138,8	
16								97,2	106,2	113,9	121,5	128,8	136,1	143,2	150,2	157,1	
17								110,3	119,3	127,9	136,4	144,7	152,9	160,9	168,7	176,4	184,0
18								123,1	133,1	142,8	152,2	161,5	170,6	179,5	188,3	196,9	205,4
	Branches, dm ³ — <i>Oksat</i> , dm ³																
2	0,6	0,5	0,4	0,2	0,1												
3	1,6	1,4	1,1	0,9	0,7	0,4											
4		2,8	2,5	2,1	1,7	1,3	1,1										
5		5,0	4,5	4,0	3,4	2,7	2,1	1,5									
6			7,4	6,4	5,6	4,8	4,0	3,1	2,3	1,4							
7			10,5	9,6	8,6	7,5	6,4	5,3	4,3	3,3							
8				13,6	12,2	10,9	9,5	8,1	6,8	5,4	4,0						
9				18,4	16,7	15,0	13,3	11,7	10,0	8,3	6,6						
10					21,9	20,0	18,1	15,9	13,9	11,9	9,8	7,8					
11					28,1	25,8	23,4	21,0	18,7	16,2	13,8	11,4	9,0				
12						32,4	29,7	26,9	24,2	21,3	18,5	15,6	12,8	9,9			
13							36,8	33,7	30,4	27,2	23,9	20,7	17,4	14,1	10,9		
14							44,9	41,3	37,6	33,9	30,3	26,5	22,8	19,1	15,4	11,6	
15							53,9	49,8	45,7	41,6	37,4	33,8	29,0	24,8	20,5	16,3	
16								59,3	54,7	50,1	45,3	40,7	35,8	31,2	26,5	21,7	
17								69,8	64,6	59,5	54,3	49,1	43,8	38,5	33,2	28,0	22,7
18								81,2	75,5	69,8	64,1	58,3	52,5	46,7	40,8	35,0	29,1
	Stem and branches, dm ³ — <i>Runko ja oksat</i> , dm ³																
2	1,2	1,3	1,4	1,4	1,5												
3	2,9	3,2	3,3	3,5	3,6	3,7											
4		5,9	6,3	6,6	6,8	7,0	7,2										
5		9,7	10,3	10,8	11,2	11,5	11,8	12,1									
6			15,4	16,1	16,7	17,2	17,7	18,1	18,5	18,8							
7			21,6	22,6	23,5	24,2	24,8	25,4	26,0	26,5							
8				30,4	31,5	32,5	33,3	34,1	34,9	35,5	36,1						
9				39,4	40,8	42,1	43,2	44,3	45,2	46,1	46,9						
10					51,5	53,1	54,6	55,8	57,0	58,1	59,1	60,1					
11					63,6	65,6	67,3	68,9	70,4	71,7	73,0	74,2	75,3				
12						79,4	81,6	83,5	85,3	86,9	88,4	89,8	91,2	92,4			
13							97,3	99,6	101,7	103,7	105,5	107,2	108,8	110,3	111,7		
14							114,6	117,3	119,8	122,1	124,3	126,2	128,1	129,9	131,6	133,2	
15							133,5	136,6	139,5	142,2	144,7	147,0	149,2	151,3	153,2	155,1	
16								157,5	160,9	164,0	166,8	169,5	172,0	174,4	176,7	178,8	
17								180,1	183,9	187,4	190,7	193,8	196,7	199,4	201,9	204,4	206,7
18								204,3	208,6	212,6	216,3	219,8	223,1	226,2	229,1	231,9	234,5

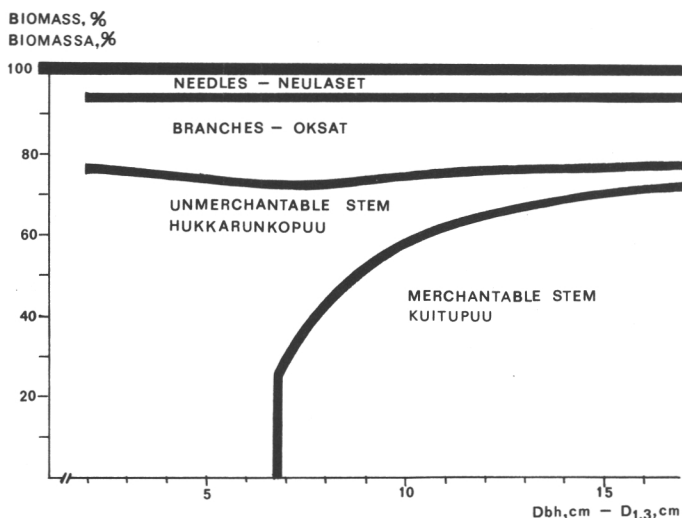


Figure 3. Composition of the above-ground biomass of young Scots pine trees.

Kuva 3. Nuoren männyn maanpäällisen osan biomassin koostumus.

Table 4. The proportion of branches and merchantable and unmerchantable stem wood of the total above-ground biomass in young Scots pine trees at the phase of the first thinning. Average data.

Taulukko 4. Markkinakelpoisen kuitupuun, hukkarunkopuun ja oksien keskimääräinen osuus ensiharvennusvaiheen männikön biomassasta. Kuitupuun pituus 2 m ja vähimmäisläpimitta 6 cm.

Dbh, cm D _{1,3} , cm	Merch. bole Kuitupuun	Unberch. bole Hukkarunkopuun	Branches Oksat	Total Yhteensä
	Proportion of biomass, % Osuus biomassasta, %			
2	—	76	24	100
3	—	75	25	100
4	—	75	25	100
5	—	74	26	100
6	—	73	27	100
7	32	41	27	100
8	46	26	28	100
9	54	19	27	100
10	60	14	26	100
11	63	11	26	100
12	66	9	25	100
13	68	7	25	100
14	70	6	24	100
15	71	5	24	100

Table 5. The proportion of wood proper in branches and merchantable and unmerchantable stem in the biomass of young Scots pine trees at the phase of the first thinning.

Taulukko 5. Puuaineen jakautuminen markkinakelpoisen kuitupuun, hukkarunkopuun ja oksien kesken ensiharvennusmännikössä.

Dbh, cm D _{1,3} , cm	Wood proper Puuaines				Bark and needles Kuori ja neulaset	Total Yhteensä
	Merch. bole Kuitupuun	Un-merch. bole Hukkarunkopuun	Branches Oksat	Total Yhteensä		
	Proportion of biomass, % Osuus biomassasta, %					
2	—	61	9	70	30	100
3	—	61	10	71	29	100
4	—	62	10	72	28	100
5	—	62	10	72	28	100
6	—	61	11	72	28	100
7	27	35	11	73	27	100
8	39	23	11	73	27	100
9	47	16	11	74	26	100
10	52	12	11	75	25	100
11	55	10	11	76	24	100
12	58	8	11	77	23	100
13	60	6	11	77	23	100
14	62	5	10	77	23	100
15	63	4	10	77	23	100

is commonly used in Finland today when harvesting traditional timber assortments. However, the costs of the method are high when small-sized trees are logged.

Fair pricing presupposes knowledge of the share in the total biomass of stem wood that meets the measurements of traditional pulpwood. Table 4 and Figure 3 show the share of merchantable stem wood when the bolt length is 2 m and minimum diameter 6 cm.

Pricing and utilization also require information on the distribution of wood proper between the different parts of the pine tree. Table 5 shows the relative proportion of actual bark-free wood in the biomass of the merchantable and unmerchantable parts of the stem as well as in the branches.

Tables 3—5 can be used for pricing the biomass of standing trees and its distribution into merchantable pulpwood, unmerchantable tops and branches. The tables are applicable solely to South Finnish pine stands that are approaching or have recently reached the early-thinning stage. It must be noted, moreover, that a part of the branches are lost during the various phases of harvesting and the wood content of the whole-tree chips arriving at the mill is greater in practice than in the biomass of standing trees. On average, the proportion of wood proper in whole-tree chips of pine is 79 per cent at the mill yard.

6. EQUIPMENT AND TECHNOLOGY USED FOR WHOLE-TREE HARVESTING IN FINLAND

Special equipment for the harvesting of whole-tree raw material appeared on the market at the beginning of the 1970s in the United States. In a period of less than five years a significant number of machines were taken into use to supply raw material in chip form to a variety of wood-using plants. 483 whole-tree chippers had been sold by the end of 1975. However, the acceptance of whole-tree chips slowed in North America in late 1974 and 1975 when the economy and markets slumped. All of these machines may thus not be actively producing today, but they are available as needed (Plummer 1976).

The whole-tree harvesting schedules were established fast in the United States. Chippers developed into reliable and effective units. Felling and forest haulage were done chiefly with standard equipment. The following equipment combination, to which sky-line transport was adapted in some mountainous districts, became the prevalent one:

- standard feller-buncher
- standard skidders
- whole-tree chipper at the upper landing
- truck transport of chips in semi-trailers.

The harvesting system was initially built around the Morbark 75 chipper which has an output of 200—300 tons of green chips

per shift. 1—2 feller-bunchers, 2—3 skidders and 2—4 trucks are generally needed for one chipper, depending on the conditions. Whole-tree chippers of lighter weight have also appeared on the North-American market subsequently. The most important of them are the Trellan D 60, Morbark 58 and Morbark 12. This harvesting equipment is suitable for North-American conditions for which, indeed, it was originally developed.

In Europe, however, the conditions for forestry are somewhat different. It is often small private forests and very small-sized trees that have to be harvested. The landing sites are fairly limited in size. In Finland, the following requirements are made:

1. The methods must be applicable also to thinnings.
2. Harvesting must be economical even in stands in which the breast height diameter of the trees is only 4—10 cm.
3. The upper landing arrangements must be simple and take little space.
4. Moving around of the equipment must be flexible because of the small size of the work sites.
5. The harvesting schedule must not be susceptible to disturbances. Machine units must not be linked closely in the schedule.
6. The raw material must not be soiled in the harvesting phase.

7. The machines must satisfy high ergonomic demands in accordance with Finnish law.
8. The capital expenditure on the machines must be minimal. It is an advantage if they can be used for other forestry work.

In North America, whole trees are hauled by a skidder to the upper landing as the chipping work progresses (Fig. 4). If chipping is interrupted, the forest haulage also must be stopped. The system is thus prone to disturbances.

An alternative has been adopted in Finland in which the interdependence of forest haulage and chipping has been loosened. The timber is brought to the upper landing before the beginning of chipping. It is stored in high stacks to reduce the need of space. This requires that the tractor has an effective loader and results automatically in forwarder transport. As the forest haulage of other timber is also done by forwarder, the solution suits the overall pattern of the harvesting organisation well.

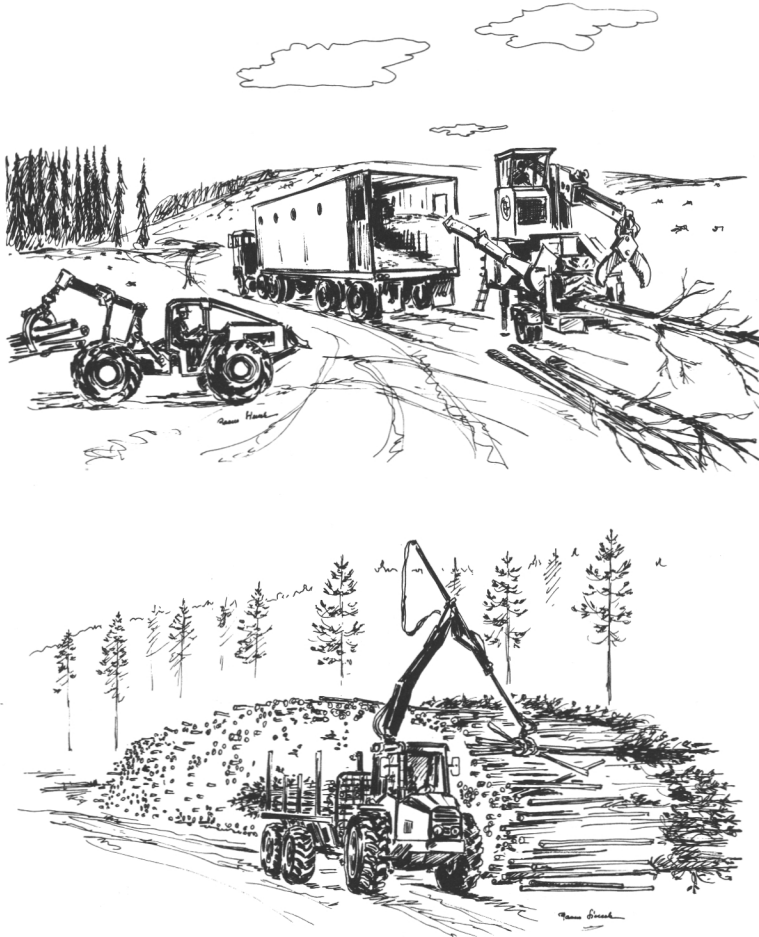


Figure 4. In the American whole-tree chipping schedules (above) forest haulage and chipping are tightly linked together. In the Finnish system (below) haulage is independent of the chipping phase.

Kuva 4. Amerikkalaisissa kokopuubaketusketjuissa (yläpuolella) metsäkuljetus ja baketus kytkeytyvät kiinteästi toisiinsa. Suomalaisessa järjestelmässä (alapuolella) kuljetus tapahtuu baketuksesta riippumatta.



Figure 5. Manual felling and bunching of whole trees is ergonomically difficult if a standard power saw is used (photo Oy W. Rosenlew Ab).
Kuva 5. Kaato ja kokonaisten puitten kasaus on ergonomisesti vaikeata käytettäessä vakiovarusteista moottorisahaa (kuva Oy W. Rosenlew Ab).



Figure 6. The Jaaranen-Rantapuu felling frame lightens and speeds up manual felling and bunching.
 Kuva 6. Jaaranen-Rantapuu kaatokabvojen käyttö keventää ja nopeuttaa kaatoa ja kokonaisten puitten kasausta.

The soiling of whole-tree raw material decreases when skidders are abandoned. On the other hand, the method requires the bucking of long trees before transport. As trees are not brought continuously to within reach of the chipper loader, flexible movement of the chipper at the upper landing is required as the work progresses.

In addition to upper-landing chipping, a harvesting schedule based on chipping on the strip road has also been developed. This method, too, is advantageous as regards landing arrangements and cleanness of the chips. It is especially competitive in easy topographical conditions. Use of the chipper on the strip road is not to the point in difficult terrain.

These factors form the framework of Finnish machine development in recent years. A number of original solutions have arisen; many of them are still under development. The most important machines in use in

Finland at the end of 1977 for the harvesting of whole-tree chips are presented in the following.

61. Felling and bunching

Manual method

Small-sized trees are still felled mainly by power saw. Felling is always accompanied by bunching, the requirements of which are dictated by the next machine in the schedule. The trees must be gathered into sufficiently large formations within reach of the tractor moving on the strip road.

Felling and bunching of whole trees is difficult ergonomically and involve the following weaknesses (Fig. 5).

1. Felling is done in a bent position. The smaller the trees, the more often is the awkward position repeated and the lower the stump-cross-section must be cut.

2. The worker has to guide the falling tree with one hand while he continues to saw. The risk of accidents is great.
3. After the tree has fallen, it is often hard work to move it undelimited to the bunch in thinnings.

Lightening the work and increasing the output are necessary in the long term. An important improvement is achieved by equipping the power saw with a special frame which permits felling with the back upright (Fig. 6). The principle is applied commonly in the Soviet Union in the harvesting of traditional timber. Finland has the Jaaranen-Rantapuu felling frame and the Finnish Forest Research Institute and Enso-Gutzeit Osakeyhtiö have developed from it a new felling-bunching method for small-sized trees.

The Jaaranen-Rantapuu felling frame is a suitable supplement to all power saws. But it has to be fitted separately to each make of saw. Light-weight saws are recommended.

The felling frame of tubular steel weighs somewhat over 1 kg. The gas trigger mechanism is in the upper part of the handles. The original gas trigger of the power saw is also retained and the saw can therefore be used for bucking when necessary.

The Jaaranen-Rantapuu device eases the working position and makes it easier to direct the felling as the worker can do this in the upright position. An essential advantage is that felling and bunching are smoothly synchronised (Fig. 7). When the tree is completely severed from the stump the worker puts the saw on the ground and grasps the falling tree. Using the momentum of the tree, he pushes it into the stack. The total weight of the tree thus does not burden the worker. He just guides the direction of its fall.

According to a recommendation by the Institute of Occupational Health in Finland, the maximum weight of a load in continuous lifting work should not exceed 35 kg. The method is therefore suitable mainly for thinnings in which the trees to be removed are very small. When the breast height diameter of pine is over 9—10 cm, the trees must be cut into two in order to ease bunching.

Careful planning of work is essential. The bunches must be placed and directed so as to leave the strip road free. The maximum distance of the bunch from the strip road depends on the next machine in the schedule. For instance, a forwarder with a long slide boom permits a strip road spacing of 20—30

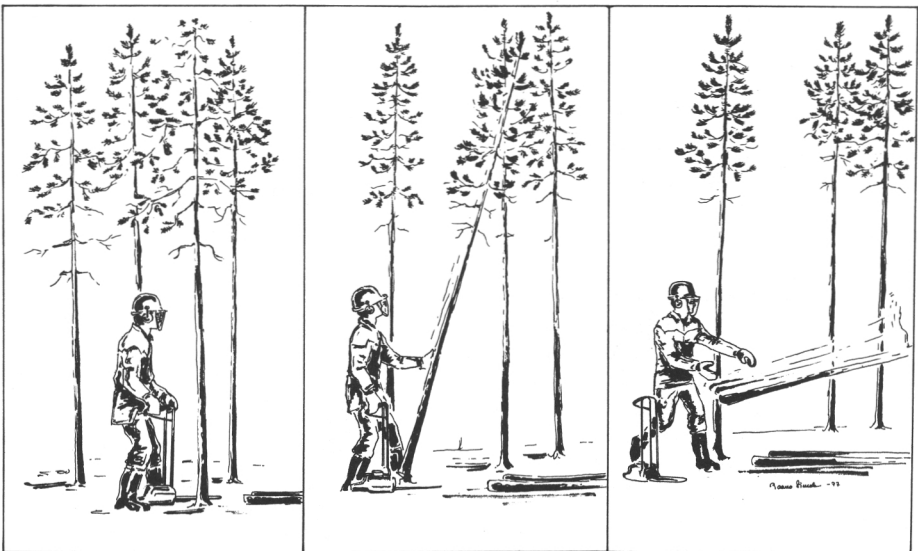


Figure 7. The Jaaranen-Rantapuu felling frame makes it possible to synchronize smoothly the manual felling and bunching of small-sized trees.

Kuva 7. Jaaranen-Rantapuu kaatokahvat mahdollistavat pienten puitten kaadon ja kasausten joustavan yhteenliittämisen.

m without the manual moving distance having to exceed a couple of metres. A telescope boom permits a strip road spacing of 30–35 m. A winch makes it possible to use strip road spacing of as much as 40–100 m.

Compared with the felling of small-sized trees by standard power saw followed by separate bunching, output increases in favourable conditions by 20–30 % when a felling frame is used. This is due to the following reasons (Lehtonen 1976):

- safety is improved
- the working position is eased
- directing of the falling tree is more effective
- two work phases are integrated closely and the tree does not have to be lifted off the ground.

The output in combined felling and bunching is affected by branchiness, distance between strip roads, the terrain and snow conditions and above all, tree size. Depending on the tree size, the average output of the worker in early thinning of a pine stand is in summer conditions 2,5–5,0 solid m³/h of whole tree material (2–4 m³/h of stem wood, excluding branches). Snow slows the work and may even prevent it.

The method cannot be applied as such if the trees to be removed are large. A standard power saw is then used for the felling and the trees must be bucked prior to bunching. A tractor-mounted feller-buncher comes into question as an alternative.

Long-range loader boom

The worker bunches the trees so that the forwarder or chipper is able to reach the whole-tree bunches while on the strip road. The bunches must be placed carefully so that the forwarder is capable of working flexibly and without damaging standing trees. If the forwarder is equipped with a standard knuckle boom the bunches must be located within the immediate range of the strip road.

When the range of the forwarder boom increases manual bunching work can be reduced and the worker need not haul the trees to quite alongside the strip road (Fig. 8). The work strain is eased and output grows. However, when the timber is placed at the maximum reach of a long-range boom the

loading output decreases. If the work is not planned carefully, damage to standing trees may increase.

An example of increasing the reach is the Marttiini slide boom which is also distributed as the Valtra LM slide boom. It can be mounted as an auxiliary device in all knuckle boom loaders in place of the original boom (Fig. 12). It is suitable for medium-sized and heavy forwarders.

The Marttiini slide boom consists of a 2,8 m casing section and a 4,9 m sliding rod. When a short boom is needed for loading the sliding rod can be readily retracted into its backward position. The rod is moved by a hydraulic motor at the end of the casing section and a chain on the upper surface of the rod. The moving speed of the sliding boom is 1 m/s.

The Marttiini slide boom increases the range of the knuckle boom loaders in common use by 4–6 m up to 10 m. To improve stability and to lower the power requirement the machine pulls the whole-tree bunch closer by raising only the front end of the bunch off the ground. Only after the sliding rod has been retracted is the bunch hoisted into the load space of the forwarder. In a tall stand the bunch is first pulled alongside the machine and the grapple is then moved to the middle of the bunch for turning and loading the trees. In early thinnings it is often possible to turn the bunch in the direction of the load without changing the grapple hold above the tree tops. Unloading is similar to the process with the knuckle boom.

The slide boom facilitates manual felling-bunching essentially (cf. Harstela and Tervo 1977). The equipment is particularly effective in the harvesting of long goods and it therefore lends itself excellently to the treatment of small-sized whole trees in a stand in which the strip road spacing is 20–30 m. However, when the forwarder must collect a part of the trees far from the strip road the haulage output is reduced by 10–15 % compared with conventional knuckle boom equipment (Melkko and Taipale 1975).

It is possible to instal the Marttiini slide boom also on a chipper. This generally does not require the same length of reach as in a forwarder.

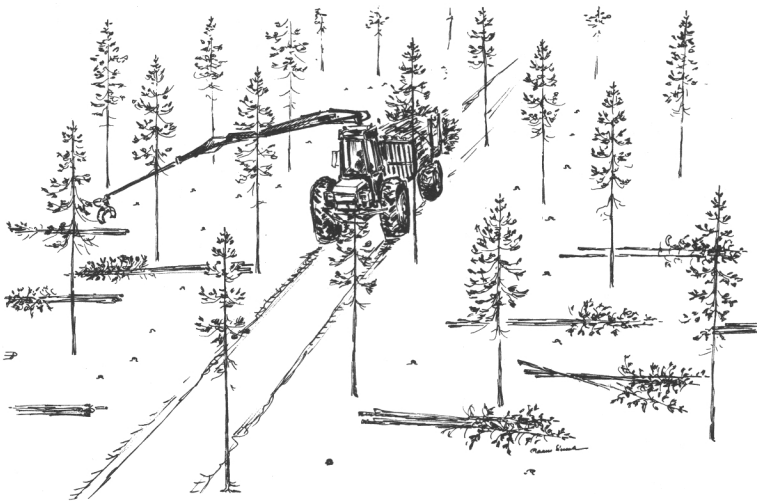
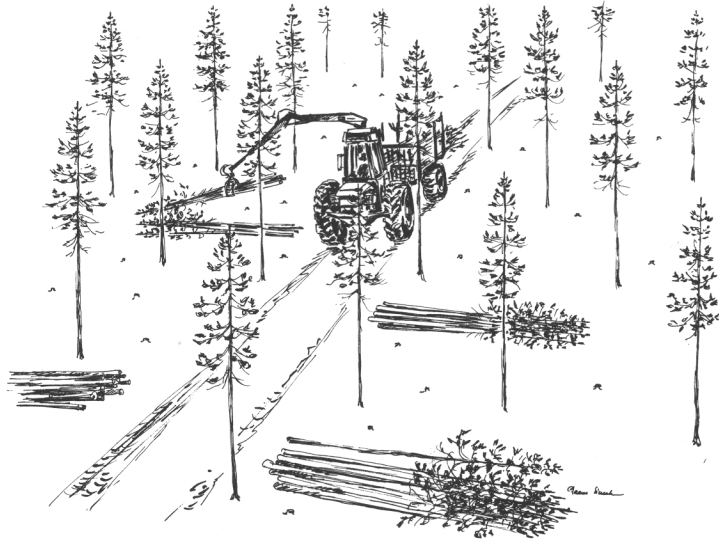


Figure 8. Compared with a standard knuckle boom (above), the Marttiini slide boom (below) eases the requirements of manual bunching to alongside the strip road.

Kuva 8. Tavanomaisen nivelpuomiin (yläpuolella) verrattuna Marttiinin liukupuomi (alapuolella) helpottaa pienten kokopuitten käsityönä tapahtuvan kasauksen vaatimuksia.

Boom-type buncher

The whole-tree bunches can be pulled from stump to strip road side with a boom-type buncher. The device is mounted on the rear frame of a medium-sized or heavy forwarder (Fig. 9). The load on the basic machine is

relatively small. The boom-type buncher is not suitable for loading or turning the trees parallel to the strip road, and forest haulage is therefore left to a separate forwarder.

The bunching device of Orion-Yhtymä Oy Normet consists of a lift boom and a transfer boom (Fig. 13). Many hydraulic functions of

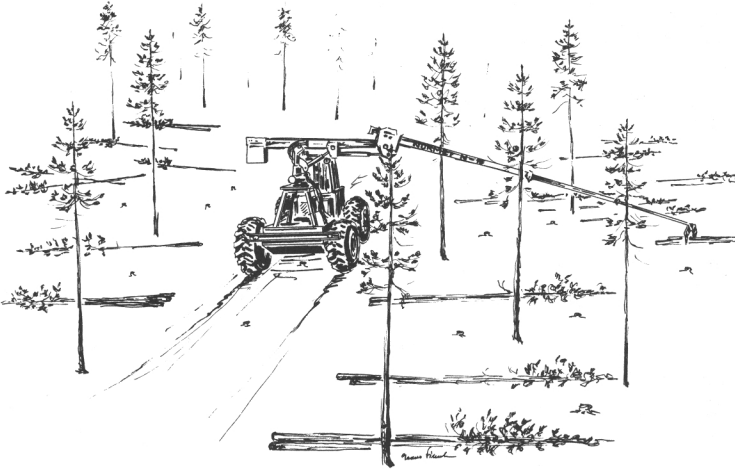


Figure 9. Collecting whole trees to alongside the strip road with a boom-type buncher.
Kuva 9. Kokonaisten puitten kasaus ajouran varteen teleskooppipuomilla.

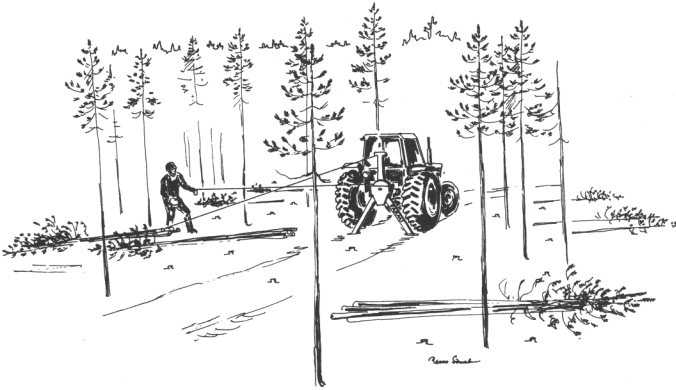


Figure 10. Bunching whole trees to alongside the strip road with a farm tractor driven winch.
Kuva 10. Kokonaisten puitten kasaus ajouran varteen maataloustraktoriin sovitetulla vintturilla.

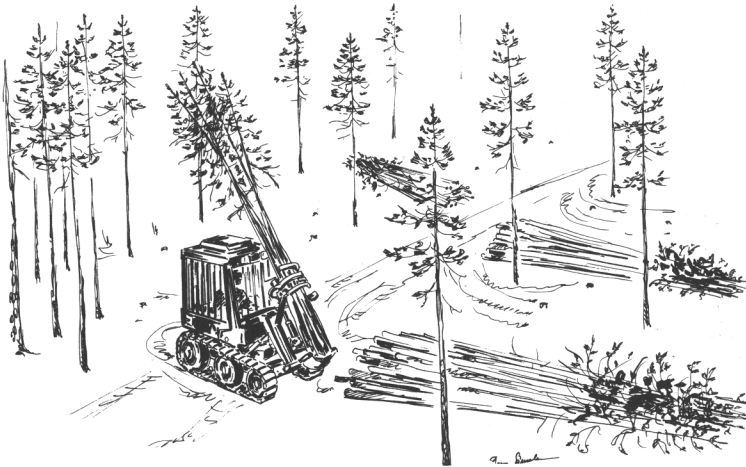


Figure 11. Felling and bunching whole trees to alongside the strip road with a small forest tractor.
Kuva 11. Kokonaisten puitten kaato ja kasaus ajouran varteen pienmetsätraktorilla.

the conventional boom crane have been changed into partly mechanical operations. The telescope-type transfer boom of the device is composed of four sleeve pipes which can be folded into one another. Lengthening and pulling the boom as well as closing the tongs is done with the help of a winch. Long and breakable hydraulic tubing has been avoided.

The Normet buncher moves backwards on the strip road. The range of the boom is 15 m. The trees are pulled close to the strip road with the butts 0,5—1 m from the strip. The maximum distance between strip roads is 30—35 m. If the stand is left exceptionally dense insufficient visibility may disturb the driver.

The buncher is preceded by felling by power saw and preliminary manual bunching. This work must be planned carefully to enable the buncher to be able to find effortlessly an open line between the standing trees from the strip road to the bunch.

The tongs are taken to the bunch by lengthening the transfer boom, and during this phase the tongs close automatically to obviate damage to stems. When the traction wire is slackened the tongs open under the influence of a spring. When the pulling of the bunch towards the strip road begins the tongs close again. The machine is capable of pulling timber from all directions from a distance of up to 15 m.

The speed of the transfer boom on pulling out and in is 1 m/s. The output of the machine is primarily affected by the size and placing of the bunches made by the worker, the strip road spacing, the timber yield per unit of area, terrain conditions, and the density of the standing trees. The machine is capable of pulling 60—100 bunches to alongside the strip road per effective work hour.

The output of the bunching work is affected by the fact that perhaps one-half of the whole trees are close enough to the strip road already as the result of the manual felling and prebunching. Thus only 40—60 % of the raw material is actually handled by the boom-type buncher if the spacing between strip roads is 30 m. In average conditions the output in bunching, including the timber which need not be handled by the Normet boom-type buncher, is 14—20 solid m³ of

whole-tree material (branches included) per productive hour.

Winching

Winching is a common method of collecting timber alongside the strip road in thinnings (Fig. 10). It makes it possible to lengthen the strip road spacing to 50 m in early thinning and even more, up to 100 m, in later thinnings. Large strip road spacing, however, increases the damage to standing trees and the physical strain on worker, and lowers the output.

Winching is popular in the Scandinavian countries, especially in Denmark, Norway and Sweden. Owing to the strenuousness of the work and the relatively low productivity it is not competitive any more in Finland. An exception are farm owners' logging systems.

Winches are applied also in the bunching of whole trees. If abundant wood is harvested per unit of area and the strip road spacing is great, difficulties may be encountered in the work. The winching of new trees onto the whole-tree bunches alongside the strip road presupposes a raised traction point.

There are two main types of winches in general use; those attached to a farm or forest tractor and those used separately. To prevent the bouncing of loads on obstacles the winch can be equipped with a sledge or cone.

Farmi winches made by Orion Yhtymä Oy Normet are in general use in Finland. They are fixed to the hoisting equipment of a farm tractor. The Farmi JL 30 (Fig. 14) or Farmi JL 45 are suitable for bunching whole trees alongside the strip road. The traction capacity of the former is 3 000 kg and its total weight is 180 kg. The wire is 8—10 mm thick and 50—80 m long. The speed is 0,5—1,0 m/sec. The device incorporates a mechanised disc coupling. A steady working position is achieved by means of adjustable stabilizer legs. The winch can also be supplied with radio control.

The output of the winch depends decisively on the strip road spacing. The closer together the strip roads are, the greater the proportion of raw material that is brought sufficiently near the strip road manually by the worker. If the strip road spacing is 30 m, only 40—

60 % of the bunches have to be winched. If the distance between the strip roads is increased to 50 m, the proportion of timber to be winched is 65—75 %.

Winching output is at its minimum in early thinnings because of the small size of the trees. When whole trees are bunched by Farmi winch and the strip road spacing is 30 m, the output per productive hour is 7—8 solid m³ of hole tree material. It must be remembered, that 40 % or more of the trees are ready on the strip road side after the manual prebunching, and thus the winch actually has to skid only up to 60 % of the total output given above.

Feller buncher

A feller-buncher built on a small-sized tractor is so far the only solution that permits concomitant mechanization of felling and bunching in early-thinning conditions (Fig. 11). A small size and manoeuvrability are required of the basic machine to enable it to thread its way among the standing trees without damaging them.

The width of the Makeri feller-buncher is 1 600 mm, length 3 600 mm and weight 2,4 tons. The engine power is 22 kW. Ground clearance is 450 mm. The machine is equipped with tracks. The machine has draw-steering. When the tracks are drawn in different directions the machine turns on the spot. The safety cap meets the ergonomic demands even of big forest tractors. The accumulating TTS felling-bunching device of the Makeri shears at the most 22 cm thick trees (Fig. 15).

The Makeri first opens the strip road. The width of the road is determined by the following machine in the harvesting schedule rather than the feller-buncher itself. The machine then collects the trees to be removed from the terrain between the strip roads. There are no technical limitations as to the strip road spacing, but it naturally affects the output and the damage to soil. The most commonly used strip road spacing is 30—50 m.

Thinning proceeds simultaneously on either side of the strip road. The machine collects a bunch of 1—6 trees, depending on the stem size, and moves them in the upright position to alongside the strip road, generally by reversing. The bunch size and direction

are selected to enable the following machine to operate as speedily as possible. The bunch usually contains 0,5—1,0 m³ of whole tree material. If required all the bunches can be concentrated on the same side of the strip road. The machine adapts flexibly to different harvesting systems, also as a pre-processor unit when the short-wood method is used in selective thinning.

As the Makeri has to move close to each tree to be felled its output depends on the size of the tree. It does not differ from other harvesting machines in this respect. But it is constructed specifically for small-sized trees and the minimum size of merchantable timber is therefore smaller than with other machines. When the breast height diameter of the trees exceeds 9 cm (30 dm³ of stem wood) the Makeri is more economical than the manual method. The output per productive work hour is in average conditions (strip road distance 30 m) in an early-thinning pine stand during the summer season as follows:

Stem volume dm ³	Output, solid m ³ /h whole trees
20	3,5
30	4,9
50	7,6

Output begins to diminish when the snow is over 30 cm deep and when it is over 60 cm work is no longer possible.

The feller-buncher is so far the only mechanized alternative to manual felling in early-thinning stands in Finland. The machine that follows the feller-buncher in the harvesting schedule, whether it is a forwarder or chipper, generally achieves a good output.

The damage caused by the feller-buncher depends on the hauling technique, the driver's care and external conditions. The best results is achieved by leaving the choice of the trees to be removed to the driver. Abandonment of the traditional advance marking is also a definite cost saving.

If 1 300 trees per hectare at most are left to grow, the damage to the stems is relatively slight. Root damage is small on dry and frozen ground. However, if the ground is softened by rain, for instance, root damage may rise to an unacceptable level, especially in a spruce stand.



Figure 12. The Marttiini slide boom mounted on a Valmet 872 forwarder (photo Valmet Oy).

Kuva 12. Marttiin liukupuomi Valmet 872 kuormatraktorissa (kuva Valmet Oy).



Figure 13. The Normet boom-type buncher mounted on a Valmet 870.

Kuva 13. Normetin teleskooppipuomi Valmet 870 traktorissa.



Figure 14. A Farmi JL 30 winch mounted on a farm tractor.
Kuva 14. Farmi JL 30 vintturi maataloustraktoriin sovitettuna.



Figure 15. Makeri feller-buncher.
Kuva 15. Makeri kaato-kasauskone.

62. Forest transport of whole trees

Whole-tree raw material can be hauled from forest to upper landing in two ways. If chipping is at the stump or on the strip road, it is chips that are hauled. If chipping is done at the upper landing or the mill, the whole tree is transported.

In many countries, such as the Soviet Union, the United States and Canada, whole trees are transported chiefly by skidder. The use of forwarders was decided upon in the Finnish system for the following reasons (Fig. 16).

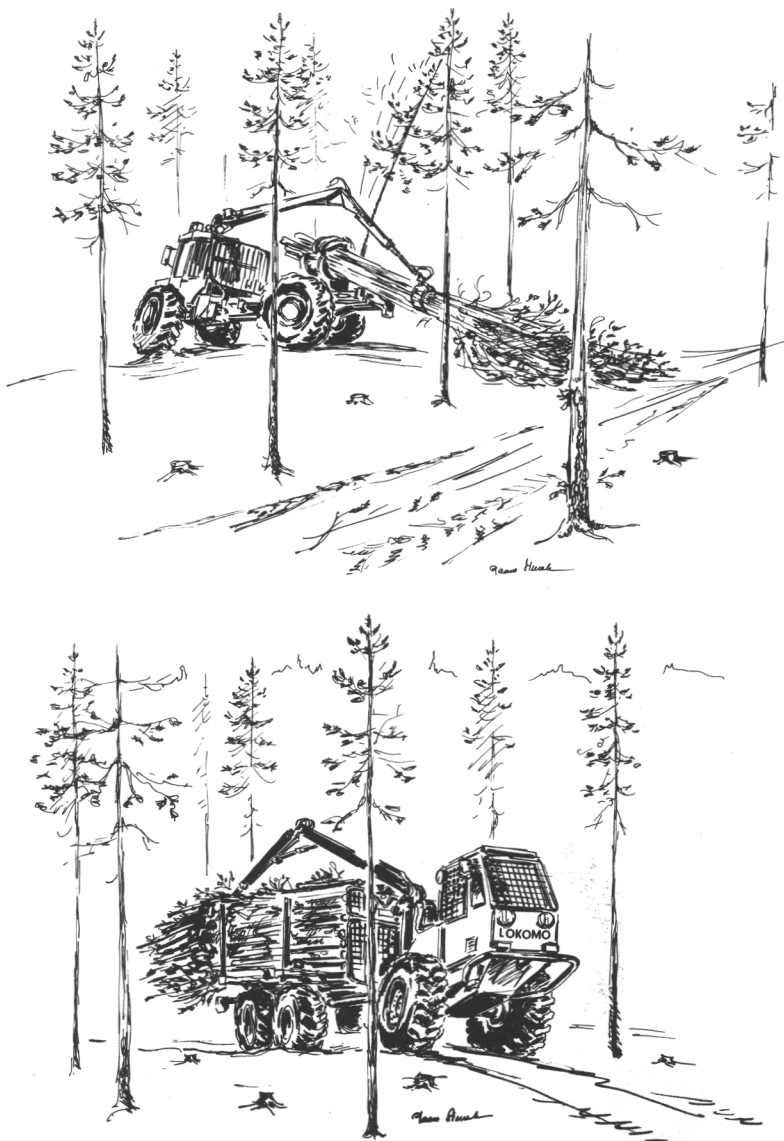


Figure 16. Skidding (above) and forwarding (below) of small-sized whole trees.

Kuva 16. Pienten kokopuitten kuljetus laabus- (yläpuolella) ja kuormatraktorilla (alapuolella).

1. The traditional timber assortments are transported solely by forwarders which are more suitable than skidders for thinnings. It is important that the transport of whole-tree raw material is adapted to the standard equipment.
2. Foreign and domestic experience shows that sand and other impurities enter the whole-tree raw material in the various phases of harvesting. They blunt the chipper knives and cause extra wear and tear on mill machinery. The most serious cause of soiling is the skidding of whole trees. Forwarders keep the trees essentially cleaner.
3. The trees of an early-thinning pine stand are so small that the skidder load is inevitably inadequate. The use of the load space in a forwarder is also somewhat unsatisfactory when whole-tree raw material is hauled, but the drawback is smaller.
4. It is sought in Finland to avoid a »hot» harvesting schedule in which the operation of successive machines is closely inter-linked. In particular, the tendency is to separate forest haulage from chipping at the landing. The timber is therefore taken to the upper landing in advance and stored

in 2—4 m high stacks (Fig. 17). This requires a boom loader which is lacking in the standard equipment of the skidder.

The forwarder load is relatively light when whole trees are transported and the heaviest tractors are therefore generally impractical. It is important that the load space is as large as possible. The weight of the load is a fourth smaller with whole trees than with cordwood (cf. K a h a l a 1974) and often less than a half of the capacity of the forwarder.

	Medium-sized forwarders
Average load size, m ³	
Saw logs	8,8
3 m cordwood	6,0
Small whole trees	4,5—5,0
Average load size, tons	
Saw logs	7,3
Cordwood	5,1
Small whole trees	3,5—4,0
Carrying capacity, tons	6—12

Some of the Finnish forwarders that are used for the forest haulage of whole trees are described in the following. All four are articulated frame steering forwarders. The Valmet Jehu 522 has front tracks.



Figure 17. Unloading whole trees at the upper landing site.
 Kuva 17. Kokopuukuormaa puretaan väliavarastolla.

	Valmet Jehu 522	Valmet 872	Lokomo 909	Lokomo 928
Length, mm	9 430	8 050	7 970	9 270 *)
Width, mm	2 400	2 500	2 490	2 670
Lowest ground clearance, mm	650	640	515	740
Dead weight, kg	9 000	11 300	8 800	13 000
Engine output, kW	40	75	63	119
Loader:				
Reach, m	5,3	5,4	5,3	6,5
Gross lifting moment, kNm	63	65	48	73
Load space:				
Length, mm	4 200	4 100	3 800	4 200 *)
Cross section area, m ²	3,0	3,0	3,4	5,0
Maximum load, kg	7 000	8 000	6 000	15 000

*) Alternatively, 10 700 mm long frame with a load space length of 5 800 mm.

The forwarder load space is not long enough for the transport of whole trees. Trees of over 7—8 m must therefore be cut in two. If the tree length is over 14—16 m it must be cut into three parts.

The bucking can be done by power saw in connection with manual felling and bunching or it can be mechanically connected with forest haulage. In the latter case the Swedish Iggesund method is used in which the forwarder loader is equipped with an ÖSA 772 grapple saw (Fig. 18). The device consists of a strong grapple containing a hydraulic chain saw. The grapple area is 0,35 m² and the effective bucking diameter is 450 mm.

The forwarder grasps the whole-tree bundle near the bucking point. With the grapple pressing the bundle firmly the saw powered by a hydraulic cylinder cuts the trees into two. The butts and tops are paralleled and lifted as a single bunch into the forwarder load.

Bucking slows the work of the forwarder slightly and the bunch handling time in loading may even be doubled. However, not every bunch must be bucked. On the other hand, the landing arrangements improve when the length of the timber is levelled.

The range of the standard loaders of medium-sized forwarders which have been found best for the transport of whole-tree

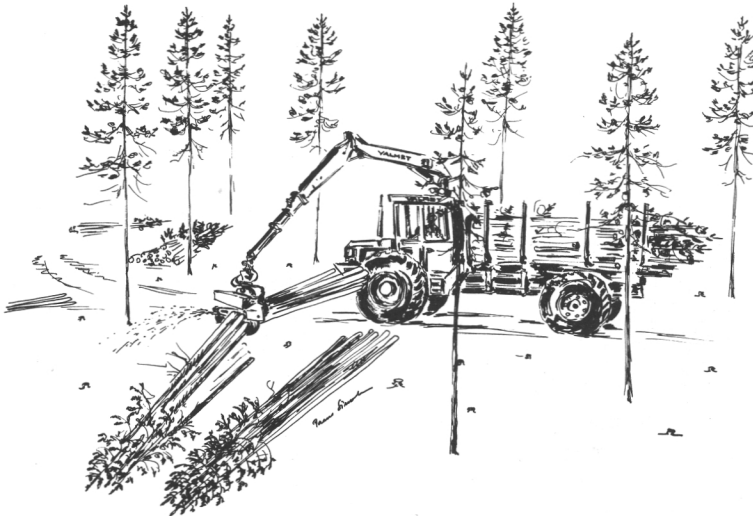


Figure 18. Combined bucking and forwarding of small-sized trees. An ÖSA 772 grapple saw mounted on a Valmet 872.

Kuva 18. Pienten kokopuiden katkaiseminen metsäkuljetuksen yhteydessä. ÖSA 772 kourasaba Valmet 872 kuormatraktorissa.

raw material is generally 4,5—5,5 m. This is good enough if the whole trees are bunched by the Normet boom-type buncher, Farmi winch or Makeri feller-buncher. But if the bunching is done solely by manual methods the range of the standard boom is insufficient.

As stated in greater detail (page 19), the Marttiini or Valtra LM slide boom is suitable for all standard loaders as an additional device. The range of the loader increases to 10 m (Fig. 8). This accelerates and lightens manual bunching. However, when the bunches have to be pulled into the load from a greater distance the consumption of time in the loading phase rises. The output of forwarder hauling decreases by 10—15 % over a distance of 300 m.

Average output figures for whole-tree transport with a medium-sized forwarder in an early-thinning pine stand are given in the following. When bunching alongside the strip road is done with a Makeri feller-buncher the forwarder output is high. The Makeri collects the trees into large bunches which speedup the loading.

Method	Hauling distance, m		
	100	300	500
	Output, solid m ³ of whole trees/h		
a	6,9	6,1	5,4
b	8,2	7,3	6,4
c	9,4	8,1	7,0

- a) The trees are felled and bucked manually. Loading is by slide boom, the maximum distance of the bunch from the strip road is 9 m. Distance between strip roads 20—30 m.
- b) The trees are felled by power saw and hauled alongside the strip road by a Normet boom-type buncher. Loading is by a knuckle boom loader. The trees are bucked by a grapple saw during loading. Distance between strip roads 30—35 m.
- c) The trees are felled and brought alongside the strip road by the Makeri. Loading is by standard knuckle boom loader. The trees are bucked by a grapple saw during loading. Distance between strip roads 30—50 m.

63. Chipping

The whole-tree harvesting schedule is built around the chipper. The equipment of the other work phases is determined for the most part by the technical properties, capacity and manoeuvrability of the chipper. The following alternatives arise, depending on the siting of the chipper:

- chipping at the stump
- chipping on the strip road
- chipping at the upper landing
- chipping at the lower landing
- chipping at the mill yard.

The first method, chipping at the stump, is intended chiefly for clear cutting conditions. It may also be applicable to systematic thinning. A Finnish solution model is based on the Pallari Busharvester which is designed for clear cutting of small-sized, unproductive hardwood stands or corridor thinning of young softwood plantations. The machine is only in the first prototype stage at the end of 1977 (cf. Hakkiila and Mäkelä 1975) and is therefore not described in more detail here.

The second alternative, chipping on the strip road, is already at the practical stage. Finland and Sweden have shown especial interest in the method. The equipment can also be used for chipping at the stump in clear cutting conditions or at the landing site.

Chipping is usually performed at the upper landing. The method is prevalent in several European countries and used exclusively in North America. The majority of the chippers have been constructed for this method.

Chipping at the lower landing or mill yard has lagged behind in the Finnish development work. It is an alternative that may prove competitive, but a condition for this is a technically and economically acceptable solution of the problem of long-distance transport of whole trees. Chipping at the lower landing has been developed farthest in the Soviet Union, but it is concerned there with separate branches, tops and other residues rather than whole trees. Another alternative is under development in Sweden; whole trees are first bucked and then delimbed and barked simultaneously in a drum at the mill yard.

This report describes the methods and machines that were in use in Finland at the end of 1977. It is thus confined to chipping on the strip road and chipping at the upper landing.

Chipping on the strip road

Exact demands are made of the terrain worthiness of a chipper operating on the

strip road. It must be lighter in weight but at the same time more versatile than a chipper working at the upper landing. Its basic capacity therefore tends to be smaller. The total output is reduced by the use of the machine for hauling the chips.

However, in certain conditions, the terrain chipper has proved to be a worth-while alternative in the harvesting of early-thinning pine stands. The method offers several noteworthy advantages.

1. The loading of long timber into a farm or forest tractor causes certain difficulties in early-thinning conditions for the trees must be first turned so that they parallel the strip road. When the chipper operates on the strip road the trees are pulled directly into the feeding device and the turning phase is omitted. Feeding the chipper may be as fast as loading the tractor. The damage to the residual trees is reduced.
2. Forwarder transport requires the bucking of over 7—9 m trees. When chipping is done on the strip road bucking is not necessary.
3. Chipping at the upper landing leaves eyesores in the form of branches. They may also hamper the work. With terrain chipping, the residues with their nutrients are left in the forest.
4. The space requirement at the upper landing is reduced and landing arrangements are simplified.
5. The terrain chipper can move unaided from one work site to another.
6. The raw material is as clean as possible.

Despite its numerous advantages, the method has limitations. The terrain worthiness of the chipper is sufficient only in fairly easy going, even when the basic machine is a forest tractor. The method lends itself poorly to winter conditions when the snow is over 30—40 cm deep. Furthermore, if the forest hauling distance is long it is not profitable to use an expensive whole-tree chipper for the transport of chips. The following requirements are therefore made of the work site:

— the terrain must be relatively easy, class I or II in the Finnish four class system

- the snow depth must not exceed 30—40 cm
- the hauling distance must not exceed 400 m
- the minimum yield is 30 m³ of whole-tree raw material per hectare.

If the stand does not fulfil the above requirements it is generally expedient to site the chipping process at the upper landing. This does not preclude the use of a terrain chipper. However, compared with its capacity, the terrain chipper is a more expensive alternative at the upper landing.

Two Finnish terrain chippers are presented here. One, the AST, represents the light-weight equipment of farm forests. The other, the TT 1000 F, is suitable for use by the forest industry and contractors at larger work sites.

AST chipper

The AST is used primarily for the preparation of fuel chips in farm forests (Fig. 19). The 320 kg chipper, attached to the three-point lift linkage of a farm tractor, fits easily between the tractor and the trailer. The minimum power requirement is 24 kW. Power is transmitted direct from the power take-off shaft to the chipper.

The diameter of the blade disc is 630 mm. The disc speed is 1 900 r/min. The three knives of the rounding disc pull small-sized whole trees without a special feeding device at a speed of up to 148 m/min. The maximum diameter of the tree is 120—150 mm, depending on the tree species. The particle size of the chips is adjustable between 6 and 26 mm.

Infeed is manual from the left side of the tractor (Fig. 21). Manual infeed limits the maximum size of the trees in practice to 20—30 dm³. For larger trees the tractor must have a loader and, in addition, the largest branches must be delimited. The latter alternative has so far not won acceptance in practice.

The chips are blown into the tractor trailer from which they are tipped onto a tarpaulin, into an exchangeable truck container or, if used as fuel by the farm owner himself, directly onto the fuel stack. In addition, a nylon mesh sack system is under



Makeri kaato-kasauskone
Makeri feller-buncher



Makeri laahustraktori
Makeri clam skidder



TT 1000 T palstahakkuri
The TT 1000 T terrain chipper



TT 1000 F palstahakkuri
The TT 1000 F terrain chipper



TT 1500 L varastohakkuri
The TT 1500 L landing chipper



TT 1500 T varastohakkuri
The TT 1500 T landing chipper



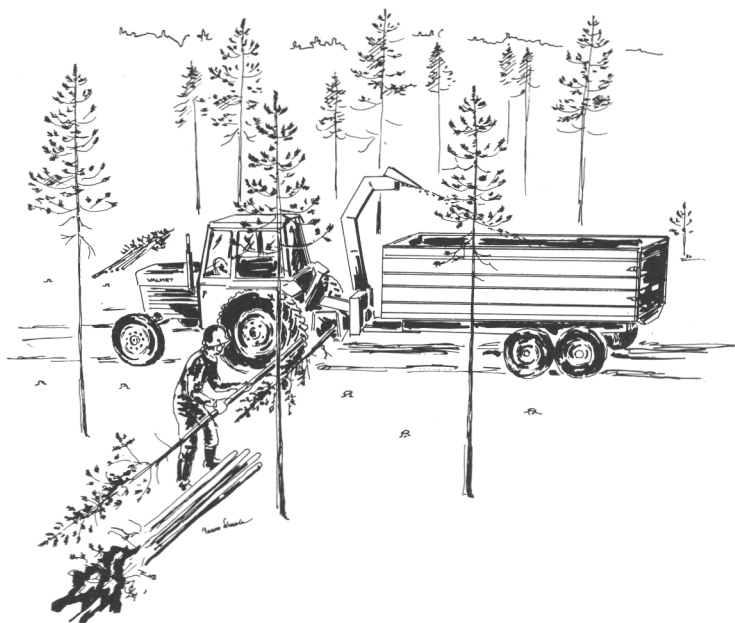


Figure 19. A light terrain chipper for small operations in farm forests.
Kuva 19. Maatilametsälön kevyt palstabakkuri pieniä työmaita varten.

development (Fig. 20). The aim is to blow the chips into 1–3 m³ sacks which can be loaded as such onto a truck.

The output of the AST chipper depends on the number of the crew, the power of the tractor, the size and properties of the trees, the chipping site and the transport distance. The following averages refer to small-sized pine in thinnings. The output includes the transport of the chips and unloading at the upper landing. The highest hourly outputs require a working team of two men.

Chipping site	Output, solid m ³ /h
At the upper landing	3,0–5,0
On the strip road, hauling distance 100 m	2,5–4,0
On the strip road, hauling distance 300 m	2,1–3,3
On the strip road, hauling distance 500 m	1,7–2,6

TT 1000 T terrain chipper

The basic machine of the TT 1000 T terrain chipper is a heavy four-wheel-drive farm tractor. In Finland, the Fiat 1300 DT tractor is used for this purpose. It weighs 5.3 tons and its engine develops 110 kW.

The chipping unit is mounted on a trailer equipped with powered bogie (Fig. 22). The 980 mm disc chipper is driven hydraulically by the engine of the basic machine. The rotation speed is 1 000 rpm. The disc is equipped with two knives.

The feeding equipment is controlled hydraulically. The measurements of the infeed opening are 250 × 250 mm. The trees are taken to the chipper by chain conveyor with a roller above it. The height of the roller can be adjusted pneumatically. The system is protected against overload. The equipment can be turned in the horizontal and vertical planes to speed up the work.

The chips are blown directly into a 15 m³ container which is emptied by tipping. The roof mesh of the container opens and closes automatically. The tipping height is 3 m. The stabiliser legs of the machine are lowered to the ground while the container is being emptied.

The loader is mounted on the tractor. The unit can be equipped with a knuckle or slide boom. The range of the knuckle boom is 4,0, that of the slide boom 6,5 m.

When the basic machine is a Fiat 1300 DT the total weight of the unit is 15.9 tons. The



Figure 20. A nylon mesh sack system for transporting whole-tree chips is under development.

Kuva 20. Kokopuuhakkeella kehitellään myös nailonverkkoosäkkien käyttöön perustuvaa kuljetusjärjestelmää.



Figure 21. The AST whole-tree chipper attached to the three-point lift linkage of a farm tractor. Manual feeding.

Kuva 21. Käsiyöittäinen AST kokopuuhakuri maatalonstraktorin kolmipistekiinnityksessä.

length is 12,3 m, width 2,5 m and height 3,4 m.

The working technique of the machine is the same as that of the TT 1 000 F terrain chipper. Its terrain worthiness is not as good, however, because of the basic machine solution, and it can be used as a terrain chipper in fact only in easy conditions. If the terrain is soft, stony or sloping or there is deep snow, the machine is used only as a landing chipper.

The output depends on tree size and branchiness, the distance of the bunches from the strip road, the driving distance, terrain, and other factors. If the average tree size is 30 dm³, driving distance 300 m and the terrain easy, the output of TT 1 000 T, including haulage, is 5—10 solid m³/productive hour in the thinning of a pine stand. If chipping is done at the landing the output is appreciably higher.

TT 1000 F terrain chipper

The basic machine of the first TT 1000 F terrain chipper is a heavy Lokomo 928 forwarder provided with a bogie (Fig. 23). Other heavy forwarders, like the Valmet 882 K, can be used as the basic machine as well (Fig. 28). The 980 mm disc chipper, the feeding device, the 110 kW power unit and the tippable 17 m³ chip container are mounted on the load space of the forwarder. The grapple loader, provided with a sliding boom, is located between the cabin and the disc chipper.

The length of the unit is 9,80 m, the width 2,50 m, the height 3,8 m and the weight 18,5 tons.

The disc chipper has two knives. The rotation speed of the disc is 1 000 rpm. The length of the chips is adjustable. The chip blowing pipe is hydraulically turnable.

The feeding opening is 250 by 250 mm. The feeding equipment consists of a chain conveyor and a roller, both hydraulically driven. The roller can be raised and lowered. The feeding equipment can be turned in the horizontal and in the vertical plane to ease and speed up the feeding. Based on the rotation speed of the disc, the equipment has automatic protection against overload.

The tipping height of the chip container is 3 m. The hydraulically operated stabilizer legs are lowered for the duration of the tipping. The chip container is covered with wire netting which opens automatically during tipping.

The TT 1000 F terrain chipper operates in a thinning stand from the strip road. The timber must be bunched vertically to the strip road so that the machine can pull it straight into its infeed device. Since the trees need not be turned the feeding process is simple and fast.

The machine is fed from the right only and therefore has to move in two directions on the strip road. However, when a feller-buncher is used all the trees can be bunched on the same side of the strip road. The larger the bunches of trees, the higher is the output.

The chip container is emptied into an exchangeable truck container on the ground or onto a tarpaulin. The tipping height is not sufficient to permit discharging of the container directly onto the truck platform.

The chipping output depends primarily on the tree size, bunch size, location of the bunches, raw material yield per unit of area, terrain, and hauling distance. The following yield figures (breaks excluded) illustrate a typical early-thinning pine stand in which the strip road spacing is 30 m and timber yield 30 solid m³ of whole-tree raw material per hectare.

Bunching method	Chipping on the strip road		
	Hauling distance, m		
	100	300	500
	Output, solid m ³ of chips/h		
a	8,8	7,7	6,8
b	10,1	8,6	7,5
c	10,8	9,0	7,6

- a) Manual felling and bunching
- b) Manual felling and boom-type buncher
- c) Feller-buncher

If bunching is done manually a part of the trees is left a little farther away from the strip road. This reduces output. The highest output in terrain chipping is achieved when the trees are brought by the feller-buncher to alongside the strip road.

The TT 1000 F terrain chipper is suitable also for work at the upper landing. When moving from bunch to bunch and the forest hauling of chips are omitted, output grows to 12—14 solid m³ of chips per hour. How-



Figure 22. The TT 1000 T driven by a Fiat 1300 DT (photo Työväline Oy).

*Kuva 22. TT 1000 T pals-
tabakkuri, vetokone-
ena Fiat 1300
DT (kuva Työ-
väline Oy).*



Figure 23. The TT 1000 F terrain chipper on a Lokomo 928 forwarder.

*Kuva 23. TT 1000 F pals-
tabakkuri Loko-
mo 928 kuorma-
traktoriin asennet-
tuna.*

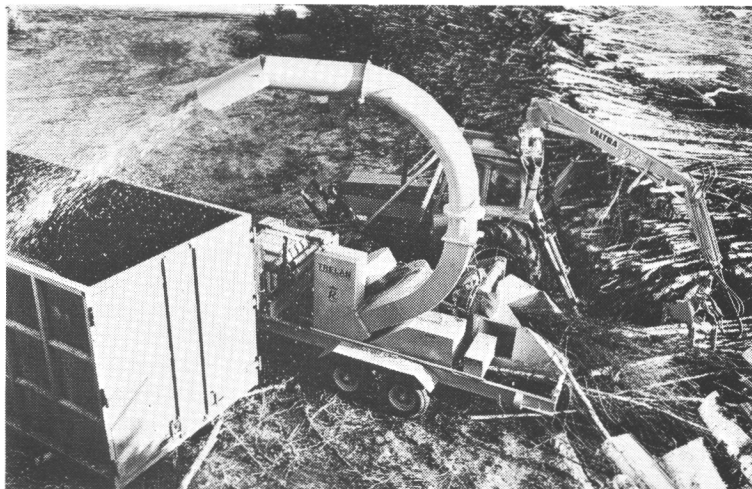


Figure 24. Trellan D 60, fed by a Valmet Valtra 1102 (photo Oy Rosenlew Ab).

*Kuva 24. Trellan D 60.
Syöttökoneena
Valmet Valtra
1102 (kuva Oy
Rosenlew Ab).*

Figure 25. The TT 1500 L landing chipper (photo Työväline Oy).

Kuva 25. TT 1500 L väli-varastobakkuri (kuva Työväline Oy).



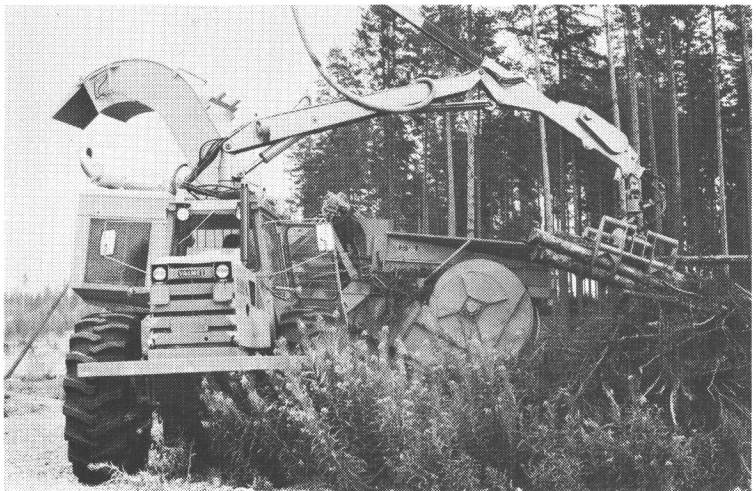
Figure 26. The TT 1500 T landing chipper (photo Työväline Oy).

Kuva 26. TT 1500 T väli-varastobakkuri (kuva Työväline Oy).



Figure 27. The Algol multi-purpose landing chipper (photo Oy Algol Ab).

Kuva 27. Algol välivarastobakkuri (kuva Oy Algol Ab).



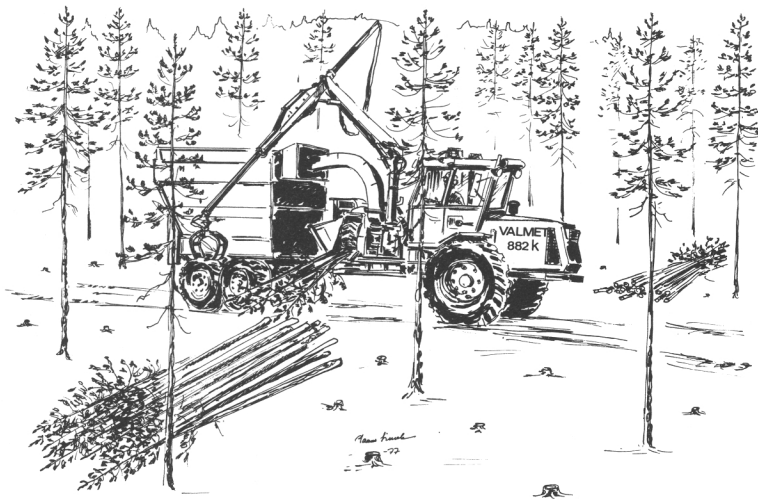


Figure 28. Terrain chipping system for larger operations.
Kuva 28. Suurten työmaitten palstabaketusjärjestelmä.

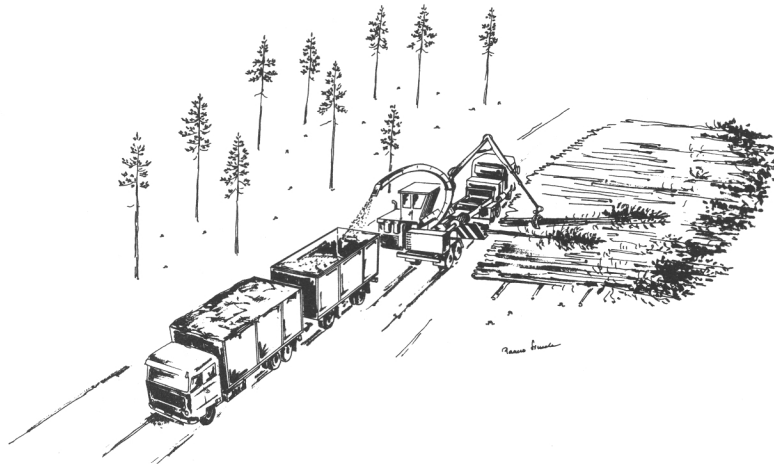


Figure 29. Landing chipping system.
Kuva 29. Välivarastobaketusjärjestelmä.

ever, the TT 1000 F cannot compete fully in costs with landing chippers proper at large and regular upper landings. In contrast, its flexibility has made it an economical alternative in the following cases:

- the landing area is so narrow that it is difficult to place the truck or exchangeable container alongside or after the chipper
- the chipper has to be moved repeatedly because the trees are stored scattered in fairly small formations

— the terrain conditions at the landing site are so difficult that trucks are incapable of driving close to the chipper.

Chipping at the upper landing

As already mentioned, it is sought in the Finnish landing-site chipping system to avoid the »hot» logging schedule in which the hauling of whole trees to the landing site and the chipping itself are done simultaneously. This has led to forwarder transport as the trees have to be stored in high stacks.

While in the American system trees are moved continuously by skidder to within the range of the chipper loader, in the Finnish system the chipper must be moved as the work progresses. This requires manoeuvrability of the chipper and must be taken into consideration when the landing site is being planned.

Upper-landing chippers are generally of simpler construction than terrain chippers as they need not move under their own power and require no chip container. An upper-landing chipper is not transported to difficult terrain. It can be of relatively heavy construction which, again, provides scope for a higher output. The maximum timber size is also greater in general than with terrain chippers.

It has been possible to avoid the »hot» logging schedule only as regards the synchronization of forest haulage with the chipper. Truck transport is still linked closely with chipping (Fig. 29). The chips are blown directly onto the truck platform, trailer or exchangeable container without which the recovery of chips is impossible. At present if the chipping is interrupted the truck transport also comes to a standstill, and vice versa. The methods in which the chips are blown onto a tarpaulin or into nylon mesh sacks do not yet meet practical requirements.

Landing chippers have been constructed in many different countries, first in the United States and more recently especially in Finland, Sweden and the Soviet Union. Several different models are in use in Finland. The most important of them are the American Trelan D 60 and the domestic makes TT 1500 L, TT 1500 T and Algol.

Trelan D 60 Landing Chipper

The Trelan D 60 is mounted on a 2-axle chassis equipped with a hydraulic stabilizer leg. The chipper has no loader of its own and therefore requires a separate infeed machine (Fig. 24). The Valmet Valtra 1102 wheel tractor, among others, has been used for this purpose. The tractor driver operates the chipper by remote control. The chipper is moved from one work site to another by the same machine.

In the American system the whole trees are skidded alongside the Trelan chipper as the work progresses. In the Finnish harvest-

ing schedule, on the other hand, the chipper must be moved at the upper landing as the infeed machine has collected all the trees within its range. The need for flexible movement of the chipper must be taken into consideration when planning the upper landing site.

The most important measurements of the Trelan D 60 are: length 6,4 m, width 2,4 m and weight 8,1 tons. Since upper-landing conditions are usually difficult in Finland, the chipper is equipped with larger wheels and stronger axles than in the United States.

The disc chipper and the feeding device are operated by a 136 kW engine. Whole trees are fed in by a steel chain in the lower tray and a floating compression roller above, both hydraulically driven. With 20 mm particle size of chips the feed rate is 24 m per minute. The chips are blown into the vehicle from behind or above.

The 152 cm chipper disc has two knives. The angle between the knives and the tree stem is 37°. The speed of the disc is 630 rpm. The maximum diameter of the tree is 43 cm.

It was earlier customary in Finland to place the whole-tree bunches at the upper landing always transversely to the direction of travel of the chipper and the infeed machine by its side. In recent times, in order to speed up the infeed, a method has also been used in which the timber is stacked in the direction of travel of the chipper.

Output depends on the tree species, tree size, branchiness, stack size and location, and the impurities lodged in the trees. Output, excluding breaks, is as follows when chipping small-sized early-thinning trees.

	Chipping output per hour	
	Solid m ³	Loose m ³
Small-sized hardwood	17—24	40—55
Small-sized pine	13—21	30—50

TT 1500 L Landing Chipper

The TT 1500 L is mounted on a truck provided with bogie drive (Fig. 25). The unit consists of disc chipper, feeding device, grapple loader and driver's cab. The power source is alternatively a separate motor or the engine of the truck. The minimum power requirement is 220 kW. The total weight is 22 tons, the length 11,7 m and the width 2,5 m.

The hydraulically driven feeding equipment has a 6,0 m chain conveyor and two rollers. The whole-tree material is moved from either side of the machine onto the conveyor by a Fiskars F 6000 loader, the range of which is 7.1 m. Work on the right side is slowed down by the position of the chip pipe, however.

The diameter of the chipper disc is 1 500 mm. The disc has three knives. The rotation speed is 625 rpm. The maximum stem diameter is 40 cm. The length of the chips is adjustable.

The chips are blown into the vehicle or interchangeable container from behind. The chip pipe is hydraulically turnable.

Output is influenced by the same factors as in the other landing chippers. The best results are achieved with trees of a breast height diameter of 8—10 cm. If the trees are long they are difficult to place on the infeed table and must therefore be bucked.

When branchiness increases and the branch angle widens, output declines because the trees take longer to move from the infeed table to the chipper. Output is therefore higher for hardwoods than for pine.

	Chipping output per hour	
	Solid m ³	Loose m ³
Small-sized hardwood	17—26	40—60
Small-sized pine	15—22	35—50

An advantage of the TT 1500 L and TT 1500 T chippers is fast and flexible movement in accordance with the progress of the work at the upper landing and on to the new work site. They are therefore suitable also in relatively small work sites.

TT 1500 T Landing Chipper

The TT 1500 T is mounted on a drawing semi-trailer hauled by a 4-wheel-drive truck (Fig. 26). The basic parts of the unit are the disc chipper, feeding system, loader, 220 kW power unit and driver's cab. The main measurements in the transportation position are: length 14,3 m, width 2,5 m, height 4,0 m, and weight without the haulig truck 15,5 tons.

The hydraulically driven feeding equipment is mounted with the disc chipper on a revolving frame. It consists of a 2,5 m chain conveyor below and two rollers above, of

which the first is vertically adjustable. To speed up the feeding the equipment can be turned and directed towards the whole-tree stacks when needed. It swings 120° to the right and 90° to the left in the driving direction.

The Fiskars F 6000 loader, located at the end of the feeding line, has a range of 7,1 m. If the height of the whole-tree stack is sufficient the TT 1500 T is capable of filling a 40 m³ chip load at the same site.

The 3-knife disc is the same as that of TT 1500 L. The chip pipe and its end piece are hydraulically turnable. This facilitates filling of the load. The chips are blown into the vehicle from above the load.

The output varies with the conditions. It increases with the size of the trees. As the location of the feeding opening is low it is easy to chip also long trees. The following figures show the output per productive hour when chipping early-thinning trees.

	Chipping output per hour	
	Solid m ³	Loose m ³
Small-sized hardwood	21—34	50—80
Small-sized pine	17—30	40—70

ALGOL Multipurpose Landing Chipper

The Algol chipper is mounted on the load space of the Valmet 880 K forwarder (Fig. 27). Other heavy forwarders, too, make suitable basic machines for the unit. The feeding and chipping devices are installed on a revolving ring and can be turned 270° in the horizontal and +5° or —15° in the vertical plane. The driver controls the functions of the machine from the cab of the forwarder. The terrain worthiness of the machine, the revolving ring and the flexible directing of the chip pipe ease the requirements of the upper landing.

The feeding, chipping and chip blowing are driven by a separate 257 kW engine. The grapple loader, mounted on top of the cab, is equipped with slide boom. It is moved by the engine of the basic machine.

The length of the total unit in the transport position is 14,1 m and in the working position 10,2 m, and that of the chipping part without the basic machine 6,6 m. The width is 2,5 m, the height 4,2 m and the total weight 26,0 tons of which the basic machine accounts for 11 tons. The entire weight of the chipping

portion bears on the rear axles of the machine. The surface pressure can be reduced by using tracks.

While all other whole-tree chippers used in Finland are based on a disc-type chipping system, the Algol is equipped with a drum-type chipper. Due to the drum the feeding opening is large enough to allow the chipping of logging residues such as branches and tops in addition to whole-tree material.

The feeding device consists of an upper, vertically adjustable 1,5 m conveyor, a lower stationary 3,5 m conveyor and a stationary roller between the lower conveyor and the chipper drum.

The width of the drum and the conveyor system is 1 000 mm. The 20 blades, overlapping on the drum in two rows, are each 50 mm wide. The diameter of the drum is 600 mm. The feeding opening is 300 × 1 000 mm. The changeable inside screen combined with the re-crushing system makes it possible to deal with over-sized fractions. The drum revolves at 810 r/min.

The Algol multipurpose chipper is capable of feeding timber from either side of the machine. This eases the arrangements at the upper landing site. The chips are blown into the load from above from a height of 5 m with such force that the cubic metre weight of the chips becomes a little higher than in other chippers. The chip pipe and the valve at its end are directed hydraulically. The pipe turning angle is 300° and thus the vehicle to be loaded can be placed beside the chipper or behind it.

The output per productive hour in average conditions (cf. Melkko 1977) is as follows. Output for logging residues is at its maximum when seasoned, over-year-old raw material is chipped.

	Chipping output per hour	
	Solid m ³	Loose m ³
Small-sized pine	16—33	35—75
Tops and branches	9—18	20—40

64. Truck transport

Long-distance transport of whole-tree raw material can be done by truck, railway, barge or pipeline. As long as the quantities to be transported are relatively modest and the area of activity is within a short radius of the

mill, truck transport is the best alternative because of its flexibility.

About 100 000 solid m³ (250 000 loose m³) of whole-tree chips was made in Finland in 1977. Most of this amount was obtained from within a radius of 70 km of the utilization point. Only in exceptional cases the distance is increased to 100 km and over. It is natural that in these conditions the long-distance transport should be by truck. When activity expands with time and the distances grow, other alternatives will become topical.

Two alternatives are available when trucks are used: transport as whole trees or transport as chips. The former is needed when chipping is concentrated at lower landing sites or the mill yard. The advantages of each of the alternatives are linked closely with the organization of the harvesting system as a whole and cannot be assessed separately from the other work phases.

Transport of whole-tree raw material takes place in Finland solely as chips. This must not be interpreted to mean that chip transport will necessarily always be more economical also in the long term. The point is, rather, that the special equipment for the transport of sawmill chips has proved to be suitable almost as such also for forest chips. With the generalization of whole-tree harvesting the existing equipment has been accepted quickly in practice.





The technique of transporting whole trees has so far taken a back seat in the development work, as the present chip transport equipment has offered a satisfactory alternative. Attention has been paid in Finnish development projects mainly to the weakest links of the harvesting schedule, first to chipping and then to felling and bunching.

Whole-tree material from the transport point of view

Transport costs depend markedly on the load size. Small loads mean high costs, especially over long distances. Timber trucks have, therefore, with the improvement of the road system, grown larger and larger, and this applies also in the transport of sawmill chips. Costs are at least 10—20 % higher with a small 30 m³ truck than with a 80 m³ vehicle with full trailer.

The size of the chip truck is determined partly by road legislation. The maximum length, width and height of a vehicle are

precisely defined. The permissible maximum load space dimensions in Finland are roughly as follows:

Maximum measurements				
Vehicle length, m	12,0	16,0	18,4	22,0
Load space:				
Length, m	10,2	12,5	15,0 *)	18,5 **)
Height, m	2,3	2,3	2,3	2,3
Inside width, m	2,4	2,4	2,4	2,4
Volume, m ³	55,4	67,9	85,0	100,4
Total weight, tons	22,0	36,0	42,0	42,0
Net weight, tons	13,7	25,0	30,5	29,7
Net load, kg/m ³	247	368	359	297

*) 7,5 m + 7,5 m = 15,0 m

***) 8,0 m + 10,5 m = 18,5 m

It is fairly commonly held that the use of load space is so ineffective in the transport of whole-tree material that the capacity of the vehicle is only partly utilized. In equipment designed originally for other types of goods the load space is often too small for whole-tree raw material. But when the truck platform is made large enough it is possible in many cases to utilize the total capacity of the truck.

The green weight of a cubic metre of timber from a young pine stand on truck platform before transport can be seen from the following table. The higher numbers represent the weights of newly felled timber. The lighter weights presuppose that some seasoning has already occurred but that the timber is still fairly green. The moisture content of whole-tree material falls in practice between these figures in most cases.

	Moisture content on green weight basis, %	
	55	45
	Kg/m ³ of load space	
Traditional short-wood logging:		
2 m pulpwood bolts	540	440
3 m pulpwood bolts	515	420
Whole-tree logging:		
Whole trees, bucked *)	240	200
Whole-tree chips	380	310

*) Whole trees bucked into lengths of 5—7 m, scaled in stacks on the upper landing site.

The figures can be compared with the cubic metre weights that are permitted for vehicle combinations of certain types. The legally permissible cubic metre weights are

readily attained with traditional cordwood and trucks can consequently drive almost without exception with full loads. But it is well to note that correct trailer and van solutions guarantee a full load also with green whole-tree chips. This is generally attained with a load space of 80—85 m³.

For whole trees, again, the load weight is short with the present-day equipment. The method seems to require, at least over longer distances, additional equipment to press the trees into a more compact load.

Truck transport of whole trees

Transport of trees whole, including branches, to the lower landing site or to the mill permits centralisation of chipping. The work can be done by stationary chippers. This has several advantages over forest chipping:

1. The close interdependence between the chipper and truck movements, which is the most critical link in forest chipping, is obviated. The reliability of the whole harvesting schedule increases.
2. Stationary chippers can be large and effective. They do not have to be moved. The costs of actual chipping are reduced.
3. Quality control of chips is most effective at a central chipping station. It is possible to link up with the chipping station a sorting plant at which the raw material is divided into industrial chips and fuel.

4. The buffer storage for raw material is increasingly in the form of whole trees rather than chips. It is possible to shorten the chip storage time, which eases keeping problems.

In the harvesting technology in use in the Soviet Union whole trees are generally transported by truck from the forest to the lower landing site for delimiting and bucking. The method functions faultlessly in the technical sense, but the transport takes place outside the network of public roads. The problem is more complex in Finnish conditions as timber transport must be fitted in with other traffic.

In spite of its significant advantages, transport of whole trees has not gained a foothold in Finland so far. This is attributable above all to two factors:

1. Load space utilization remains unsatisfactory.
2. Transport of whole trees on public roads requires that branches and tops jutting out from the sides and back of the load are lopped off. This is at present a time-consuming job and increases the costs.

Transport of whole trees presupposes the development of machines. Attention has been paid to this in Denmark, Norway and Sweden, but no serviceable solution has been found yet for the conditions of the Scandinavian countries, though there has been some progress. Some examples may be mentioned of methods which have brought improvement in load space utilization.

1. In a Danish experiment trees were loaded into a removable truck container the side poles of which were tilted 30 deg. outwards for the duration of loading. After loading, the poles were raised by tractor winch. The upper part of the poles was then bent inwards from a joint at the height of 2 m to lower the load height. The cubic metre weight of the load increased by 56 % for small-sized spruce trees (Møller and Bakken 1975).
2. In a Swedish experiment the whole-tree load was compacted from above by a balk which was connected with the truck chassis by two chains. The power for the hydraulic cylinders of the balk was taken

from the loader boom of the truck. The cubic metre weight of the load grew by 15 % (Hansen 1975).

3. In a Finnish experiment bucked whole trees were placed in the load first with butts foremost. The load was then compacted with one chain and pulley arrangement by the truck's own loader. The compressed load was reduced to 10—30 cm in size and it was possible to raise its cubic metre weight by 10 % (Peltola 1976b).
4. The above experiment was repeated, but with the butts placed in different directions. The compression method was the same. The load weight was now 30 % heavier than in the original alternative without compacting. The importance of the placing of the trees was greater than that of compression by the loader.
5. In a Norwegian experiment with compression by winch the load was increased by 7—19 % (Skar 1977).

Before a whole-tree load can be allowed on public roads the branches and tops that jut out beyond the load space must be lopped off to avoid endangering other road users and obscuring the driver's rear vision. To reduce this tidying work, the truck container may be equipped with sides. They may be either the length of the load space (cf. Bakken and Wefald 1974), or only for the back of the load at the tops of the trees (cf. Meng 1976) or movable by winch along the length of the load (cf. Skar 1977).

The experiments described above have shown that there are relatively simple solutions from which truck transport of whole trees can be developed. However, there is so far no equipment on the market that meets practical needs.

Truck transport of whole-tree chips

Chips are a homogeneous mass article the loading and unloading of which can be mechanized and even automated extensively. The precondition is adoption of the correct equipment and methods.

Chips are generally taken directly from the chipper to the long-distance transport vehicle. In chipping at the landing this is done by



Figure 30. The Multilift ML-14 pallet system in connection with terrain chipping by a TT 1000 F.

blowing from the back of the load or from above it. If the chip pipe is directed from above the load the truck does not have to move every time that the chipper changes position as the work progresses. Filling from the back, on the other hand, offers the following advantages:

- it is not necessary to remove for the duration of chipping the protective cover on the load
- the load can be filled without wasting any chips. When chips are blown from above some of the material falls on the ground in the last phase of the filling



Kuva 30. Multilift ML-14 vaihtolavajärjestelmä palstahaketuksen (TT 1000 F) yhteydessä.

procedure. Losses of several per cent units have been measured, but that was because the blower used was too strong.

The terrain chipper transfers the chips into the long-distance transport vehicle by tipping. The chips are unloaded onto a pallet. The

pallet is lowered to ground level because its upper edge is too high when it is on wheels. The tipping height of TT 1000 F terrain chipper is 3 m.

Transferring the chips from the chipper to the long-distance transport vehicle is technically simple. However, difficult organisational

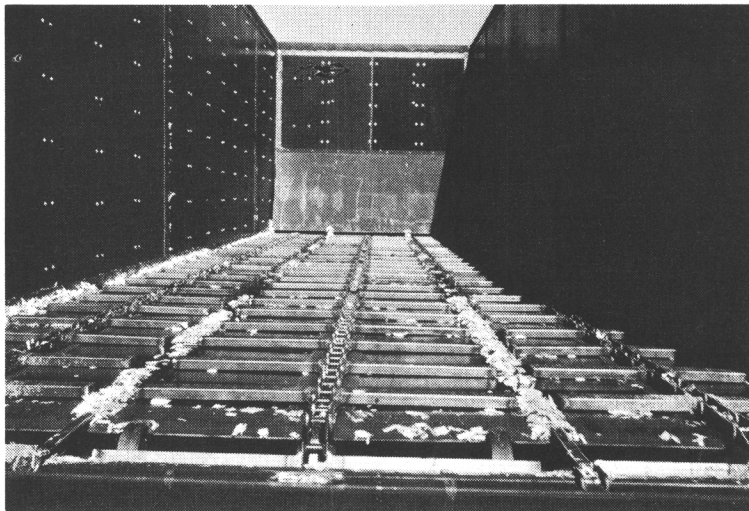


Figure 31. Närko chip van.
Kuva 31. Närko hakelava.

problems arise when the work of the chipper and the transport equipment must be synchronised. A readily vulnerable hot system originates, which is just what the Finnish wood harvesting method seeks to avoid.

Chipping and long-distance transport can be separated if the chips are stored at a landing for a short time. The chips can be moved into the truck by wheel loader or knuckle boom loader equipped with a chip grapple.

It is necessary then to place a protective ground covering under the chips to keep

quantitative and qualitative losses in check. Plastic protective covers have been tried, but found lacking in durability, and pieces of plastic in the chips disturb the industrial process. The method has not won general use in practice. More promising results have been achieved with nylon mesh sacks, but they are still in the course of development.

Chips are best transported by trucks with full trailer and the greatest possible load volume. If the terrain chipping system is used the chip pallets must be lowered to the ground for tipping of the TT 1000 F chipper

to be successful. The Multilift ML-14 pallet system (Fig. 30) has been developed for this purpose.

The ML-14 is an automatic chain pallet system for truck and trailer. The bodies, equipped with pneumatic locking, are available in lengths of 4,5—7,0 m. The volume cannot be quite as large as with fixed containers.

The sub-frame of the body is of standard truck width, made of two parallel beams. A low-speed hydraulic motor, chain wheel installed direct on the motor axle, 1½ inch single roller chain including hook, and double-acting underfloor lifting rams are used for lifting and lowering the bodies. The front of the body is fitted with a simple attachment for hook location.

The movements of the pallet during loading and unloading are controlled by guided pull-push chains, operated entirely from the cab of the truck. The hook automatically connects to the front of the body which is lifted onto or lowered from the vehicle in less than one minute with the linear chain. Pneumatic locks secure the body to the vehicle front and rear. The body can be further pushed horizontally backwards with the chain onto the trailer without additional hydraulics. The lifting capacity including the body is 14 tons.

The Multilift ML-14 chip transport unit is suitable as a long-distance transport method for the terrain chipping system. The require-

ments to be made of the landing are small and if space is short the trailers can be left alongside better roads.

In chipping at a landing the chipper moves as the work progresses. Smooth working permits the lowering of the pallets onto ground only in exceptional cases. The common practice is for the entire long-distance transport unit, or at any rate the trailer, to wait on the spot until the load is filled.

Unloading a chip load at the mill is a fast procedure. In Finland every truck and trailer has a tipper. Tipping is usually done from behind, in some cases from the side. A quite new system is the Närko method in which a conveyor on the bottom of the platform is used for unloading (Fig. 31).

Forest chipping calls for careful planning of long-distance transport to prevent either chipper or truck from needless waiting. This vulnerability can be relieved by using extra chip bodies (Multilift ML-14 system) or trailers. It has been established in practice that unforeseen costs arise easily in this phase of the schedule. The system is a hot one even at its best.

From one to three chip vehicles plus possibly extra trailers for buffering are needed per large-sized chipper in Finnish conditions. The transport capacity requirement depends on the chipper output, the transport distances and the quality of the roads. An 80 m³ chip load takes at least 2 hours to make in practice.

7. ALTERNATIVE LOGGING SCHEDULES

Harvesting of wood removed in thinning is traditionally based in Finland on the short-wood method in which cordwood bolts are made and bunched manually alongside the strip road. Forest haulage is done mainly by forwarder, in small private forests often also by farm tractor. The new SCAPE application of the method eases the work ergonomically (cf. H a r s t e l a et al. 1977).

This harvesting technology has proved to be advantageous in most cases of selective thinning cuttings. However, for the first commercial thinning of a young forest the present practice does not give a satisfactory result. The drawbacks include:

1. The recovery of raw material is insufficient. Only 40—55 % of the above-ground biomass, depending on the size of the trees removed, is actually recovered. 45—65 % of wood proper, excluding bark and needles, is recovered.
2. The productivity of the work is low. Making and carrying the bolts to alongside the strip road takes 0,200—0,220 man-days per cubic metre. To this must be added forest haulage, about 0,015 man-days per cubic metre.
3. Low productivity means high costs. Logging and forest haulage costs, excluding stumpage price, are 45—65 marks per m³ of unbarked timber.

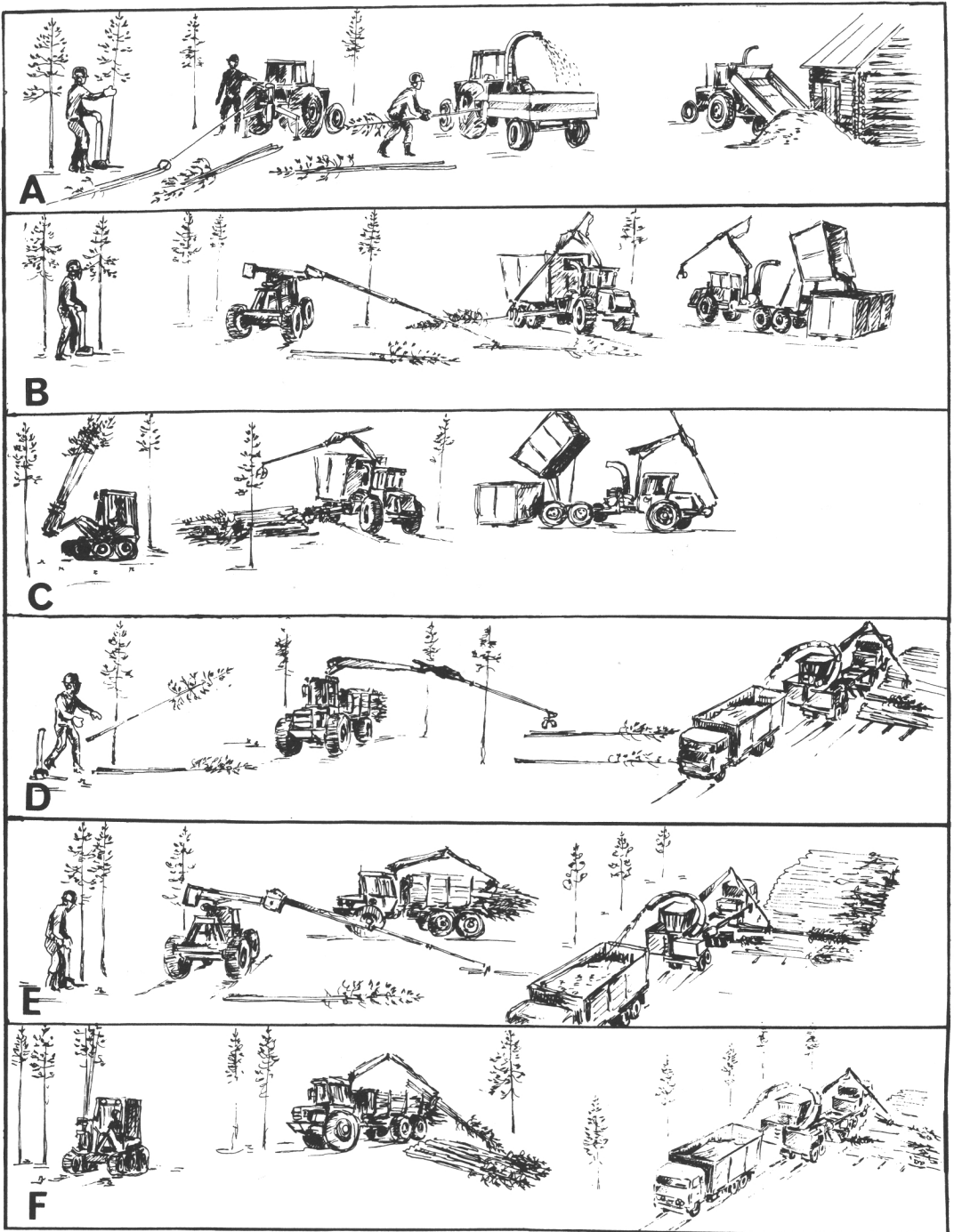


Figure 32. Alternative whole-tree chipping schedules for the early thinning of pine:

A Logging schedule for the farm owner

B, C Logging schedules for chipping on the strip road

D, E, F Logging schedules for chipping at the upper landing site

Kuva 32. Vaihtoehtoisia kokopuuhaketusketjuja männikön ensiharvennukseseen:

A Isännänlinjan korjuuketju

B, C Palstahaketusketjuja

D, E, F Välivarastohaketusketjuja

This report describes a number of machines designed for selective thinning of a young pine stand by the whole-tree harvesting system. Different harvesting schedules can be built up of them. A common feature to all of them is the effective, over 90 %, recovery of the above-ground biomass.

Three simplified alternatives are presented in the following (Fig. 32). They must be understood only as examples. The harvesting schedule always moulds itself in practice to local conditions, adapts as flexibly as possible to the overall picture of the wood harvesting organization.

71. Logging schedule for the farm owner (Alternative A)

A farm owner is likely to prepare whole-tree chips for one of two purposes: to sell as industrial raw material or to have fuel chips for his own use in order to reduce the need for heating oil. This article is confined to the latter case.

It does not matter how fuel chips are divided between wood proper, bark and needles. They are therefore usually made of very small-sized trees which have no commercial value otherwise. It is often a matter of precommercial thinning. It is assumed here that the trees to be removed are under 9 cm in breast height diameter.

The biological status of a young stand requires a precommercial thinning in a certain phase. If the wood has no commercial value, the forest owner has to pay 300—400 marks/hectare for this silvicultural treatment. The costs of making fuel chips must be examined against this background.

The harvesting schedule must be based on light-weight and cheap equipment for the total of utilization days per annum is small. The basic essentials are a medium-sized farm tractor, a tippable trailer and a power saw, all of which the farm owner has anyway. For whole-tree chipping the following additional equipment is necessary:

	Cost of equipment Fmk
Jaaranen-Rantapuu felling frame for small-sized chain saw	500
Farmi JL 30 winch for farm tractor ...	3 100
AST whole-tree chipper for farm tractor	6 400
Additional equipment in total	10 000

With this equipment the farm owner can prepare fuel chips himself without outside help. The felling and prebunching are done manually using a felling frame. The bundles are winched onto the strip road and the chipping is done there. The chips are moved in a trailer straight to the point where they are to be burnt. The time consumption per solid m³ of whole-tree raw material in the different phases is as follows:

	Time consumption man-days/m ³
Manual felling-prebunching	0,055
Winching to alongside strip road	0,024
Chipping + transport (500 m)	0,083
Total	0,162

The farm owner is able with this method to make 6 solid m³ (14—15 loose m³) of whole-tree chips in a day. It equals in thermal value almost one ton of fuel oil.

The economicalness of the work depends on the burning unit available and on the prices of the alternative fuels. The retail sales price of heavy fuel oil in Finland at the end of 1977 was 390 marks/ton and of light fuel oil 680 marks/ton.

72. Logging schedules for chipping on the strip road (Alternatives B and C)

Whole-tree chipping on the strip road may offer significant advantages also for harvesting at the industry level. However, certain exacting demands are set for the stand. The most important is fairly easy terrain (see p. 30). Figure 31 shows two alternatives, B and C; they differ only as regards the felling and bunching phase.

	Cost of equipment Fmk
Alternative B	
Felling and prebunching by chain saw (Jaaranen-Rantapuu felling frame) ..	2 400
Bunching to alongside strip road by Normet buncher	290 000
Chipping on strip road and hauling of chips to landing site by TT 1 000 F	630 000
Alternative C	
Felling and bunching by Makeri feller-buncher	190 000
Chipping on strip road and hauling of chips to landing site by TT 1 000 F	630 000

If the equipment is used solely in whole-tree chipping schedules, approximately the following combination is needed in alternative B: 5 or 6 men for manual felling + 1 boom-type buncher + 2 terrain chippers. However, it is generally preferable to use a Normet buncher according to need also in the harvesting of other timber. The schedule then consists of 2—3 men for manual felling, 1 buncher and 1 terrain chipper.

Two or 3 feller-bunchers are needed per terrain chipper in alternative C. The ratios vary with the circumstances. Alternative B is more suitable for small-sized growing stock, whereas alternative C is more competitive for somewhat larger-sized first thinnings. Alternative C also allows wider strip road spacing. It is naturally possible to use a combination of B and C.

The following figures show the capital and manpower involved in terrain chipping.

They exclude the maintenance and work supervision echelons. It is possible in alternative B to manage with a smaller capital investment compared with capacity.

Alternative	Number of men	Annual *) output, m ³	Cost of equipment, Fmk	Investment for annual capacity, Fmk/m ³
B	8—9	20 000—25 000	1 562 000	62—78
C	3—5	10 000—12 500	1 100 000	88—110

*) Annual output in solid m³ of whole-tree chips in one shift. Average stem volume 30 dm³.

Manual prebunching of whole trees is difficult for ergonomic reasons when the stem size exceeds 30 dm³. Alternative B is recommended therefore chiefly for the smallest-sized first-thinning trees. With 50 dm³ trees the feller-buncher method is more favourable as regards labour productivity and ergonomic factors.

	Alternative B	Alternative C	
	Stem size 30 dm ³	Stem size 30 dm ³	Stem size 50 dm ³
	Time consumption man-days/m ³		
Manual felling-prebunching	0,055	—	—
Boom-type buncher	0,010	—	—
Feller-buncher	—	0,034	0,022
Terrain chipper + chip hauling (300 m)	0,017	0,016	0,015
Total	0,082	0,050	0,037

The labour productivity per m³ of biomass recovered in the terrain chipping method is 2,5—4,5 times that in the traditional short-wood method. If bark and needles are disregarded and the comparison is limited to wood proper, the productivity of the whole-tree chipping methods is still 2,3—4,1-fold that of the short-wood method.

73. Logging schedules for chipping at the upper landing site

(Alternatives D, E and F)

The basic solution in whole-tree harvesting is chipping at the upper landing. It is the sole method in many countries. Depending on the conditions, there are several alternatives available. Three harvesting schedules which differ as regards felling and bunching are presented in the following (Fig. 31).

	Cost of equipment, Fmk
Alternative D	
Felling and prebunching by chain saw (Jaaranen-Rantapuu felling frame) . .	2 400
Hauling to landing site by medium-sized forwarder, equipped with long-range slide-boom	450 000
Chipping at upper landing site	600 000
Alternative E	
Felling and prebunching by chain saw (Jaaranen-Rantapuu felling frame) . .	2 400
Bunching to alongside strip road by Normet buncher	290 000
Hauling to landing site by medium-sized forwarder, equipped with knuckle boom and grapple saw . . .	450 000
Chipping at upper landing site	600 000
Alternative F	
Felling and bunching by Makeri feller-buncher	190 000
Hauling to landing site by medium-sized forwarder, equipped with knuckle boom and grapple saw . . .	450 000
Chipping at upper landing site	600 000

The main part of the equipment is suitable also for the harvesting of traditional timber, which lowers the cost of moving the machines and eases the organisation of the work. However, if the question is one of harvesting whole-tree chips exclusively, the following combinations are recommended.

From 4 to 6 men for manual felling, 2 forwarders and 1 landing chipper are needed in alternative D. Alternative E foresees 4–6 men for manual felling, 1 boom-type buncher, 2 forwarders and 1 landing chipper. The other forwarder can participate at times also in the transport of other timber. The equipment requirement in alternative F is 5 feller-bunchers, 2 forwarders and 1 chipper.

The labour force and capital tied up in the schedule appear from the following table. The annual output in solid m³ of whole-tree chips is achieved in one shift when the average stem volume is 30 dm³. Maintenance

and work supervision personnel and equipment are not included in the figures.

Alternative	Number of men	Annual output, m ³	Cost of equipment, Fmk	Investment for annual capacity Fmk/m ³
D ...	7–9	20 000–25 000	1 512 000	60–76
E	8–10	20 000–25 000	1 802 000	72–90
F	8	20 000–25 000	2 450 000	98–122

Capital costs are clearly highest in alternative F. But it is more suitable than the other alternatives for work sites where the tree size is essentially higher than the 30 dm³ assumed here. The output of the feller-buncher increases with the tree size, whereas manual bunching becomes too strenuous ergonomically. The advantages include the possibility of using a wide strip road spacing.

The work productivity appears from the following figures.

	Alternative D Stem size 30 dm ³	Alternative E Stem size 30 dm ³ Time consumption, man-days/m ³	Alternative F Stem size 30 dm ³	Alternative F Stem size 50 dm ³
Manual felling-prebunching	0,060	0,055	—	—
Boom-type buncher	—	0,010	—	—
Feller-buncher	—	—	0,034	0,022
Forwarding of whole trees	0,024	0,021	0,017	0,017
Chipping at landing site	0,009	0,009	0,009	0,009
Total	0,093	0,095	0,060	0,048

In the landing chipping method the labour productivity is 2,3–4,5 times that of the traditional short-wood method in first commercial thinning conditions. When bark and

needles are disregarded and wood proper is examined instead of the biomass, the productivity is still 2,1–4,1 times greater (cf. pp. 8 and 45).

8. COST OF WHOLE-TREE CHIPS AT THE MILL

The costs of whole-tree chips obtained from first-thinning forests can be examined in two ways in Finland:

1. The price of whole-tree chips is compared with that of the alternative raw materials of the mill. These may be conventional cordwood, waste wood of the mechanical forest industry, imported timber, etc. This is the common method of studying the price differences between raw materials from the mill's point of view.

2. The price of whole-tree chips is compared with the price that has to be paid for timber obtained from a first-thinning pine stand by the traditional methods. This assumes that the overall forestry programmes presuppose the implementation of first thinnings whatever the cost. Finnish wood production programmes are based on just this premiss.

The mill price of whole-tree chips consists of harvesting costs, long-distance trans-

port costs, overhead costs and the stumpage price of the timber. The main cost component is harvesting, which can be seen from Table 6. The calculation is based on the following hourly costs: feller-buncher 90 Fmk/h, boom-type buncher 100 Fmk/h, medium-sized forwarder 100 Fmk/h, terrain chipper 180 Fmk/h and landing chipper 180 Fmk/h.

Stumpage price is also an important cost factor in Finnish conditions. Its irregular fluctuation from one year to another with the business cycle makes calculations difficult.

The stumpage price of whole-tree material in Finland is made up of two parts. The part of the raw material that meets the minimum dimensions (6 cm/2 m) of cordwood is priced as traditional cordwood. A considerably lower price is paid for stem wood under 6 cm in diameter and for branches. The share of cordwood in the total biomass can be determined with the help of Table 4. The pricing principle is shown by an example which represents the level during the early autumn of 1977.

The price of unbarked cordwood is 50 marks/m³. For other raw material, including branches, it is 4 marks/m³. If the share of cordwood in the total biomass on the basis of measurement of standing trees and Table 4 is 52 %, the average price of whole-tree chips is $\frac{52 \cdot 50 + 48 \cdot 4}{100} = 27,92$ marks/m³.

Whole-tree chips are compared here with small-sized cordwood (Table 6). Both cases involve the thinning of a young stand. The forest haulage distance is 300 m and the truck transport distance 70 km, which correspond to average conditions in Finland.

When the costs are converted into marks per bark-free cubic metre, the bark percentage of cordwood is assumed to be 13. The bark and foliage percentage of whole-tree chips is assumed to be 21.

The first-thinning wood of pine is delivered to the mill as whole-tree chips at a slightly lower cost than when the traditional methods are used, assuming the cost level of autumn 1977. If the mill equipment is planned and dimensioned for reception of whole-tree chips, at least in a certain mixture ratio, the advantage of the method is evident also for the mill.

However, the majority of mills require in practice that most of the bark and needles are removed before the process. Methods for separation and segregation of bark and green matter are under development in many countries. They are so far unsatisfactory as regards capacity, wood waste and costs and are in more or less the prototype stage. Hence, any estimation of the sorting costs of whole-tree chips in the next few years

Table 6. The cost of whole-tree chips from the first thinning of pine at the upper landing site in the autumn of 1977. Stumpage price excluded.

Taulukko 6. Ensibarvennumänniköstä saatavan kokopuuhakkeen kustannukset välivarastolla ilman kantobintaa syksyllä 1977.

Cost factor Kustannustekijä	Logging schedule *) — Korjuusketju *)						
	B	C	C	D	E	F	F
	Stem size, dm ³ — Rungon koko, dm ³						
	30	30	50	30	30	30	50
	Fmk/m ³ — Mk/m ³						
Manual felling and bunching — <i>Kaato ja keaus käsityönä</i>	11,50	—	—	12,60	11,50	—	—
Feller-buncher — <i>Kaato-keauskone</i>	—	24,50	15,80	—	—	24,50	15,80
Boom-type buncher — <i>Teleskooppi-puomikeaus</i>	8,00	—	—	—	8,00	—	—
Forwarder — <i>Kuormatraktori</i>	—	—	—	19,20	15,30	13,60	13,60
Terrain chipper — <i>Palstabakkuri</i>	24,50	23,00	21,60	—	—	—	—
Landing chipper — <i>Välivarastobakkuri</i>	—	—	—	12,00	12,00	12,00	12,00
Planning, measurement etc. — <i>Suunnittelu, mittaus jne.</i>	9,00	9,00	7,00	9,00	9,00	9,00	7,00
Total — <i>Yhteensä</i>	53,00	56,50	44,40	52,80	55,80	59,10	48,40

*) For explanations, see Fig. 32.
Selitykset kuvassa 32.

would be premature. The following calculation gives an idea of how high costs could be permitted to rise at the current Finnish price level before the price of whole-tree chips exceeds that of wood harvested from the same forest as bolts.

	2-m pulpwood bolts from the first thinning Cost Fmk/m ³
Unbarked bolts at the mill	126,00
Drum-barking and chipping of bolts ...	21,00
Cost of the 13 % debarking loss	18,70
<hr/>	
Total cost of bark-free chips	165,70

According to the example in Table 7, the costs of whole-tree chips at the mill yard per unit of wood proper is 137,20 mk/m³. The considerable margin of 28,50 mk/m³ is thus available for the screening of whole-tree chips when the parallel alternative gives 165,70 mk/m³ as the mill price of bark-free chips. The thermal value of bark and foliage, which further improves the economicalness of whole-tree harvesting, has been disregarded in the simplified calculation. On the other hand, wood waste and the quality of barking must be taken into consideration in the final comparison.

Comparison of whole-tree chips with competing raw material alternatives, like pulpwood bolts from later thinnings and clear-cuttings, is appreciably more difficult. The outcome depends essentially on the supply and demand ratio for wood, the stumpage price level and the raw material quality requirements.

The calculation must be made separately for each mill and it is pointless here to present a detailed comparison. Suffice it to mention that the utilization possibilities of whole-tree chips are great where

- there is a shortage of raw material
- there is a labour shortage
- the stumpage price level is high
- early commercial thinning is regarded as imperative for the wood production programme.

Table 7. The cost of whole-tree chips and 2 m bolts at the mill. Both assortments are harvested from a young Scots pine stand in the same thinning conditions.

Taulukko 7. Kokopuuhaakeen ja 2-metrin pölkekyjen hinta tehtaalla. Kumpikin puutavaralaji korjataan nuorta männikköä harvennettaessa samoissa oloissa.

Cost factor <i>Kustannustekijä</i>	2-m bolts <i>2-m pölkyt</i>	Whole-tree chips <i>Kokopuuhaake</i>
	Cost, Fmk/m ³ <i>Kustannus mk/m³</i>	
Stumpage price — <i>Kantohinta</i>	50,00	27,90
Logging — <i>Korjuu</i>	54,00	55,00
Truck transport — <i>Autokuljetus</i>	16,00	17,50
Overhead costs — <i>Yleiskustannukset</i>	6,00	7,00
<hr/>		
Total — <i>Yhteensä:</i>		
— Wood, bark and needles <i>Puu, kuori ja neulas</i>	126,00	107,40
— Wood proper — <i>Varsinainen puuaines</i>	143,80	137,20

9. MEASUREMENT OF WHOLE-TREE RAW MATERIAL

Harvesting of the entire above-ground part of trees is an epochal change in traditional forestry practice. The change is reflected in one way or another in almost all activity. This is true also of the measurement of timber.

The inclusion of branches complicates the measuring of whole-tree material (Fig. 33). Determination of the volume of branches is a very laborious task which enters into question only at the research level. The

irregular variation of the amount of branches from tree to tree and from stand to stand weakens the accuracy of the averages. The result of the measurement cannot be as reliable as it is for stem wood alone.

The measuring result is needed for calculation of the stumpage price payable to the forest owner, for setting wage tariffs, for cost calculation and for mill stock-keeping. The aim is to establish at least the following:

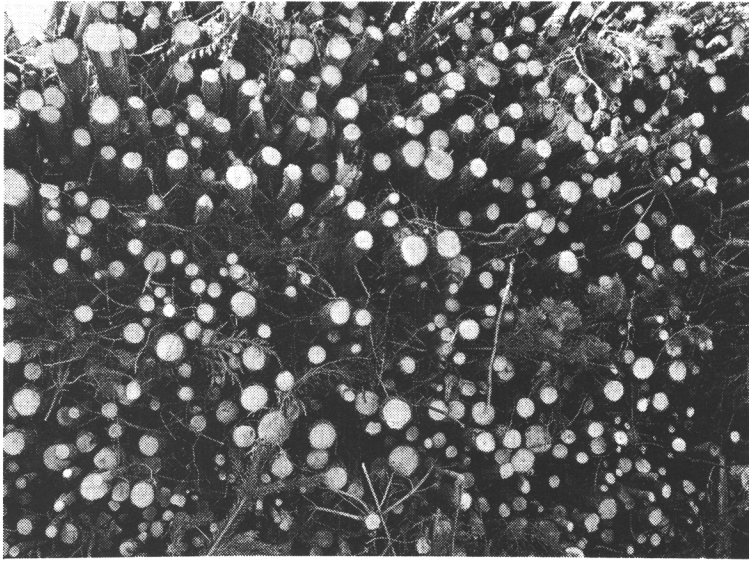


Figure 33. Branches interfere with the measurement of whole-tree stacks.
Kuva 33. Oksat vaikeuttavat kokopuupinojen mittausta.

- total biomass in solid cubic metres
- proportion of stem wood
- proportion of merchantable pulpwood.

Three methods have been evolved in Finland for measuring the volume of whole-tree raw material. The methods are used alternatively, depending on the situation.

1. Measurement of standing trees.
2. Measurement of whole-tree stacks at landing site.
3. Measurement of whole-tree chips on truck.

When measuring standing trees the breast height diameter of the trees to be removed is recorded. The number and diameter distribution of the trees are often measured only from sample lots. The result becomes more accurate when the length of random sample trees is also measured. Calculation of volume and determination of the share of the different components are done in South Finland by means of Tables 2—5.

It may be necessary to do measurement on stacks at the landing. The piled volume of a stack is the product of length, width and average height. It is converted to solid measure by a coefficient which is an average

of 0,29 for small-sized pines in South-Finnish conditions. The solid volume content of the stack varies with the tree properties, the carefulness of stacking and the stack size, and thus the accuracy of the mean value is poor. To establish the share of the different components, the breast height diameter distribution of sample trees is measured from standing trees or a stack.

The third alternative is to measure the volume or weight from chips on the truck platform. The total biomass is obtained fairly accurately by this method, but its distribution between merchantable stem wood, unmerchantable stem wood and branches can be obtained only from the diameter distribution of the trees.

The measuring result for a chip load can be converted into solid cubic metres with the following figures:

A loose cubic metre of pine whole-tree chips before truck transport equals:

345 kg of green biomass
 165 kg of dry biomass
 0,43 solid m³ of biomass.

A solid cubic metre of pine whole-tree chips equals:

800 kg of green biomass
 385 kg of dry biomass
 2,33 loose m³ of biomass (before transport).

It should be noted when measuring chips that some settling of the load takes place during transport. The load volume is smaller than the original volume when the truck reaches the mill. Settling is due to the composition of the chips, the loading method, the condition of the road, the length of the trip, the time of the year, etc.

Studies on the settling of whole-tree chips are still in progress at the time of writing.

Therefore, one particular study (U s - v a r a 1972) is used in the following. It gives an idea of the average settling of saw-mill chips during transport in Finland.

	Summer time Settling, %	Winter time of volume
Chips on trucks	5,5	3,6
Chips on trailers	8,4	4,9

10. FUTURE PROSPECTS

Whole-tree chip harvesting and utilization experiments began in Finland in 1974. Highly encouraging results were soon achieved in several branches of industry. A boom prevailed and industry was ready to process all available raw material. In that situation, industry which suffered from a shortage of labour and timber placed great hopes on whole-tree harvesting. The boldest forecasts suggested that the forest industry would be ready by 1980 to utilize as much as 2,5 million solid m³ of whole-tree chips yearly (cf. E l o v a i n i o 1974). Generalization of the method seemed to be halted chiefly by the absence of harvesting equipment.

There was marked progress in machine development during 1975—1976. Methods were developed with which whole-tree chips could be got to the mill at a competitive price. But at the same time demand for the products of Finland's forest industry and its international price competitiveness weakened threateningly. The pulp and board industry had to cut production by several tens of per cent. The shortage of wood raw material changed to a situation of over-supply.

Some mills had already decided to enlarge production on the basis of whole-tree chips, but because of marketing difficulties they have now had to cut even existing production. At certain other mills which as the result of positive experience were planning a change-over to the use of whole-tree chips, sawmill and plywood waste wood alone now sufficed to satisfy the wood requirement.

At the end of 1977, the Finnish forest industry is still struggling with the same difficulties. The persisting consequence of the serious marketing situation has been that whole-tree harvesting cannot be expanded although effective harvesting methods are now available.

Utilization of whole-tree chips has thus of necessity remained modest. The main motivation for the continuation of this limited activity in the present market situation is the accumulation of experience in order to be ready when production rises again to its former level. The following companies were the most important users of whole-tree chips in 1977:

Company	Estimated consumption of whole-tree chips, solid m ³ in 1977		Main product
	Hardwoods	Softwoods	
Pellos Oy	38 400	4 000	Particle boards
Veitsiluoto Osakeyhtiö		12 000	Sulphate pulp
Oy W. Rosenlew Ab	3 730	15 000	Sulphate pulp, furfural
Enso-Gutzeit Osakeyhtiö	5 500	4 000	Sulphate pulp
A. Ahlström Osakeyhtiö	5 400	1 000	Fibre boards
Savon Sellu Oy	530	3 420	Corrugated medium
Saastamoinen Yhtymä Oy	2 240	560	Particle boards
Oy Wilh. Schaumann Ab	1 530	1 020	Particle boards
	Total	57 330	41 000
Others	1 670	2 000	
	Total	59 000	43 000

Whole-tree chips differ in composition from traditional cordwood in that the wood content is exceptionally low. For this reason, since mill machinery is designed and dimensioned for bark-free chips, a variety of difficulties arises unless the wood content of whole-tree chips can be increased in one way or another before processing. The following table shows the average composition at the mill of whole-tree chips made of small-sized pine, according to the preliminary material of Olli Uusvaara, Finnish Forest Research Institute. It is noteworthy that the wood content of chips is higher than in the biomass of standing trees in Table 5.

	Proportion of different components in whole-tree chips of pine at the mill, %
Stem wood	73
Branch wood	6
Bark, total	13
Needles	4
Dust, 0—3 mm	4
Total	100

Industry's experience shows that despite certain difficulties the utilization of pine whole-tree chips is possible in many processes. For instance, it is possible to produce a high-quality product in the sulphate pulp industry. However, the process-technical difficulties reduce the capacity of the mill. Yet, this factor cannot be decisive today when the mills are working at some 30 % under-capacity if the other process-technical problems are overcome.

On the whole, however, the result is really advantageous only after the wood content of the raw material has been raised by sorting to the 95 % level (cf. Hakkila et al. 1975). Many countries are now paying great attention to the development of the sorting of whole-tree chips by screening, air flotation, compression debarking and other principles (cf. Arola et al. 1976, Erickson 1976, Hakkila 1976). As regards Finland mention must be made above all of the Roxon method which is in the prototype stage at the end of 1977. There is every reason to assume that new solutions will appear in the near future, and they will broaden the uses of whole-tree chips.

Promising results have been achieved in machine development work to reduce the share of branch raw material before the whole-tree chipping stage. Examples of new prototypes are the Swedish bundle debarker of AB Constructor and the Finnish felling device of Rovaniemi Konepaja engineering works. Both can be mounted on forwarders for whole-tree logging schedules in order to decrease the amount of branches before chipping.

Once the Finnish forest industry emerges from its economic difficulties its wood utilization will increase appreciably from the level in 1977. The next decade will see a shortage of forest labour, growing energy costs and a large age class of young softwood plantations which will soon make the problem of first commercial thinnings acute. Whole-tree chipping will then offer a serviceable alternative for solving the complex of arising problems.

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SELOSTE

Työn tausta

Suomen Itsenäisyyden Juhlavuoden 1967 Rahasto, SITRA, käynnisti kesällä 1973 lyhytkiertopuun kasvatus- ja käyttöprojektin, jonka toteuttaminen uskottiin paljolta metsätutkimuslaitoksen metsäteknologian tutkimusosastolle. Monitahoisessa työssä, jota myös Suomen Akatemia on tukenut vuodesta 1976 lähtien, painopiste on ollut pienpuun korjuumenetelmien kehittämisessä kokopuun käytön periaatteen pohjalta.

Metsä- ja konepajateollisuuden sekä tutkimuslaitosten yhteistoimin kehitys on edennyt arvaamattoman nopeasti. Vuoden 1977 päättyessä käytettävissämme on useitakin kotimaassa kehitettyjä kokopuuraaka-aineen korjuuketjuja, jotka edustavat korkeinta kansainvälistä teknistä tasoa. Käsillä oleva raportti, joka sanoman selventämiseksi rajoittuu yksinomaan ensiharvennusmänniköihin, on yhteenveto suomalaisen kokopuun korjuuteknologian perusteista ja menetelmistä. Koska myös ulkomailla tunnetaan tieteellistä ja kaupallista mielenkiintoa tekniikkaamme kohtaan, julkaisu ilmestyy tällä kertaa englanninkielisenä.

Ongelmakenttä

Ensiharvennushakkuitten korjuutekniset olot ovat koneellistamisen kannalta vaikeat. Nopeasti laajeneva ensiharvennusurakka saattaa nykytekniikan puitteissa (kuva 2) osoittautua ennen pitkää ylivoimaiseksi metsätaloudellemme. Ensiharvennus on kuitenkin havupuuviljelmän kasvatuksen välttämätön vaihe, josta luopuminen horjuttaisi vakavasti koko puuntuotanto-ohjelmamme pohjaa.

Tyypillisestä Etelä-Suomen ensiharvennusmänniköstä korjataan puita, joitten rungon tilavuus on vain 20–35 dm³. Hehtaaria kohti kaadetaan 30–40 m³*) runkopuuta. Kasvamaan jää metsikkö, jossa 4 metrin levyiset ajourat puikkelehtivat 30 metrin etäisyydellä toisistaan ja puitten runkoluku on 1 000–1 500 hehtaaria kohti.

Perinteinen tavaralajimenetelmä, jossa puita joudutaan käsittelemään liian pitkään yksin pölkyin, ei näissä oloissa johda täysin tyydyttävään tulokseen. Voidaan luotella useitakin epäkohtia.

1. Huomattava osa puuainesta — kolmannes rungotta ja oksat kokonaisuudessaan — jää tähteinä metsään.
2. Työn tuottavuus on järeämpiin leimikoihin verrattuna alhainen. Puukuutiometrin korjaaminen väli-varastolle sitoo 0,200–0,250 miestäöpäivää.

*) Ellei toisin osoiteta, m³ tarkoittaa aina kiintokuutiometriä.

3. Menetelmä edellyttää pölkkyjen kantamista ajouran varteen ja on niin ollen ergonomisesti rasittava. Tältä osin on tosin kehitystä tapahtumassa uusien koneratkaisujen ja LEKA-menetelmän ansiosta.
4. Korjuukustannukset nousevat kohtuuttoman korkeiksi, syksyllä 1977 teko- ja lähikuljetusvaiheen osalta jopa 45–65 markkaan kuutiometriä kohti.

Vaikeuksia voidaan lieventää, kun pölkkymenetelmän sijasta tähdätään jo korjuuketjun varhaisessa vaiheessa raaka-aineen joukkokäsittelyyn siten, että karsimisesta ja osin katkomisestakin luovutaan. Puun maanpäällinen osa otetaan talteen miltei kokonaisuudessaan ja työstetään sellaisenaan kokopuuhaakkeeksi.

Menetelmä merkitsee käänntekeväää muutosta totunnaisessa käytännössä. Uusi korjuu- ja käyttöteknologia heijastuu monissa toiminnoissa metsätalouden ja -teollisuuden eri aloilla. Tässä väliraportissa rajoitutaan vain välittömästi korjuuseen liittyviin näkökohtiin.

Nuoren männyn biomassassa

Kokopuun korjuun yhteydessä raaka-aineen määrä ja arvo lasketaan uudelta pohjalta. Luvussa 5 esitetään yhtälöitä ja taulukoita, joilla rungon, oksien ja kokopuun tuorepaino (taulukko 2) ja tilavuus (taulukko 3) voidaan arvioida puun rinnankorkeusläpimitasta ja pituudesta riippuen. Lisäksi annetaan tietoja biomassan (taulukko 4) ja varsinaisen puuaineen (taulukko 5) jakautumisesta markkinakelpoisen runkopuun, hukkarunkopuun ja oksien kesken.

Suomessa käytetty kokopuun korjuukalusto

Suomalaisen kokopuuraaka-aineen korjuukalusto soveltuu myös harvennusmetsiin. Sille on ominaista monipuolisuus, joustava siirrettävyys sekä puitten säilyminen ketjun eri vaiheissa suhteellisen puhtaina (kuva 4).

Erityisesti kaatoon ja kasaukseen on tarjolla omaperäisiä ratkaisuja (kuvat 5–15). Vaihtoehtojen keskinäinen edullisuus riippuu lähinnä puitten koosta, ajourien välisestä etäisyydestä ja leimikon suuruudesta. Tässä raportissa käsitellään yksityiskohtaisesti Rantapuu-Jaaranen kaatokahvojen käyttöön perustuvaa siirtely-kaatoa, Makeri kaato-kasauskonetta sekä kokopuutaakkojen kasausta ajouran varteen Marttiini liukupuomilla, Normet teleskooppiuomilla ja Farmi vintturilla.

Kokonaisten puitten metsäkuljetus tapahtuu Suomessa yksinomaan kuormatraktorilla (kuvat 16 ja 17). Näin raaka-aine säilyy verraten puhtaana, ja samalla mahdollistuu korkeitten kokopuupinojen rakentaminen välivarastolle. Itse asiassa ei tosin aina kuljeteta kokonaisia puuta, vaan useimmiten karsimattomat puut katkotaan kuljetuksen helpottamiseksi 5—8 metrin pätkiksi tekovaiheessa moottorisahalla tai kuormauksen yhteydessä metsätraktorin katkaisukouralla (kuva 18).

Haketus sijoitetaan yleisimmin välivarastolle (kuvat 24—29). Tässä raportissa ovat mukana Trelan D 60, TT 1500 L, TT 1500 T sekä Algol välivarastohakkurit. Tietyissä leimikko-oloissa, joista mainittakoon lyhyt ajomatka ja edullinen maasto, palstahaketus on osoittautunut varsin kilpailukyiseksi vaihtoehdoksi. Raskas TT 1000 F palstahakkuri (kuvat 23 ja 28), joka suorittaa myös hakkeen kuljetuksen välivarastolle, saattaa yltää jopa korkeampiin tuotoksiin kuin kuormatraktori pelkässä kokopuun kuljetustehtävässä. Maataloustraktorin kolmipistekiinnitykseen sovitettava kevyt AST hakkuri puolestaan edustaa isännänlinjan kalustoa, joka soveltuu esimerkiksi maatilametsälön tai muitten pienkuluttajain polttohakkeen valmistukseen (kuva 19—21).

Kokopuuraaka-aineen autokuljetus tapahtuu toistaiseksi yksinomaisesti hakkeena (kuvat 29—31). Taloudellisuus edellyttää suuria lavarakenteita. Tehokkaat täysperävaunuyksiköt ottavat jopa 80—90 irtokuutiometriä haketta. Välivarastohaketuksessa hake puhalletaan suoraan ajoneuvoon, joka siis odottaa kuormauksen ajan paikan päällä. Palstahaketuksessa taas turvaututaan Multilift vaihtolavajärjestelmään. Oikeata kalustoa käytettäessä hakkeen kuljetuskustannukset ovat lähes samansuuruiset kuin pinotavaralla.

Vaihtoehtoiset korjuuketjut

Koska leimikko-olot vaihtelevat ja tarjolla on suuri joukko koneita, käytännössä voi esiintyä hyvinkin monenlaisia korjuuketjuja. Luvussa 7 esitellään esimerkin luontoisina kuusi vaihtoehtoista perusratkaisua (kuva 32).

Isännän linjan korjuuketju A perustuu siirtelykaatoon, vintturikasaukseen ja ajouralla toimivaan maataloustraktorisovitteeseen hakkuriin. Ajan käyttö, mukaan luettuna hakkeen kuljetus 500 metrin matkalla, on 0,162 miespäivää kuutiometriä kohti. Työpäivän kuluessa mies siis valmistaa 6 k-m³ kokopuuhaketta, mikä vastaa polttoarvoltaan lähes yhtä öljytonnia.

Kaksi seuraavaa ketjua, B ja C, rakentuvat raskaan palstahakkurin ympärille. Edellinen perustuu siirtelykaatoon ja teleskooppipuomikasaukseen, jälkimmäinen taas pientraktoriin asennettuun kaatokasaukseen. Kun rungon keskikoko on 30 dm³, vaihtoehdossa B käytetään 0,082 miestyöpäivää välivarastolle tuotua kuutiometriä kohti. Vaihtoehdossa C, jossa pääoman tarve on kolmanneksen suurempi, ajan käyttö on vastaavasti 0,050 miestyöpäivää kuutiometriä kohti. Tämän kaato-kasauksetta käyttävän ketjun kilpailukyky kasvaa puitten koon mukana.

Välivarastohaketuksista esitetään ketjut D, E ja F, jotka nekin poikkeavat toisistaan vain kaato- ja kasausvaiheessa. Pääoman tarve on 10 % suurempi

kuin vastaavissa palstahaketusketjuissa. Työn tuottavuus jää 10—20 % pienemmäksi.

Perinteiseen tavaralajimenetelmään verrattuna tuottavuus paranee koko biomassaa kohti lasketuna palstahaketuksessa 2,5—4,5 kertaiseksi ja välivarastohaketuksessa 2,3—4,5 kertaiseksi. Jos otetaan huomioon vain pelkkä puuaine, vastaavat kertoimet ovat 2,3—4,1 ja 2,1—4,1.

Kokopuuhakkeen tehdashinta

Jos ensiharvennumännystä tehtyä kokopuuhaketta verrataan eräisiin muihin levy- ja kuituteollisuuden raaka-aineisiin, sen hinta saattaa vielä tällä hetkellä näyttää korkealta. Mutta kun vertailukohtaksi otetaan samoissa oloissa pölkkyinä korjatun ensiharvennumännyn tehdashinta, kokopuuhakkeen edullisuus on ilmeinen. Edellinen tarkastelutapa edustaa puuta käyttävän tehtaan näkökantaa puun ylitarjontatilanteesta. Jälkimmäinen on kuitenkin metsätalouden kokonaisuuden kannalta mielekkäämpi, koska ensiharvennus katsotaan välttämättömäksi toimenpiteeksi.

Kokopuuhaketuksen taloudellisuus ensiharvennuspuita korjattaessa ei vielä toistaiseksi perustu niinkään säästöihin varsinaisissa korjuukustannuksissa, sillä siinä suhteessa erot pölkkymenetelmään ovat pienet. Mutta kokopuuna korjuussa saadaan talteen muutoin markkinakelvotonta runko- ja oksapuita, mikä alentaa ratkaisevasti tehdashintaa. Kokopuuhakkeen tehdashinnan edullisuus riippuu näin ollen kiinteästi kantohintatasosta.

Taulukon 7 suuntaa-antavassa esimerkissä ensiharvennumänniköstä saatavan pölkkytavaran kuutiometrihintana alkusyksyn 1977 tasolla 126 mk, kokopuuhakkeen taas 108 mk. Vähentämällä kuoren ja viheraineen osuudet, edellisessä 13 ja jälkimmäisessä 21 %, tulee varsinaisen puuaineen kuutiometrihinaksi vastaavasti 144 ja 137 mk.

Kokopuuraaka-aineen mittaus

Kokopuuraaka-aine mitataan pystyssä, pinossa tai hakekuormassa. Pystymittausta (taulukko 3) rasittavat kohtuuttomat kustannukset. Pinomittauksen heikkoutena taas on epätydyttävä tarkkuus. Keskimäärin 5—8 metrin pätkiksi katkotun kokopuutavaran kiintotilavuusprosentti on välivaraston kasoilta 29.

Hakkeesta biomassan kokonaisuus voidaan mitata melko tarkkaan, mutta sen jakaantumista markkinakelpoisen kuitupuun sekä halvemman oksa- ja hukkarunkopuun kesken on vaikea arvioida. Männyn kokopuuhakkeen irtokuutiometrin keskimääräinen tuorepaino ennen kuljetusta on 345 kg, kuivapaino 165 kg ja kiintotilavuusprosentti 43.

Kehitysnäkymät

Kokopuuna korjuun menetelmät ovat vuoden 1977 päättyessä saavuttaneet sekä teknisesti että taloudellisesti tason, joka mahdollistaa niiden laajamittaisen käytön. Suomalaisen konepajateollisuuden kehittämät koneet soveltuvat mittaviinkin kokopuuraaka-aineen korjuutehtäviin.

Tästä huolimatta kokopuuhakkeen käyttö ei ole kohonnut lähellekään sitä tasoa, jota eräissä ennusteissa on aikaisemmin pidetty mahdollisena. Vuonna 1977 metsäteollisuutemme käytti kaikkiaan 100 000 m³ kokopuuhaketta.

Että kokopuuhakkeen käyttö ei ole yleistynyt nopeammin, on suoranainen seuraus metsäteollisuutemme hintakilpailukyvyn heikkenemisestä maailmanmarkkinoilla parin viime vuoden aikana. Tuotanto on romahtanut ja puun tarve supistunut. Puun niukkuuden tilalle on tullut ylitarjonta, eikä uudenlaisen raaka-aineen läpimurtautuminen ole näissä oloissa ollut mahdollista.

Teollisuuden kokemukset osoittavat joka tapauksessa, että normaaliksi luonnehdittavassa markkina-tilanteessa monilla tuotannon aloilla on mahdollista ja kannattavaa jalostaa kokopuuhaketta sellaisenaan. On niin ollen odotettavissa, että markkinain jäl-

leen avautuessa kasvava osa ensiharvennuspuusta toimitetaan tehtaalle kokopuuhakkeena.

Todella laajamittaiseksi paisuakseen kokopuuhakkeen käyttö näyttää kuitenkin edellyttävän, että menetelmät viher- ja kuoriaineen osuuden vähentämiseksi nykyisestä 21 %:sta vaikkapa 5 %:iin tehostuvat. Tällä alalla onkin uscissa maissa käynnissä suuria kehitysprojekteja, joista osa tähtää viher- ja kuoriaineen vähentämiseen jo ennen haketusta, osa taas hakkeen lajitteluun tehdasvarastolla. On perusteltuja syitä odottaa, että uusia ratkaisuja tulee esiin jo lähitulevaisuudessa. Jos ne ovat valmiina silloin, kun metsäteollisuutemme selviää markkinointivaikeuksista tai kun puun käyttö öljyä korvaavana poltto-aineena yleistyy, kokopuunakorjuun voidaan odottaa välittömästi yleistyvän männikön ensiharvennusmenetelmänä.

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