WORKING PAPER

A TECHNOLOGICAL MODEL OF WOOD-HARVESTING SYSTEMS IN POLAND CONSIDERING CHANGES IN STAND PRODUCTIVITY AFFECTED BY INDUSTRIAL AIR POLLUTION

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IIASA
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FOREWORD

Within IIASA's Environment Program, the Biosphere Dynamics Project seeks to clarify the policy implications of long-term, large-scale interactions between the world's economy and its environment. The project conducts its work through a variety of basic research efforts and applied case studies. One such case study, the Forest Study, has been underway since March 1986 and focuses on the forest-decline problem in Europe. Objectives of the Forest Study are:

a) to gain an objective view of the future development of the European forest resources;

b) to illustrate the future development of forest decline attributed to air pollution and the effects of this decline on the forest sector, international trade and society in general;

c) to build a number of alternative and consistent scenarios about the future decline and its effects; and

d) to identify meaningful policy options, including institutional, technological and research/monitoring responses, that should be pursued to deal with these effects.

In the framework of the Forest Study a whole series of working papers on the conditions of the Polish forest sector have been published. This paper is one in the Polish series under the auspices of the Forest Study. Because of increased decline, harvesting and transportation operations have to be adapted to the new conditions. The objective of this study is to illustrate the required changes of the machinery structure and increased decline.

B.R. Döös
Leader
Environment Program

ABSTRACT

We built a simulation model of the timber-harvesting system in Poland to enable estimation of costs and the number of machines necessary for accomplishment of tasks under conditions of changing stand productivity including effects by industrial air-pollutant emissions. Taking into account the purpose of modeling, the main production factors we included are: forest area, production of wood assortments, machines needed for the technological process, technological processes carried out by means of these machines, and timber receivers. To each of the factors, some characteristics are ascribed which influence the accomplishment of production. Changes in stand productivity resulting from industrial emissions are considered in the data base as being a set of characteristics of the forest areas.

The input–output model assumes the choice of machines (from the assumed set), cost estimates for the whole harvesting process, and determination of the number of machines by means of which production tasks would be performed at the lowest costs. Predicting the changes in stand characteristics for a given time interval, including the timber volume possible to obtain, the cost and structure of machines can be estimated. The calculations given in this study are based on data from 1986.

The results of our calculations indicate that, for better economic effect, the structure of machinery should be reviewed, especially in view of possible continued forest decline in Poland.

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1. INTRODUCTION

Industrial air pollution and the resulting poor health condition of Polish forests is leading to concerted attempts to maximize the utilization of timber. This can be done either by optimizing the timing of final felling, or by silvicultural improvements and sanitary fellings. The latter provide greater quantities of timber, increase stand productivity and improve the health condition of forest stands.

In order to accomplish these tasks on time, forest enterprises must have a sufficient number of machines suitable for the conditions in which they operate. The machines at the disposal of the forest enterprises, together with services contracted out to other enterprises, ensure completion of current production plans. Will this still be possible when conditions have changed? What changes in the structure and number of machines should be made to ensure the lowest capital expenditure for the accomplishment of production tasks? Answers to these questions can be explored by using a technological model of the timber-harvesting process which would, in sufficient degree, simulate real conditions including the assumed timber-harvesting process.

2. AIM AND SCOPE OF THE STUDY

The purpose of the study is to construct such a technological model of timber harvesting which would consider changes in forest production resulting from altered stand development, and in the construction of machines accessible to the forest enterprises. The model should simulate the harvesting process of timber obtained by the use of machines being presently in possession of a forest enterprise or enterprises and those which may be available in future.

The maximization of economic effect is the main assumption for planning the structure of the machine inventory. The simulation should determine:

(a) costs of harvesting and supply of wood assortments to the receiver;

(b) the set of machines optimal under specific forest conditions; and

(c) the structure of the machine inventory for the accomplishment of production tasks.

3. STRUCTURE AND CHARACTERISTICS OF THE SIMULATED SYSTEM

3.1. Main Factors

Taking into account the purpose of simulation, its main factors are as follows: forest area (L), production of wood assortments (S), machines needed for harvesting operations (M), processes carried out by these machines (T), and timber receivers (O). The model for the technological system (X) simulates real conditions of the wood-harvesting process and is described by the following set:

$$X = (L, S, M, T, O) \ .$$

Besides the above-mentioned factors, the model of the wood-harvesting process has its own structure of relations (R). If R is taken into account, the complete structure of the wood-harvesting process (P) is the orderly pair written as:

$$P + < X, R > \ .$$

Figure 1 shows the set of relations R defined on set X, representing some types of relations between the differentiated elements of X.

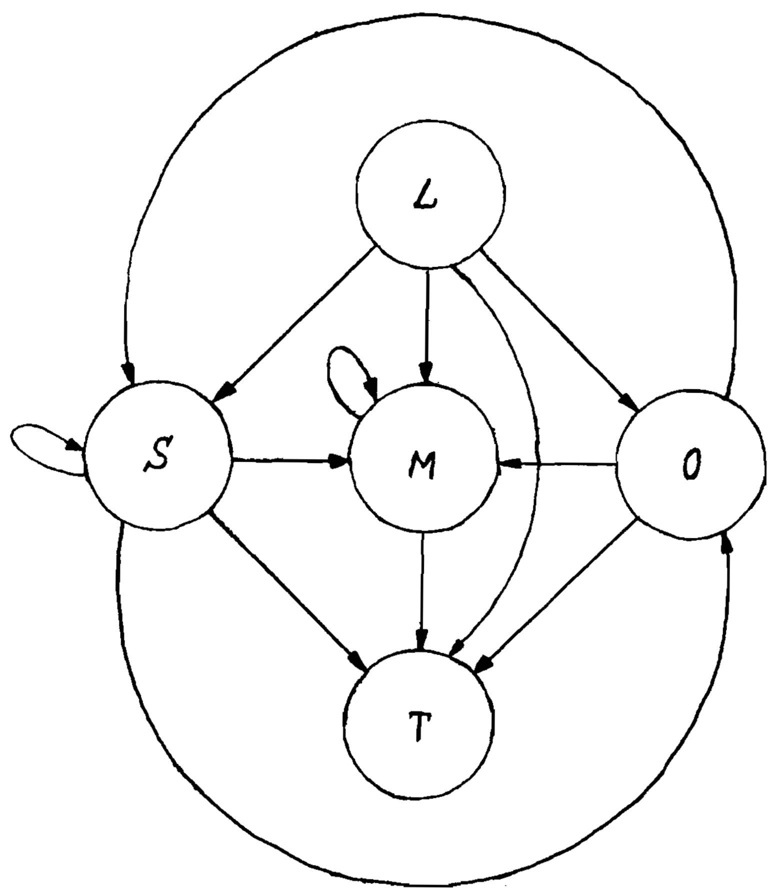

Figure 1. Statistically significant relations in our model of timber harvesting.

3.2. Technological Characteristics of Stands

The changing conditions in Polish forests are predicted for natural forest regions and not for the administrative divisions of forest enterprises. To plan the number of machines necessary for timber production it is assumed, for the need of the model, that the natural forest region (A) will be the operation area for the forest enterprise. The natural forest region is divided into subregions (B) (see Figure 2). The whole country is divided into eight natural forest regions (in Figure 2 they are marked with roman numerals). So, the whole area can be expressed in the form of a set

$$A + (Aa,\ a = 1,...,8)\ ,$$

and each region comprises the following sets of subregions:

- Baltycka $A1B = (Bb,\ b = 1,...,8)$;
- Mazursko–Podlaska $A2B = (Bb,\ b = 1,...,6)$;
- Wielkopolsko–Pomorska $A3B = (Bb,\ b = 1,...,9)$;
- Mazowiecko–Podlaska $A4B = (Bb,\ b = 1,...,7)$;
- Slaska $A5B = (Bb,\ b = 1,...,6)$;
- Malopolska $A6B = (Bb,\ b = 1,...,11)$;
- Sudecka $A7B = (Bb,\ b = 1,2,3)$; and
- Karpacka $A8B = (Bb,\ b = 1,...,0)$.

To determine the operational possibilities of machines, each subregion is further divided into so-called basic areas (H) with the following characteristics:

- forest group (C) which includes commercial forests (C1) and protection forests (C2):

$$C = (Cc,\ c = 1,2)\ ;$$

- air pollution risk zones (D) which include forests not endangered by pollutants (D1), first-degree danger zone (D2), second-degree danger zone (D3), and third-degree danger zone (D4):

$$D = (Dd,\ d = 1,2,3,4)\ ;$$

- dominating tree species (E) which include coniferous species (E1) and deciduous species (E2):

$$E = (Ee,\ e = 1,2)\ ;$$

- forest site type (F) distinguishing:
  (a) Group I (F1) which includes dry coniferous forest, fresh coniferous forest, highland mixed coniferous forest, fresh mixed deciduous forest, highland mixed deciduous forest, fresh deciduous forest, highland deciduous forest;
  (b) Group II (F2) which includes humid coniferous forest, marsh coniferous forest, humid mixed coniferous forest, humid mixed deciduous forest, marsh mixed deciduous forest, humid deciduous forest, alder forest, ash-alder forest, riparian forest; and
  (c) Group III (F3) which includes mountain coniferous forest, mountain humid coniferous forest, mountain marsh coniferous forest, mountain mixed coniferous forest, mountain mixed deciduous forest, mountain deciduous forest, mountain riparian forest:

$$F = (Ff,\ f = 1,2,3)\ ;\quad \text{and}$$

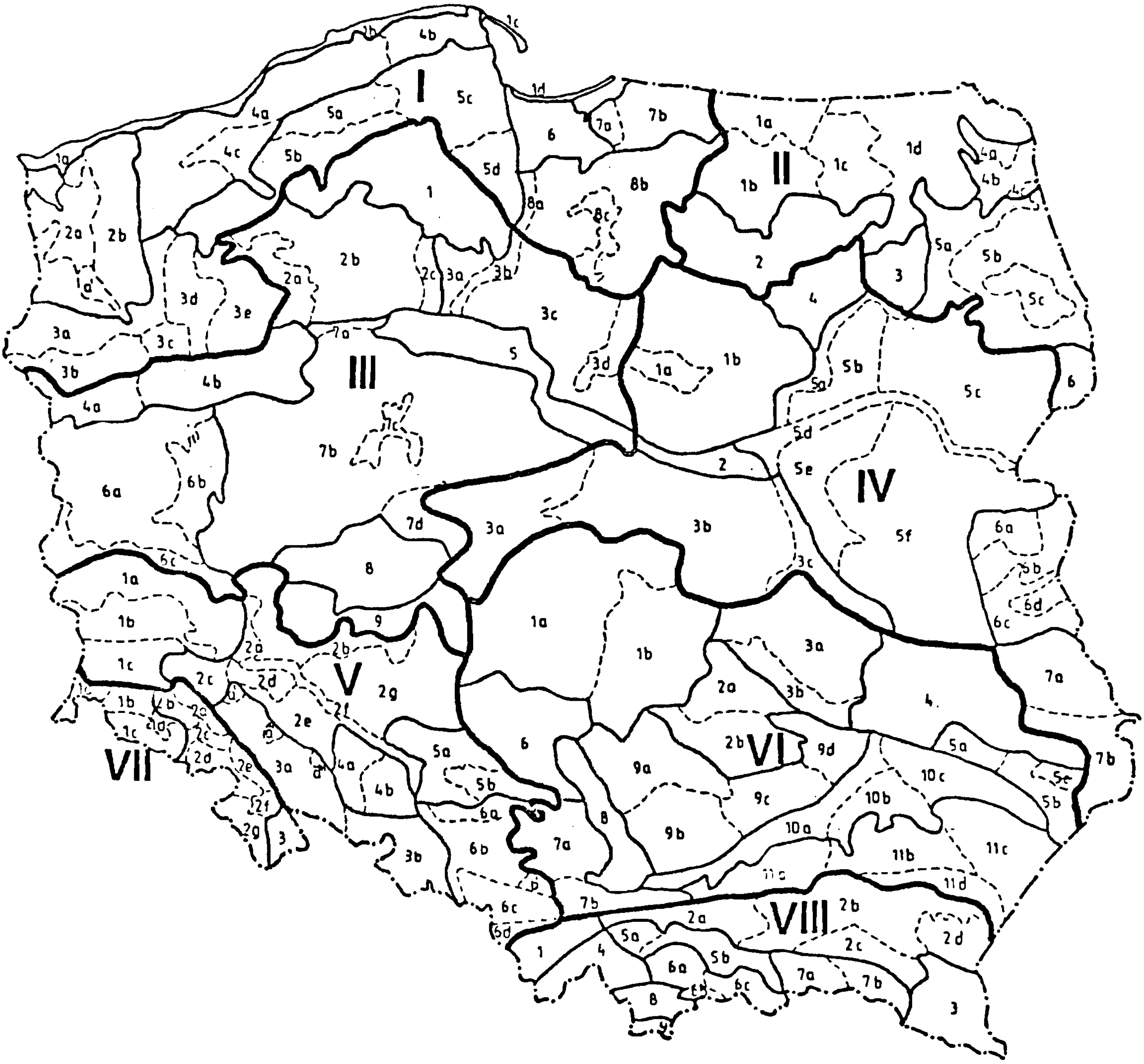

Figure 2. Forest regions of Poland according to Trampler et al. (1986).

- stand age class (G):
  - (a) Class I (G1), including stands below 40 years of age;
  - (b) Class II (G2), including stands between 41 and 80 years of age; and
  - (c) Class III (G3), including stands above 81 years of age:

$$G = (Gg, \ g = 1,2,3) \ .$$

The basic area $H = (H_i, i(N))$ is a sum of forest areas of the same characteristics over the whole subregion Bb or region Aa.

Each i-th basic area has the following parameters:

- tree volume $Q_i(m^3)$;
- coefficient k_i estimating the wood volume harvested from the given area ($k_i \leq 1$); and
- coefficient $a_{ij} = (a_{ij},\ j = 1,...,5)$ estimating the percentage volume of the five wood assortments produced, where

$$\sum_{1}^{5} a_{ij} = 100 \ .$$

The wood volume obtained from the basic area $V_i(m^3)$ is calculated from the equation

$$V_i = Q_i \cdot k_i \ ,$$

whereas the volume of particular wood assortments $V_{ij}(m^3)$ is estimated from the equation

$$V_{ij} = 10^{-2} vi_i \quad a_{ij} = 10^{-2} Q_i \, k_{ij} \, a_{ij} \ ,$$

where $j = 1,...,5$.

It is shown from the above that the basic area is an element of the following set:

$$Hi = Aa\ Bb\ Cc\ Dd\ Ee\ Ff\ Gg \ , \qquad \begin{array}{l} (a = 1,...,8) \\ (b = 1,...,\max 11) \\ (c = 1,2) \\ (d = 1,2,3,4) \\ (e = 1,2) \\ (f = 1,2,3) \\ (g = 1,2,3) \end{array}$$

3.3. Characteristics of Wood Assortments and Receivers

The forest enterprises in Poland produce several wood assortments and supply them to the receivers. From the point of view of technology, five groups of timber can be differentiated: sawnwood (S1), mining timber (pit props) (S2), pulp wood (S3), other assortments (S4), and chips (S5).

This will be the following set:

$$S = (Ss,\ s = 1,...,5) \ .$$

Sawnwood and mining timber are long-sized wood and can be transported on trucks adapted to transporting stems or logs. It is assumed that wood from the group "other assortments" (S4), which includes mainly fuel wood, is short-sized wood and can be transported on the same trucks as used for pulp wood. Chips require special means of transport. In the first stage of production, each assortment group requires different machines. Therefore, the production of a given wood assortment determines the most adequate set of machines.

The receivers of wood assortments are characterized by distance from the cutting area. In this way they contribute to the duty of the means of transport. Since the transport cost and duty vary with the type of machine, the location of the receiver will affect the choice of transport method assuming optimization of the harvesting process.

3.4. Sets of Machines and Flow-Sheets

Machines used in Poland and other countries are planned for the process of wood harvesting. They form adequate subsets for the following operations: felling, delimbing and cross-cutting, chipping, off-road transport, and road transport of wood assortments. Some of the machines belong to several subsets at the same time, e.g., harvesters. In this case they are assigned to the subset felling.

Each machine is characterized by two indices: annual output W(m^3), and cost per unit Z (Zloty/m^3). In the case of skidders and trucks, the indices depend on the distances of these operations. These indices were calculated in accordance with the *Polish System of Forest Machines* (Anonymous 1982). The calculations were based on 1986 prices.

Each machine is described according to its operation possibilities: mobility on the basic area, production potential of wood assortments and assembling with other machines. Each subset of machines has its own symbol. A machine is described by two letters and two digits. The first letter (M) denotes the set, the second one denotes the selected subset (S = felling, O = delimbing and cross-cutting, Z = skidding, R = chipping, T = road transport). The first digit denotes the type of machine, the second one denotes the group of indices characterizing the machine. The full set of machines considered as an initial set for the model is given in Table 1.

Flow-sheets for the wood-harvesting process, including road transport, are produced on the basis of the set of machines working on given basic areas. The flow-sheets are conditioned by area characteristics, wood assortments and assembling possibilities of machines.

The operation possibilities for particular machines working on basic areas are shown in Table 1. In addition, the following restrictions are assumed:

(a) In Poland, 90% of the timber from stand group G1 (below 40 years of age) is cut with power saws. The remaining stock is cut with axes (therefore Table 1 has item MZ51). Such proportions are set in the model.

(b) In the groups G2 and G3, the mobile fellers can cut 60% and 50%, respectively, of the stand volume planned for removal. The remaining volume is cut with power saws. These restrictions are related in the same percentage to the processors; this results from their maximum cutting diameter.

(c) Due to the high stand density in stands of age class G1 on site type F1, the winch is used for winching from the interior of the stand to the stack. The assumed distance of winching equals 1 = 50 m. In the model, the winch (MZ41) operates at lowest costs. It is assumed that if the distance of winching exceeds 50 m the farm tractor with the winch will operate in the first stage of winching whereas in the second stage a different type of tractor is used.

(d) Since the access of machines to timber on site types F2 and F3 (humid and mountain sites) is difficult, it is assumed that spar-yarders (MZ71 and MZ72) will be used and the distance for this operation will be 150 m. For longer distances other means will be used.

(e) The mean skidding distance in Poland depends on the means of road transport. If timber is transported on middle-tonnage trucks, the skidding distance equals ca. 400 m; if on high-tonnage trucks, the skidding distance equals 1,000 m which is due to the smaller net of adequate roads.

The model assumes that all wood assortments will be skidded for the same distance. The distances 400 m or 1,000 m are taken for calculation with regard to the type of truck used.

The flow-sheet produced for each of the basic areas must account for both the characteristics of particular machines and the above restrictions.

4. THE INPUT–OUTPUT MODEL

The input–output model (Figure 3) illustrates the procedure of estimating the minimum costs of wood harvesting and determining machines needed for this purpose. The input consists of two sets: a data base describing forest areas and stands, and the set of machines used in the process of wood harvesting including transport to the receiver (see above). The receiver is either the production plant or forwarding depot.

Taking into consideration the predictions of changes in forest stands resulting from the industrial air pollutants, and silvicultural and production practices, the elements included in the data base can be verified. The set of machines can also be verified by supplementing the set with new machines, eliminating the redundant ones, or modifying the characteristics of particular machines.

The basic area is the elementary calculation unit. The choice of the subset of machines is determined by the characteristics of basic areas on which the machines can perform their production tasks, from cutting to timber transport. From this subset all other subsets are derived, which allow for restrictions and flow-sheets. For each flow-sheet, total costs of wood-assortment production are calculated. To plan the number of machines, the flow-sheet of lowest cost is chosen.

The calculations made for each of the basic areas are followed by adding the operation cost estimates of particular machines and number of machines, total harvesting costs for the natural forest region, and then for the whole country.

The flow-sheets and cost estimates of the process are affected by the timber travel distance. To minimize the estimation it is assumed that the timber transport distances will be the same for the whole natural forest region. However, the possibility of calculations for different distances is given. This helps in estimating the effect of transport distance on the changes in the structure of machines and production costs.

5. ESTIMATES

The simulation model has been used to estimate production costs and structure of the machine inventory under given conditions of work in Poland in 1986. It helps to estimate how the present state of the machine inventory in forest enterprises in Poland meets the requirements resulting from minimization of production costs.

The analysis included forest areas of total area equaling 6,573,277 ha managed by the State Forest Enterprise (Wyleziński and Więsik 1989). In 1986, 22,526,700 m^3 of timber was harvested from this area. It has been assumed that only wood from stand age class I (G1), which is unsuitable for production of other assortments, will be chipped. In the old-growth stands, wood chips made only from the top parts and branches of trees are not yet produced on a large scale in Poland. Thus, the mobile chipper (MR31) specified in Table 1 is not applicable.

Cost estimates for wood harvesting, including transport of assortments for distances 10, 30 and 50 km with machines necessary for wood harvesting in the whole country, are given in Table 3. The main factors influencing the cost of harvesting, and the number and structure of the machine inventory are as follows: forest area conditions, volume and structure of wood harvested, and timber travel distance.

As shown in Table 2, the cost per unit of wood harvested in mountain areas (A7 and A8) is higher by 20–29% than in lowlands (A1, A3). This is due mainly to the complex, two-stage skidding in order to protect the natural environment, and to use in the first stage of the spar-yarder which is very expensive.

An increase in the volume of wood harvested causes an increase in the number of machines needed for the accomplishment of production tasks. However, the structure of the machine inventory depends on the timber volume harvested in commercial and precommercial stands. The greater volume of wood harvested obtained by precommercial

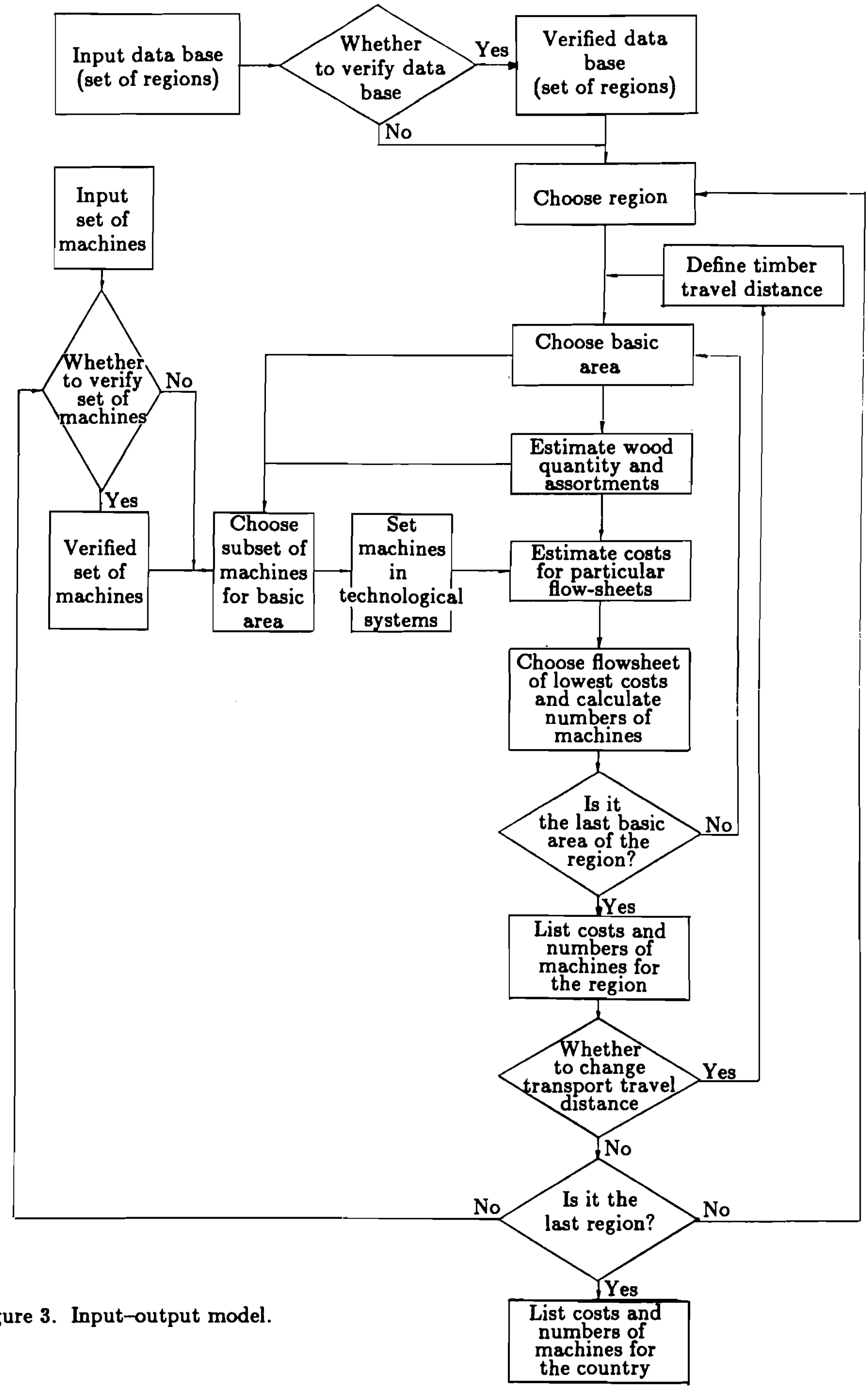

Figure 3. Input–output model.

thinnings requires, for instance, more light power saws (MS21 and MO21) and fewer heavy power saws (MS11 and MO11). In this case also the structure of skidders changes, that is, the number of tractors with a winch (MZ41) which are used for winching from the interior of the stand to the strip roads.

The change of transport distance of wood assortments causes changes in the structure of skidders and truck units. For longer distances the high-tonnage trucks (MT31) appear to be more economical. While for the distance of 30 km their number is still small, for the distance of 50 km they become the main means of transport. The high-tonnage trucks require a longer distance, which is reflected in the structure of skidders, that is, the number of forwarders (MZ21 and MZ22) considerably increases.

The increase of transport distance of wood assortments, despite the change in the structure of the machine inventory, causes an increase of costs per unit of wood harvested. If the travel distance increases from 10 km to 30 km, the costs of harvesting increase by 15–20%. If the travel distance increases from 30 km to 50 km the costs of harvesting increase by 9–12%. Smaller differences at longer distances result from greater changes in the structure of machine inventory.

Costs of wood harvesting calculated from the simulation model can be roughly compared with costs of wood harvesting presently borne by the State Forest Enterprises. Only ca. 50% of the timber volume is removed by the forest enterprises' own means of transport, while the skidding of the remaining volume, mainly with horses, is contracted to other enterprises which is much less expensive. The simulation model assumes that the total timber volume is mechanically skidded and at the same time that in mountain forests and precommercial stands in the whole country, a two-stage skidding is used, the first stage being winching due to environmental protection. Thus, according to the simulation model, the average costs of wood harvesting amount to 980 Zloty/m^3 (GUS 1987).

Comparing the state of the machine inventory in Poland with the number of machines resulting from the calculations (see Table 3), it can be noted that if the total timber volume is to be mechanically skidded, at the lowest possible costs, the present machinery structure should undergo some significant changes. For instance, there is an abundance of heavy power saws, whereas there is deficiency of light power saws and of forest tractors, especially forwarders. In order to reduce negative effects of mechanization in precommercial stands, it is necessary to use a considerable number (1,086) of spar-yarders – at present there is only one spar-yarder. In order to reduce the costs of wood removal, high-tonnage units for short- and long-sized wood (MT31) should increase in number, especially in those enterprises which transport wood assortments for distances over 30 km.

The prediction of number and structure of machinery in the period up to 2020 has been considered in relation to scenarios of forest production in that period (Tables 4–12). From several variants simulating the developmental changes in forest stands affected by industrial pollution, three have been chosen – variants 5, 7 and 12 (Nilsson et al. 1988). Variant 5 assumes the recently progressing dynamics of forest decline and intensive sanitary felling, and therefore the timber volume obtained from precommercial stands, especially at the beginning of the period discussed, is greater than from commercial stands. A similar situation occurs in variant 12. Some differences in relation to variant 5 result from a different viewpoint concerning the industrial-pollution effect on forest stands, and prediction of this effect in this case was made according to Trampler et al. (1988). Variant 7 assumes that the intensity of annual volume increment of stands will not decrease despite the increasing forest areas affected by industrial pollution. In such a situation, it is possible to increase the wood harvesting from commercial stands and to reduce it from precommercial stands. In this variant the timber volume simulated for particular 5-year periods is much greater than in variants 5 and 12.

The structure and number of machines necessary for wood harvesting in individual variants have been determined assuming a haul distance of 30 km. The results of our calculations are given in Tables 13–39. The volume of wood harvested in commercial and precommercial stands conditions the indispensable number and types of machines. So, if the volume of wood harvested in both types of stands is similar to the simulated variants (as, for instance, in the majority of natural forest regions for variants 5 and 12), the differences in structure and number of machines are small. It can be noted that only in Region III do the volumes of timber harvested according to these variants differ significantly (see Table 6). Thus, the structure and number of machines differ too (compare Tables 15 and 33).

Variant 7, simulating future changes of stand development in Poland, allows for a threefold greater volume of timber from commercial stands. In this case a much greater number of heavy power saws, skidders, farm tractors of class 1 and 4, and middle-tonnage units (Tables 22–23) is required than in variants 5 and 12.

6. CONCLUSIONS

The simulation model for wood harvesting ensures a quick estimation of production costs and structure of machines under given conditions of work. It enables the analysis of production costs and machinery structure under the changing situation in forestry and helps to verify the set of machines by means of which production tasks would be performed at the lowest possible costs.

The model can also be used for verification of the efficiency of new or modernized machines. On the basis of the model, the composition of expenditure can be estimated, and in consequence, the trends in new technical, technological and organizational solutions indicated.

The model is intended for simulation of production processes at a macro scale since it describes economic effects for regions and the whole country. This results from the way the forest-resources data base was prepared. If an adequate data base is made for forest area units, such as a forest division or a forest district (State Forest Enterprise), such an analysis can also be made for still smaller units. In this case, to obtain precise results of estimation, it is advisable to attribute the transport travel distance to each wood assortment, unlike in the discussed model in which the transport travel distance is the same for all assortments. Such a modification would require verification of the input–output model.

The model discussed in this study does not account for concentration of forest operations in a definite time, resulting from, for example, sanitary reasons, natural calamity and export demands. In such cases the number of machines should be increased over that estimated according to this model, i.e., with the assumption of even work for the machines through the whole year. To provide the model with such casual production tasks, information on their frequency and range distribution should be collected.

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Table 1. The set of machines and their characteristics.

Name of Machines	Symbol	Operation Possibilities on Basic Area	Output W (m^3/year)	Costs Z (Zl./m^3)
Felling Machines				
Power saw	MS11	ABCDEFG3	9,000	60
Light power saw	MS21	ABCDEFG1	2,000	120
Light power saw	MS22	ABCDEFG2	4,500	110
Feller-buncher up to 50 cm diameter	MS31	ABCDE1,F1,G3	25,000	90
Harvester up to 30 cm diameter	MS41	ABCDE1,F1,G2	3,000	1,110
Felling with axe	MS51	ABCDEFG1	1,200	200
Processing Machines				
Power saw	MO11	ABCDEFG3	2,000	240
Light power saw	MO21	ABCDEFG1	300	980
Light power saw	MO22	ABCDEFG2	1,200	330
Processors up to 30 cm diameter	MO31	ABCDE1,F1,G2	5,500	740
Processors up to 50 cm diameter (after felling with power saws)	MO41	ABCDE1,F1,G3	20,000	300
Processors up to 50 cm diameter (after felling with feller-buncher)	MO42	ABCDE1,F1,G3	25,000	240
Skidding and Forwarding Machines				
Skidder	MZ12	ABCDEFG1,2	5,400,000 800 + 1	311 + 0,39.1
Skidder	MZ13	ABCDEFG3	7,087,500 575 + 1	170 + 0,30.1
Forwarder	MZ21	ABCDEFG1,2	30,240,000 2,780 + 1	387 + 0,13.1
Forwarder	MZ22	ABCDEFG3	39,000,000 2,900 + 1	309 + 0,11.1
Forwarder	MZ23	ABCDE1,F1,G2,3	49,725,000 2,825 + 1	242 + 0,08.1
Farm tractor with trailer	MZ31	ABCDEFG1,2	14,175,000 3,050 + 1	483 + 0,17.1
Farm tractor with trailer	MZ32	ABCDEFG3	13,162,500 1,925 + 1	333 + 0,17.1
Farm tractor class 0.9 with winch	MZ41	ABCDEF1,G1,2	900,000 500 + 1	533 + 1,07.1

Table 1. Continued.

Name of Machines	Symbol	Operation Possibilities on Basic Area	Output W (m^3/year)	Costs Z (Zl./m^3)
Farm tractor class 0.9 with grapple	MZ42	ABCDEFG1,2	3,600,000 800 + 1	261 + 0,59.1
Farm tractor class 1.4 with equipment	MZ51	ABCDEFG3	4,050,000 350 + 1	149 + 0,41.1
Mobile spar-yarder	MZ71	ABCDEF2,3,G2,3	4,500,000 750 + 1	350 + 1,4.1
Mobile spar-yarder	MZ72	ABCDEF2,3,G1	5,000,000 1,850 + 1	510 + 1,6.1
Chippers				
Chipper on farm tractor	MR11	ABCDEFG1	6,000	250
Chipper with feeding device on farm tractor	MR21	ABCDEFG1	7,000	300
Mobile chipper	MR31	ABCDEFG2,3	10,000	260
Road Transport Units				
Middle-tonnage unit for short-sized wood	MT11	ABCDEFG	138,050 15 + 1	217 + 14,3.1
Middle-tonnage unit for long-sized wood	MT21	ABCDEFG	175,500 17 + 1	216 + 12,4.1
High-tonnage unit for short- and long-sized wood	MT31	ABCDEFG	793,500 59 + 1	343 + 5,7.1
Middle-tonnage unit for chips	MT41	ABCDEFG	195,000 29 + 1	253 + 8,7.1
High-tonnage unit for chips	MT51	ABCDEFG	1,200,000 140 + 1	503 + 3,7.1

Notes:

(a) The lack of a digit after the letter in the symbol of the basic area does not reduce the operation possibilities of a given machine.

(b) In Table 1, the distance (1) for skidding and road transport should be given in meters and kilometers, respectively.

Table 2. Cost estimates for wood harvesting in Poland in 1986 from the optimum flow-sheets on the basis of travel distance (L).

Region	Area (ha)	Harvest (m^3)	L = 10 km		L = 30 km		L = 50 km	
			Harvest Cost (1,000 Zl.)	Cost Per Unit (Zl./m^3)	Harvest Cost (1,000 Zl.)	Cost Per Unit (Zl./m^3)	Harvest Cost (1,000 Zl.)	Cost Per Unit (Zl./m^3)
A1	1,219,248	4,451,100	5,214,600	1,171.5	6,272,400	1,409.2	7,037,300	1,581.0
A2	713,717	2,132,000	2,753,100	1,291.3	3,249,600	1,524.2	3,610,300	1,693.4
A3	1,698,277	5,065,000	6,405,000	1,264.6	7,508,300	1,482.4	8,348,200	1,648.2
A4	586,621	1,528,000	2,022,700	1,323.7	2,369,000	1,550.4	2,627,200	1,719.4
A5	736,431	2,520,600	3,603,100	1,429.5	4,165,300	1,652.5	4,574,600	1,814.9
A6	988,008	2,785,500	3,828,300	1,374.4	4,463,300	1,602.3	4,926,200	1,768.5
A7	158,376	1,192,500	1,192,500	1,511.4	1,371,700	1,738.5	1,493,100	1,892.3
A8	472,599	2,852,000	2,852,000	1,507.3	3,284,700	1,736.0	3,570,100	1,886.8
Total	6,573,277	22,526,700	27,871,300	1,317.0	32,684,300	1,544.4	36,187,000	1,709.9

Table 3. Number of machines necessary for harvesting timber in Poland in 1986, on the basis of travel distance (L).

No.	Name of Machines	Region I Travel Distance L (km)			Region II Travel Distance L (km)			Region III Travel Distance L (km)		
		10	30	50	10	30	50	10	30	50
1	Power saw	1,573	1,573	1,573	662	662	662	1,504	1,504	1,504
2	Light power saw	3,372	3,372	3,372	1,964	1,964	1,964	4,861	4,861	4,861
3	Skidder	467	467	660	228	216	282	516	516	664
4	Forwarder	140	164	180	69	87	106	183	200	248
5	Farm tractor class 0.9 with winch	304	304	304	177	177	177	448	448	448
6	Farm tractor class 1.4 with equipment	28	28	28	51	51	51	64	64	64
7	Chipper on farm tractor	26	26	26	12	12	12	43	43	43
8	Middle-tonnage unit for short-sized wood	274	330	137	140	179	65	295	418	191
9	Middle-tonnage unit for long-sized wood	342	471	21	165	209	12	370	558	42
10	High-tonnage unit for short- and long-sized wood	0	109	466	0	58	230	0	75	483
11	Middle-tonnage unit for chips	0	46	61	15	22	23	51	78	98
12	High-tonnage unit for chips	0	0	1	0	0	3	0	0	2

Table 3. Continued.

No.	Name of Machines	Region IV Travel Distance L (km)			Region V Travel Distance L (km)			Region VI Travel Distance L (km)			Region VII Travel Distance L (km)		
		10	30	50	10	30	50	10	30	50	10	30	50
1	Power saw	418	418	418	845	845	845	844	844	844	305	305	305
2	Light power saw	1,678	1,678	1,678	2,118	2,118	2,118	2,604	2,604	2,604	438	438	438
3	Skidder	160	160	209	326	312	196	322	319	279	108	71	17
4	Forwarder	56	60	74	41	52	182	74	81	177	4	28	75
5	Farm tractor class 0.9 with winch	168	168	168	96	96	96	177	177	177	7	7	7
6	Farm tractor class 1.4 with equipment	16	16	16	285	285	285	187	187	187	142	142	142
7	Chipper on farm tractor	12	12	12	17	17	17	17	17	17	3	3	3
8	Middle-tonnage unit for short-sized wood	99	157	64	132	207	42	138	214	79	58	57	2
9	Middle-tonnage unit for long-sized wood	110	163	12	209	341	7	249	399	14	54	81	0
10	High-tonnage unit for short- and long-sized wood	0	19	150	0	20	272	0	25	298	0	22	91
11	Middle-tonnage unit for chips	14	22	24	20	30	18	21	31	29	4	6	1
12	High-tonnage unit for chips	0	0	2	0	0	9	0	0	5	0	0	3

Table 3. Continued.

No.	Name of Machines	Region VIII Travel Distance L (km) 10	30	50	Country Travel Distance L (km) 10	30	50	Total Number of Machines Currently Available (1986)
1	Power saw	674	674	674	6,825	6,825	6,825	29,500
2	Light power saw	1,269	1,269	1,269	18,304	18,304	18,304	15,300
3	Skidder	254	195	60	2,381	2,256	2,367	1,347
4	Forwarder	18	57	175	585	729	1,217	56
5	Farm tractor class 0.9 with winch	32	32	32	1,409	1,409	1,409	144
6	Farm tractor class 1.4 with equipment	313	313	313	1,086	1,086	1,086	1
7	Chipper on farm tractor	8	8	8	138	138	138	131
8	Middle-tonnage unit for short-sized wood	138	174	10	1,274	1,736	590	722
9	Middle-tonnage unit for long-sized wood	130	178	1	1,629	2,400	109	2,201
10	High-tonnage unit for short- and long-sized wood	0	46	217	0	374	2,207	225
11	Middle-tonnage unit for chips	10	15	5	135	250	259	127
12	High-tonnage unit for chips	0	0	6	0	0	31	30

Table 4. Prognosis for timber harvest (in thousands m^3) in State Forests in Region I according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	1,312	1,542	1,737	1,898	2,026	2,122
	Immature	2,209	2,150	2,141	2,106	2,042	1,967
	Total	3,521	3,692	3,878	4,004	4,068	4,089
7	Mature	4,913	4,112	3,872	3,777	3,737	3,713
	Immature	1,271	1,196	1,201	1,078	1,118	1,123
	Total	6,184	5,308	5,073	4,855	4,855	4,836
12	Mature	1,312	1,529	1,704	1,840	1,936	1,997
	Immature	2,209	2,095	2,036	1,961	1,868	1,772
	Total	3,521	3,624	3,740	3,801	3,804	3,769

Table 5. Prognosis for timber harvest (in thousands m^3) in State Forests in Region II according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	812	1,542	1,069	1,199	1,327	1,450
	Immature	1,443	852	1,472	1,463	1,433	1,395
	Total	2,255	2,394	2,541	2,662	2,760	2,845
7	Mature	4,563	2,771	2,311	2,218	2,245	2,313
	Immature	1,108	1,077	1,028	991	982	983
	Total	5,671	3,848	3,339	3,209	3,227	3,296
12	Mature	812	938	1,069	1,199	1,326	1,449
	Immature	1,445	1,456	1,471	1,461	1,430	1,392
	Total	2,257	2,394	2,540	2,660	2,757	2,841

Table 6. Prognosis for timber harvest (in thousands m^3) in State Forests in Region III according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	1,879	2,862	2,867	2,606	2,732	2,674
	Immature	2,930	2,223	2,526	2,787	3,003	3,123
	Total	4,809	5,085	5,393	5,393	5,735	5,797
7	Mature	5,401	4,757	4,543	4,517	4,576	4,650
	Immature	1,569	1,426	1,350	1,302	1,282	1,270
	Total	6,970	6,183	5,893	5,819	5,858	5,920
12	Mature	1,879	2,204	2,477	2,698	2,864	2,973
	Immature	4,930	2,787	2,727	2,633	2,508	2,379
	Total	6,809	4,991	5,204	5,331	5,372	5,352

Table 7. Prognosis for timber harvest (in thousands m^3) in State Forests in Region IV according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	445	573	704	831	948	1,051
	Immature	1,032	1,053	1,077	1,075	1,047	1,006
	Total	1,477	1,626	1,781	1,906	1,995	2,057
7	Mature	1,324	1,259	1,345	1,466	1,588	1,699
	Immature	813	763	766	726	699	679
	Total	2,137	2,022	2,111	2,192	2,287	2,378
12	Mature	445	569	694	812	917	1,006
	Immature	1,032	1,034	1,040	1,022	983	935
	Total	1,477	1,603	1,734	1,834	1,900	1,941

Table 8. Prognosis for timber harvest (in thousands m^3) in State Forests in Region V according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	1,425	1,502	1,554	1,587	1,605	1,611
	Immature	1,577	1,553	1,572	1,533	1,473	1,411
	Total	3,002	3,055	3,126	3,120	3,078	3,022
7	Mature	3,225	2,468	2,193	2,089	2,055	2,044
	Immature	686	638	616	600	598	608
	Total	3,911	3,106	2,809	2,689	2,653	2,652
12	Mature	1,423	1,486	1,519	1,529	1,522	1,502
	Immature	1,577	1,498	1,478	1,410	1,330	1,255
	Total	3,000	2,984	2,997	2,939	2,852	2,757

Table 9. Prognosis for timber harvest (in thousands m^3) in State Forests in Region VI according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	750	990	1,219	1,424	1,598	1,737
	Immature	1,719	1,569	1,471	1,384	1,295	1,210
	Total	2,469	2,559	2,690	2,808	2,893	2,947
7	Mature	2,792	2,709	2,784	2,884	2,972	2,992
	Immature	1,002	926	858	797	756	770
	Total	3,794	3,635	3,642	3,681	3,728	3,762
12	Mature	752	980	1,190	1,369	1,510	1,613
	Immature	1,720	1,522	1,377	1,259	1,155	1,062
	Total	2,472	2,502	2,567	2,628	2,665	2,675

Table 10. Prognosis for timber harvest (in thousands m^3) in State Forests in Region VII according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	201	219	226	224	217	205
	Immature	471	432	385	341	300	266
	Total	672	651	611	565	517	471
7	Mature	951	790	736	706	678	647
	Immature	162	146	130	121	115	112
	Total	1,113	936	866	827	793	759
12	Mature	201	214	215	207	194	178
	Immature	491	414	352	299	253	216
	Total	692	628	567	506	447	394

Table 11. Prognosis for timber harvest (in thousands m^3) in State Forests in Region VIII according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	193	242	287	326	361	392
	Immature	964	888	833	773	713	655
	Total	1,157	1,130	1,120	1,099	1,074	1,047
7	Mature	2,330	1,946	1,839	1,802	1,796	1,799
	Immature	552	498	465	445	432	423
	Total	2,882	2,444	2,304	2,247	2,228	2,222
12	Mature	193	240	282	317	347	373
	Immature	943	865	791	718	649	584
	Total	1,136	1,105	1,073	1,035	996	957

Table 12. Prognosis for timber harvest (in thousands m^3) in all State Forests according to simulations 5, 7 and 12.

Simulation	Forest Stand Category	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
5	Mature	7,017	9,472	9,663	10,095	10,814	11,242
	Immature	12,365	10,720	9,740	11,678	11,306	11,033
	Total	19,382	20,192	19,403	21,773	22,120	22,275
7	Mature	25,499	20,812	19,623	19,459	19,647	19,857
	Immature	7,163	6,666	6,414	6,113	5,982	5,969
	Total	32,662	27,478	26,037	25,572	25,629	25,826
12	Mature	7,017	8,160	9,150	9,971	10,616	11,091
	Immature	12,349	11,671	11,272	10,763	10,177	9,595
	Total	19,366	19,831	20,422	20,734	20,793	20,686

Table 13. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region I according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	795	782	1,053	1,151	1,228	1,287
2	Light power saw	4,048	3,914	4,042	4,103	4,056	3,956
3	Skidder	320	346	383	412	431	442
4	Forwarder	190	186	178	170	161	153
5	Farm tractor class 0.9 with winch	390	374	402	422	426	420
6	Farm tractor class 1.4 with equipment	8	9	11	13	14	14
7	Chipper on farm tractor	33	32	34	36	37	36
8	Middle-tonnage unit for short-sized wood	239	254	280	301	313	320
9	Middle-tonnage unit for long-sized wood	244	283	317	346	368	384
10	High-tonnage unit for short- and long-sized wood	136	133	128	122	116	110
11	Middle-tonnage unit for chips	60	58	62	66	66	66
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 14. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region II according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	417	577	657	738	817	892
2	Light power saw	2,511	2,559	2,652	2,671	2,625	2,555
3	Skidder	191	211	235	255	217	282
4	Forwarder	129	130	128	126	123	120
5	Farm tractor class 0.9 with winch	227	235	250	254	249	242
6	Farm tractor class 1.4 with equipment	21	22	23	24	25	25
7	Chipper on farm tractor	15	16	17	17	17	16
8	Middle-tonnage unit for short-sized wood	153	168	185	199	209	218
9	Middle-tonnage unit for long-sized wood	149	172	195	218	239	260
10	High-tonnage unit for short- and long-sized wood	98	98	97	95	93	90
11	Middle-tonnage unit for chips	27	28	30	31	30	30
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 15. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region III according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	1,160	1,373	1,560	1,721	1,855	1,957
2	Light power saw	5,659	5,439	5,631	5,702	5,632	5,500
3	Skidder	467	504	560	605	637	658
4	Forwarder	205	204	197	188	178	168
5	Farm tractor class 0.9 with winch	570	537	576	601	605	600
6	Farm tractor class 1.4 with equipment	17	19	20	22	23	24
7	Chipper on farm tractor	53	50	54	56	57	56
8	Middle-tonnage unit for short-sized wood	533	548	576	593	600	600
9	Middle-tonnage unit for long-sized wood	570	625	673	709	736	753
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	97	91	98	103	103	103
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 16. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region IV according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	269	346	526	503	573	636
2	Light power saw	1,875	2,045	1,993	2,007	1,953	1,871
3	Skidder	126	144	176	186	199	210
4	Forwarder	73	74	74	73	72	69
5	Farm tractor class 0.9 with winch	182	184	196	201	195	186
6	Farm tractor class 1.4 with equipment	2	3	3	3	5	5
7	Chipper on farm tractor	13	13	14	14	14	13
8	Middle-tonnage unit for short-sized wood	172	194	216	235	251	264
9	Middle-tonnage unit for long-sized wood	172	194	216	235	251	264
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	23	23	25	25	25	23
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 17. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region V according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	871	918	950	970	982	710
2	Light power saw	2,800	2,797	3,000	3,001	2,927	2,837
3	Skidder	353	360	376	378	374	316
4	Forwarder	83	82	79	76	73	70
5	Farm tractor class 0.9 with winch	165	160	184	197	201	202
6	Farm tractor class 1.4 with equipment	200	209	221	219	214	119
7	Chipper on farm tractor	20	21	24	25	25	24
8	Middle-tonnage unit for short-sized wood	292	295	306	306	300	264
9	Middle-tonnage unit for long-sized wood	427	438	443	443	439	351
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	37	38	44	45	45	44
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 18. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VI according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	451	596	733	857	962	1,046
2	Light power saw	3,542	3,064	2,835	2,673	2,514	2,366
3	Skidder	279	280	295	312	326	337
4	Forwarder	92	93	91	87	83	78
5	Farm tractor class 0.9 with winch	194	185	192	195	191	186
6	Farm tractor class 1.4 with equipment	175	127	97	80	69	61
7	Chipper on farm tractor	26	21	19	18	17	17
8	Middle-tonnage unit for short-sized wood	262	251	252	255	256	256
9	Middle-tonnage unit for long-sized wood	340	374	406	432	452	467
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	47	38	35	33	32	30
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 19. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VII according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	124	136	140	139	134	127
2	Light power saw	591	526	493	457	420	386
3	Skidder	29	32	34	35	35	33
4	Forwarder	56	49	43	37	32	28
5	Farm tractor class 0.9 with winch	0	6	7	7	6	6
6	Farm tractor class 1.4 with equipment	196	115	106	98	88	79
7	Chipper on farm tractor	2	2	2	3	3	3
8	Middle-tonnage unit for short-sized wood	24	25	27	27	27	25
9	Middle-tonnage unit for long-sized wood	32	35	37	37	35	34
10	High-tonnage unit for short- and long-sized wood	44	39	34	29	25	22
11	Middle-tonnage unit for chips	4	3	4	5	5	5
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 20. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VIII according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	119	149	177	201	223	242
2	Light power saw	1,622	1,527	1,423	1,305	1,187	1,078
3	Skidder	72	75	78	79	80	80
4	Forwarder	86	81	76	71	66	62
5	Farm tractor class 0.9 with winch	44	39	34	31	27	25
6	Farm tractor class 1.4 with equipment	182	285	165	155	146	137
7	Chipper on farm tractor	12	11	10	9	8	7
8	Middle-tonnage unit for short-sized wood	68	70	71	71	71	71
9	Middle-tonnage unit for long-sized wood	33	40	47	52	57	61
10	High-tonnage unit for short- and long-sized wood	69	65	61	57	53	49
11	Middle-tonnage unit for chips	22	21	19	17	15	13
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 21. Prognosis of the number of machines necessary for harvesting timber in all State Forests according to simulation 5, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	4,206	4,880	5,796	6,280	6,774	6,897
2	Light power saw	22,648	21,871	22,069	21,921	21,314	20,549
3	Skidder	1,837	1,952	2,137	2,262	2,299	2,362
4	Forwarder	914	899	866	828	788	748
5	Farm tractor class 0.9 with winch	1,772	1,720	1,841	1,908	1,900	1,867
6	Farm tractor class 1.4 with equipment	801	789	646	614	584	464
7	Chipper on farm tractor	174	166	174	178	178	172
8	Middle-tonnage unit for short-sized wood	1,743	1,805	1,913	1,988	2,027	2,018
9	Middle-tonnage unit for long-sized wood	1,967	2,161	2,334	2,472	2,577	2,574
10	High-tonnage unit for short- and long-sized wood	347	335	320	303	287	271
11	Middle-tonnage unit for chips	317	300	317	325	321	314
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 22. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region I according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	2,982	2,495	2,350	2,292	2,268	2,253
2	Light power saw	2,278	2,062	2,001	1,937	1,947	2,005
3	Skidder	744	655	619	602	597	597
4	Forwarder	90	99	86	84	82	81
5	Farm tractor class 0.9 with winch	18	15	15	14	15	16
6	Farm tractor class 1.4 with equipment	196	167	161	155	159	169
7	Chipper on farm tractor	18	15	15	14	15	16
8	Middle-tonnage unit for short-sized wood	516	438	414	403	400	400
9	Middle-tonnage unit for long-sized wood	866	728	686	669	662	657
10	High-tonnage unit for short- and long-sized wood	65	63	61	60	59	58
11	Middle-tonnage unit for chips	33	28	27	26	27	29
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 23. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region II according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	2,798	1,700	1,419	1,361	1,379	1,421
2	Light power saw	2,022	1,881	1,694	1,581	1,581	1,620
3	Skidder	683	434	362	344	349	362
4	Forwarder	94	95	95	94	93	91
5	Farm tractor class 0.9 with winch	178	156	127	109	109	116
6	Farm tractor class 1.4 with equipment	195	130	109	100	95	90
7	Chipper on farm tractor	13	11	9	8	8	9
8	Middle-tonnage unit for short-sized wood	505	324	268	253	255	263
9	Middle-tonnage unit for long-sized wood	768	471	394	378	384	397
10	High-tonnage unit for short- and long-sized wood	73	73	73	72	71	70
11	Middle-tonnage unit for chips	23	20	17	15	15	16
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 24. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region III according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	3,334	2,937	2,805	2,333	2,825	2,871
2	Light power saw	2,989	2,474	2,275	2,203	2,238	2,280
3	Skidder	884	767	727	720	731	745
4	Forwarder	92	91	89	85	82	79
5	Farm tractor class 0.9 with winch	272	195	170	167	179	190
6	Farm tractor class 1.4 with equipment	140	127	121	118	116	115
7	Chipper on farm tractor	27	20	17	17	18	19
8	Middle-tonnage unit for short-sized wood	605	533	506	498	502	508
9	Middle-tonnage unit for long-sized wood	1,070	953	911	902	908	917
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	49	36	32	31	33	35
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 25. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region IV according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	801	762	815	887	962	1,043
2	Light power saw	1,518	1,392	1,250	1,120	1,060	1,043
3	Skidder	258	242	245	254	267	281
4	Forwarder	42	44	44	44	43	41
5	Farm tractor class 0.9 with winch	135	112	91	73	67	67
6	Farm tractor class 1.4 with equipment	59	64	67	69	71	71
7	Chipper on farm tractor	11	9	7	6	5	5
8	Middle-tonnage unit for short-sized wood	222	210	211	214	221	229
9	Middle-tonnage unit for long-sized wood	289	280	294	311	329	344
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	19	16	13	11	10	10
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 26. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region V according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	1,976	1,512	1,343	1,280	1,258	1,252
2	Light power saw	1,288	1,134	1,085	1,061	1,083	1,131
3	Skidder	501	393	354	338	335	336
4	Forwarder	31	30	30	29	29	29
5	Farm tractor class 0.9 with winch	88	71	67	65	67	72
6	Farm tractor class 1.4 with equipment	297	231	209	201	198	197
7	Chipper on farm tractor	10	8	8	8	8	9
8	Middle-tonnage unit for short-sized wood	300	242	221	212	210	212
9	Middle-tonnage unit for long-sized wood	667	524	471	450	442	440
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	18	15	14	14	15	16
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 27. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VI according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	1,681	1,631	1,676	1,736	1,789	1,823
2	Light power saw	1,847	1,612	1,442	1,320	1,280	1,295
3	Skidder	466	442	443	449	459	468
4	Forwarder	56	55	53	49	46	43
5	Farm tractor class 0.9 with winch	140	112	93	82	82	88
6	Farm tractor class 1.4 with equipment	188	169	162	159	158	158
7	Chipper on farm tractor	12	9	8	7	7	8
8	Middle-tonnage unit for short-sized wood	288	271	266	265	267	271
9	Middle-tonnage unit for long-sized wood	649	627	634	645	655	660
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	22	17	15	13	13	14
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 28. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VII according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	589	489	456	437	420	401
2	Light power saw	211	185	171	170	175	180
3	Skidder	117	97	91	88	86	83
4	Forwarder	18	16	14	13	11	11
5	Farm tractor class 0.9 with winch	3	2	2	2	3	3
6	Farm tractor class 1.4 with equipment	206	168	153	146	140	133
7	Chipper on farm tractor	1	1	1	1	1	2
8	Middle-tonnage unit for short-sized wood	95	79	74	71	69	66
9	Middle-tonnage unit for long-sized wood	151	125	117	112	108	103
10	High-tonnage unit for short- and long-sized wood	14	13	11	10	9	8
11	Middle-tonnage unit for chips	2	1	2	2	3	3
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 29. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VIII according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	1,431	1,196	1,130	1,108	1,105	1,106
2	Light power saw	1,007	825	718	669	656	656
3	Skidder	310	258	241	235	235	236
4	Forwarder	48	46	46	44	43	41
5	Farm tractor class 0.9 with winch	27	20	14	11	10	11
6	Farm tractor class 1.4 with equipment	505	401	365	350	344	342
7	Chipper on farm tractor	8	6	4	4	4	4
8	Middle-tonnage unit for short-sized wood	300	245	226	220	218	219
9	Middle-tonnage unit for long-sized wood	323	272	258	253	253	254
10	High-tonnage unit for short- and long-sized wood	38	37	37	36	34	33
11	Middle-tonnage unit for chips	15	10	8	7	7	7
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 30. Prognosis of the number of machines necessary for harvesting timber in all State Forests according to simulation 7, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	15,592	12,722	11,994	11,506	12,006	12,170
2	Light power saw	13,160	11,565	10,636	10,061	10,020	10,210
3	Skidder	3,993	3,288	3,082	3,030	3,059	3,108
4	Forwarder	471	476	457	442	429	416
5	Farm tractor class 0.9 with winch	861	683	579	523	532	563
6	Farm tractor class 1.4 with equipment	1,786	1,457	1,347	1,080	1,281	1,276
7	Chipper on farm tractor	100	79	69	65	66	72
8	Middle-tonnage unit for short-sized wood	2,831	2,342	2,186	2,402	2,142	2,168
9	Middle-tonnage unit for long-sized wood	4,783	3,980	3,765	3,720	3,741	3,772
10	High-tonnage unit for short- and long-sized wood	190	186	182	178	173	169
11	Middle-tonnage unit for chips	181	143	128	119	123	130
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 31. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region I according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	795	927	1,033	1,115	1,174	1,210
2	Light power saw	4,048	3,779	3,797	3,786	3,699	3,583
3	Skidder	320	337	367	391	405	411
4	Forwarder	190	182	172	159	148	137
5	Farm tractor class 0.9 with winch	390	356	371	385	387	382
6	Farm tractor class 1.4 with equipment	8	9	11	12	13	14
7	Chipper on farm tractor	33	30	32	33	33	33
8	Middle-tonnage unit for short-sized wood	237	247	268	284	293	297
9	Middle-tonnage unit for long-sized wood	244	279	310	334	350	360
10	High-tonnage unit for short- and long-sized wood	136	131	123	114	106	98
11	Middle-tonnage unit for chips	60	55	58	60	60	60
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 32. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region II according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	499	577	657	738	816	892
2	Light power saw	2,512	2,557	2,649	2,667	2,621	2,251
3	Skidder	191	211	234	255	271	286
4	Forwarder	129	129	128	126	123	119
5	Farm tractor class 0.9 with winch	227	234	249	254	249	241
6	Farm tractor class 1.4 with equipment	21	22	24	24	25	25
7	Chipper on farm tractor	15	15	17	17	17	16
8	Middle-tonnage unit for short-sized wood	153	167	185	199	209	217
9	Middle-tonnage unit for long-sized wood	150	172	195	218	339	260
10	High-tonnage unit for short- and long-sized wood	98	98	97	95	93	90
11	Middle-tonnage unit for chips	27	28	30	31	30	30
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 33. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region III according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	1,160	1,361	1,529	1,666	1,769	1,836
2	Light power saw	6,559	5,248	5,298	5,287	5,174	5,022
3	Skidder	467	492	539	576	600	614
4	Forwarder	205	200	190	177	163	150
5	Farm tractor class 0.9 with winch	570	511	535	553	556	552
6	Farm tractor class 1.4 with equipment	17	18	20	21	23	23
7	Chipper on farm tractor	53	48	50	52	52	52
8	Middle-tonnage unit for short-sized wood	533	535	552	560	559	552
9	Middle-tonnage unit for long-sized wood	570	617	654	679	693	698
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	97	87	91	94	95	94
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 34. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region IV according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	269	344	420	491	555	608
2	Light power saw	1,875	1,862	1,909	1,898	1,832	1,746
3	Skidder	126	142	162	179	191	200
4	Forwarder	73	73	72	70	67	64
5	Farm tractor class 0.9 with winch	182	183	197	206	210	212
6	Farm tractor class 1.4 with equipment	2	3	3	4	5	5
7	Chipper on farm tractor	13	12	13	13	13	12
8	Middle-tonnage unit for short-sized wood	172	183	197	206	210	212
9	Middle-tonnage unit for long-sized wood	172	192	211	228	241	250
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	23	22	24	24	23	22
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 35. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region V according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	870	908	929	935	931	919
2	Light power saw	2,798	2,666	2,793	2,747	2,649	2,550
3	Skidder	353	351	359	356	348	338
4	Forwarder	83	80	75	70	66	61
5	Farm tractor class 0.9 with winch	165	150	169	180	184	185
6	Farm tractor class 1.4 with equipment	200	202	209	204	197	190
7	Chipper on farm tractor	20	19	22	23	22	22
8	Middle-tonnage unit for short-sized wood	292	286	291	285	276	266
9	Middle-tonnage unit for long-sized wood	427	430	429	421	410	397
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	37	35	40	41	41	40
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 36. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VI according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	452	590	716	824	909	972
2	Light power saw	3,549	2,947	2,611	2,396	2,224	2,081
3	Skidder	279	273	280	291	301	308
4	Forwarder	92	91	87	81	75	68
5	Farm tractor class 0.9 with winch	194	174	174	173	170	167
6	Farm tractor class 1.4 with equipment	175	123	89	70	59	52
7	Chipper on farm tractor	26	20	17	16	15	15
8	Middle-tonnage unit for short-sized wood	263	244	237	235	233	230
9	Middle-tonnage unit for long-sized wood	341	374	391	409	420	426
10	High-tonnage unit for short- and long-sized wood	0	0	0	0	0	0
11	Middle-tonnage unit for chips	47	36	32	29	28	27
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 37. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VII according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	124	133	133	128	120	110
2	Light power saw	591	500	449	402	359	323
3	Skidder	29	31	32	32	31	29
4	Forwarder	56	47	39	32	26	22
5	Farm tractor class 0.9 with winch	6	5	6	6	6	5
6	Farm tractor class 1.4 with equipment	126	109	99	87	73	66
7	Chipper on farm tractor	2	2	2	2	2	3
8	Middle-tonnage unit for short-sized wood	24	24	25	25	24	22
9	Middle-tonnage unit for long-sized wood	32	34	35	34	32	29
10	High-tonnage unit for short- and long-sized wood	44	37	31	25	21	17
11	Middle-tonnage unit for chips	3	3	4	4	4	5
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 38. Prognosis of the number of machines necessary for harvesting timber in State Forests in Region VIII according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	119	148	174	196	214	230
2	Light power saw	1,622	1,478	1,341	1,205	1,080	968
3	Skidder	71	73	74	75	75	75
4	Forwarder	85	79	73	67	61	55
5	Farm tractor class 0.9 with winch	44	37	32	28	25	23
6	Farm tractor class 1.4 with equipment	182	169	156	144	133	123
7	Chipper on farm tractor	12	11	10	9	8	7
8	Middle-tonnage unit for short-sized wood	68	68	68	67	66	66
9	Middle-tonnage unit for long-sized wood	33	39	46	50	55	58
10	High-tonnage unit for short- and long-sized wood	68	63	58	53	48	44
11	Middle-tonnage unit for chips	22	20	18	16	14	12
12	High-tonnage unit for chips	0	0	0	0	0	0

Table 39. Prognosis of the number of machines necessary for harvesting timber in all State Forests according to simulation 12, with a travel distance of 30 km.

No.	Name of Machines	Five-year period					
		1991–1995	1996–2000	2001–2005	2006–2010	2011–2015	2016–2020
1	Power saw	4,288	4,988	5,591	6,178	6,488	6,777
2	Light power saw	23,557	21,037	20,847	20,378	19,638	18,524
3	Skidder	1,836	1,910	2,047	2,155	2,222	2,261
4	Forwarder	913	881	836	782	729	676
5	Farm tractor class 0.9 with winch	1,778	1,650	1,733	1,785	1,787	1,767
6	Farm tractor class 1.4 with equipment	731	655	431	566	528	498
7	Chipper on farm tractor	174	157	163	165	162	160
8	Middle-tonnage unit for short-sized wood	1,742	1,754	1,823	1,861	1,870	1,862
9	Middle-tonnage unit for long-sized wood	1,659	2,137	2,271	2,373	2,540	2,478
10	High-tonnage unit for short- and long-sized wood	346	329	309	287	268	249
11	Middle-tonnage unit for chips	316	286	297	299	295	290
12	High-tonnage unit for chips	0	0	0	0	0	0