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Forestry in the Republic of Belarus: Current State and Development Prospects

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HIGHLIGHTS

- The Republic of Belarus is one of the ten largest forest-covered countries in Europe.
- The country has its own forest machinery industry, which covers most of the domestic needs of forestry.
- Scientific research in the field of forestry and forest industry is financed within the framework of state programs and privately by enterprises and interested private companies.

GRAPHICAL ABSTRACT

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ABSTRACT

This article presents data on the current state and prospects of development of forestry and forest industry in the Republic of Belarus. Issues related to the forest structure, species, age, and composition, as well as the degree of their involvement in the country's economy are considered. Ownership and management of the forest resources is noted, and the study considers the issues of mechanization of forest operations and describes the used technologies. Directions for further improvement of the fleet of forest machines are indicated. A special attention was paid to the analysis of informatization in forest production processes. The structure of forest road network and its influence on the efficiency of production was considered. The problems faced by the forestry in Belarus are discussed in the study, then solutions are proposed to overcome the current challenges. Data about the existing programs and projects of scientific research aimed at solving these problems are given.

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1. INTRODUCTION

Being one of the main renewable natural resources, forests represent the most important national treasure of the Republic of Belarus. Forests and forest resources are of great importance for the sustainable socio-economic development of the country, ensuring its economic, energy, environmental and food security. This article is intended as a technical communication and it analyzes the current state and prospects of development of the forestry in the Republic of Belarus, particularly in the following areas: structure and general state of the forests, forest technology, availability of machines and equipment, forest roads and logistics of timber products.

2. CHARACTERIZATION OF FOREST RESOURCES AND THEIR CONTRIBUTION TO THE ECONOMY

According to the specific indicators of the forest area (0.88 ha/person), the growing stock of wood (194.7 m^3/pers.) and the forest cover (39.9%), the Republic of Belarus is among the top ten forested states in Europe. In absolute figures, the current indicators of the country's forest resources are as follows: a forested area of 8,280.3 thousand ha, a total standing stock of 1,831.8 million m^3, an average stock of timber per unit area of 221 m^3/ha, a stock of mature and over-mature stands of 272 m^3/ha, and an average age of the forest stands of 56 years.

Table 1. Dynamics of the indicators of the forest in the Republic of Belarus over the last 26 years

Name of the indicator	Measurement unit	1994	2001	2010	2020
1. Total area of the forest lands	thousand ha	8,676.1	9,247.5	9,416.6	9,620.9
1.1. Forest lands	thousand ha	7,775.9	8,275.7	8,598.2	8,799.1
	%	89.6	89.4	91.3	91.5
1.2. Forest covered lands	thousand ha	7,371.7	7,850.6	8,002.4	8,280.3
	%	85	85.0	85.0	86.1
1.3. Mature and over-mature forest lands	thousand ha	350.1	623	804.4	1,379.1
	%	4.7	7.9	10.1	16.7
2. Forest cover	%	35.5	37.8	38.5	39.9
3. Total plantation stock	million m^3	1,093.2	1,339.9	1,566.1	1,831.8
4. Total average stock change	million m^3	24.9	28.2	30.2	33.4
5. Average growing stock	m^3/ha	148	171	196	221
5.1. Mature and over-mature stands	m^3/ha	213	220	244	283
6. Average age	years	44	48	52	53

The dynamics of the forest indicators of Belarus over the last 26 years (**Table 1**) shows that the introduction of the principles of sustainable and non-depleting use of forests had a positive impact on the overall structure of the forests and on the quality of economic activity developed in them [1].

3. DESCRIPTION OF FOREST MANAGEMENT AND OF THE USE OF FOREST RESOURCES

In contrast to many European countries, all the forests from the Republic of Belarus are the exclusive property of the state, which determines the order of forest management and timber production. In the structure of the state forest management there are 7 forest owners. The general distribution of the forests in the Republic of Belarus [2] by ministries and departments as of 01.01.2020 is given in **Table 2**.

Table 2. Distribution of forest land by department

Name of ministries, organizations	Area, thousand hectares	Percentage of total area	Number of legal entities engaged in forestry
The Ministry of Forestry	8,461.3	87.9	98
The Ministry of Defence	90.1	0.9	2
The Ministry of Emergency Situations	216.9	2.3	1
The Ministry of Education	27.8	0.3	2
The Office of the President of the Republic of Belarus	767.8	8.0	7
The National Academy of Sciences of Belarus	41.6	0.4	3
Local executive and administrative bodies	15.4	0.2	6
Total	**9,620.9**	**100.0**	**119**

Open statistical information regarding a number of forest owners presented in **Table 2** is either absent or statistically insignificant, so the further analysis is done mainly for the largest of them - the Ministry of Forestry.

4. CHARACTERIZATION OF MECHANIZATION IN OPERATIONS

In recent years, the number of forestry machines by enterprises of the Ministry of Forestry of the Republic of Belarus has not changed significantly. As at July 2020, 2,788 units of harvesting and timber transporting machines were operated by the enterprises of the Ministry of Forestry. Among them are 305 harvesters, 353 forwarders, 823 trucks and 1307 towed loader-transporters. Since 2010, the implementation of the program of technical equipment of enterprises of the industry has increased the total number of machines by 1,385 units [3]. In comparison with the same period of the previous year, the total number of harvesters increased by 2 units, forwarders - by 3 units, trucks - by 6 units, and trailed loader-transporters - by 22 units. The slight increase in the number of machines in general and by relevant types indicates the current structure of the machine fleet.

During the first half of 2020, enterprises of the Ministry of Forestry of the Republic of Belarus harvested 10.757 million m^3 of wood. For instance, 3.445 million m^3 were harvested by their own harvesters and 1.8 million m^3 by harvesters of external organizations providing logging services. The share of mechanized timber harvesting operations was 48.8%. Data on the volume of timber harvesting production [4] by state production forestry associations (SPFA) is given in **Table 3**.

Table 3. Volume of timber harvested by the Ministry of Forestry enterprises

Name of the state production forestry association	Total harvested volume, thousands m^3	Volume harvested by the Ministry of Forestry, thousands m^3	Volume harvested by contractors, thousands m^3	Share of fully mechanized timber harvesting operations[a]
Brest	1,420.0	386.7	212.1	42.2
Vitebsk	1,470.2	474.8	148.1	42.4
Gomel	2,601.5	625.7	424.8	40.4
Grodno	1,326.5	458.9	295.8	56.9
Minsk	2,160.5	852.9	337.1	55.1
Mogilev	1,718.4	645.9	381.8	57.8
Total	**10,757.1**	**3,444.9**	**1,799.7**	**48.8**

Notes: [a] – in the total volume harvested by the Ministry of Forestry

The provision of timber harvesting services by contracting has developed significantly. On average, such contractors harvest about 52% of all the timber harvested in Belarus by the use multifunctional machines. For the enterprises operating under the Ministry of Forestry, the fleet used to harvest timber is mainly composed of the machines manufactured by JSC Amkodor. Harvesters produced by JSC Amkodor are shown by four of the most used models in **Figure 1**.

The enterprises of the Mogilev State Production Forestry Association are equipped with the most modern harvesters. With a total number of 55 units, the number of harvesters older than 5 years does not exceed 25%. The largest number of harvesters in use is that of the Minsk State Production Forestry Association - 77 units, of which 45 are older than 3 years. The majority of the machines are currently working in a 2-shift mode. As a rule, older machines work in single-shift mode. The oldest harvester fleet is located in the Vitebsk State Production Forestry Association, which holds only 9 units having less than 3 years of operation (**Table 4**).

The harvesters of Vitebsk State Production Forestry Association have been repaired for the longest time, averaging 5,5 days of maintenance and repairing per month per one harvester. The harvesters of the State Forestry Institution "Rossonsky Forestry" spent 82 days in repairs (as of 2012), with a harvested volume of 8.55 thousand m^3, achieved in a single-shift mode of operation. Low indicators of work and long downtime are not only due to the physical deterioration of the machines [5], but also due to much more difficult conditions of operation in this area. For comparison purposes, the oldest machine of this type has been working since 2010 in the State Forestry Institution "Minsk Forestry" and in the first half of 2020 it harvested 14.4 thousand m^3, working in one shift and being repaired in this period only for 12 days.

Figure 1: A description of the commonly used harvester and forwarder models produced by Amkodor

In general, the fleet of harvesters held by the Ministry of Forestry needs to be updated by 17 - 35%, figures which depend on the affiliation of the machines to a particular State Production Forestry Association.

Table 4. Main indicators characterizing the fleet of harvesters used in the Republic of Belarus

Name of the state production forestry association	Total number of harvesters	Number of harvesters under 3 years of operation	Number of harvesters from 3 to 5 years of operation	Number of harvesters over 5 years of operation	Number of harvesters under repair, days per month for 1 unit
Brest	41	23	3	15	2.9
Vitebsk	37	9	7	21	5.5
Gomel	51	14	16	21	2.9
Grodno	44	22	5	17	2.3
Minsk	77	32	11	34	3.0
Mogilev	55	33	8	14	2.7
Total	**305**	**134**	**48**	**123**	**3.1**

In comparison with the harvesters, the forwarder fleet [5-6] of the Ministry of Forestry enterprises is older (**Table 5**). 57.8% of forwarders hold more than 5 years of operation. This can be explained by the fact that the use of forwarders in timber harvesting operations began earlier than that of harvesters. Before the large-scale introduction of the harvesters in the 2010s, the technology of logging operations was based on the use of gasoline-powered saws and log transportation by

forwarders (in the most difficult operational conditions) and trailer loading and transportation machines (in easier operational conditions).

Table 5. Main indicators characterizing the fleet of forwarders used in the Republic of Belarus

Name of the state production forestry association	Total number of forwarders	Number of forwarders under 3 years of operation	Number of forwarders from 3 to 5 years of operation	Number of forwarders over 5 years of operation	Number of forwarders under repair, days per month for 1 unit
Brest	47	20	1	26	2.9
Vitebsk	70	14	9	47	6.5
Gomel	51	8	16	27	3.5
Grodno	43	12	7	24	4.2
Minsk	88	32	6	50	4.1
Mogilev	54	18	6	30	3.1
Total	**353**	**104**	**45**	**204**	**4.2**

In the Vitebsk State Production Forestry Association (SPFA), which holds the most worn-out forwarder fleet, the monthly downtime is about 6.5 days/unit. The downtime of such machines during half a year is 10 - 36 days. Average productivity of the most worn forwarders is in the range of 13.6 - 32.7 m^3 per shift, which is much lower than the industry average of 56.7 m^3. However, in what concerns the harvesters, low productivities are often the result of harsh operating conditions.

The average output of trailed loaders compared with forwarders is 21.8 m^3 lower and stands at 34.9 m^3. At the same time, the specific monthly downtime averages 3.1 days (**Table 6**). It should be noted that the operation of loading and transporting machines is less intensive and occurs mainly in the conditions of the I and II types of forests (group I of forests includes forests whose main purpose is to ensure water protection, protective, sanitary-hygienic, health-improving, and other functions, as well as forests of protected natural areas; group II of forests includes production forests). This explains the average monthly downtime of tractor trailers, which is comparable to that of forwarders, despite their older fleet (in 44% of cases the age of tractor trailers is more than 7 years). More than 500 tractor trailers will need to be replaced with new ones in the near future. The process of transition to the use of new-type tractor trailers should take into account a number of industry specifics [7-8].

At present, the domestic practice of using tractors and forest machines in forestry production differs from the foreign practice by the delineated use of machines: universal tractors (agricultural) for forestry work, and specialized forest machines in timber harvesting operations. Moreover, the fleet of forestry farm tractors consists mainly of tractors produced by OJSC "Minsk Tractor Works": MTZ-82 and MTZ-1221, which are used to perform most of the forestry work [8]. At the same time, the design of these universal tractors has some flaws that prevent their more effective use in timber harvesting operations. On the contrary, JSC "Amkodor" produces and releases machines for the use in timber harvesting operations such as loaders, harvesters, skidders and chippers [9-11].

Table 6. Main indicators characterizing the fleet of tractor trailers used in the Republic of Belarus

Name of the state production forestry association	Total number of tractor trailers	Number of tractor trailers over 7 years of operation	Number of tractor trailers under repair, days per month for 1 unit	Average volume transported per shift, m³
Brest	216	110	3.1	34.9
Vitebsk	210	89	4.6	31.0
Gomel	323	111	3.0	34.1
Grodno	117	57	2.0	34.9
Minsk	268	121	2.7	36.7
Mogilev	173	90	2.8	38.7
Total	**1307**	**578**	**3.1**	**34.9**

Taking into account the growth in the amount of the performed forest operations, exploring the possibilities of using modern tillage and forest planting machines, to reduce the number of personnel, to develop a multifunctional forestry tractor, needs to be approached to be able to perform a wide range of operations, including forest transportation operations on I and II types of terrain. According to preliminary calculations, the total technological need of forestry organizations in what regards the tractors with an engine power of over 120 kW does not exceed 5-8%, while the share of forestry tractors with an engine power of 80 - 120 kW can reach 60-70%. The specified numbers reflect the difference in mechanization of the forest operations compared to the agricultural ones, where the use of high-power tractors allows reducing the cost of work.

Vimek AB harvesters and forwarders (**Figure 2**) are widely used for clearing and felling operations. The most used models are the Vimek 404 harvester and Vimek 610.2 forwarder.

Figure 2: Machines models produced by Vimek AB which are used in timber harvesting operations

The structure of the Ministry of Forestry operates 79 units of Vimek harvesters and 78 units of Vimek forwarders. The average daily output per each harvester of this brand in the first half of 2020

was 25.8 m³ (from 17.7 to 30.8 m³, for different SPFA), while the average daily productivity of forwarders from this brand was of 31.5 m³ (25.5 - 40.8 m³). It should be noted that Vimek forwarders were used on relatively long extraction distances, averaging 933 m. The highest timber extraction distances - 1250 m - are noted in the forests of Vitebsk and Gomel SPFA. In most cases, this is due to the underdeveloped network of forest roads in these areas, which are characterized by ages of the forest stands of 20-40 years.

The harvested wood is transported mainly by log trucks of trailed and semi-trailed type. The total number of machines in use is of 823 units, of which 242 units (29%) are more than 7 years old and will soon require replacement. Each vehicle has an average monthly idle time of 3.8 days. The average output per machine is of 67.3 m³ per shift (**Table 7**).

Table 7. Main indicators characterizing the fleet of log trucks used in the Republic of Belarus

Name of the state production forestry association	Total number of log trucks	Number of log trucks over 7 years of operation	Number of log trucks under repair, days per month for 1 unit	Average volume transported per shift, m³
Brest	118	39	2.9	70.4
Vitebsk	139	47	5.0	62.7
Gomel	185	53	3.9	69.2
Grodno	92	32	2.6	60.7
Minsk	163	47	3.9	71.4
Mogilev	126	24	3.8	69.4
Total	**823**	**242**	**3.8**	**67.3**

The average distance for hauling wood assortments by trucks exceeds 40 km in 75% of the cases. Most of the log trucks are not all-wheel-drive and hold a 6 x 4-wheel arrangement. All-wheel-drive log trucks account for less than 20% of the total number.

Besides the production of timber assortments, the enterprises of the Ministry of Forestry implement technologies for obtaining woodchips. For this purpose, mobile chippers of their own production made in the form of semi-trailers (MTZ MR-40, MR-100), on specialized forest chassis (Amkodor 2904) [9-10], and also truck-mounted (MAZ 6944C9) are used. It should be noted that tracked machinery is not used in the logging industry of Belarus. At the same time, conditions for its rational use exist in a number of regions; these are found in the areas of Gomel and Vitebsk SPFA, where the forests are often located on poorly boggy soils, which make difficult the movement of wheeled machinery, and in some cases not possible. In this regard, an important area of research should be framed around the study of the machines' compatibility with the forest environment in terms of using different wheeled, combined and tracked locomotion systems, and their compliance with the requirements of regulatory and legal acts and forest certification systems.

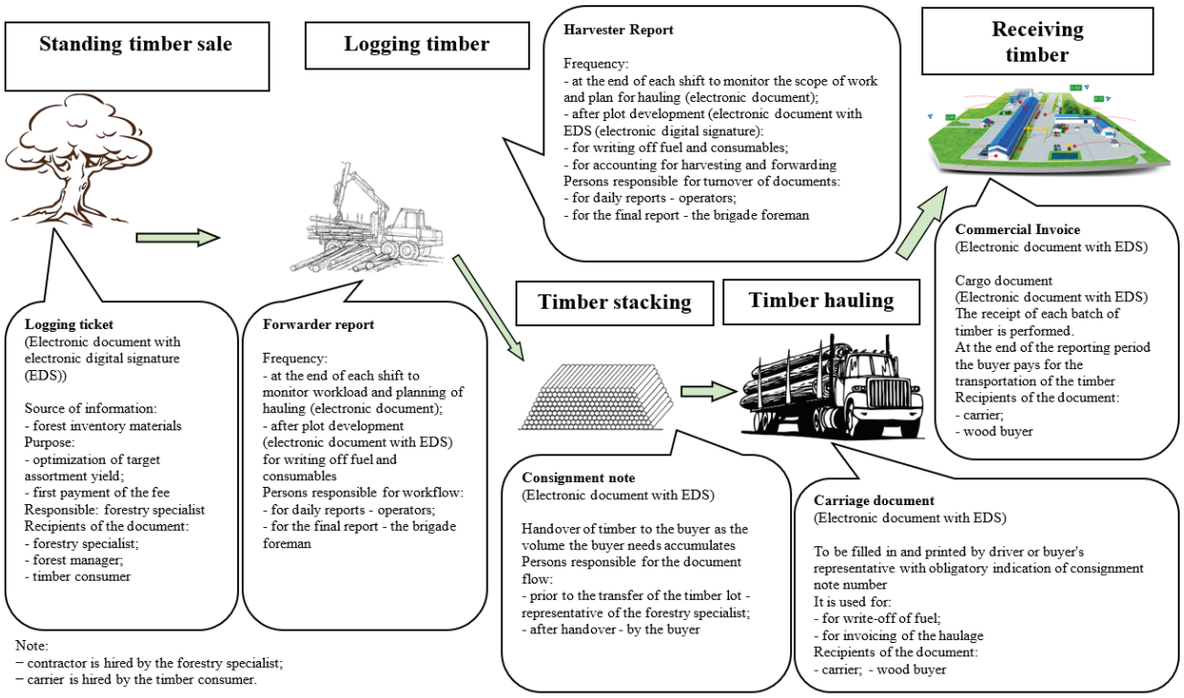

Figure 3: The main concept behind the unified state automated information system (USAIS)

The control over the operation of machines used in timber harvesting operations is carried out by installing navigation systems that can transmit data through mobile operators' networks. Such systems are installed on 75% of harvesters, 79% of forwarders, 95% of log trucks, 90% of forestry tractor trailers, as well as on a number of service cars and other equipment involved in the production. Wide dissemination of the navigation equipment will make it possible to switch to the unified state automated information system (USAIS) by the end of 2021. Its general structure is shown in **Figure 3**.

5. CHARACTERIZATION OF THE FOREST ROAD NETWORK

For the transportation of round timber in the Republic of Belarus, public roads and departmental (forestry) roads are used. The total length of the network of public roads in the country is 86,967 km. Among them, 15,929 km are republican roads and 7,038 km are local roads. At the same time, all republican roads hold an improved pavement system. The density of the public road network is of 418 km × 1000 km^{-2}. The ability to move heavy timber trucks on a number of republican roads is limited by their carrying capacity. Thus, 1,884 km of national roads have a carrying capacity of 6 tons per axle, 11,954 km - 10 tons per axle, and 2,091 km - 11.5 tons per axle.

In addition to general-purpose roads, forest roads are constructed and operated in the country. The density of forest roads should be 0.5 km × km^{-2} in order to ensure the efficient development of the forestry. Currently, this indicator is of 0.27 km × km^{-2}. For the purposes of developing the road and transportation network in forested areas, in the period of 2011-2015, a state program for their

construction was in effect. As a result, 570.1 km of forest roads were commissioned in 5 years. In 2016-2020, the subprogram "Construction of forest roads" of the State program "Belarusian forest" was in effect, which allowed the commissioning of 997 kilometers of forest roads in the forests managed by the Ministry of Forestry from 2010 to 2019. In 2019, 17 forest roads with a total length of 102.5 kilometers were put into operation, and in 2020 about 105 kilometers of roads were constructed. Therefore, there is an increase in the rate of forest road construction.

The average construction cost of 1 kilometer of forest road is of 69.19 thousand euros, therefore 69.19 euros per meter of constructed road. It should be taken into account that many roads are built in the forest areas dominated by soils with a low bearing capacity. Geosynthetic materials are used in the constructions of such roads, which leads to a significant increase in the strength of the constructed road systems. In general, the procedure for the construction of forest roads in the country is determined by technical code of practice (TCP) 500-2016 (33090) "Forest roads. Design standards and rules of construction".

6. CURRENT AND CRITICAL CHALLENGES IN THE FORESTRY AND FOREST ENGINEERING OF BELARUS

Despite the systematic development of the forestry in the Republic of Belarus, to date, several problems have arisen, the solutions of which have either already begun or will be implemented in the near future. The most important challenges are the following:

- Uneven age and species composition of the forests. As a result of the World War II, the amount of mature forests in the country declined significantly (in 1945, the forest cover was not more than 21.5% of the total country area). Only now we have managed to bring the share of mature and overmature forests up to 0.16-0.18% of total forest cover (forest cover of about 40%). At the same time, 30.7% of the species composition of such forests is made up by soft broadleaved species, such as birch and alder. Improvement of the age and species structure of forests is a rather long process. Scientists of the Belarusian State Technological University, the Forest Institute of the National Academy of Sciences of Belarus, the Kuprevich Institute of Experimental Botany, the Institute of Microorganisms of the National Academy of Sciences of Belarus, and the Institute of Microorganisms of the National Academy of Sciences of Belarus are working on ways to accelerate it;

- Drying and mortality of the coniferous forests. This problem is typical not only for Belarus, but also for the neighboring countries. Shrinkage of areas covered by spruce and pine occurs as a consequence of climate change and the spread of insect pests. For these factors, the limits of country territories are very conditional, so the solution of these issues must be intergovernmental. The ways to combat this problem are being developed within the framework of projects of the state scientific and technical program "Forests of Belarus";

- The ageing of the forestry machinery fleet. Due to the fact that the Ministry of Forestry is the main logging company and forest owner in the country, the aging of the machine fleet is more noticeable than in the case of private ownership of forests and machines. In the coming years, the country will have to seriously reequip and replace its logging machinery. For this purpose the

country has several forest machinery enterprises of its own: OJSC Amkodor - managing company of the holding company" (specialized forest machinery and equipment: harvesters, forwarders, skidders, mulchers, forest chassis, trailed carts, choppers), OJSC Minsk Tractor Plant (harvesters, forwarders, trailed carts, forest modifications of tractors manipulators, technological equipment for forestry work), OJSC Minsk Automobile Plant (sorting trucks, chip carriers, trailers and semi-trailers, choppers). New models of multifunctional machines have been already developed;

- High costs of logging in conditions of low access forest areas. As noted earlier, about a quarter of the country's forests are on soils with low bearing capacity. Increasing the efficiency of logging in such conditions is a complex task. It is mainly solved by increasing the transport accessibility of such forests (construction of roads), improving harvesting technologies, development of new means of mechanization (including: the use of rope units, the use of light multi-support machines with low ground pressure indicators, a general increase in machine efficiency), increasing the training of engineers and workers in the field of timber harvesting operations;

- Underdevelopment of information systems of timber accounting and transactions with it. To date, the Unified State Automated Information System is at the stage of industrial testing and has not been introduced everywhere. However, its advantages are already in demand on the market of wood raw materials. The main problem in the near future will be the integration of accounting systems for timber harvested by harvesters into it. There are at least 5 different timber accounting systems installed on harvesters in the country. The practice of verification and calibration of such systems has not been widely implemented so far.

7. RESEARCH AND TECHNOLOGICAL DEVELOPMENT – STATE OF THE ART IN RELATION TO BELARUSIAN FORESTRY AND FOREST INDUSTRY

The effort of providing efficient solutions to the above problems is carried out at different levels. In the scientific direction, it takes place within the framework of state scientific and technical programs: "Forests of Belarus", "Machine building and machine building technologies", "Resource saving, new materials and technologies", a number of regional programs within the framework of the EAU, as well as with the financial support of the World Bank. A considerable amount of attention is paid to the use of wood raw materials as a local fuel and energy source and the impact of logging on the environment. These studies have found a significant reflection in the formation of sustainable development goals of countries.

In addition, we should note a number of scientific and practical problems and tasks of paramount importance for the development of forestry-related production at the sawmills, as part of the forestry industry. For the authors of the article, this problem is the closest and constitutes the immediate area of scientific research.

8. CONCLUSIONS

1) The depreciation of the fleet used in timber harvesting and transportation puts the forest industry and forestry enterprises under the task of its modernization. Old and technically worn-out machines should be replaced only by the new ones, more advanced machines with improved characteristics. The domestic enterprises of forest machine building are those facing the task of creating such machines. Both tasks should be solved jointly, which requires appropriate scientific and technical support. Within its framework, it is important to consider the following issues:

    a. The operating efficiency of the harvester-forwarder systems, taking into account the type of harvesting operations, operating conditions, energy and layout characteristics of the machines;

    b. Methods and techniques of the harvester and forwarder operators, taking into account the need to increase the work pace of the harvester-forwarder system, and the variability of the subsequent use of harvesting residues;

    c. Ecological compatibility of machines with the forest environment in terms of the use of different wheeled systems, the use of combined and tracked systems, as well as the compliance with the requirements of regulations and forest certification systems.

2) It is advisable to develop guiding documents or instructions on existing and prospective systems of machines, to implement various logging and forestry technologies based on the principles of sustainable forest management, to create sets of technological schemes for different types of harvesting operations and methods used, to develop recommendations for amendments to existing regulations in the field of timber harvesting operations or, if necessary, to create new regulations;

3) Based on the analysis of the collected data on the volume of harvested timber it was found that the level of timber harvested by multifunctional machines in the forests owned by the enterprises of the Ministry of Forestry exceeded 50%. At the same time, most of the timber harvested by machines is obtained with the involvement of third-party organizations. The structure of the harvesting machines fleet in the enterprises of the Ministry of Forestry could be considered as well established. Its further change has a weak tendency for a proportional increase of each type of machines. Significant structural changes are possible in the area of mechanization of forest operations, especially for thinning and clearing, where the existing machinery does not meet the requirements adequately or it is purchased from foreign manufacturers. National enterprises that are developing and releasing forestry machines have formed and are updating the assembly lines of harvesting machines designed and built for felling and processing as a primary use. A significant disadvantage is the lack of domestic small-sized machines capable of working in thinning operations;

4) It is also noteworthy that there is a significant trend of increasing installation of navigation and information equipment on logging machines, which in general

contributes to a more uniform transition to the unified state automated information system;

5) The analysis of the technical condition of the machine fleet for a number of GPLHF has established a trend of reducing the volume of harvesting with increasing age of the machines. In general, significant changes were observed in the age of machines: more than 3 years for harvesters and more than 5 years for forwarders. However, when comparing the volumes harvested by machines of different ages in the country as a whole, there is no such a clear correlation between these indicators. There are not isolated cases in which machines of significantly older age harvest larger volumes of timber. The reasons for this are the significant differences in operating conditions of machines in the regions of the country and the difference in the experience of operators. In this regard, there is a need for scientific and practical research into the operating conditions of machines in different regions of the country. For such an attempt, the most influential factors should be noted: soil and ground driving conditions, forest type, type of harvested assortments by species, size and quality, thickness of the forest floor etc.;

6) Along with the noted directions of development of the machine fleet, special attention should be paid to the study of forestry machinery ownership costs and its impact on the cost of production.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu în română: *Silvicultura în Republica Belarus: Starea actuală şi direcţii de dezvoltare*

Rezumat: *Lucrarea prezintă date cu privire la starea actuală şi prospectele de viitor legate de dezvoltarea silviculturii şi industriei forestiere în Republica Belarus. Sunt tratate aspecte legate de structura pădurilor, specii, vârste şi compoziţii, precum şi aspecte legate de contribuţia pădurilor în economia ţării. Se trec în revistă tipul de management şi proprietate a pădurilor, lucrarea tratând la un nivel mai adâncit aspecte legate de mecanizarea operaţiilor forestiere, prin descrierea tehnologiilor utilizate în sectorul forestier. Pe baza rezultatelor prezentate se indică direcţii de îmbunătăţire a flotei de utilaje. O atenţie sporită s-a acordat analizei nivelului de informatizare a proceselor de producţie forestieră precum şi structurii reţelei de drumuri forestiere şi influenţei acesteia asupra eficienţei producţiei. La final, lucrarea caracterizează principalele provocări ale sectorului forestier din Republica Belarus şi creionează principalele soluţii pentru rezolvarea problemelor curente, inclusiv prin descrierea principalelor programe şi proiecte ştiinţifice relaţionate cu astfel de probleme.*

Cuvinte cheie: *Belarus, tehnologie, harvester, forwarder, maşină de tocat.*

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Forestry of Ukraine: Current Situation, Challenges and Ways to Tackle Them

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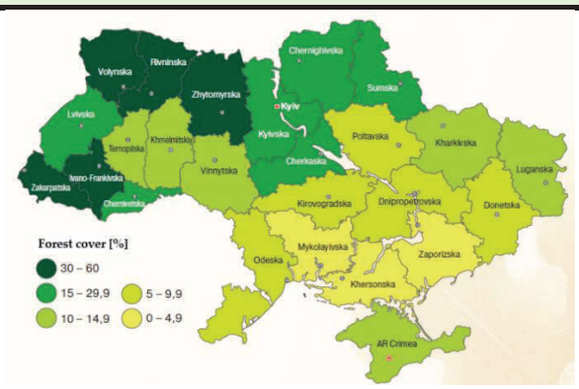
HIGHLIGHTS

- Ukraine's forests perform many functions.
- Forest resources meet the country's need for timber, and their use is done sustainably.
- Ensuring the sustainability of forests requires comprehensive technical re-equipment and introduction of innovative and environmentally sound technology in forestry.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper analyzes the current state of the forest sector in Ukraine, by the special features of forests and forest management. It has been found that the forest cover does not meet the optimal level, which should be 20 %. It has been proved that the actual wood use is smaller than the allowable cut, ensuring a sustainable forest management. The total volume of the harvested merchantable timber is around 21-22 million m³. The analysis of the forest roads network in Ukraine has shown that its density is insufficient and several times lower than in Europe. To ensure a sustainable forest development it is advisable to work out a strategy for the development of the forest industry in Ukraine. The main objectives of such a strategy should be those of improving the forestry regulatory framework, the models and mechanisms of forest public administration, the state's financial system of forestry and economic support, and of developing state programs for the forest roads construction, technical re-equipment, introduction of modern innovative and environmentally-friendly technologies for forest growing, care, protection, conservation and logging.

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1. INTRODUCTION

The forests of Ukraine are its national wealth and by their purpose and location perform mainly water-conservation, protection, sanitary-hygienic, health-improving, recreational, aesthetic, and educational as well as other functions. In addition, forests are a source to meet the needs of society for forest resources.

All forests on the territory of Ukraine, regardless of the land on which they grow and in whose ownership they are, form the Forest Fund of Ukraine, which is protected by the State. The rational use and protection of forest resources is currently an urgent task, the resolution of which guarantees the economic, environmental and social stability of our country.

The period of independent formation and development of Ukraine is the period of the creation of a market-oriented economic system, new social relations and values. Political and economic reforms have posed a number of new challenges for the country's forestry, related to reprioritization within the society as a whole. Modern views of the role of forests not only as a source of timber and forest products, but also as a significant environment- and climate-forming factor, have necessitated the improvement of existing and the development of new strategic approaches to the forestry management.

The purpose of this paper is to study and analyze the current state of forest management in Ukraine, to establish the main trends and urgent problems and to outline promising directions for the development of the country's forest complex for the fullest possible implementation of its existing potential.

2. METHODS

During this research the methods of empirical and experimental-theoretical analysis, as well as the methods of mathematical statistics, were used. To achieve the objective, it was necessary to collect and analyze a significant amount of information, in particular data characterizing the state of forest resources and their contribution to the country's economy (the amount of forest stock, the rate of forest cover, age and species composition), forest owners and users, peculiarities of forest management (volumes and methods of logging and forest regeneration, the state and specifics of forest management planning, monitoring and certification, forest protection against pests, diseases and fires, electronic system of timber tracking), characteristics of the forest road network, technical support and the degree of forest-related processes mechanization etc. A significant part of such data was obtained from open sources, such as annual public reports of individual forest users, State statistical authorities, and alike. Methods of mathematical statistics were used for data processing and generalization.

However, some information, such as current data on technologies and machinery used for logging, reforestation and road construction, was difficult to find in open sources. The professional literature often lacks these data or the data may be irrelevant (outdated) due to the rapid pace of

changes in the forest road construction and technical support of forest-related processes. For this reason, to process and generalize the forestry engineering data, the empirical research methods (observation, measurement, interviewing individual specialists and experts, scientists, representatives of forest users and contractors performing certain works) were used. To establish individual characteristics, the optimal forest cover and density of forest roads in particular, the analogy and comparison methods were used.

3. RESULTS

3.1. Characteristics of Forest Resources and their Contribution to the Economy

The total area of forest land belonging to Ukraine is of 10.4 million hectares, and it includes 9.6 million hectares covered with forest vegetation. The forest cover of Ukraine is 15.9%. But, despite the rather small forest cover of the territory, Ukraine ranks 9th in Europe in terms of forest area and 6th in terms of timber stocks [1].

The main features of forests and forestry in Ukraine are:

- Relatively low average level of forest cover of the territory;
- Forest growth in different natural areas (Polissya, Forest-steppe, Steppe, Carpathians and Crimea);
- Mainly environmental values of the forests and their large share (about 50%) with a regime of limited forest use;
- A large share of protected forests (over 16%), which has a steady upward trend;
- Affiliation of forests by numerous permanent forest users;
- A large area of forests is in the area of radioactive contamination, etc.

The vast majority of forests are state-owned. About 1.3 million hectares (13%) of forest land are in the permanent use of communal enterprises subordinated to local authorities' bodies. The share of privately owned forests is less than 0.2% of the total forest land area. About 800 thousand ha of forest lands of state ownership is not provided for use and attributed to reserve lands.

Ukraine has historically formed a situation with subordination of state forests to numerous permanent forest users (managed forests are given for permanent use to enterprises, institutions and organizations of various ministries and agencies). The largest area of forest land (about 73%) is used by forestry enterprises, which are coordinated by the State Forest Resources Agency of Ukraine (SFRA). The main tasks of the SFRA are:

- Implementation of state policy in the field of forestry and hunting, as well as protection, conservation, rational use and reproduction of forest resources;
- Implementation of public administration in the field of forestry and hunting;

- Participation in the development and implementation of national, interstate and regional programs in the field of protection, increasing of productivity, management and regeneration of forests.

The structure of the State Forest Resources Agency of Ukraine consists of its territorial bodies, enterprises, institutions and organizations of state ownership. Forest management at the local level is carried out by the state forestry enterprises. They are responsible for all types of forest operations. In addition, some enterprises have primary wood processing facilities.

An effective tool for forest conservation is the creation of natural protected areas. To date, 16.8% of forests belonging to the State Forest Resources Agency of Ukraine are protected. It should be noted that over the past 30 years, the area and number of natural reserves in the forest lands has increased 4 times. In **Figure 1** is shown the distribution of forests by their main target functions.

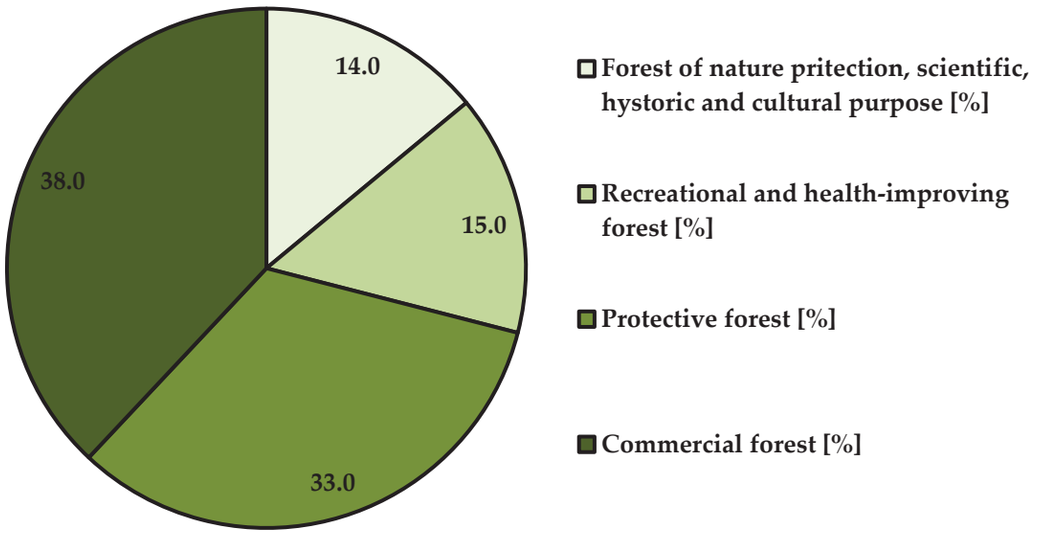

Figure 1. Distribution of Ukrainian forests by their main target function

Conditions for afforestation in Ukraine are extremely heterogeneous, so forests are distributed throughout the country unevenly (**Figure 2**). Forest cover in different natural areas has significant differences and does not reach the optimal level at which forests have the most positive effect on climate, soils, water resources, counteract erosion processes, as well as to provide the maximum amount of wood. According to experts, in order to achieve the optimal level of forest cover in Ukraine, which should average 20%, it is necessary to plant about 3 million hectares of trees. The forest structure in relation to age is dominated by middle-aged plantations, while the proportion of harvestable stands is 18.7% (**Figure 3**). The average age of forests is over 60 years, and there is a gradual aging of forests, which leads to the deterioration of their sanitary condition. Ukrainian forests are composed by more than 30 species of trees, among which the dominant ones are the pine (*Pinus silvestris*), oak (*Quercus robur*), beech (*Fagus sylvatica*), spruce (*Picea abies*), birch (*Betula pendula*), alder (*Alnus glutinosa*), ash (*Fraxinus excelsior*), hornbeam (*Carpinus betulus*), fir

(*Abies alba*). Coniferous plantations hold 43% of the total area, in particular, pine - 35%. Hardwood plantations hold 43%, particularly oak and beech - 37% (**Figure 4**).

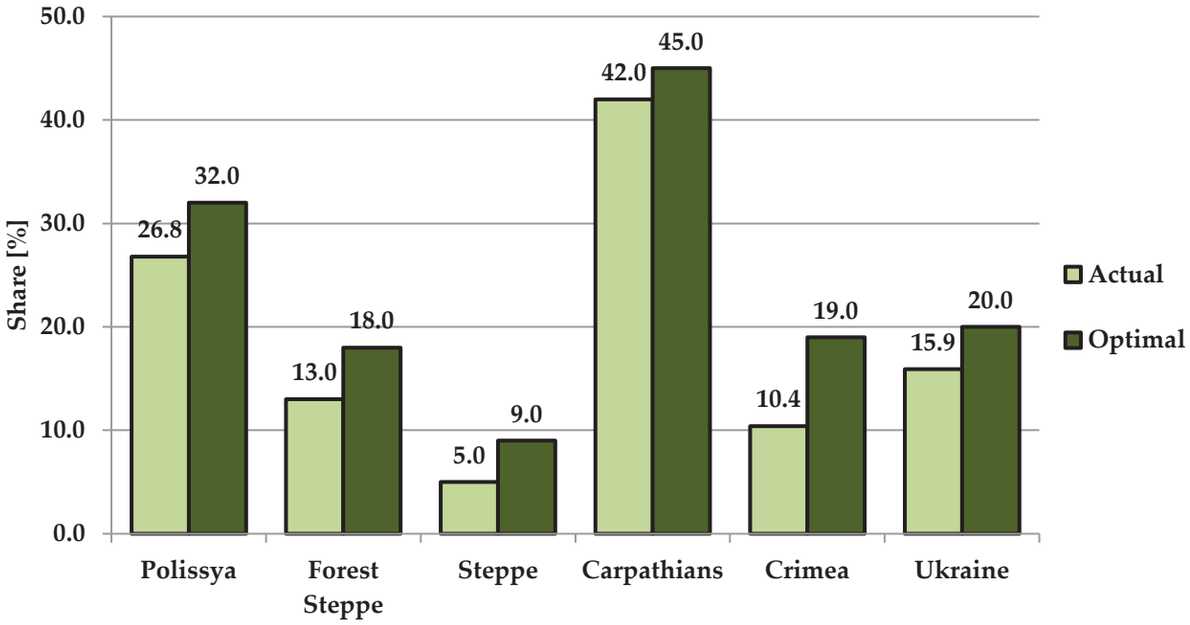

Figure 2. Forest land-cover share on natural regions in Ukraine

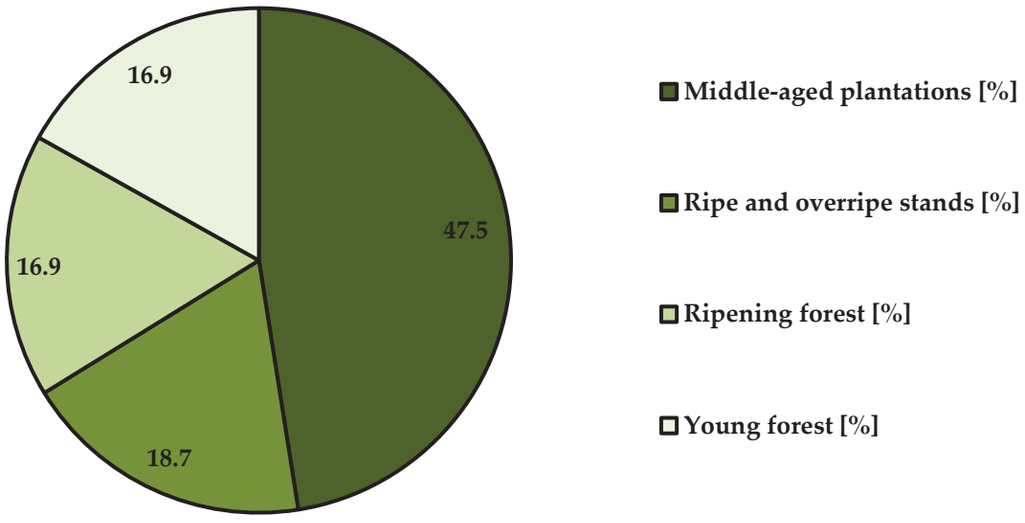

Figure 3. The age structure of Ukrainian forests

The growing stock is estimated at 2.1 billion m^3. The forests of Ukraine grow an average rate of 35 million m^3 per year. The average annual growing stock in the forests of the State Forest Agency is 3.9 m^3 per 1 hectare and ranges from 5.0 m^3 in the Carpathians to 2.5 m^3 in the Steppe

zone. There is a gradual increase in stock, which confirms the significant economic and environmental potential of forests.

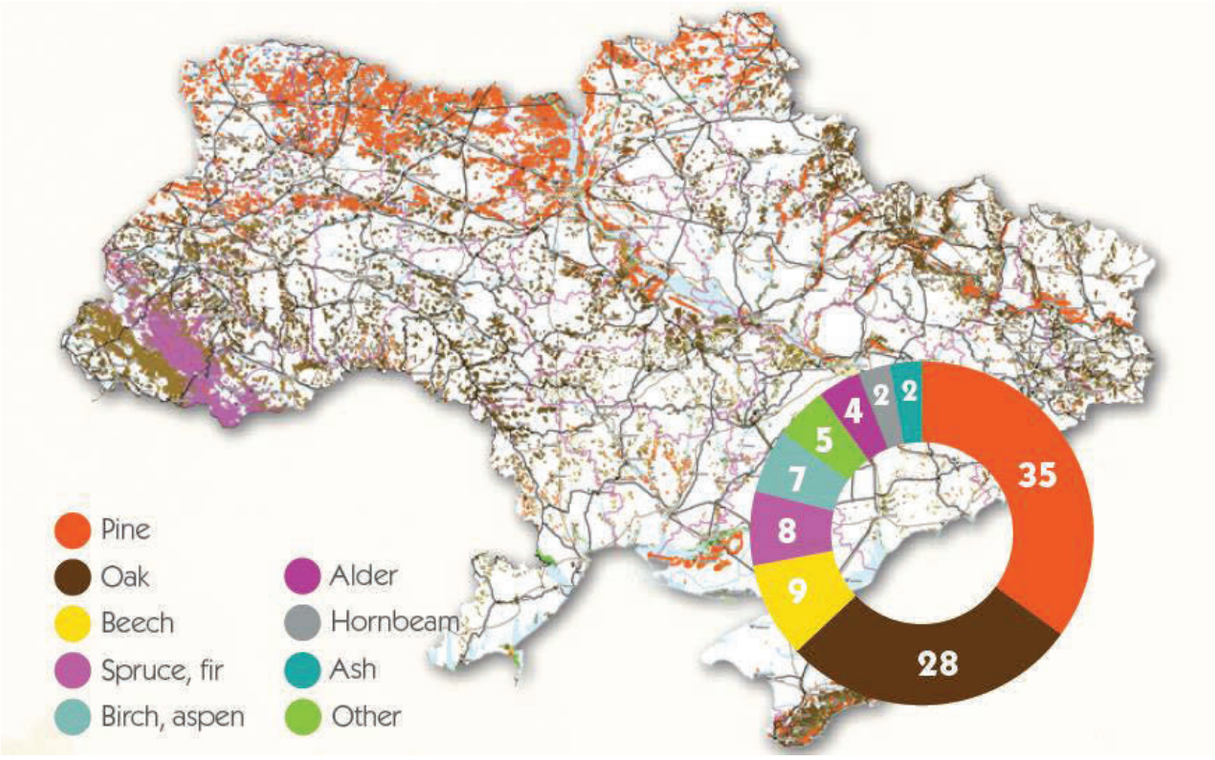

Figure 4. Species composition in the Ukrainian forests. Legend: numbers represent the shares.

In the forests of the State Forest Agency, the stock per hectare is about 240 m^3 (7^{th} position in Europe); however, in Ukraine this indicator is lower - 218 m^3 (ranking Ukraine on the 9^{th} position in Europe) – mainly due to the forests of reformed agricultural enterprises, which are spared and are in a bad sanitary condition.

The activity of forestry enterprises belongs to those types of economic activity, the share of which in the structure of Ukraine's economy is insignificant: the value of their products in the total structure of gross domestic product is 0.40 - 0.45% [2]. At the same time, the development of local communities and business, job creation, formation of a healthy ecological environment, etc. depend on its efficiency.

3.2. Forest Management and Use of Forest Resources

Forest management involves the implementation of a set of measures for the protection, conservation, rational use and extended forest regeneration. The main requirements for forestry in Ukraine, the use of forest resources, regeneration of forests, increasing their productivity,

organizing protection and conservation, financing relevant measures etc., are regulated by the Forest Code of Ukraine [3]. Enterprises, institutions, organizations and citizens conduct forest management taking into account the economic purpose of forests, environmental conditions, and are obliged to:

- Ensure the strengthening of water-protection, protective, climate-regulating, sanitary and hygienic, health-improving and other useful functions of the forests in order to improve the environment and protect human health;
- Ensure continuous, sustainable and rational use of forest resources to meet the needs of manufacturing industries and population in timber and other forest products;
- Carry out forest regeneration;
- Ensure the increased productivity, improvement of the qualitative composition of forests, as well as the conservation of biotic and other biodiversity in forests;
- Protect forests against fires, pests and diseases, illegal logging and other damage;
- Ensure the rational use of the forest areas.

Forest resources are the basis of the forestry economics and the volume of their use is set to ensure the continuity of different forest functions (conservation, protection, sanitation, health-improving and economic). As a result of use of the forest resources, forestry gets its own funds to cover regeneration, protection and other forest-related measures (recently the state has stopped the forestry financing). Wood is harvested within the final fellings, thinning, sanitary and other cutting types. The limit of timber harvesting within final felling is provided by allowable cut, which should be approved taking into account the principles of continuity and sustainability of use of forest resources. Recently, allowable cut was set at 9.6 million cubic meters, and its actual implementations was up to 90% [1]. So, the actual volume of forest use is smaller than the allowable cut, which ensures an environmentally sustainable forest management (**Table 1**).

Table 1. Volumes of final felling in the forests belonging to the State Forest Resources Agency of Ukraine (merchantable timber, million m³)

Indicators	By years				
	2015	2016	2017	2018	2019
Allowable cut	9.6	9.6	9.8	9.9	9.6
Actual cut	8.4	8.4	8.5	7.5	7.4
% of the allowable cut	88	88	87	76	77

The total volume of merchantable timber harvested from all fellings is around 21-22 million cubic meters (**Table 2**). Timber harvested within final fellings stands for 40% of the total amount of harvested timber. The potential reserves and capacity of Ukrainian forests are large and, according to expert opinions, not fully utilized. The use of annual growth is about 64%, while in Europe this figure is 70-80%. Taking into account the increase in the area of mature and overmature stands in Ukraine, an increasing of amount of harvested timber can be foreseen for the coming years.

Table 2. Volumes of merchantable timber harvested in the forests of Ukraine, (million m³)

Indicators	By years				
	2015	2016	2017	2018	2019
Total volume, of which	21.9	22.6	21.9	22.5	20.9
- final felling	9.1	9.3	9.4	8.3	7.9
% of the total volume	42	41	43	37	38
- thinning and other felling	12.8	13.3	12.5	14.2	13.0
% of the total volume	58	59	57	63	62

It should also be noted that since 2017 there has been a steady trend towards a decrease in the volume of clear cuttings. This is due to the adopted policy of phased transition from clear to gradual and selective cutting systems, which is typical within the European Union.

The main task of forest users is the cultivation and regeneration of forests. According to the legislation, any area of clear cuttings has two years during which the forest needs to be restored. Such a period is due to prepare the soil and carry out other activities necessary for planting a forest or promoting its natural regeneration. Reforestation is usually carried out the next year after felling or sometimes, if all the conditions are met, the very same year. Reforestation of harvested forest areas are increasing and are carried out by means of forest regeneration and afforestation. Over the past two years the annual average work of forest regeneration covered 50 thousand ha (**Figure 5**). The decrease in reforestation work was due to a decrease in the volume of clear cuttings and a consistently higher level of natural regeneration.

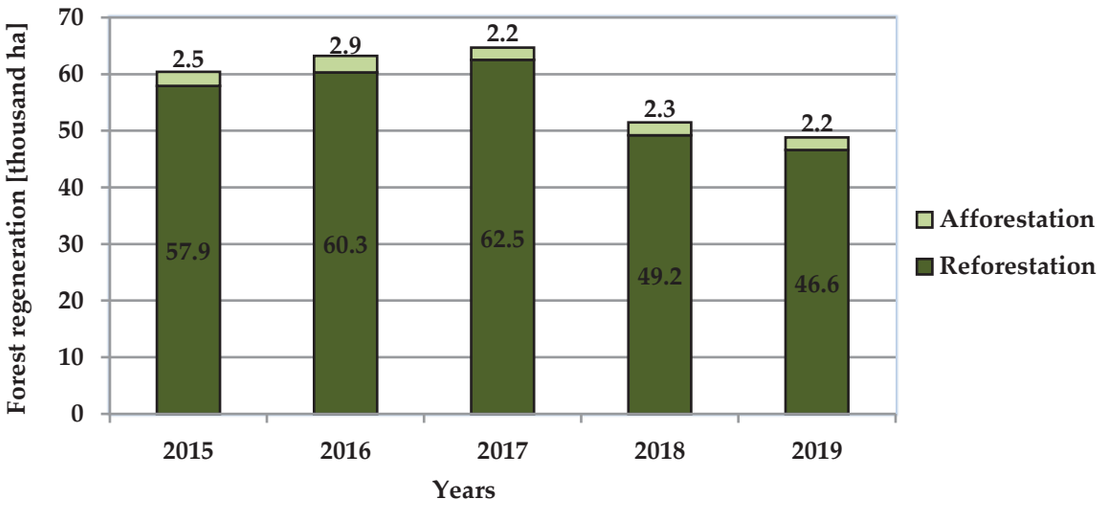

Figure 5. Dynamics of forest regeneration in Ukraine

To sustain large-scale afforestation operations, sufficient facilities were created. State forest enterprises, subordinated to the State Forest Resources Agency of Ukraine, own 3.4 thousand ha of forest nurseries, 11 ha of greenhouse complexes, where about 246 million standard seedlings and 3.6 million plants for landscaping were grown in 2018. To receive high-quality forest seeds, a permanent 40.9 thousand ha forest base was established, including:

- 2.1 thousand ha of plus stands;

- 1.1 thousand ha of permanent seed orchards;

- 15.6 thousand ha of permanent seed stands;

- 22.0 thousand ha of genetic reserves;

- 4.6 thousand plus trees.

The current increasing trend of the state forest cover is one of priority areas of forest management development. In Ukraine, every second hectare of forest is created artificially. Over the last half century, more than 1,4 million ha of soil protection stands were planted on agricultural non-usable lands, of which 150 thousand ha along the banks of small rivers and reservoirs. In addition, there were planted 440 thousand ha of forest shelter belts to protect more than 13 million ha of arable land.

Forest management planning, as a set of measures aimed to organize an effective forest management, is required for all forests in Ukraine. Forest management planning provides authorities and forest users with valuable information about the current state of forests, forest resources, qualitative and quantitative changes of forest reserves, makes forecasts, determines scientifically-based regulations of sustainable, rational and environmentally balanced forest management, as well as develops a range of measures for forest regeneration, conservation and protection. Currently, two categories of forest inventory are carried out:

- Economic (basic forest management planning);

- Operational (permanent forest management planning);

Basic forest management planning is the basis for working out promising projects on forestry organization and development for a 10-year period. The main objective of permanent forest management planning is to maintain up-to-date information about the forests. Based on primary and permanent forest management planning data, forest maps and geospatial databases were created and maintained up-to-date. Forest maps and geospatial (mapping) databases were established for almost all forests subordinated to State Forest Resources Agency of Ukraine, as well as for large forest areas of other forest users. Databases are part of the informational support for a sustainable forest management and are often used for production and scientific purposes.

Regulatory framework for forest monitoring includes the Forest Code of Ukraine, Laws of Ukraine "On Environmental Protection" and "On Flora". Forest monitoring is part of the state environmental monitoring system. According to the Regulation on the State Environmental Monitoring System approved by the Cabinet of Ministers of Ukraine, State Forest Resources Agency of Ukraine is responsible for monitoring of forest soil, forest vegetation and game fauna. Ukraine joined the pan-European process of forest protection and signed the Strasbourg Resolution S1 on monitoring of forest ecosystems (Resolution "European Network of Permanent Sample Plots for Monitoring of Forest Ecosystems"). The necessity of forest monitoring is caused by the implementation of a number of other international obligations of Ukraine, in particular: the UN Convention on Long-Range Transboundary Air Pollution, the UN Convention on Biological Diversity, and the United Nations Framework Convention on Climate Change.

Forest monitoring in Ukraine is conducted in accordance with the requirements of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests within the region of the United Nations Economic Commission for Europe (UNECE ICP Forests). Monitoring under UNECE ICP Forests is carried out at two levels: Level I (large-scale monitoring), which provides a systematic collection of information on changes in forest state over time and space, and Level II (intensive monitoring), which provides an in-depth study of the impact of stress factors on forest ecosystems. Based on the forest monitoring results the overall condition of forests in Ukraine was found to be satisfactory.

Implementation of certification activities is carried out by internationally or nationally accredited companies. Such certification procedures guarantee the independence, impartiality and objectivity of the forest management assessment. Ukraine adheres to the international forest certification scheme of the Forest Stewardship Council (FSC), an international non-profit non-governmental organization dedicated to promote responsible forest management worldwide. As of March 1, 2019, the area of certified forests in Ukraine reached 4.281 million hectares (41% of forests respectively). The vast majority (97.6%) of all certified forests is in the permanent use of state forestry enterprises, subordinated to the State Agency of Forest Resources of Ukraine. Certified forests are unevenly distributed and concentrated mainly in the western and northern regions of the country.

An important focus area of forestry enterprises of the State Agency of Forest Resources of Ukraine, which requires a set of organizational and practical measures, is the protection of forests from pests, diseases and other negative impacts. As of January 1st, 2019, the total forest area affected by drought amounted to 413 thousand hectares, of which Scots pine (*Pinus silvestris*) – 222 thousand hectares, Norway spruce (*Picea abies*) – 27 thousand hectares, European oak (*Quercus robur*) – 100 thousand hectares, other plantations – 64 thousand hectares. According to updated information (2019), the total forest area affected by drought in the State Forest Resources Agency of Ukraine was 270 thousand hectares (**Figure 6**), which indicates a decline in outbreaks of bark beetle drying due to timely measures to improve the sanitary state of forests (sanitary felling).

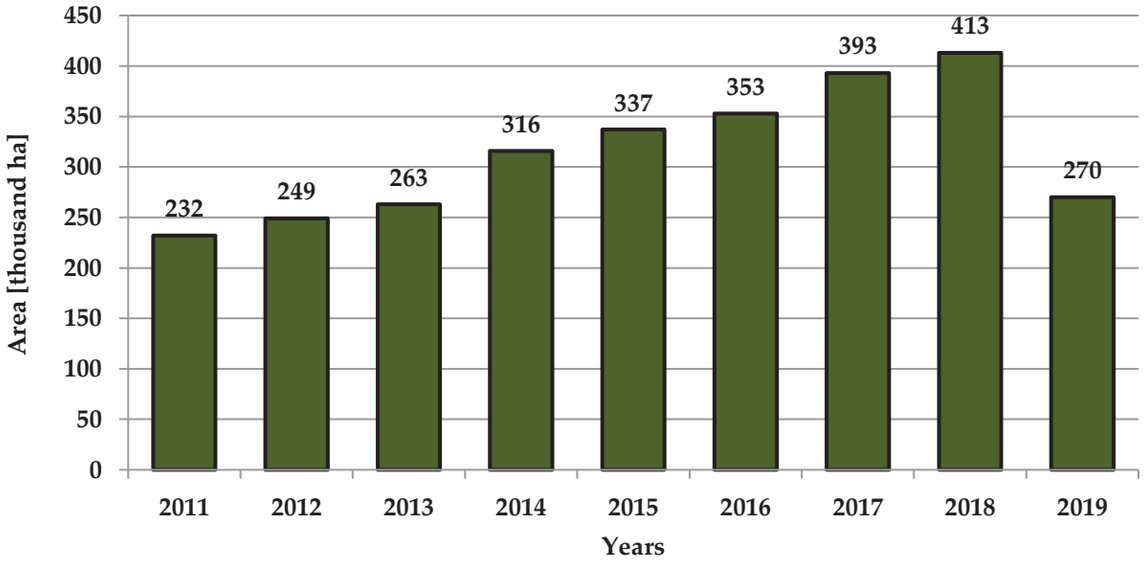

Figure 6. Dynamics of forest areas affected by drought in the State Forest Resources Agency of Ukraine

The area of plantations damaged by windfalls and windbreaks in 2019 amounted to 19.9 thousand hectares, accounting for 670 thousand cubic meters. In the past, artificial forests in the south and east of Ukraine suffered the most from pests and diseases, but recently, due to favorable climatic conditions, the forest pests and diseases have spread throughout Ukraine. The dynamics of areas affected by forest pests and diseases is shown in **Figure 7**.

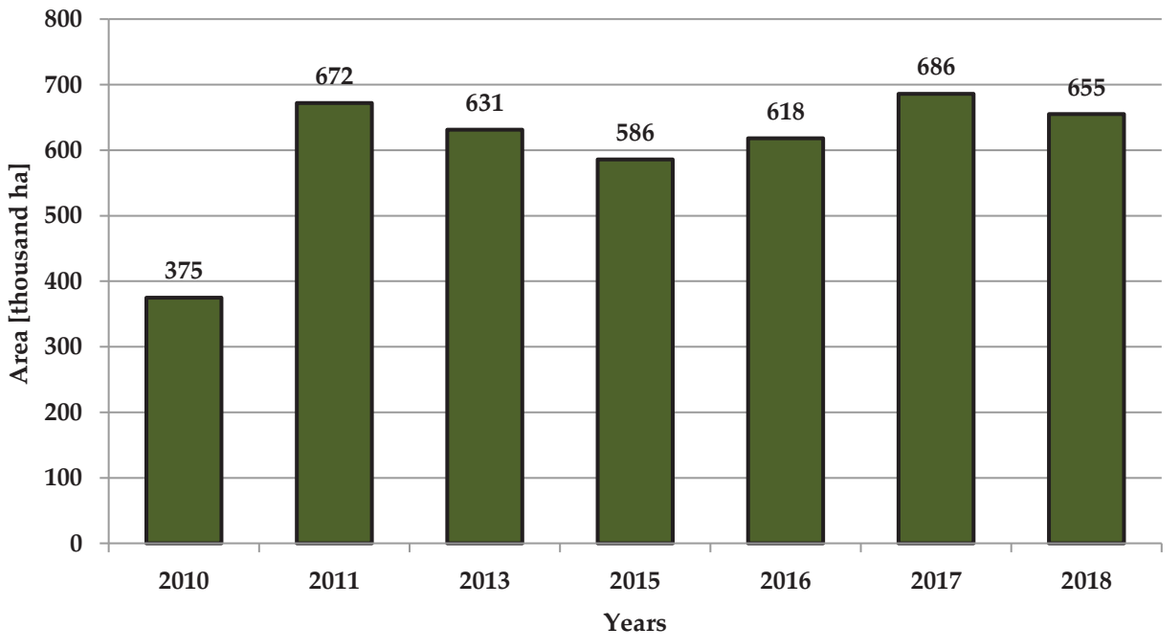

Figure 7. Dynamics of pests and diseases in forests of the State Forest Resources Agency of Ukraine

Forest protection against pests and diseases is carried out by a state specialized forest protection service, which is based on 7 state specialized forest protection enterprises. This service performs the following tasks: supervision, inventory of forest pests and diseases, forest pathology research, assignment and implementation of forest protection measures, methodological assistance to field employees. The priority of the state forest protection service is the development and implementation of biological pest control agents. Such agents are not harmful to humans or the environment and are used in densely populated areas of Ukraine and in forests where the use of chemical pesticides is prohibited.

As a rule, the main cause of forest fires in Ukraine is the violation of fire safety requirements in forests during periods of high and extreme fire danger, as well as burning on agricultural lands. The dynamics of forest fires is shown in **Figure 8**. A network of 507 fire observation towers has been set up in the forests of the State Forest Resources Agency, of which 337 are equipped with a television surveillance system. The enterprises of the State Forest Resources Agency systematically raise public awareness as to complying with fire safety requirements in forests, detecting violators of these requirements and fining them.

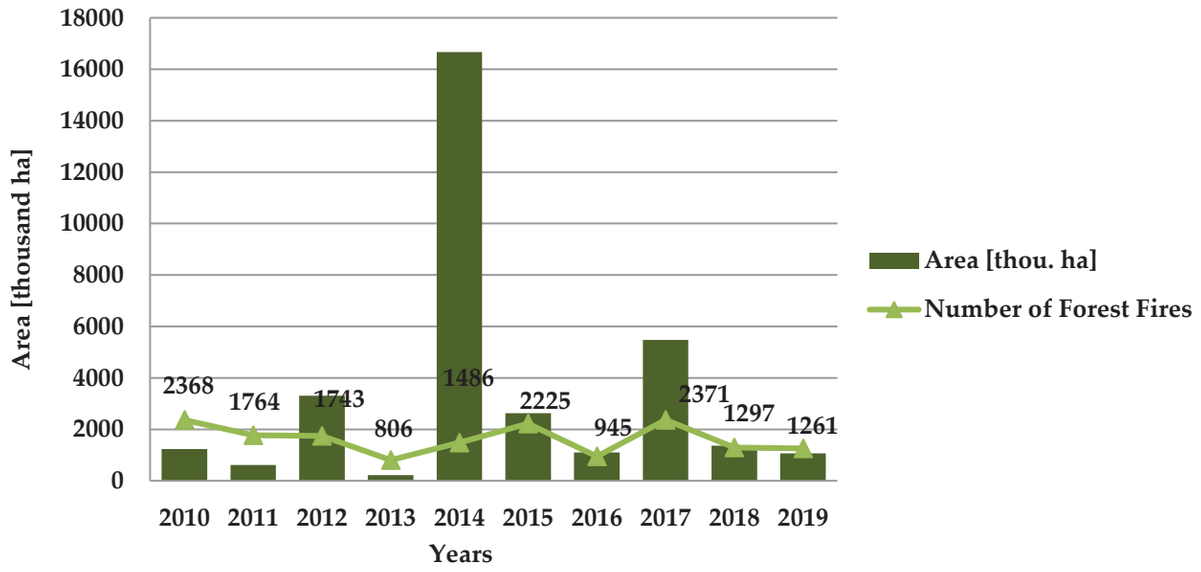

Figure 8. Dynamics of forest fires in the forests of the State Forest Resources Agency of Ukraine

More than 1.7 thousand forest units, 273 forest fire stations and about 17 thousand employees of the state forest protection center directly protect forests from fires. Forest fire departments are equipped as follows: 644 fire trucks, 467 forest fire protection modules, 1107 power pumps, 8.9 thousand back-pack sprayers, more than 2.1 thousand radio stations, etc.

3.3. Characterization of Forest Transport Network

The basis of sustainable development of forestry in Ukraine, rational and environmentally safe use of natural resources, efficient operation of tourism and recreation industries is a balanced network of forest roads. Transport routes play an extremely important role in the forestry sector of mountainous regions, where forest areas are located in large areas and are characterized by difficult terrain, soil and hydrological conditions, low concentration of harvested wood per unit area, one-sided flows of cargo and other factors.

The transport network of the Ukrainian forestry industry combines a network of skidding trails, by which it carries out the primary transportation (skidding) of timber from the felling site to loading points, and a network of forest roads to deliver wood from forest to the consumer. Skidding trails are divided into branch (within the felling area) and main (for delivery of wood to forest roads). The state of the skidding trails network is characterized by the value of the average skidding distance. Currently, the values of average skidding distances, in particular in the Carpathians, exceed the optimal several times and in some cases reach the length of several kilometers, indicating a significant distance of operational forests from forest roads, insufficient density and low branching of the road network.

According to their purpose, forest roads are divided into three types [4] (**Figure 9**):

- I type – the main directions which connect forest roads into a forest transport network and connect forests with general purpose roads;
- II type – roads that serve separate territories of the forest area, connect them or separate forestry objects with the main directions;
- III type – provides access to forestry sites and haven't further branching, as well as fire roads.

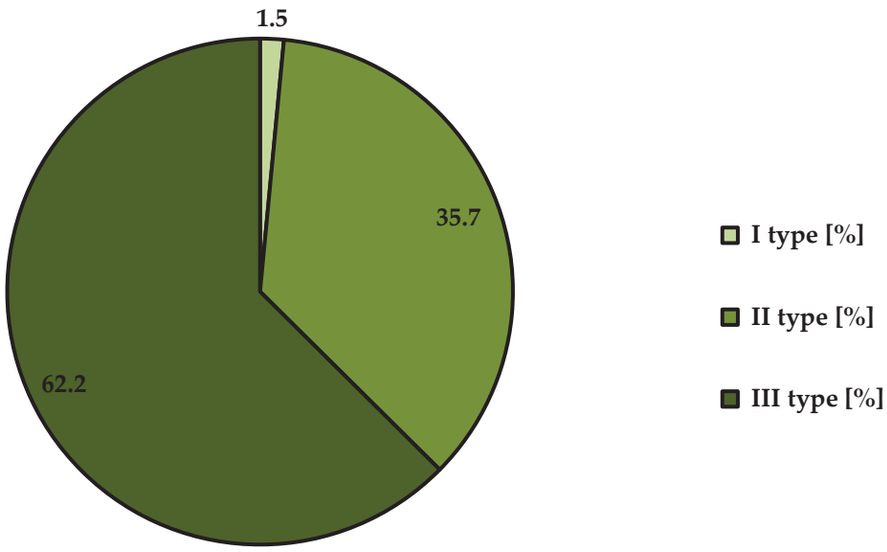

Figure 9. Structure of forest roads network in the Ukrainian forests

At the beginning of 2007, the total length of roads in the forests of the State Forest Resources Agency of Ukraine was 74.4 thousand km (including about 17 thousand km - public roads, which run through the state forest area) [5]. However, about 62% of all forest roads were type III roads (**Figure 6**). More than half of them had a width of the roadbed less than the normative values. Improved pavements (asphalt, gravel or gravel treated with binders) are rare on forest roads. More than 75% of the length of forest roads is not properly drained. Forest roads in the Carpathians are characterized by significant longitudinal slopes. On some sections, it exceeded the normative value more than twice. The year of 2007 was a turning point in the improvement of forest transport infrastructure, primarily due to the fact that in this year government funding was allocated for the construction of new forest roads and it has been introduced a new, more efficient, and more environmentally friendly, "excavator" construction technology. New forest roads began to be laid by methods of landscape design, at a sufficient distance from water flows, equipped with appropriate coverage and drainage structures.

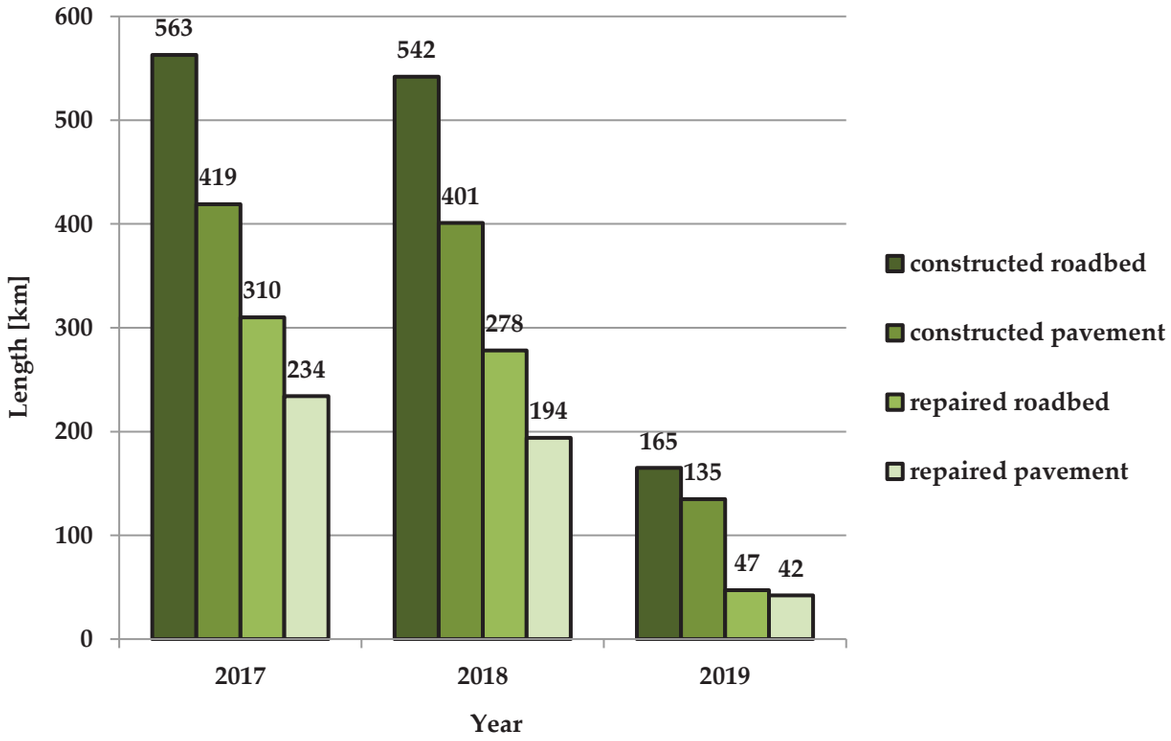

Figure 10. Construction and repairing of the forest roads in Ukrainian forests. Sources: [1, 6, 7]

Only in 2007–2016 about 5.3 thousand km of forest roads were constructed, repaired and put into operation, of which, about 1.9 thousand km in the Carpathian region. In some years, up to 1,000 km of forest roads were constructed and repaired. However, with the cessation of government funding in 2012 and subsequent changes in the regime of payment of taxes and fees by forest enterprises, construction works dropped, and in recent years amounted to several hundred km, which is several times less than the annual demand based on the position of transport development of new forests (**Figure 10**).

3.4. Characterization of Mechanization for Timber Harvesting

Two timber harvesting systems predominate in the forestry of Ukraine:

- Chainsaw - agricultural tractor with a trailer or with a winch/clam bunk (occasionally) – in Polissya;
- Chainsaw - skidder or (occasionally in inaccessible places) chainsaw - cable yarder - skidder) – in Carpathians.

Wood is transported mostly in assortments from 2 to 6 m long (85-88%) and occasionally in half-stems or stems. To perform certain types of work, including logging, construction of forest roads and so on, the state forest enterprises use their own technical means, or hire contractors from

among private companies that have the appropriate permits and technical support. In 2019, about 83% of forestry work was performed by own technical means (**Table 3**).

Table 3. Availability of equipment at the enterprises of the State Forest Resources Agency of Ukraine (January 2020)

Name	Quantity, pcs	Name	Quantity, pcs
Tractors (skidders), total, of which	3577	Special machines, total, of which	585
Caterpillar tractors	305	Graders	44
Wheeled tractors	3272	Bulldozers	163
Forwarders	3	Excavators	309
Tractor trailers, total, of which	1428	Uprooters	6
Universal trailers	1233	Loaders	48
Timber trailers	195	Compactors	3
Skidding tractor winches	91	Scrapers	8
Mobile cable yarders	5	Other	4

Consider the example of the Lviv Regional Department of Forestry and Hunting use of forest machines for harvesting and transportation of wood. The forests of this department roughly model the production and operational conditions of the whole of Ukraine. Here, annually harvests are about 900 thousand m^3 of wood in mountain, foothill and plain forests. Today, forestry enterprises of Lviv region harvest wood on their own (52%), as well as by contracting private companies (48%). So far, all the wood here is felled and processed by the use of chainsaws. As of the beginning of 2020, Lviv region enterprises used 397 chainsaws, most of which (57%) were produced by Stihl [8] (**Figure 11**).

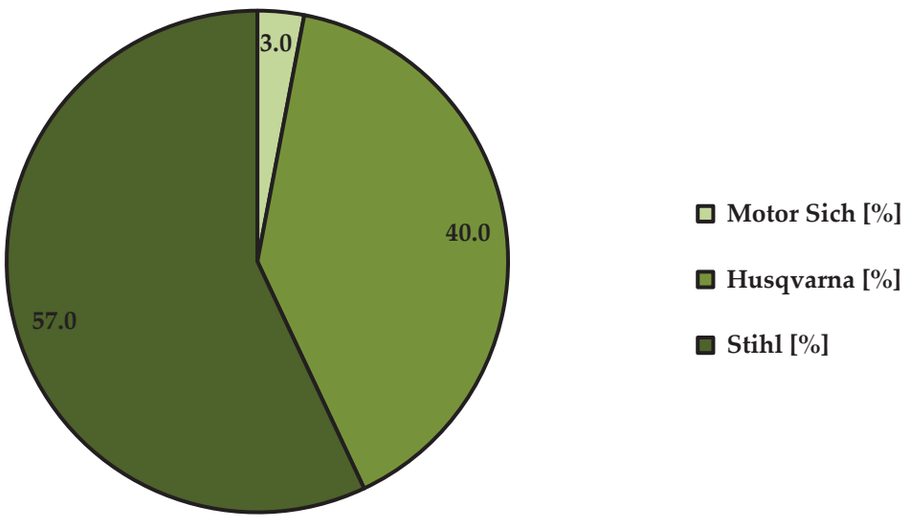

Figure 11. Availability of chainsaws at forestry enterprises of Lviv region

There have been isolated attempts to use harvesters in logging. However, these were machines of private foreign contractors. All harvested timber is usually skidded to the loading site located near a forest road. To do this, there is a variety of equipment in use, starting with the use of horse skidding and ending with the use of forwarders. Cable systems are used in difficult mountain natural and operational conditions. In total, the enterprises of Lviv region operates 2 mobile cable systems manufactured in Slovenia MOZ 300 and the Czech Republic - LARIX 3T.

Wheeled agricultural tractors equipped with skidding winches are often used for the primary transportation of timber. This greatly facilitates the work and makes it possible to pull the wood to the tractor from a distance of up to 50 m. The forestry enterprises of Lviv region use 44 tractor winches, the vast majority of which are manufactured by Tajfun [8] (**Figure 12**).

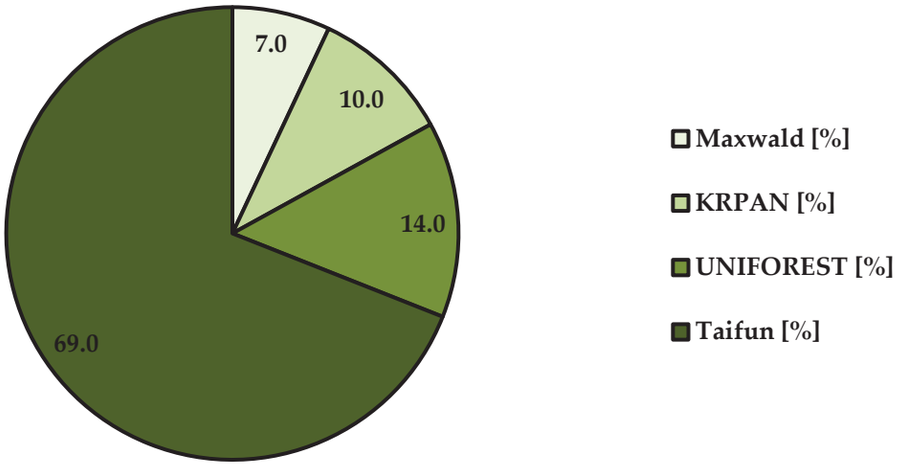

Figure 12. Availability of tractor skidding winches at the forestry enterprises in Lviv region

Recently, timber trailers with hydraulic manipulators in combination with agricultural tractors have been used to replace skidding machines. There are 32 such machines (**Figure 13**), most of which were produced by Weimer [8]. Productivity of timber transportation by timber trailers is from 20 to 50 m^3 per work shift.

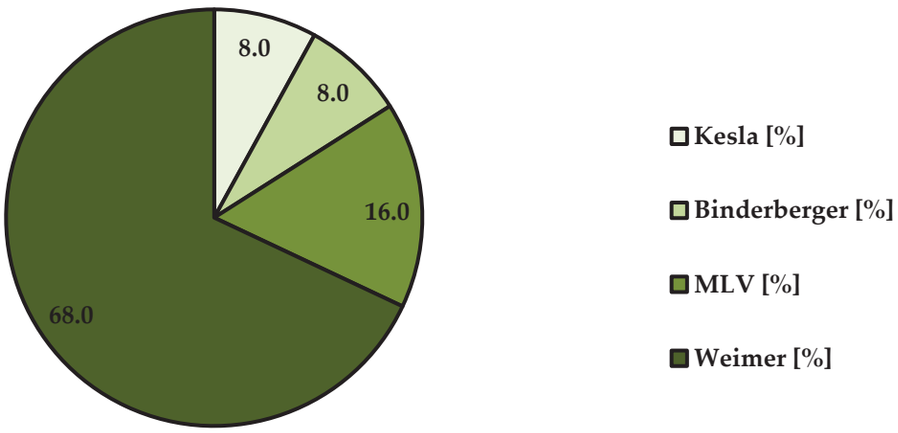

Figure 13. Availability of tractor timber trailers at the forestry enterprises of Lviv region

Forwarders show a much higher performance. However, such machines are mostly operated by contractors. The brands used in timber harvesting are Timberjack, Ponsse, Mini Bruunett, Kockums, and Valmet - total of 5 units. So far, only one of the 16 forestry enterprises in the Lviv region, SE "Brody Forestry", holds its own forwarders. There are Amkodor 2662 (3 units) produced by the Republic of Belarus [8]. The performance of these machines depends on the operating conditions and the distance transportation and it is of 30 to 120 m^3 per shift. A significant advantage of using such machines is that the wood supplied to consumers is uncontaminated, without damage, and the environmental condition of the logging sites after the work of forwarders is much better.

More than 130 units of timber transport vehicles are used for timber transportation on the basis of KrAZ, MAZ, URAL, KAMAZ and ZIL trucks. The vast majority of timber trucks are equipped with hydraulic manipulators. The most common of them are Epsilon Palfinger - 18 units, OMTL - 15 units, Weimer - 14 units and Oniar - units [8]. At the forestry enterprises of Ukraine, as a whole, operate more than 2 thousand units of timber transport vehicles (**Table 4**).

Table 4. Availability of vehicles for timber transportation at the enterprises of the State Forest Resources Agency

Name of the indicator	Value
Number of own vehicles for transporting timber, units, of which:	2199
Vehicles for stem transportation	241
Vehicles for wood assortments transportation	1450
Vehicles for non-timber transportation	508

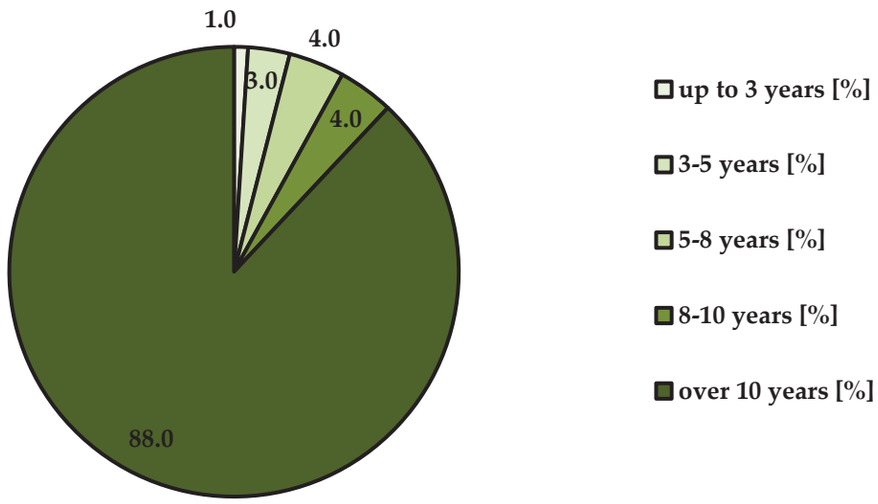

Figure 14. Age structure of the timber transport vehicles

The age structure of timber transport vehicles is shown in **Figure 14**. Among the available vehicles, machines over 10 years of age predominate (about 88%).

4. DISCUSSION

At the present stage the global community requirements are those for a forest management that should sustain the multifunctional importance of forests to ensure the stability, quality and diversity in conjunction with annual incomes and employment opportunities for local people. In addition, the recently proclaimed European Green Course, which is the European Union's strategy and program of action for the near future, calls for Europe to become the world's first climate-neutral continent. This document pays special attention to nature protection, biodiversity conservation, climate change reduction, waste management, air pollution, industrial pollution, etc., which places additional, demands on the forestry industry.

One of the most environmentally dangerous economic activities is logging. A key part of logging operations is the primary wood transportation, during which a number of factors arise that directly or indirectly affect the forest environment, in particular the development of the skidding trails. It should be noted that the amount of mechanical soil damage depends on the skidding distance. Reducing this indicator allows to reduce both the economic costs (for the construction of skidding trails, fuels and lubricants, depreciation of machines, etc.) and environmental damage caused to the forest environment. In addition, skidding trails are usually not provided with transverse drainage and during heavy rainfall become places of intense surface runoff, which reduces the hydrological role of forests. The average skidding distance is derived from the degree of branching and density of the forest road network.

Analyzing the state of the forest road network in Ukraine, we can conclude that its density is several times lower than in European countries. In particular, in the mountainous forests of the Carpathian region, where it is concentrated to 40% of the usable wood stock, the density of the road network is critically low. It is only 3.5-6.0 m/ha. However, over 10% of the forest roads length, which are on the balance of state forestry enterprises require reconstruction or repair. This state of the forest transport network does not contribute to the successful implementation of a set of environmental measures, the introduction of environmentally friendly harvesting technologies, improved care of forest plantations, involvement in the use of pest and disease-affected wood in the Carpathians and Polissya, creating conditions for operational access of fire extinguishers to forest fires in the southern and eastern regions of Ukraine.

The creation of an efficient transport infrastructure in the forest is a prerequisite for the introduction of the principles of sustainable forest management. Forest roads are essential not only for forest management, restoration and protection, but also for the overall development of the region, the creation of new jobs and the improvement of working and living conditions. To ensure an integrated forest management there is a need in the coming years to build annually at least 300 km of new roads and to restore by reconstruction or by repair 600 km of forest roads, which requires substantial financial and logistical costs.

Given that the creation of an optimal structure of the forest road network is a long multi-stage process that requires significant investment, at the end of 2020 the State Forestry Agency of Ukraine initiated the development of the Concept of the State Targeted Economic Program of Forest Roads for the 2022-2026 years. The purpose of this program is to improve the existing forest

transport infrastructure in accordance with regulatory requirements and to expand the network of forest roads to a level that meets the needs of the State in forest resources on the basis of inexhaustible forest use.

Implementation of most of the forest operations on the basis of sustainable development is also impossible without the use of modern systems of forest machines, resource-saving and environmentally friendly logging technologies. Today, the forestry of Ukraine is dominated by the traditional timber harvesting equipment, which is based on the use of hand chainsaws. The use of multifunctional machines (harvesters) is very limited. Usually, these are second-hand machines, having an age that reaches more than 10 years. This situation is due to the low financial capacity of Ukrainian forestry enterprises. Subsequently, the harvested timber is transported to forest roads. In mountainous conditions, skidders are usually used in these operations, and forwarders are used in the plains. However, due to the high cost of forwarders, there is a preference toward agricultural tractors equipped with trailers, which are characterized by low productivity, ergonomics and environmental safety. Skidders are typically harmful to the environment, in particular to the soil surface. In the conditions of Ukraine there are also used agricultural tractors fitted for forest operations, which in the case of repeated passes can cause irreparable damage to the forest environment.

As the analysis of the age structure of technical means for primary transportation of wood shows, these are often morally and technically obsolete machines. As for the timber delivery transport, the Ukrainian automobile plant KrAZ produces modern timber trucks, which are increasingly used for timber delivery in the condition of Ukraine. At the same time, these vehicles also need updating and modernization.

Modernization of logistics of forestry enterprises, updating of forest machinery systems should undoubtedly take into account global trends in forestry engineering, the use of multifunctional machines and mechanisms and minimize their impact on the environment, in particular:

- Transition to the production of a new generation of forest machines and mechanisms using the latest advances in automation and electronics;
- Design of machines using a modular approach;
- Expansion of universality, interchangeability of technical means in various technological processes;
- Improving the mobility and versatility of forest machines used in extreme conditions (soil with low bearing capacity, extreme conditions - frosts, high temperatures);
- Increasing the quality and reliability of machines using ultra-light and durable materials.

This necessitates the development of the State program for the production of domestic logging equipment and timber transport machines on the basis of the existing powerful machine-building base in Ukraine (HTZ, “Pivdenmash”, “Motor Sich” and others). This program requires combining the efforts of the engineering industry with scientific, educational and design

institutions of the forest sector. It is also necessary to resolve the issue of acquiring licenses for production of modern foreign forest machines.

5. CONCLUSIONS

The current state of forestry in Ukraine, which is largely the result of numerous changes in regulations and the formation of the market relations over the past decades, cannot be characterized as satisfactory. Establishment of new economic relations, ensuring sustainable development of the forestry, improving its management, multi-purpose and efficient use of forest lands and forest resources, overcoming contradictions between economic, environmental and social goals, etc. necessitate the formation of a specific strategy for forestry development in Ukraine. The main objectives of such a strategy should be:

- Improvement of the legal framework, the model and mechanisms of public administration in the field of forestry, taking into account the world experience and international obligations of Ukraine;
- Separation of the state control functions from the functions of management;
- Improvement of the state system of financial and economic support of forestry;
- Development of state programs to improve forest transport infrastructure, comprehensive technical re-equipment, introduction of modern innovative, environmentally safe technologies in forestry, forest care, forest protection and logging activities;
- Increasing the forest cover of the territory, preserving and increasing the biological diversity of forest ecosystems, strengthening their resilience to negative factors, in particular, climate change;
- Efficient use of forest resources on a market basis;
- Development of forestry science and education, expansion of international cooperation and improvement of the communication process, public awareness in the field of forestry, etc.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu în română: *Silvicultura în Ucraina: Situația actuală, provocări şi modalități de abordare ale acestora*

Introducere: *Lucrarea de față analizează starea actuală a sectorului forestier din Ucraina şi descrie caracteristicile de bază ale pădurilor şi ale managementului forestier, în principal cele legate de suprafețele reduse ocupate de păduri, creșterea pădurilor în diverse zone geografice ale Ucrainei, importanța ecologică a pădurilor cu funcții principale de protecție, care ocupă o pondere însemnată (circa 50%) şi în care recoltarea lemnului este limitată, ponderea mare a ariilor protejate (16%), caracterizată de un trend constant crescător, subordonarea pădurilor unui număr mare de utilizatori permanenți şi, respectiv, localizarea unei părți importante din suprafața împădurită în zone cu contaminare radioactivă etc.*

Rezultate: *Există diferențe majore legate de gradul de împădurire specific diverselor zone din Ucraina, în general, acesta neîntrunind nivelul considerat a fi optim pentru a se asigura efectele pozitive necesare cu privire la climat, sol şi resurse de apă, prevenirea eroziunii şi furnizarea de lemn. Pentru a se atinge un nivel optim din acest punct de vedere, care este considerat a fi de 20% din suprafața țării, trebuie plantat un număr de circa 3 milioane de hectare. Volumul de lemn recoltat în prezent este mai mic decât posibilitatea stabilită, aspect care asigură un management sustenabil al pădurii din punct de vedere al efectelor asupra mediului. Volumul total de lemn recoltat în scop comercial este de circa 21-22 milioane metri cubi, ceea ce indică că nu este utilizat întregul potențial productiv al pădurilor din Ucraina. Analiza rețelei de drumuri forestiere din Ucraina indică faptul că densitatea acesteia este insuficientă şi mult mai mică decât cea din Europa. În particular, zonele forestiere localizate în Munții Carpați, unde este concentrat 40% din volumul potențial valorificabil al pădurilor din Ucraina, densitatea rețelei de drumuri este foarte mică, de numai 3,5 – 6,0 m/ha. De asemenea, mai mult de 10% din lungimea drumurilor forestiere, care sunt în administrarea întreprinderilor forestiere de stat, necesită reparații majore. Pentru a se întruni necesitățile şi prioritățile managementului forestier din Ucraina, în anii următori este necesară construcția anuală a cel puțin 300 km de drumuri noi şi reabilitatea prin reparații a cel puțin 600 km de drumuri forestiere. Tranziția la aplicarea principiilor sustenabilității necesită re-echiparea industriei forestiere şi introducerea de tehnologii moderne, inovative şi prietenoase cu mediul. Contribuția sectorului forestier Ucrainian în Produsul Intern Brut al țării este considerată a fi nesemnificativă, fiind de ordinul a 0.40 – 0.45%.*

Concluzii: *Pe baza studiului realizat, se poate concluziona că starea actuală a pădurilor şi a sectorului forestier din Ucraina este una nesatisfăcătoare, fiind rezultatul numeroaselor schimbări de natură legală şi a relațiilor de pe piață. Pentru a se asigura o dezvoltare sustenabilă a pădurilor şi a sectorului forestier, este necesară utilizarea polivalentă şi eficientă a pădurilor, îmbunătățirea eficienței managementului, rezolvarea contradicțiilor care există între obiectivele de natură economică, de mediu şi socială; acestea se pot realiza prin construirea unei strategii de dezvoltare a industriei forestiere in Ucraina. Principalele obiective ale unei astfel de strategii ar trebui să fie: îmbunătățirea cadrului legal prin luarea în considerare a experienței acumulate la nivel internațional şi a obligațiilor internaționale ale Ucrainei, îmbunătățirea modelului şi mecanismelor de administrare publică a pădurilor, dezvoltarea de programe de stat pentru construcția de drumuri forestiere, re-echiparea industriei şi introducerea de tehnologii noi pentru operațiile necesare în pădure.*

Cuvinte cheie: *Industria forestieră din Ucraina, probleme actuale, management forestier sustenabil, infrastructură de transport forestier, reechipare tehnologică.*

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Forestry and Forest Operations in Turkey: Challenges and Developments

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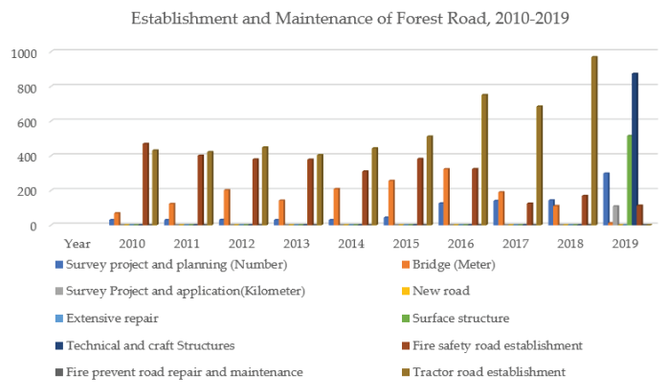
HIGHLIGHTS

- Comprehensive planning will help improving forest operations and all of activities.
- Increasing the integrated planning and programming capacity of the institutional structure is important for sustainable planning.
- Forest roads can be developed in such a way that ensures the continuous and regular supply of forest products to the market.

GRAPHICAL ABSTRACT



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ABSTRACT

There are damages or losses in natural resources due to many social-economic-ecological effects such as increasing demand for the use of forest resources over time, climate change and development needs. Therefore, there have been recent changes in management of forest resources in Turkey. Today, forest management plans are developed and implemented based on the principles of sustainable and functional forestry approaches. Up-to-date information on production of wood-based forest products and forestry activities in Turkey was presented. Besides, statistical information on forest road standards and quantities of existing and planned roads were revealed. As a result of the study, it was recognized that one of the important developments in forestry activities was the implementation of sustainable forest management approach with the new planning system. In addition, depending on the developing technology, the use of mechanization in forestry activities has increased in Turkey. Depending on the increasing demand on mechanization, improvements in forest road standards are considered and there are observations that they are being implemented in some areas.

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1. INTRODUCTION

Forests have important ecological and social functions besides being an important source of raw materials from which wood and non-wood forest products are produced. The management of forests in a way that is both suitable for environmental conditions and socially and economically beneficial to society constitutes the basis of today's forest management philosophy. For this purpose, various certification systems have been established to ensure good environmental and economic management [1]. By changing the former planning method of forests, based solely on wood production, sustainable forest management approach has been put into practice. Forestry activities have been directed according to ecosystem-based functional management plans that take into account the ecological, economic and social functions of forests.

Considering environmental problems, climate change, insufficiency of usable and healthy water resources, food security and social expectations, sustainable management of forests becomes even more important. Population growth rate, income level, urbanization, industrialization, increase in education level, improvements in infrastructure facilities are the main effects that cause societies to undergo economic, social, cultural, technological and political changes [2]. The basic approach of today's forestry understanding is to consider its biological and technical characteristics and ecological, economic, social, cultural and administrative dimensions within an ecosystem integrity. Nowadays, multi-purpose afforestation and soil conservation works have been carried out in Turkey. Thus, while increasing forest areas, it is aimed to prevent soil erosion and sediment transport to the water resources.

Turkey has 22.34 million ha of forest lands which means approximately one-quarter of Turkey's land are covered by forests. As in the world, environmental awareness, social developments, demands to wood raw material, and expectations from natural resources have been significantly increased in Turkey. Despite covering only 0.5% of the Earth's surface, Turkey has a very high species diversity especially in the forest lands [3].

Gümüş [4] defines forestry as activities carried out to meet the forest products and services demands of the society. The data used for forest operations in Turkey is composed of data obtained by the management plans and various measurement methods [5]. This study aimed to give information on the economic contribution of forest resources and forest management in Turkey. In addition, methods used in forest operations and forest roads are presented. In the study, the progress in forestry and forest engineering in Turkey were examined in 6 main sections. Thus, an assessment of the developments and challenges in forestry and forest engineering has been conducted.

2. MATERIAL AND METHODS

The literature synthesis about the current challenges in forestry and forest engineering in Turkey was provided based on the information collected from the scientific studies, academic researches, state documents, and institutional reports. The aspects of the study cover the relevant issues including forest resources, forest management plans, forest engineering, forest operations, forestry mechanization, and forest roads. The outcomes of the study were presented under Results and Discussion through following six sub-sections listed under: i) characterization of forest resources and their contribution to the economy, ii) description of forest management and of the use of forest resources, iii) characterization of mechanization in forest operations, iv) characterization of forest roads; v) current/critical challenges in forestry and forest engineering and vi) state of the art in relation to research done and developments to respond to those challenges.

3. RESULTS AND DICSUSSION

3.1. Characterization of Forest Resources and their Contribution to the Turkish Economy

In Turkey, 99.9 percent of the forest land are owned by the State, reflecting the nationalization of forests in 1945 (Law of Nationalization, Law 4785) in an attempt to safeguard resources and combat over-exploitation. The definition of forest in Turkey excludes areas of forest less than 3 ha and areas with species not found in natural forests [6]. Forest areas with a canopy cover of 10 percent or more are classed as "productive forests" and are required to have an allowable cut identified in the forest management plan. As of 2019, 94.72% of the forests are high forest while the rest is coppice forests in Turkey [7]. In the last fifteen years, the share of high forest area increased due to the decrease in the coppice forests, degraded forest areas, and establishment of new forests (**Figure 1**).

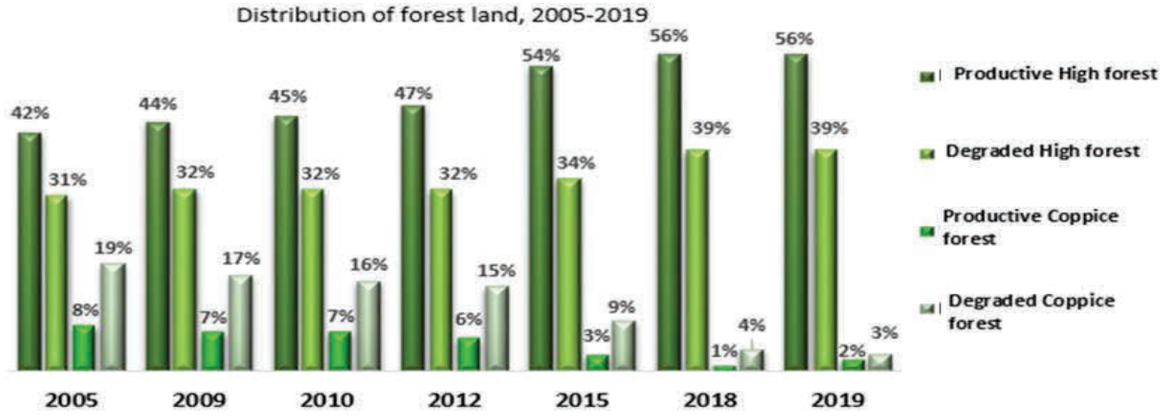

Figure 1: Distribution of forest land in Turkey between 2005 and 2019. Source: [7]

Table 1. Forest Area and Growing Stock in 2019

Forest Type	Area (million ha)			Growing Stock (million m^3)		
	Productive Forest	Degraded Forest	Total	Productive Forest	Degraded Forest	Total
High forest	12.73	8.81	21.54	1,595.83	64.79	1,660.62
Coppice forest	0.35	0.85	1.20	14.01	4.72	18.74
Total	**13.08**	**9.66**	**22.74**	**1,609.84**	**69.51**	**1,679.36**

The changes in forest area in recent years also affect the growing stock distribution. According to the statistics stated by the General Directorate of Forestry (GDF), the growing stock has increased in the last 10 years. In addition, according to the statistics of 2019, 95.9% of the growing stock was specific to productive forests, while 4.1% was that of degraded forests. The total growing stock was estimated at 1.66 billion m^3 in 2019 (**Table 1**). Approximately 50% of the forests are classified as having an economic function, mainly that related to the production of round wood, fire-wood, and non-wood forest products, 42% an ecological function with the purpose of watershed and erosion control and the remaining 8% have functions related to social and cultural aspects [8].

Natural resources are important for the local economy of Turkey [9]. Strategic planning for local economic development is in the duty of local or urban governments, which are considering the advantages of the region's humanitarian, social, economic, institutional and natural resources, as well as its geographic location, in a large-scale, long-term and future-oriented vision framework [10]. Strategic planning or management approach has been implemented by the private sector since the 1950s with the aim of increasing efficiency and effectiveness, and after 1980, this approach has been used by the public administration as the traditional public management approach has lost its effectiveness. Then, strategic planning started to have a place in the national planning system in the 2000s [11]. In public administrations, strategic plans are classified as long-term (five years or more), medium-term (one to five years) and short-term (less than one year) plans. In terms of functions fulfilled by the plans, it is seen that they are handled in the form of strategic action plans [12]. Strategic planning was considered in order to examine its contribution to the planning of forest resources.

According to the Turkey Export Council's 2023 Export Strategy Report, exports of forest products in 2023 is predicted to be 16 billion US dollars with an annual average growth rate of 13.7% [13]. The forestry sector, which has an economic size of 12 billion dollars and exports of 2.4 billion dollars in 2013, targets an economic size of 25 billion dollars and an export figure of 8 billion dollars in 2023 [14]. In 2018, exports of 571 million dollars versus 624 million dollars of imports were recorded considering wood product types [15].

In Turkey, the economic contribution of the forest sector is about 0.8% according to the calculations of Turkey Statistical Institute which was made based on the monetary value of primary and secondary forest products and services. Considering the subsidies arising from inputs given free of charge or with low cost to other sectors, this ratio reaches up to 2% [16]. According to GDF

data for 2018, the contribution of wood-based product sales to the national economy was 4.263.569.558 TL. A total of 140,994 people, 72,174 of which are forest cooperative members and 68,820 non-cooperative employees, were employed in forest operations, and 36,106 personnel were employed in GDF organizations [17].

According to Development Plan for 2019-2023, the contribution of forests to the economy will be increased through sustainable forest management. The support provided for forest villagers will be maintained within certain programs, and professionalization will be raised through training activities in order to increase quality of production and labor productivity in forestry.

3.2. Description of Forest Management and of the Use of Forest Resources

Forest planning in Turkey has begun with the first management plan developed in 1917-1918 [18]. Today, management plans are developed according to ecosystem-based functional planning (ETFOP) approach [19]. Within the frame of Sustainable Development Goals, Turkey's forest resources are managed according the international conventions and processes to which Turkey is a party, national forestry strategic plans, forestry master plans, forestry programs, and regional and local action plans designed with a participatory approach. The main strategies aim and plan to protect forest and forest resources, develop a close understanding of nature, manage in sustainable ecosystem integrity and provide multidimensional benefits to the society, and vision [20].

In line with forestry policies and strategies, the objectives of sustainable forest management are as follows:

- Improving institutional, administrative and human capacity and information infrastructure;
- Ensuring effective coordination between forestry organizations;
- Ensuring supply guarantee in production based on forest products;
- Increasing the life quality of forest villagers, strengthening the economic and social infrastructure;
- Capacity building for Ecosystem Services;
- Increasing the integrated planning and programming capacity of the institutional structure.

Sustainable forest management has been applied in Turkey, which faces many challenges for an efficient utilization of forest ecosystem services [21]. The General Directorate of Forestry (GDF) is the main institution in the sector, responsible for the integration policy and supervision of the protection and sustainable forestry management of forest resources in Turkey, and it is part of the Ministry of Agriculture and Forestry (MAF). The majority (over 99%) of forest land is state owned and managed by GDF. Decision making and forest operations have been planned, organized, guided, managed, and controlled through the Chief Office of the Forest District (COFD), the Directorate of the Forest District (DFD), the Regional Directorate of Forestry (RDF), and also GDF [21], as respectively and hierarchically [22]. Most of the wood raw material demand is met by GDF. Within the admission of GDF, there are 28 Regional Directorates of Forestry and 12 Forestry Research Institutes [23].

Planning production in forestry is a relatively complicated problem that requires the harmonious implementation of issues such as primary (logging) and secondary (hauling) transport [24]. During the forest operations, the decision maker should consider various factors: weather conditions, climate, vegetation, topography, social structure, logging techniques, harvesting methods, amount of production, existing forest road network [25, 26].

The most effective way to improve especially forest operations is through comprehensive planning of all activities. At the tactical level, multifunctional forest management plans have been prepared for each planning units in COFD. In addition to other decisions, these plans provide the harvestable compartments (blocks) in each year within a planning horizon. Harvest decisions are based on 10–20-year forest management plans and silvicultural prescriptions for a mid-time horizon [21]. The harvesting decisions from COFDs to GDF have been executed by governmental legislation the name of which is "Official Communique about Harvesting of Wood-based Forest Products No: 310" [27].

Nowadays, by the use of forest resources, products such as logs, telephone poles, mining poles, other industrial wood, pulpwood, fiber-chip wood, fuelwood are produced as wood raw materials. Non-wood forest products are typically the resin, resinous wood, *Buxus*, *Laurus nobilis*, *Thymus*, *Salvia* sp., *Tilia* sp., natural mushrooms, flower bulbs, etc. In **Table 2**, wood raw material production values are indicated based on the statistics provided by the GDF.

Table 2. Annual production amount of the main forest-related products in Turkey (2012-2019). Source: [3]

Annual production amount									
Description	**Unit**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Log	m^3	5,027,738	4,629,829	5,001,861	5,904,015	5,786,106	5,474,260	7,152,776	**8,514,026**
Telephone pole	m^3	59,613	32,641	37,527	54,257	57,574	60,610	71,147	58,333
Mining pole	m^3	692,944	541,771	570,156	663,689	632,168	561,967	731,604	929,259
Other industrial wood	m^3	874,793	701,688	728,971	764,010	835,157	752,253	875,403	1,008,952
Pulpwood	m^3	2,333,651	2,196,434	1,966,963	2,375,172	2,486,595	2,169,059	2,874,882	3,175,505
Fibre-chip wood	m^3	5,424,794	5,551,397	6,608,416	6,866,356	7,201,462	6,494,372	7,361,714	**8,417,096**
Fuel wood	m^3	4,824,506	4,486,277	3,943,496	3,767,240	3,657,801	3,269,734	3,667,841	4,201,807
Total	**m^3**	**19,238,039**	**18,140,037**	**18,857,390**	**20,394,740**	**20,656,862**	**18,782,255**	**22 735,367**	**26,304,977**

The forest products with the highest amounts were the log and fiber-chip wood production between 2012-2019. In the last 8 years, average quantities of 6,740,700.924 m^3 of fiber-chip wood and 5,936,326.391 m^3 of logs have been produced. In the case of non-wood forest products, which is another area of use of forest resources, in the last eight years, an average of 21,916,726 kg of *Laurus nobilis* and an average of 11,563,283 kg of resinous wood were produced. About 72% of Turkey's wood supply is provided by GDF while 17% and 11% of it is given by the private sector and through import, respectively. When we look at the distribution of wood raw material usage in Turkey, the board sector is at the top with 55%, while the timber industry comes next with 25%, being followed by pallet-packaging with 15%, plywood-coating with 2%, paper with 2%, and pole sector with 1% [27].

Turkey has a great capacity on non-wood forest products due to the advantage provided by high biodiversity. Additionally, people in Turkey have a wide range of experience on the utilization of wild plants and there is a significant diversity of use of non-wood forest products as a result of geographical location and historical heritage. Despite these advantages, it is difficult to mention that sustainable management of non-wood forest products is totally guaranteed in Turkey, as is the case in many other countries [28]. When the production amounts of non-wood are examined according to GDF statistics, the annual average proportional increase of non-wood forest products sales income between 2003 and 2017 is 15.8%, and the production amount of non-wood produced in state forests will exceed 1 million tons in 2022, and GDF's 12.5 Million TL sales revenue is estimated [29].

3.3. Characterization of Mechanization in Forest Operations

The development of the technology level used in wood harvest operations is classified according to its historical course; it is known that basic technology was used until the 19th century, semi-mechanized intermediate technology in the 19-20th century, machine-advanced technology in the 20-21th century, and highly-automated technology with artificial intelligence and smart machines after the 21st century, have been used in the world forestry [30]. The characteristics of Turkish State Forestry may be characterized as holding and using a basic to moderate forest operations technology [22].

As stated by [31], mechanized harvesting began in Turkey in 1949 by using long distance winch skylines. Wyssen, Bako and Hintereger model skylines (21 sets) were widely used in the northeast forests of Turkey. The most used equipment in the Turkish timber harvesting operations is based on human-animal power and partly mechanical systems. In recent years, mechanical methods have been used more frequently, especially in areas with intensive forestry practices [32].

According to the legal obligation, forest acts and regulations in Turkey, all of the forest operations must be accomplished by villagers who live in the forest villages nearest to the workplace. Forest work is the main income for those villagers also called as “forest villagers” and around 6.97 million people live over 22,941 forest villages [7]. In Turkey, forest harvesting activities are performed by forest villagers and/or their cooperatives that have 190,000-300,000 members. On

the other hand, the forestry workers do not receive adequate training and professional education [21].

In Turkey, tree felling, delimbing, topping, bucking, and debarking operations are mostly performed in the woods. In some cases, debarking is done at the roadside. The motor-manual method with chainsaw is used in felling, delimbing and topping, bucking, and partly in debarking by means of equipment attachments [33]. On the other hand, debarking is mostly done by using axe and hand tools. In recent operations, debarking stage is omitted from the harvesting system depending on the sale type. Timber extraction from stump to landing area or roadside is mostly (over 60%) conducted by rolling, throwing, and sliding/skidding methods on the steep ground depending on gravity and by using manpower techniques [34]. In recent years, animal-powered techniques have not been used very often and their proportions are decreasing gradually. The use of farm tractors in logging operations however has an uptrend [35]. The cable logging methods with various distances have been used on mountainous region in Turkey.

The old cable yarders, purchased by the GDF in 1980s, have been replaced as all of them had fulfilled the economic lifetime. In addition, log chute systems are available for extraction of small diameter wood products [36]. Mechanized harvesting equipment with advanced technologies such as harvester, forwarder, and skidder have been implemented by few private forestry companies [32,37,38]. In Turkey, the most common harvesting method is cut-to-length, generally facilitating the use of chainsaws and farm tractors. During loading and unloading operations, grapple loaders or hydraulic cranes are used on roadside or landing areas. Transportation of wood-based forest products is done by logging trucks and trailers on forest and main roads [22].

In addition, leading domestic companies in the production of wood-based panels meet their wood raw material needs in large quantities through supplier companies that can produce wood raw materials in a short time and in large areas by using mechanical harvesting systems [39]. Thus, the forest industry is witnessing an increase of interest in mechanized harvesting systems. The configurations of these systems typically consist of harvesters, feller bunchers, and grapple skidders [40].

The legal obligations in Turkey make it compulsory and necessary to employ forest villagers or to offer the job to the forestry cooperatives mostly established by the villagers. However, local people and cooperatives cannot afford the advanced mechanized forestry equipment due to their high purchase prices and operating costs. In order to make this equipment available for local people, GDF owns equipment that can be rented to them with an acceptable price range [37].

3.4. Characterization of Forest Roads

Forest roads are the basic facilities that enable safe and effective access to the forest for the purpose of carrying out main forestry activities such as timber extraction, forest transportation, forest protection, afforestation, and wildlife management [41], recreation and firefighting [42] activities throughout the year. In Turkey, the forest roads are classified as primary or secondary (types A or B) roads, with type B secondary roads predominating. The main regulation for forest road planning and construction is presented in Communication 292 (**Table 3**). Road density is a

significant factor in the accessibility of forest stands and in the environmental impact of forest harvesting. Forest roads have been planned and constructed according to road density (m/ha) and yield/forest area (m^3/ha) criteria to meet the needs of Turkish forestry. However, forest road density should be determined according to all aspects of forestry operations [31].

Table 3. Forest road standards in Turkey

Road Features	Unit	Main forest road	Secondary Forest Roads				Tractor roads
			A-Type	B-Type			
				HBT	NBT	EBT	
Platform width	**m**	7	6	5	4	3	3,5
Number of lanes	**-**	2	1	1	1	1	1
Maximum slope	**%**	8	10	9	12	12	20
Minimum radius	**m**	50	35	20	12	8	8
Lane width	**m**	3	3	3	3	3	3
Shoulder width	**m**	0.50	0,50	0,50	0,50	0,50	
Ditch width	**m**	1	1	1	1	0,50	
Pavement width	**m**	6	5	4	3	3	
Bridge width	**m**	7+(2x0.6)	6+(2x0.6)	5+(2x0.6)		4+(2x0.6)	

Note: HBT: High standard B type forest road, NBT: Normal B type forest road, EBT: Extreme B type forest road.

In previous studies, it was stated that the target road density is to be 20 m/ha. However, this value can change depending on the technique used during harvesting, the number of skidding roads and also other functions of road use (i.e., firefighting etc.). It was reported that 17,651 new roads were build, 17,538 roads were repaired, and 1,637 bridges were built in last 10 years. The information about the planned and implemented road projects is shown in **Table 4**.

Table 4. Establishment and maintenance of forest roads, 2010-2019 [7].

Year	Projects	Bridges (m)	Projects (km)	New roads (km)	Extensive repair (km)	Surface structure (km)	Technical and craft structure (km)	Fire safety road establishment (km)	Fire prevention road repair and maintenance	Tractor road Establishment (km)
2010	30	69	3,600	1,400	1,000	1,179	1,832	469	18,459	431
2011	30	123	3,644	1,468	1,064	1,162	1,817	401	18,509	422
2012	31	202	4,618	1,518	1,022	1,860	1,959	379	19,440	448
2013	30	142	4,728	1,479	1,421	1,532	1,881	378	18,306	404
2014	30	209	5,394	1,542	1,661	2,094	2,387	310	20 481	443
2015	44	256	5,717	1,624	1,753	2,261	2,823	382	19,871	511
2016	126	323	6,188	1,852	2,276	2,142	3,131	324	23,675	751
2017	140	190	7,721	2,542	2,768	2,520	3,210	125	23,765	684
2018	143	111	8,826	2,902	3,184	2,843	3,696	169	24,584	969
2019	298	12	109	1,324	1,389	515	873	113	24,911	1,025
Total	**902**	**1,637**	**50,545**	**17,651**	**17,538**	**18,108**	**23,609**	**3 050**	**212,001**	**6,088**

At the end of 2020, the length of the planned roads for proving sufficient access to the forests was updated at 320,000 km in Turkey. The current total length of the roads (including the highway, rural roads and other roads) that pass through the forest is about 265,000 km. Approximately 200,000 km of this roads are forest logging roads. Most of the forest roads in Turkey are classified as type B secondary forest roads with standard size (i.e. platform width of 4 m, ditch width of 1 m, gradient less than 12%, minimum curve radius of 12-20 m). However, in the last decade, the forest road standards have been improved and the platform width increased to 5 m. In addition, routine and major repairs are being carried out on forest roads built in the last 50 years.

In 2019, the amount of forest roads planned for all forestry activities was 302,000 km which has been revised since 194,000 km of it has been completed. 66,092 km of village roads are passing through the forest and the total length of roads that can be used in forestry, including highways is 260,092 km. As of 2019, the total forested area has been determined as 22,740,297 hectares [7]. According to these values, road density is 11,45 m/ha. New road planning continues within the scope of development and strategic planning.

In recent years, 2,500 to 3,000 km of new roads have been constructed annually, depending on the economic situation of GDF and the general forestry sector. With these roads, both the overall road density and the actual road density increase. In forests managed for their production function, the road density can exceed 20 m/ha and the road spacing can be reduced below 500 m. Moreover, the skidding distances can be reduced by increasing the road density [43]. Most of the forest roads in Turkey are developed on slopes. Especially the middle and upper hill roads undertake an important function in the management of mountainous forest lands. Valley roads are generally collector roads and their standards are relatively higher. In mountainous forest with steep slopes (particularly in northeast of Turkey), the use of ridge roads and valley roads are an effective way for implementing cable logging methods.

3.5. Challenges in Forestry and Forest Engineering

Sustainability of forestry depends on the dynamics in the use of forest resources. However, factors such as climate change and air pollution direct forestry work to a more detailed planning. Problems may arise in the planning stage of natural resources due to different effects. One of them is the decrease in forest resources as a result of the increase in natural disasters. Extraordinary situations can create problems during planning. The increase in other diseases and harmful organisms in the world disrupts this balance. In addition to the problems mentioned above, the use of highly-mechanized equipment is a problem in Turkey because it is economically expensive for the forest villagers. In addition, the decrease in the young population in forest villages, the increase in labor and production costs, are already challenges in forestry. As mentioned earlier, 99% of the forests are managed by the state in Turkey. Accordingly, besides the facilities provided by the institutional structure, there can be also difficulties. As stated by [6], one of the challenges for the GDF is that of how to mobilize its annual timber harvest in a cost-efficient and sustainable fashion, thereby facilitating the development of a competitive domestic timber processing sector by reducing costs and reconfiguring the timber supply chain.

3.6. Main Research Done to Support Turkish Forestry

Another important aspect of the Turkish forestry is that related to the research and development. With the application of the findings obtained from studies, positive developments occurred, by enabling the continuity in the flow of product and services. As a result of the rapid developments in the forest products industry, new solutions and approaches are available.

One of the current developments is that related to increasing the possibilities of using the LIDAR data supply systems. LiDAR technology has an important potential to enable many forestry activities to be carried out effectively [44]. Advanced tools such as satellite images contribute significantly to the planning and implementation stages in forestry. This type of technology can be provided with the supporting logistics (e.g. recording, analysis and reporting software, training). Especially when LIDAR technology provides uninterrupted and high-resolution data for large areas, it will make great contributions to forest inventory studies conducted to organize forest management plans [45]. As stated by [46], the use of LIDAR data has also a great potential in determining the amount of fuel load in forest areas.

Depending on the developed technology, the possibilities of using computer programs such as In road, NetCAD, Netpro Platea, Geomedia have emerged in the planning of forest roads in Turkey. In recent years, forest road planning has been improved with the use of these programs and besides, forest road planning became more cost efficient [47-49]. In terms road standards, recent studies conducted on improving standards of forest roads have suggested that the total discounted costs of forest roads can be reduced by about 5% in the case of improved road standards [50]. Even though improving road standards may cause extra costs in road construction, but total road costs decrease since maintenance and repair costs decrease considerably in the long run.

In recent years, there is an interest in utilizing logging residues for renewable energy generation in Turkey. The forests have great potential to supply large amount of biomass as there is an annual increment of 46 million m^3 in forest lands [51]. In fact, logging residues can be considered as the most readily available source of biofuel [52]. Thus, logging residues from the industrial forests consisting of fast-growing trees should be used as biofuels to provide renewable resources for energy generation in Turkey [51].

In Turkey the tree cutting stage is mostly carried out by using a chainsaw, while the stage of extracting the wood raw materials is carried out by using human-animal power and partly machine power. In recent years, mechanical production methods have started to be preferred more frequently, especially in areas with intensive forestry [32]. In addition, domestic organizations, which are at the top of the Europe in the wood-based panel industry, supply a significant part of their high wood raw material demands from domestic forest resources. In order to produce wood raw materials in large areas in a short time, contractors purchase alternative machinery and use mechanical systems intensively. In this context, they are willing to invest in modern harvesting equipment which includes harvesters, feller-bunchers, and skidders [39]. In addition, there are ongoing studies on developing own mechanized harvesting equipment in Turkey [53].

Another important development was that related to forest products, taking into account national conditions and international markets. It is aimed at increasing the area of certified forests by developing standardization and certification systems. By GDF, certification studies are considered as one of the most important auxiliary tools; they started in 2010, within the scope of sustainable forest management principles.

4. CONCLUSIONS

Considering the demands of the society and the structure of the country's forests, forest management aims at ecosystem integrity, balancing ecological, economic, social, cultural and administrative dimensions. It is known that there are significant developments in terms of taking into account the versatile services offered in the planning and management of forest resources and in the protection, development and expansion of forests within the framework of sustainable management approach. It is important that forest roads are developed in a way that ensures the continuous and regular supply of forest products to the market. For this purpose, improvements in forest road standards and new road planning continue in Turkey.

In Turkey, the use of mechanization follows an increasing trend. This contributes to the increase of industrial production and to the country's overall economy. In addition, various support opportunities are provided to forest villagers in order to strengthen practices in the production, processing and marketing of non-wood forest products and to exchange and evaluate experiences in this field.

There are large forest lands with high fire risk due to the climate zone in which Turkey is located in. It is clear that firefighting activities will become even more important in the future due to the effects of global warming on wildfire incidents. In this context, various projects and action plans have been implemented by GDF in the subject of fire extinguishing.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

EXTENDED ABSTRACT – REZUMAT EXTINS

Titlu în Română: *Silvicultura şi exploatarea lemnului în Turcia: Provocări şi realizări*

Introducere: *Schimbările climatice, nevoile de dezvoltare şi cererea crescândă cu privire la resurse ameninţă resursele naturale, inclusiv pădurile. Din acest punct de vedere managementul pădurilor trebuie să urmeze filozofia conform căreia beneficiile oferite societăţii nu trebuie să compromită valorile pădurilor relaţionate cu mediul. În acest scop s-au adoptat diferite sisteme de certificare care să echilibreze toate valorile oferite de păduri. Prezenta lucrare insistă pe*

problemele actuale legate de silvicultura şi utilizarea lemnului în Turcia, descriind resursele forestiere, contribuțiile economice şi de mediu precum şi logistica aprovizionării cu lemn.

Materiale şi metode: *Lucrarea are la bază informaţii culese din studii ştiinţifice, cercetări, documente de stat şi rapoarte ale diferitelor instituții din Turcia. Studiul a fost sintetizat în cinci capitole principale, dintre care primul caracterizează resursele forestiere şi contribuția lor în economie, al doilea descrie tipul de management forestier şi modul de utilizare a resurselor, al treilea face referire la nivelul mecanizării în operaţii forestiere, al patrulea caracterizează rețeaua de transport forestier iar ultima parte prezintă provocările actuale şi realizările relaţionate cu silvicultura din Turcia.*

Rezultate şi discuții: *În Turcia, 99.9% din suprafața pădurii este deținută de stat, reflectând naționalizarea acestei resurse care a avut loc în 1945. Aproximativ 95% din suprafața pădurii este gestionată în regimul codru, iar restul în regimul crâng. S-a constatat o creştere semnificativă a suprafețelor gestionate în regimul codru în ultimii 15 ani, în principal datorită plantării de noi păduri. Aproximativ 50% din păduri sunt încadrate în grupa funcțională de producţie, 42% au rolul de a proteja bazinetele împotriva eroziunii, iar restul au roluri socio-culturale. Potrivit Raportului Strategic de Export al Consiliului Turciei pentru Export, exportul de produse forestiere în 2023 este previzionat a fi în valoare de 16 miliarde de dolari SUA, cu o rată de creştere anuală de 13.7%. Sectorul forestier vizează o participare economică de 25 de miliarde de dolari şi o valoare a exportului de 8 miliarde de dolari în 2023. Contribuția silviculturii la economia ţării este de circa 0.8%, bazat pe calculele Institutului de Statistică al Turciei. În prezent amenajamentele silvice sunt realizate pe baza planificării funcționale, iar resursele forestiere sunt gestionate în acord cu convențiile internaționale şi procesele în care este implicată Turcia, planurile strategice naționale cu privire la păduri, master planuri, programe forestiere şi planuri de acțiune regionale şi locale. Direcţia Generală pentru Păduri este principala instituție responsabilă pentru integrarea politicilor, supervizare, protecție şi management sustenabil al pădurilor în Turcia. În prezent, principalele produse generate de sector includ bușteni, stâlpi, lemn de mină, lemn industrial, lemn pentru industria celulozei, tocătură şi lemn de foc. Principalele produse forestiere nelemnoase sunt rășina, lemn cu rășini şi alte specii de interes ornamental sau farmaceutic, ciupercile şi florile. Planificarea producției de lemn este o problemă complexă care necesită luarea în considerare a transportului primar şi secundar. În Turcia, exploatarea lemnului se bazează, în principal, pe efortul uman şi sisteme parțial mecanizate, dar s-au introdus şi utilaje moderne în ultimii ani, mai ales în zonele caracterizate de practici forestiere mai intensive. Utilaje precum mașinile multifuncționale de recoltare, tractoarele forwarder şi skidder sunt utilizate în prezent de câteva companii private. În conformitate cu sistemul legal din Turcia, este necesară angajarea cu prioritate a localnicilor în activitatea forestieră. Cu toate acestea, localnicii şi cooperativele pe care aceştia le-au dezvoltat nu pot să își permită achiziționarea de echipament forestier mecanizat datorită costurilor mari de achiziție şi operare. Ca răspuns, Direcţia Generală pentru Păduri a achiziționat astfel de utilaje pe care le închiriază localnicilor la prețuri acceptabile pentru utilizarea în operaţii forestiere. Drumurile forestiere se proiectează şi se construiesc pe baza densității țintă şi a volumului de masă lemnoasă la hectar, în acord cu necesitățile Turciei. În prezent, densitatea drumurilor este de 11,45 m/ha iar densitatea țintă este de 20 m/ha. La finalul anului 2020, lungimea planificată a drumurilor a fost actualizată la valoarea de 320,000 km. Problemele actuale, cum sunt cele relaționate cu schimbările climatice şi poluarea aerului direcționează silvicultura către o planificare mult mai detaliată şi pot să apară probleme de planificare în diferite stadii ale acesteia. Cercetarea de profil încearcă să rezolve problemele curente ale sectorului prin studii ale căror rezultate conduc la dezvoltarea sustenabilă şi asigurarea continuității de produse şi servicii forestiere. Problemele care apar în industria de profil sunt rezolvate prin noi soluții şi abordări oferite prin cercetare.*

Concluzii: *Există un progres semnificativ legat de serviciile oferite în planificarea şi managementul resurselor forestiere, precum şi de protecția, dezvoltarea şi extinderea pădurilor printr-o abordare sustenabilă în managementul acestora. În Turcia, mecanizarea operațiilor forestiere urmărește un trend crescător, înlocuind metodele şi munca manuală. Statul furnizează oportunități şi suport localnicilor pentru a întări producția, procesarea şi comercializarea produselor pădurii şi pentru schimbul de experiență în domeniu. Este de o mare importanță ca dezvoltarea drumurilor forestiere să se realizeze astfel încât să se asigure continuitatea aprovizionării cu produse forestiere şi, ca atare, îmbunătățirea standardelor şi a modalităților de planificare a drumurilor forestiere continuă în Turcia.*

Cuvinte cheie: *resurse forestiere, amenajament forestier, inginerie forestieră, operaţii forestiere, mecanizare forestieră, drumuri forestiere*

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Estimarea consumului de timp şi a productivității muncii pentru operaţii de săpare mecanizată a gropilor pentru puieți şi sade de plop

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REPERE

- Săparea mecanizată a gropilor este caracterizată de o performanță productivă ridicată.
- Productivitatea muncii la săparea de gropi pentru sade de plop este de ordinul a 50-70 gropi pe oră.
- Productivitatea muncii la săparea de gropi pentru puieți de plop este de ordinul a 170-210 gropi pe oră.

REZUMAT GRAFIC

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REZUMAT

Pădurile de plop, care sunt distribuite pe suprafețe importante din fondul forestier național, permit extinderea mecanizării în operații de plantare, abordare care poate să conducă la efecte pozitive pentru managementul acestor păduri. Lucrarea de față analizează consumul de timp şi productivitatea muncii pentru operaţiile de săpare mecanizată a gropilor pentru puieți şi sade de plop pe fondul existenței unor date limitate de natură statistică care să permită aprecierea acestor parametri. În ambele cazuri, consumul de timp specific săpării propriu-zise a fost dominant în structura consumului de timp la locul de muncă. Productivitatea operației de săpare a gropilor pentru puieți a fost mult mai mare (170-210 gropi/oră) decât cea a săpării gropilor pentru sade (50-70 gropi/oră), fenomen care se pot datora condițiilor operaționale specifice precum gropi mai adânci în cel de-al doilea caz, săpate în soluri nepregătite. Datele prezentate pot fi utile pentru practică, inclusiv sub formă de norme de producție locale.

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1. INTRODUCERE

Arboretele de plop ocupă suprafețe importante la nivel mondial [1, 2], fiind întemeiate, de multe ori, pe cale artificială şi preferate datorită unor caracteristici specifice cum ar fi cele legate de valorificarea foarte bună a potențialului staţional, creşterea rapidă şi furnizarea de lemn ce poate fi valorificat în diverse industrii. O caracteristică aparte a acestor arborete este cea legată de tipul, numărul şi modul de implementare a operaţiilor silviculturale [3], astfel de arborete permițând mecanizarea avansată a multora dintre operaţiile specifice, inclusiv a celor de plantare, care caracterizează regenerarea artificială. În unele regiuni geografice este preferată întemeierea unor culturi de plop caracterizate de o densitate mare şi de adoptarea unor cicluri de producţie foarte scurte, de 1-4 ani [4]. În alte zone geografice şi tipuri de management forestier, inclusiv în România, ciclurile de producţie sunt mult mai lungi.

Depinzând de tehnologia disponibilă, tipul de management forestier şi condiţiile operaționale, operaţiile de plantare pot fi realizate complet mecanizat [6, 7], parțial mecanizat [8] sau manual [5]. În România, instalarea artificială a vegetației forestiere se realizează, predominant, prin folosirea de puieți, care presupune o suită de operaţii ce include lucrările de pregătire a terenului şi a solului în vederea împăduririi, pichetarea terenului la schema de plantare stabilită, efectuarea mecanizată sau manuală a gropilor pentru plantat la dimensiunile stabilite şi plantarea manuală a puieților [5], la care se adaugă alte operaţii cum ar fi cele de transport a puieților şi a utilajelor la locul de muncă. Pe fondul lipsei forței de muncă şi a costurilor ridicate ce pot fi generate de munca manuală, precum şi pe fondul necesității de realizare în timp util a planurilor de regenerare a arboretelor, se consideră că extinderea mecanizării în operaţiile forestiere poate fi o soluție sustenabilă. De asemenea, în unele situații tehnice, cum sunt, de exemplu, cele care presupun utilizarea de sade ca material săditor, săparea gropilor pentru plantat nu mai poate fi făcută manual, ea necesitând o abordare mecanizată.

Studiul operaţiilor de plantare sub raportul productivității muncii este necesar în situațiile în care se schimbă tehnologia de muncă sau condiţiile operaționale [9], implementându-se, în mod obișnuit, atât pentru a obține informație ştiințifică cu privire la performanța operațională cât şi pentru a furniza datele necesare pentru planificarea producției [10]. Pe de o parte, practica din sectorul silvic a înregistrat o tendință de modernizare a parcului de utilaje, inclusiv a celor utilizate în operaţiile de plantare a plopului. În prezent sunt folosite agregate compuse din tractoare şi maşini de săpat gropi, care au fost adaptate şi se utilizează atât pentru execuția gropilor pentru puieți cât şi a celor pentru sade. Pe de altă parte, pentru astfel de utilaje nu există norme tehnice care să descrie şi să reglementeze productivitatea muncii, cauzând probleme legate de sistemul de remunerare al operaţiilor în cauză.

Scopul acestei lucrări a fost acela de a evalua consumul de timp şi productivitatea muncii pentru operaţiile de săpare mecanizată a gropilor pentru puieți şi sade de plop. Prin urmare, obiectivele lucrării au fost: i) de a estima principalii indicatori statistici cu privire la consumul de timp la nivel de fază (element) de muncă şi la nivel de operație şi ii) de a evalua performanța productivă (productivitatea şi eficiența) a operaţiilor de săpare a gropilor pentru puieți şi sade de plop.

2. MATERIALE ŞI METODE

2.1. Locurile de realizare a studiului şi descrierea condiţiilor operaţionale

Observaţiile de teren au fost realizate în sudul României, în apropierea fluviului Dunărea, în judeţul Dolj. Pădurile de plop ocupă o suprafaţă importantă în zona luată în studiu, fiind gestionate de Regia Naţională a Pădurilor, prin intermediul Direcţiei Silvice Dolj. Pentru studiu s-au ales cinci subparcele (**Tabelul 1**), astfel încât să se surprindă, pe cât posibil, variabilitatea operaţională specifică precum şi utilizarea principalelor tipuri de material săditor. Variabilitatea operaţională luată în studiu a fost cea legată de schemele de plantare şi de starea solului.

Tabelul 1. Descrierea locaţiilor luate în studiu, a schemelor de plantare şi a stării solului înainte de operaţii

Abrevierea după materialul săditor folosit	Suprafaţa (ha)	Abrevierea după localizare şi mod de operare	Localizare geografică	Altitudine (m)	Suprafaţa parcursă (ha)	Schema de plantare (m × m)	Starea solului
T1 (sade)	5,04	T_{11}	N 44°06'09.54" E 22°58'40.91"	40	1,42 [a]	4 × 4	Nepregătit
		T_{12}	N 44°06'09.54" E 22°58'40.91"	40	1,42 [b]	4 × 4	Nepregătit
T2 (puieţi)	2,91	T_{21}	N 43°50'47.65" E 23°12'25.34"	43	0,38	3 × 2	Pregătit
	5,82	T_{22}	N 43°50'52.58" E 23°12'05.87"	38	1,45	3 × 2	Pregătit
	4,36	T_{23}	N 43°50'13.60" E 23°11'10.32"	35	0,84	3 × 2	Pregătit
	3,06	T_{24}	N 43°50'50.82" E 23°10'19.67"	38	0,60	3 × 2	Pregătit

Note: a – suprafaţa aproximativă parcursă transversal, b – suprafaţa aproximativă parcursă longitudinal.

Observaţiile de teren din primul grup (T1) s-au realizat pentru o suprafaţă de 2,84 ha în care s-au efectuat operaţii de săpare a gropilor prin luarea în considerare a unei scheme de plantare de 4 × 4 m şi prin săparea unor gropi cu adâncimea de 200 cm şi cu diametrul de 20 cm. Astfel de gropi sunt utilizate ulterior pentru plantarea de sade. Operaţiile s-au realizat pe un sol nepregătit, starea acestuia fiind cea specifică, de după operaţiile de exploatare a lemnului. Diferenţa dintre T_{11} şi T_{12} (**Tabelul 1**) a fost aceea că în T_{11} operaţiile de săpare a gropilor s-au realizat paralel cu latura scurtă a subparcelei, iar în T_{12} acestea s-au desfăşurat pe latura lungă a subparcelei. Observaţiile din cel de-al doilea grup (T2) s-au realizat în patru subparcele, care au fost parcurse cu lucrări pe o suprafaţă cumulată de 3,27 ha. Înainte de operaţii solul a fost pregătit, schema de plantare a fost de 3 × 2 m, iar operaţiile de săpare a gropilor s-au realizat prin utilizarea unui burghiu cu lungimea de 60 cm şi cu diametrul de 60 cm. Ulterior săpării gropilor, în T1 au fost plantate sade de plop euramerican iar în T2 au fost plantaţi puieţi de plop alb.

Observaţiile de teren pentru T1 s-au realizat în datele de 10-11, 15 şi 17-18 octombrie 2018, iar cele pentru T2 s-au realizat în datele de 20-24 şi 27 noiembrie 2018. Observaţiile s-au realizat pentru suprafeţe parcurse cu lucrări care au acoperit circa 20% şi, respectiv, 56% din suprafeţele iniţiale luate în studiu. Pe durata observaţiilor de teren condiţiile vremii au fost bune.

2.2. Descrierea echipamentelor utilizate şi a modului de organizare a muncii

Operațiile de săpare a gropilor s-au realizat prin utilizarea unui tractor românesc echipat cu o mașină de săpare de construcție italiană (**Figura 1**). Principalele detalii tehnice ale tractorului folosit, ale mașinii de săpare şi ale burghielor utilizate sunt redate în **Tabelul 2**.

(i)

(ii)

Figura 1. Descrierea echipamentelor utilizate, a operațiilor realizate şi a dimensiunilor gropilor. Legendă: (i) gropi pentru sade: a – agregatul folosit, b – detalii ale mașinii de săpat (1 – cadru, 2 – dispozitiv de ajustare, 3 – corpul mașinii; 4 – cadru lateral; 5 – burghiu), c & d – detalii ale sistemului de transmisie şi ale burghiului, e – imagine de ansamblu a suprafeței după operare, f – groapă pentru sade; (ii) gropi pentru puieți: a – agregatul folosit, b – detalii ale mașinii de săpat şi ale burghiului (1 – burghiu, 2 – corpul mașinii, 3 – dispozitiv de ajustare; 4 – sistem de transmisie; 5 – cadru lateral), c – imagine de ansamblu a suprafeței după operare; d – elementele dimensionale ale unei gropi

Tabelul 2. Descrierea echipamentului pentru săpat gropi

Tip de echipament şi principalii parametri tehnici	Specificare şi descriere
Tractor U650	
Anul construcției	2004
Tip	Universal, sistem de rulare pe roți, D110, 2 axe
Motor	Diesel, patru timpi, injecție directă
Masă	4.310 kg
Puterea motorului	47,8 kW
Cilindree	4,76 l
Lungime	4.070 mm
Lățime	2.370 mm
Înălțime	2.630 mm
Pneuri	Spate: 14.00-38PR, Faţă: 6.50-20 8PR/7.5-20 8PR
Capacitatea rezervorului de combustibil	98 l
Viteză maximă	29 km × h^{-1}
Mașină de săpat gropi Selvatici T11	
Lungime	2.900 mm
Înălțime	860 mm (fără burghiu)
Burghie	
Lungime	1000[a], 2000[b] mm
Diametru	600[a], 200[b] mm

Note: a – dimensiunile burghiului folosit în T2, b – dimensiunile burghiului folosit în T1.

În ambele grupuri de subparcele s-a folosit același tractor, echipat cu aceeaşi mașină de săpat gropi. Principalele diferențe dintre cele două grupuri de subparcele au fost cele legate de dimensiunile burghiului folosit şi cele ale gropilor săpate. Din punct de vedere al organizării muncii, pentru desfășurarea operaţiilor este necesară deplasarea agregatului de la locul de garare la locul de muncă. La locul de muncă, operaţiile de săpare a gropilor constau din deplasări ale agregatului, intercalate cu săparea de gropi conform schemei de plantare. Deplasările agregatului au fost cele dintre pozițiile în care s-au săpat gropile precum şi cele de la capetele subparcelei pentru ieșirea şi reintrarea pe un nou rând de gropi de săpat. În studiul de faţă s-au inclus observațiile legate de activitățile desfășurate la locul de muncă iar locurile în care s-au executat gropile nu au fost pichetate în avans. Observațiile s-au efectuat asupra muncii a doi operatori de tractor care au fost selectați pe baza experienței extinse în muncă cu privire la operațiile luate în studiu. Înainte de a se realiza studiul, muncitorii în cauză au fost informați cu privire la scopul studiului şi la modalitățile în care vor fi utilizate datele colectate şi li s-a cerut acordul de a fi observați în timpul desfășurării muncii.

Pentru scopul studiului de faţă s-au separat două elemente de muncă care au stat la baza analizei şi clasificării consumului de timp, ultimele realizându-se la nivel global şi nu la nivel de ciclu de muncă. Toate manevrele agregatului constând din deplasări la capete şi între locurile în care s-au săpat gropile s-au încadrat în elementul de muncă denumit în continuare *Deplasare*. Toate manevrele legate de săparea efectivă a gropilor s-au încadrat în elementul de muncă denumit în continuare *Săpare*. Întreruperile de natură tehnică s-au încadrat, din punct de vedere al consumului de timp, în categoria întârzierilor denumite în continuare *Tehnic*, iar întreruperile de natură personală s-au încadrat în categoria întârzierilor denumite în continuare *Personal*.

2.3. Colectarea datelor

Datele cu privire la consumul de timp au fost colectate în toate subparcelele luate în considerare folosindu-se o cameră video de dimensiuni mici care a fost amplasată în cabina tractorului astfel încât

câmpul de vizualizare al acesteia să fie orientat înspre mașina de săpat. Camera a fost configurată pentru colectarea de fișiere video consecutive, fiecare dintre acestea având o durată de 20 de minute. Fișierele video în cauză au fost stocate pe un card de memorie de 34 GB care a fost introdus în camera video. Date cu privire la localizarea generală a agregatului de săpare au fost colectate prin folosirea unui receptor GPS Garmin GPSMap 62 stc. La sfârșitul fiecărei zile de observație, datele video şi GPS au fost transferate într-un calculator personal, unde au fost organizate pe zile şi locuri de studiu.

2.4. Prelucrarea şi analiza statistică a datelor

Datele cu privire la consumul de timp au fost prelucrate printr-o analiză de detaliu a fişierelor video colectate din teren, ocazie cu care s-a stabilit şi structura bazei de date în care s-au înregistrat datele sub formă numerică. Fiecare fișier video a fost analizat în detaliu, stabilindu-se timpul de început şi de sfârșit al fiecărui element de muncă identificat, timpi care s-au transpus într-un fișier Microsoft Excel şi care au servit la calculul consumului de timp efectiv pentru fiecare observație, prin diferență. După separarea duratelor pe elemente de muncă, s-au calculat timpii cumulați pentru fiecare element de muncă şi pe baza lor s-au calculat proporțiile de participare în structura consumului de timp. Baza de date a fost utilizată pentru estimarea consumului de timp mediu pentru fiecare element de muncă şi alternativă operațională. Cu ocazia analizei fişierelor media s-a notat şi numărul de gropi săpate în fiecare subparcelă. Eficiența operațiilor s-a apreciat prin raportarea consumului de timp cu şi fără întârzieri la producția realizată (numărul de gropi), calculându-se astfel indicatorii neți şi bruți pentru fiecare alternativă operațională. Productivitatea operațiilor s-a apreciat prin indicatori similari, raportând numărul de gropi săpate la consumul de timp cu şi fără întârzieri. Procesarea şi analiza statistică a datelor s-au realizat în programul Microsoft Excel. Conceptul cu privire la studiul timpului şi al productivității muncii a fost adaptat pe baza celor precizate în [10-12].

3. REZULTATE ŞI DISCUȚII

3.1. Consumul de timp

Indiferent de opțiunea tehnică luată în studiu, săparea efectivă a fost elementul de muncă caracterizat de proporția majoritară în structura consumului de timp la locul de muncă. Deşi nu se prezintă date de detaliu în această lucrare, în cazul săpării de gropi pentru sade, operarea pe latura lungă a subparcelei a generat situația cea mai favorabilă din punct de vedere al eficienței muncii. La nivel global (T1), circa 46% din consumul de timp a fost cel specific săpării efective de gropi. Deplasările de diferite tipuri au ocupat circa 30% din consumul de timp iar întreruperile de natură tehnică şi personală au ocupat restul de circa 24% (**Figura 2a**). În medie, săparea unei gropi pentru sade a durat circa 32 de secunde, iar deplasările agregatului de săpare au generat o valoare medie de circa 21 secunde pe deplasare. Datele cu privire la structura consumului de timp, indicată în **Figura 2a**, au la bază o durată totală de observare a procesului de muncă de circa 21 de ore, timp în care au fost săpate 1089 de gropi pentru sade.

În ceea ce privește operația de săpare a gropilor pentru puieți, structura consumului de timp la locul de muncă a variat pentru anumite elemente de muncă, între anumite limite (**Figura 2b**). Astfel, consumul de timp pentru săparea efectivă a gropilor a fost de ordinul a 33-55%. La nivel global (T2), consumul de timp pentru săparea efectivă a gropilor a reprezentat circa 43% din consumul de timp la locul de muncă. Deplasările agregatului între locurile de săpare şi la capetele subparcelelor au reprezentat circa 35%, iar restul de 22% au fost reprezentate de către diferitele

tipuri de întreruperi. Datele cu privire la structura consumului de timp au la bază observații realizate pe o perioadă de circa 33 de ore, timp în care au fost săpate 5453 de gropi pentru puieți. În aceste condiţii, durata medie de săpare a unei gropi a fost de circa 9 secunde iar durata medie a unei deplasări a agregatului de săpat a fost de ordinul a 8 secunde. În ambele cazuri (T1 şi T2), consumul de timp generat de deplasări a variat foarte amplu, de la câteva secunde până la mai multe minute.

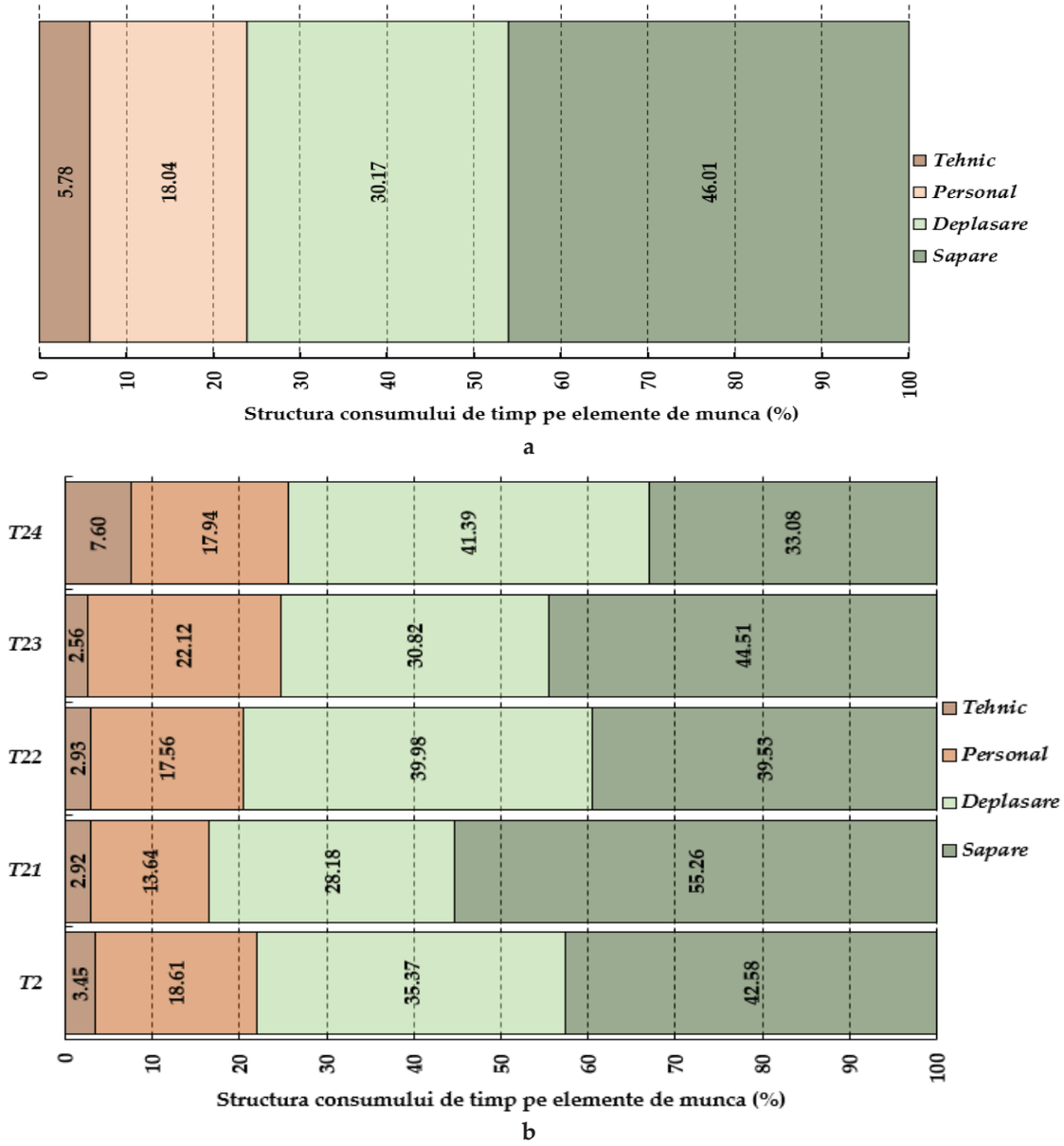

Figura 2. Structura consumului de timp pe elemente de muncă. Legendă: a – săparea de gropi pentru sade; b – săparea de gropi pentru puieți

În ambele cazuri (T1 şi T2) întreruperile care au apărut în procesul de muncă au fost cele cauzate de diverse motive precum mici defecțiuni şi ajustări ale agregatului de săpat gropi şi, respectiv, cele cauzate de evenimente precum pauzele de odihnă şi necesități firești etc.

3.2. Performanța productivă

În condiţiile precizate cu privire la consumul de timp şi la producția realizată, eficiența muncii pentru operația de săpare a gropilor pentru sade a fost caracterizată de valori de ordinul a 0.015-0.020 ore/groapa săpată (**Figura 3a**). Prima valoare a fost cea estimată prin excluderea diferitelor tipuri de întârzieri. În condițiile descrise, productivitatea muncii a fost de ordinul a 50-70 gropi săpate pe oră.

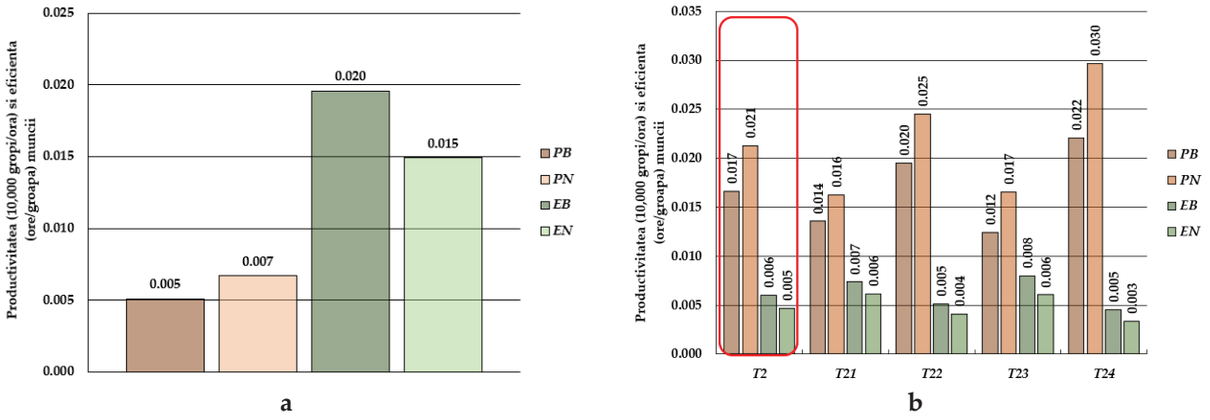

Figura 3. Structura consumului de timp pe elemente de muncă. Legendă: a – săparea de gropi pentru sade; b – săparea de gropi pentru puieți; PB – productivitatea brută, calculată prin includerea consumului total de timp; PN – productivitatea netă, calculată prin excluderea întârzierilor, EB – eficiența brută; EN – eficiența netă.

Atât productivitatea cât şi eficienţa muncii a variat destul de amplu în cazul subparcelelor în care s-au executat operații de săpare a gropilor pentru puieți (**Figura 3b**). La nivel global (T2, **Figura 3b**), eficienţa muncii a fost caracterizată de valori de ordinul a 0.003-0.005 ore/groapa săpată. Productivitatea muncii a fost de ordinul a 170-210 gropi/oră. Interpretarea valorilor pentru eficienţa şi productivitatea muncii este similară cu cea de la săparea gropilor pentru sade.

3.3. Discuții

Comparând situația specifică săpării gropilor pentru sade cu săparea mecanizată a gropilor pentru puieții de plop, eficiența muncii în cazul săpării mecanizate a gropilor pentru plantat puieți a fost, global, mai mare de circa 3-3.5 ori. Acest lucru poate fi pus pe seama condițiilor contrastante între cele două situații sub raportul dimensiunilor gropilor săpate, tipului de sol şi a stării acestuia (pregătit sau nepregătit), precum şi schemelor de plantare. Din punct de vedere al dimensiunilor gropilor săpate, volumele gropilor pentru puieți au fost mult mai mari decât cele specifice gropilor pentru sade, însă stratul de sol natural nepregătit pe care a trebuit să îl străbată burghiul în cazul forării gropilor pentru sade a fost mult mai mare față de cel al forării gropilor pentru plantarea puieților.

Productivitatea estimată în acest studiu pentru operațiile de săpare a gropilor pentru puieți este net superioară valorilor aferente redate de studiile de normare [9] existente la nivelul

sectorului silvic, care indică, pentru utilaje similare din punct de vedere constructiv, valori de ordinul a 39 până la 50 gropi/oră, în funcție de condițiile specifice de muncă. Rezultă faptul că sunt necesare studii mai aprofundate pentru acest tip de lucrări care să reproiecteze normele de timp și producție la condițiile tehnologice actuale. De asemenea, prin comparație cu alte studii în care au fost executate gropi cu moto-burghie, dar de dimensiuni cuprinse între 150-200 mm [8], observăm că diametrul gropii și condițiile de muncă influențează substanțial productivitatea muncii. Pentru operațiile de săpare mecanizată a gropilor în vederea plantării de sade nu există studii normate la nivelul sectorului silvic din țara noastră. Ca atare, nu se pot compara rezultatele privind productivitatea, aspect care necesită dezvoltarea unor astfel de studii de normare care să acopere toată variabilitatea condițiilor operaționale specifice. Execuția manuală a gropilor pentru plantat sade nu este posibilă fizic și nici fezabilă, acest mod de execuție implicând o forță mare aplicată burghiului, forță ce nu poate fi disponibilă decât mecanizat, cu ajutorul unui utilaj specific care să poată acționa și purta un astfel de dispozitiv.

Productivitatea muncii în cazul săpării manuale a gropilor pentru plantat puieți de plop în teren pregătit, cu dimensiunile de 60 × 60 × 60 cm, descrisă de aceleași studii de normare [9], are valori cuprinse între 3.6 – 7.5 gropi/oră/muncitor. Valorile respective ale productivității muncii, care sunt scăzute, necesită frecvent utilizarea unor formații de muncă mari, alcătuite din mai mulți muncitori (20 – 40 persoane) care să poată furniza productivități ale muncii comparabile cu cele generate prin folosirea unui utilaj ce execută mecanizat astfel de gropi. Astfel de abordări implică un consum substanțial de manoperă, costuri ridicate cu manopera şi, respectiv, o organizare adecvată a șantierelor de plantare. Prin urmare, studiul de față demonstrează superioritatea evidentă a lucrărilor executate mecanizat față de cele efectuate manual, atât din punct de vedere economic, al resurselor materiale și de manoperă (un singur muncitor față de o echipă de muncitori), cât și calitativ (uniformitatea gropilor efectuate conform standardul solicitat), ceea ce conduce la o concluzie evidentă a promovării modului mecanizat de execuție a gropilor în practica silvică, desigur, cu limitarea dată de resursele financiare necesare procurării unui asemenea agregat de săpare (tractor şi mașină echipată cu burghiu).

4. CONCLUZII

Principalele concluzii ale lucrării sunt următoarele:

1. Productivitatea muncii specifică operaţiilor de săpare mecanizată a gropilor pentru puieți şi sade de plop este ridicată, favorizând extinderea mecanizării pentru acest tip de operații şi permițând o gestionare eficientă a arboretelor de plop;
2. Săparea gropilor pentru puieți a fost identificată a fi de circa 3-3.5 ori mai productivă în comparație cu săparea gropilor pentru sade. Acest spor de productivitate se datorează condițiilor operaționale generale cum sunt cele legate de starea solului, schema de plantare şi dimensiunile gropilor de săpat;
3. Există un potențial ridicat de creștere a productivității muncii printr-o mai bună gestionare a timpului de muncă şi prin perfecționarea tehnologică a agregatului folosit la realizarea gropilor. Astfel, îmbunătățirea din punct de vedere constructiv-ergonomic

poate să conducă la eliminarea timpului consumat excesiv sub formă de pauze de odihnă iar îmbunătățirea din punct de vedere mecanic poate să conducă la eliminarea întârzierilor cauzate de defecțiuni tehnice.

MATERIALE SUPLIMENTARE

Nu este cazul.

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CONFLICT DE INTERESE

Autorii nu declară niciun conflict de interese.

ANEXE

Nu este cazul.

REZUMAT EXTINS – EXTENDED ABSTRACT

Title in English: *Estimation of Time Consumption and Productivity in Mechanized Pit Drilling Operations for Poplar Cutting and Seedling Planting.*

Introduction: *Poplar forests represent a valuable wood production alternative being spread on wide areas worldwide. In Romania, such forests are predominantly restocked by the use of seedlings, requiring various operations such as those of soil preparation, marking of planting spots, manual or mechanical pit drilling etc. Besides the effective planting operations, there are needed logistics to supply the planting material and to transport the planting equipment to a given site. Given the current situation in which the available manual labor is following a decreasing trend, mechanized operational alternatives may provide a sustainable management of poplar forests. This resulted in testing and using new pit-drilling machines with results which were found to be good in practice; however, a scientific approach to the problem of using new machines is missing in the Romanian forest sector to provide informed grounds on the productivity of operations as well as the statistics needed to develop suitable labor payment systems. This holds true as the existing piece-rate standards describe operations for machines that are not used anymore, while the practice has shown that the use of large cuttings could be a good alternative for poplar planting. This study aimed at evaluating the time consumption and productivity of poplar planting operations by the use of two mechanized pit-drilling alternatives: large cutting vs. seedling planting.*

Materials and Methods: *Field observations were implemented in five forest compartments located in the southern part of Romania (Dolj County), in the forest area managed by the National Forest Administration – RNP Romsilva, with the aim to include the operational variability given by the planting scheme, type of planting material and the condition of the soil before the operations. Pits were drilled by the use of Romanian made tractor equipped with*

an Italian made pit-drilling machine. A video camera and a GPS unit were used to document the operations and to collect the data needed for a detailed time-and-motion study. The collected media files were analyzed in detail to separate the events as specific to the operations. For this, four categories of time consumption were delimited, namely, effective drilling, machine movement, personal and technical delays. Based on the number of drilled pits and on the time consumption analysis, indicators characterizing the productive performance such as the productivity and efficiency were calculated in the office phase of the study, by including and excluding the delays.

Results and Discussions: *Irrespective of the studied technical option, the effective pit-drilling accounted for the most in the time consumption structure. For instance, in the pit-drilling for planting large cuttings, approximately 46% of the time consumption was used for effective pit-drilling, 30% for machine moving and 24% were delays. These results were based on a study covering approximately 21 hours, in which a number of 1089 pits were drilled. On average, drilling a pit took approximately 32 seconds and moving the machine took approximately 21 seconds. Based on above, the net and gross efficiencies and productivities were estimated at 0.015-0.020 hours/pit and at 50-70 pits/hour, respectively. In the case of pits drilled for seedlings, the net and gross efficiencies and productivities were estimated at 0.003-0.005 hours/pit, and at 170-210 pits/hour, respectively, and the average time consumption for effective drilling and moving was of 9 and 8 seconds per pit and moving maneuver, respectively. Therefore, the productivity of drilling pits for seedlings was 3 – 3.5 times higher. The study indicates a higher efficiency of the mechanized operations compared to manual ones and the quality of work could be also higher as of using machines for drilling. However, the fully mechanized option for pit-drilling could be limited by the availability of machines and by the financial investments needed to purchase equipment, but it also could contribute to the sustainability of operations.*

Conclusions: *Productivity of mechanized pit-drilling operations for poplar planting was found to be high compared to the manual and mechanical alternatives described by the existing (Romanian) piece-rate systems. However, the operational conditions affect to a great extent the performance of operations. For instance, the planting scheme, depth of the pits and the condition of the soil before operations have been found to generate contrasting figures of productive performance; as such, the productivity of drilling pits for seedlings was found to be 3 to 3.5 higher compared to that specific to large cuttings. Measures to increase the productivity, irrespective of the option, rest in a better management of the workplace time which could be achieved by improvements of the machine in terms of ergonomics and mechanics.*

Keywords: *Poplar, planting, drilling, pit, seedlings, cuttings.*

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