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PLANTATION FORESTRY AND ENERGY PLANTATIONS IN UKRAINE: RESOURCE POTENTIAL AND DEVELOPMENT PROSPECTS



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Forest plantation cultivation for today and for the future is the most important factor of increasing wood resource in Ukraine. Therefore, it is important to develop special programmes for growing short-rotation plantations and their widespread introduction into forestry production to meet the industrial needs for wood and also wood as a renewable energy source. The conversion of part of the Forest Fund area (8-10 %) to forest plantation cultivation will make it possible to obtain significant amounts of wood (1.2-1.7 thousand m³/ha) for industrial purpose in a relatively short period of time, reduce the volume of cutting in primary forest stands, optimize the energy balance of the country due to the production of wood on energy plantations, partially replace fossil fuels with cheaper and renewable wood raw material. The practical aspects of the introduction of forest plantations and energy plantations with the participation of fast-growing species in the territory of the western region of Ukraine are considered. Identified is the place of forest plantations in the general cycle of forest cultivation on the principles of species alternation.

Keywords: plantation forestry; forest plantations; fast-growing tree species; energy plantations; species alternation.

Introduction

In the era of the global aggravation of the energy crisis, the search for alternative forms of energy has become a critical issue both in terms of meeting the resource and energy needs of humans and in view of the urgent need to reduce anthropogenic load on the environment. Amid the progressive depletion of fossil fuels, there is a clear trend towards increased use of biofuels, including fuelwood as an alternative source of renewable energy (Korzhov, 2008; Lakyda & Domashovets, 2009).

Wood and energy are two closely interrelated concepts complementing each other. At present, we have every reason to assert that in the coming decades wood will play rather a prominent role in the world's energy system. The rapid development of bioenergy worldwide is determined by the increase in the production and processing of wood as a renewable energy resource.

The use of biofuels is relevant in those regions where there is a permanent raw material base, high demand and technical capabilities for replacing fossil fuels. According to the Department of the Food and Agriculture Organization of the United Nations (FAO), when the price of oil is around \$ 70 per barrel, biofuels today is more competitive, and in 15-20 years, renewable fuels can meet about 25 % of the world's energy requirements (Forest and energy, 2008). As oil prices tend to increase, biofuel production will be accelerated.

The tendency of plantation forestry development in the countries of Europe and America, in addition to receiving "fast" wood, is determined by a focus on the conservation

of natural forests and meeting industrial needs for wood resources obtained on a small area of land using fast-growing species with a short period of cultivation.

The relevance of introducing plantation forestry

Nowadays, the issue of accelerated production of wood for industrial needs is becoming increasingly burning, and now it presents a worldwide problem. The trend is due to the rapid industrial development of countries, resulting in increasing use of natural resources, including wood. For such sparsely forested country like Ukraine, this problem is particularly pressing. Following coal, gas and oil, wood is a strategic raw material and, as it relates to renewable natural resources, there is an urgent need to find effective ways of increasing the volume of its cultivation (Kenney, 1993). According to the existing forecasts, in 2050, most of the wood will be harvested in artificial forests (75 %), including 50 % in plantation crops (Sedjo, 2001).

Forest resources in Ukraine are limited and, for economic reasons, their import is complicated. With this background, it is necessary to produce wood in the country in the largest possible amounts and in the shortest possible time so it would satisfy both various domestic and export needs. Therefore, the use in Ukraine of an energy source such as woody biomass, which, unlike gas, oil, coal, is a renewable natural resource and one of the few environmentally-friendly fuels, is becoming increasingly widespread. The high forest-site potential of the land ensures the success of this task (Debrynyuk, Krynytskyi & Tselen, 2016).

Under conditions of aggravation of environmental problems, first of all, global climate change in the direction of

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its xerophytization, there is a need to grow additional volumes of "fast" wood in the territory of the country as a strategic raw material in the largest possible amount in the shortest possible time in the quantities that would satisfy both industrial and local needs for wood. Rich forest site conditions, extensive silvicultural experience, significant scientific and production potential are a real basis for solving this problem. Forest plantation cultivation at the present stage and in the near future has no alternative and determines the urgency of developing both state and regional integrated programmes for cultivation of high-yielding, short rotation, plantations in order to obtain both industrial assortments and energy wood on a national scale.

At present, the potential use of forest biomass in the total energy consumption in Ukraine is about 0.8 %, which is evidence of its insignificance now, but significant prospects in the future – provided economic incentives and scientific and technical assistance (Lakyda & Domashovets, 2009).

According to estimates of scientists (Lakyda, et al., 2009), annual burning of energy wood in Ukraine in the amount of 2.1 million tons of arbitrary fuel will emit into the atmosphere about 1.7 million tons of carbon. It should be noted that sequestration of atmospheric carbon by trunks and root systems of trees in the forests of Ukraine is about 11 million tons annually, that is, the use of woody biomass, as energy raw material, does not imply any significant impact on the change in the carbon balance of the atmosphere.

Objectives and objects of plantation forestry

Due to the need to optimize the energy balance of the country, to reduce the operating load on valuable primary forests, to increase the productivity of forest lands, it is urgent to solve the problem of introducing effective technologies for plantation forest growing.

By forest plantation (FP), we mean artificial plant communities grown under the human control with a targeted focus on accelerated industrial production of special forest products in larger volumes and in much shorter time than it is done in forests managed by using traditional technologies. The establishment of forest plantations is primarily focused on the accelerated production of woody biomass upon special projects drawn up for the entire cycle of growing such plantations according to their objectives.

Under conditions of the western region of Ukraine, we consider it a promising measure to use the following tree species for this purpose – Norway spruce (*Picea abies* L. Karst.), European larch (*Larix decidua* Mill.), Campfer larch or Japanese larch (*Larix kaempferi* Carr.), Dunkeld larch or hybrid larch (*Larix eurolepis* Henry), and Douglas-fir (*Pseudotsuga menziesii* Mirb. Franco) which in a relatively short period of time are capable of producing significant amounts of woody biomass (Debrynyuk, 2013; Debrynyuk, Krynytskyi & Tselen, 2016). The reason for this choice was high and very high growth rate of these species, the value of wood, the ability of forming highly productive pure and mixed forest stands, the ability to quickly accumulate considerable amounts of phytomass, the availability of research and production experience in cultivating these tree species. In case of the introduction of intensive technologies of plantation forestry, the quality wood of the desired size can be grown much faster than with traditional forest crops.

Forest plantations can be either pure (spruce, larch, Douglas-fir, pine, oak) or mixed (pine-larch, fir-larch, spruce-

larch, broadleaved-larch, spruce-Douglas-fir). The latter deserve special attention because they contribute to the rational use of forest-site potential for formation of significant volumes of phytomass, also they provide a high biotic resilience of tree plants.

The species that are introduced for production of plant biomass on energy plantations must meet the basic requirement – to accumulate the maximum amount of wood raw material in the shortest possible time. In the mid-latitudes, willows and poplars are suitable for this purpose – both "pure" species and their hybrids (Onyskiv, et al., 2003; Fuchylo, Onyskiv & Sbytna, 2006).

Areas and perspectives of usage

For Ukraine, the use of wood, especially as energy resource, is a promising measure, first of all, for the needs of the population (for households), which would partially replace expensive gas with cheaper wood fuel. In this aspect, the use of phytomass of trees as energy raw materials, as well as the production of industrial assortments, is divided into three areas (Debrynyuk & Solovii, 2012; Debrynyuk, 2008): 1) the use of logging residues and sawmilling waste; 2) establishment of short-rotation energy plantations (EPs) for production of significant amounts of biomass for energy needs; 3) establishment of forest plantations (FP) to meet industrial needs for wood.

All the three areas are promising in Ukraine. With regard to *the first area*, Ukraine has important advantages over other countries considering both the significant amount of unused logging residues and the high trophic potential of forest-site types. The following materials can be used as fuel: logging residues that are accumulated during timber harvesting; industrial waste formed in wood processing; post-consumer wood which has already passed the usage cycle. The problem resides in the efficiency of collecting, storage, transportation and use of these wastes.

However, one cannot focus on the full use of logging residues since such an activity can reduce the potential fertility of forest lands while in mountain conditions this can intensify erosion processes on steep slopes. However, industrial wood residues and post-consumer wood need to be used in full.

The second area of using tree biomass as energy wood is the creation of energy plantations of fast-growing tree species. This will allow production of wood in large quantities in a relatively short period of time, where it would be possible to harvest wood raw material as fuel. The production experience has shown that it is possible to successfully establish and grow in Ukraine willow and poplar EPs to obtain phytomass that can be used as biofuel for future fuel-wood-operating power plants (Fuchylo, Onyskiv & Sbytna, 2006).

It should be noted that the existing technologies for growing energy plantations (especially – willow and poplar) require certain investments to establish such plantations. On the other hand, the introduction of plantations will lead to creation of new jobs, which, accordingly, will increase the employment rate of the population. The positive aspect is the fact that the lands (especially in moist and wet site types) which are virtually empty will be used productively by meeting the needs of industry with energy wood.

The third area, which involves obtaining significant volumes of valuable industrial assortments in a relatively

short time, can be realized through the establishment of forest plantations. The main objective of establishing such plantations is to satisfy industrial needs for wood raw material and to reduce the pressure on natural forest ecosystems by shifting the emphasis of forest-use to plantation management. In turn, this measure will help improve the age structure of forest stands, which is unbalanced today. The high annual growth of woody biomass in forest plantations will allow logging to be concentrated on a significantly smaller area than in natural or artificial forests, which is economically profitable.

In order to ensure (1) high productivity and stability of FP, (2) accumulation of large volumes of phytomass in a short period of time, (3) avoiding significant investments, it is proposed to use the potential forces of nature, which involves cyclic natural alternation of tree species (for example, conifers → broadleaved → conifers, etc.). Instead of broadleaved, it is proposed to introduce fast-growing coniferous species for the period of 40-60 years as an intermediate link in the overall cycle of forest-growing. Species alternation of this kind will contribute to eliminating the phenomenon of soil exhaustion, help reduce the adverse effects of pests and disease of trees due to changes in the species composition of the forest plantation, raising the level of use of the soil and climatic potential of the forest-site type, significantly increase the overall productivity of forest areas.

Principles of functioning and resource potential

Effective functioning of the FP is based on the following principles (Debrynyuk, 2008, 2009a, 2009b):

- the initial density of the FPs should ensure their rapid closure;
- the cultivation of the FP should take place in the regime of optimal density with regular thinning in predetermined periods with the aim of avoiding natural mortality;
- thinning treatments should be planned so that at the expense of intermediate felling to partially (or fully) cover the costs of establishing and growing FP even before the age of the final cutting;
- the use for the creation of FP of large-sized planting stock grown from seeds of higher selection categories will ensure the rapid closing of plantations and further intensive growth of tree plants;
- the introduction of plantation forestry system should be based on the principle of species alternation and provide for a successive changes in the growing cycle in the chain *derivative low-yield forest stand* → FP → *primary high-yield forest stand*;
- the application of the species alternation principle will ensure a sufficient fertility level of forest lands throughout a limited cycle of plantation cultivation as a result of which the need for fertilization disappears;
- adherence to cultivation regimes will allow maintaining the successful functioning of the PF for a specified period of time.

In order to enhance the functioning and productivity of forest plantations, it is necessary to introduce a number of measures which should be merged into three groups.

The first of these includes the natural and technological aspects – the choice of species, ecotype, variety or form of the plant, the choice of a plot, the type of forest site, the use of selected planting material, the choice of initial density, mixing schemes, placement of planting holes, soil cultivation systems.

The second group includes aspects aimed at improving the growth of plantations and quality of wood, measures to

increase the intensity of accumulating phytomass by woody plants, regulation of density.

The third group should include measures for the effective sale of plantation forestry products

When establishing EP, the selected areas are mainly in wet site types, the principle of choosing sites for establishment of FP is somewhat different. Thus, according to our data (Debrynyuk, 1995), the forest land potential, especially in the conditions of the western region of Ukraine, is far from being fully utilized. The reason is the presence of low-yielding stands that grow in relatively rich and rich types of forest sites. It is these sites that are potential areas for laying out plantations. The criterion for selecting areas is the ability to achieve maximum effect during forest growing, harvesting and transportation of wood. The richer site conditions, the less investment is needed for the production of tree phytomass.

Our proposed approach to obtaining wood on forest plantations based on species alternation (Debrynyuk, 2004) is focused on intensive forest growing with rational use of natural potential of forest site types. It consists in the production of large amounts of wood in the shortest possible time without the use of high-cost forestry practices (e.g. intensive soil cultivation, fertilizer application) and the full or partial return on investments into plantation cultivation at the expense of intermediate use (Christmas trees, small- and medium-sized timber, etc.). Skillful use of natural potential of forest-site types is the essence of our conceptual approach to the issue of plantation forestry, in contrast to the existing traditional ways of forest stand regeneration (Shutov, et al., 1984; Morozov, 1985; Onyskiv, et al., 2003).

The basis of this process is the principle of species alternation, which takes into account the natural cyclic process of species succession with consideration of the effect of the "predecessors" and "successors" on the edaphic environment according to the scheme: secondary or primary low-yield forest stand → forest plantation → primary high-yield forest stand (Debrynyuk, 2010, 2013). Forest plantations are established to function for a relatively short period of time – 40-70 years, after which they are clearcut and a primary forest stand is regenerated through the introduction of forest crops.

The application of the principle of species alternation eliminates the contradictions between the cultivation of primary forest stands and the establishment of forest plantation. Species alternation is a supplement, a logical extension of traditional forest management in Ukraine, and takes into account, first of all, the factor of interaction between woody species, activities to build up the edaphic potential of forest sites and its most full use. Here we have an example of a short-term interruption of the cultivation of a permanent crop through creation of "intermediate link" – plantation cultures with the subsequent regeneration of the primary stand (Debrynyuk, 2009a, 2009b).

Another important issue is the establishment of appropriate volumes of forest plantations. Let us consider this on the example of the Western Forest-steppe of Ukraine. Thus, the total area covered with forest vegetation in the region is 845,436 hectares (Debrynyuk, 2008, 2009a, 2009b). If you accept the area of the stands which are subject to gradual replacement with forest plantation at a 10 % level instead of the proposed 20 % (Gavrylenko, et al., 1996), the total area of the forest plantation will be 84,540 hectares. Taking the average rotation age for FP as 50 years, in Western Forest-

steppe it is necessary to annually establish forest plantations on 0.2 % of the land covered with forest vegetation (1,700 ha).

After the first stage of the main cutting of forest plantations in the area of 1,700 hectares in 50 years, primary forest stands are regenerated on this territory according to the type of forest, while a site of the same size of the secondary or low-yield primary stands is allocated for FP. From this point on, the scheme *low-yield stand* → *forest plantation* → *high-yield stand* will operate in a steady regime with annual cycling, allowing for harvesting at least 680-850 thousand cubic meters of stem wood annually without taking into account the volumes of intermediate use.

The proposed scheme of forest plantation cultivation, where "intermediate" plantations act as an element of the *species alternation*, is aimed at significant improvement of the efficiency of forest product production due to: a) short rotation period in FP, which accumulates significant amounts of woody biomass; b) production throughout the entire period of stands growing; c) increased productivity and stability of primary stands established after clearcutting of the

forest plantation due to the positive biochemical impact of preceding species on the soil.

We propose to lay out a FP in a relatively rich (fairly fertile) site types because in fertile site types (oak forests, beech forests, fir forests, spruce forests) priority should be given to planting indigenous species. However, in some cases, it is possible to establish a FP in fertile site types as well, where the stem wood volume, as compared with fairly fertile conditions, increases by 25-30 %.

Forest plantations composed of Norway spruce are created pure in composition with planting scheme 1.0×1.0 m. High initial density promotes rapid closure of the crops and ensures the production of Christmas trees as early as 4-6 years of age (extraction of every second spruce tree). At the age of 8-10, each second row of spruce is removed, leaving 2.5 thousand pcs of trees per hectare with their spacing 2.0×2.0 m. By the age of the final cutting, it is recommended to leave 625 trees per hectare. The total volume of stem wood production during the period of the FP operation is 350-500 m³/ha (Table 1).

Table 1. Forest-inventory indices for FP with fast-growing tree species

Indices	Tree species and the final cutting age, years				
	<i>Picea abies</i> (41-50)	<i>Larix decidua</i> (61-70)	<i>Larix kaempferi</i> (51-60)	<i>Larix eurolepis</i> (51-60)	<i>Pseudotsuga menziesii</i> (61-70)
Number of trees (initial/final), pcs/ha	10000/625	625/625	3300/410	2500/625	4500/500
Growing space of one tree (initial/final), m ²	1.0/16.0	2.0/16.0	3.0/24.0	2.0/16.0	2.0/20.0
Average height range at final cutting age, m	20.1-22.0	25.8-28.1	27.5-30.0	28.9-31.2	29.1-32.0
Average diameter range at final cutting age, cm	20.6-23.0	32.7-34.4	32.3-34.6	36.2-38.5	43.2-46.7
Stem wood volume during final harvest of FP, m ³ /ha	205-280	630-750	455-570	915-1120	1055-1350

Note. FP of woody species is recommended to establish in the following types of site: *Picea abies* – C₃, *Larix decidua* – C₂, *Larix kaempferi* – C₂-C₃, *Larix eurolepis* – D₂, D₃ (for fairly fertile site types no data is available), *Pseudotsuga menziesii* – D₃ (for fairly fertile site types no data is available).

Forest plantations of European larch need to be created mixed, where larch forms the upper storey of stocking 0.5-0.6. It is distributed uniformly over the area (4.0 x 4.0 m) on the principle of "chess board". The share of larch in the crop composition at the initial stage of cultivation is only 12.5 %. It is advisable to use small-leaved lime as an associated species of the second storey. The scheme of mixing – 1 row SLI with EL 1 row SLI, where larch in the mixed rows is planted after every three lime seedlings. Initial density – 5000, including larch – 625 pcs/ha. Thinning of the FP must be performed at the expense of the associated species, while larch should be grown in the same amount until the final cutting age. The total volume of stem wood during the period of growing the FP, including lime wood, is 720-840 m³/ha.

Forest plantations of Japanese larch, taking into account the high density of its crown, are initially created pure. The first thinning is performed at the age of 8-12 years, removing every second tree of the species based on the principle of "chessboard". As a result of three thinnings, the number of individuals of Japanese larch is adjusted to 410 pcs/ha. The total volume of stem wood during the period of forest growing (51-60 years) is 680-850 m³/ha.

The model of growing the Dunkeld larch (hybrid) FPs is developed for rich site types (D₂, D₃). In order to optimize the costs, the FPs at the first stage are mixed according to the scheme: 1 row HL 1 row NS with initial density of 7,500 pcs/ha, including larch – 2,500 pcs/ha. At the age of 4-6 years, spruce trees are extracted for Christmas trees, after which larch plantations are grown pure in composition. As a result of three thinning operations, there remain

625 larch trees by the age of the final cutting (51-60 years). The total volume of stem wood accumulated by larch during the period of forest growing is approaching 1,500 m³/ha.

During the establishment of the Douglas fir FPs under conditions of the moist fertile site type, we recommend to use the spruce as associated species with the introduction of the species mixture in rows with initial width of 2.0 m between the rows and initial density of 4.5 thousand pcs/ha, including Douglas fir – 1000 pcs/ha. To save the Douglas fir planting material, each second spot in the adjacent row is also occupied by spruce. The scheme of mixing is as follows – 1 row NS 1 row DF with NS.

The first thinning is performed at the age of 7-10 years by removal part of the spruce trees. The full extraction of spruce is completed in the course of the third thinning (35-40 years). Part of the Douglas fir trees (250 pcs/ha) is removed during the fourth thinning (50-55 years), after which the growing space of one tree is 20 m² (4.0×5.0 m), which is sufficient for the successful growth of the species up to the age of the final cutting.

The total volume of stem wood obtained from the Douglas fir forest plantations during the growing cycle (61-70 yrs) is 1.2-1.7 thousand m³/ha depending on the forest site type, the volume of thinning and the provenance of the species.

The principles of plantation-based forestry proposed by us do not involve significant expenditures (intensive tillage, application of mineral fertilizers, herbicides, pruning, etc.). The substantiated application of the principle of species alternation will ensure the maintenance of forest soil fertility

at sufficiently high level. Timely conducting of predetermined stages of thinning treatments with the establishment of optimal density at different age stages will ensure uniform distribution of trees over the site, well-formed clear trunks. The use of fresh cutovers will allow for just partial treatment of soil, while high initial density will result in the rapid closure of the FP and conducting a minimum amount of agrotechnical treatments. Product sales of the intermediate use (small-sized wood, Christmas trees) will help partly cover the cost of growing forest plantation even before the age of the final cutting.

Another area of production of large volumes of wood in Ukraine is establishing energy plantations. The use of wood as energy raw materials is a very promising business. In particular, this is possible to do by involving wood of fast-growing tree species, first of all – various varieties of poplar. They grow rapidly, their wood is characterized by high calorific value and relatively low requirements concerning cultivation.

In Ukraine, in recent years, there has been a clear trend to increase the area of plantations of fast-growing tree plants. Compared with other European countries, the area of plantations of woody plants in Ukraine is rather small so far (about 1.5 thousand hectares). However, the use of this renewable energy source has been successfully launched, and in the near future the range of this use can be greatly extended.

We have investigated energy plantations of different clones of poplar in an area of about 150 hectares (the *Verbawa, LLC* in Ivano-Frankivsk region). The plantations are located in the floodplain lands of the Dniester river which are periodically exposed to flooding during heavy floods, the last of which took place in 2010. The soils are rich –

dark grey forest loam, the type of forest site is D3. A high similarity between the trophotope and the hygrotrope in the study area allows for making correct comparisons concerning the peculiarities of the growth and accumulation of phytomass by different clones of poplar (Debrynyuk & Solovii, 2016).

Five poplar clones aged 3 years were studied: MAX-4, AF2, Oxford, AF8, MAX-5. On all the five study sites, a complete tillage with the use of agricultural implements (ploughing, two-time discing, harrowing) was carried out. So much attention was given to the soil cultivation because this aspect is crucial for the rate of cuttings rooting, their further growth and the amount of agrotechnical treatments carried out during the first two years after planting. In the spring, mechanized planting of poplar cuttings was carried out, the cuttings being of 8-12 mm in thickness and 20 cm in length, vertically, leaving the tops of the cuttings (2-3 cm) above the soil surface. The width of row spacing in all cases was 3.0 m. The plant spacing was 0.5 m (for clones of Italian selection AF2 and AF8), and 0.4 m (for clones of Czech selection MAX-4 and MAX-5, and Oxford).

Because of the rich forest site type, mechanized discing between rows was conducted 2 or 3 times during the first year of cultivation, and the same number of times was carried out manual tillage between the rows of the plants. During the second year, the number of agrotechnical treatments was reduced to 1-2. In the third year of cultivation, agrotechnical treatments were not carried out, although the complete closure of crowns in the rows of individual clones did not occur. No herbicides were applied during the plantation cultivation.

Forest-inventory characteristics of plantations of different poplar clones are given in Table 2.

Table 2. Forest-inventory indices for 3-year-old plantations of various poplar clones

Name of clone	Density, pcs/ha		Survival rate of clones, %	Average			Stocking, m ² /ha	Growing stock, m ³ /ha	Greenwood, ton
	initial	During the study period		d ₀ , cm	d _{1,3} , cm	h, m			
MAX-4	8330	6916	83	7.7 ^{±0.21}	6.4 ^{±0.16}	8.6 ^{±0.14}	22.08	102	74.5
AF2	6660	4330	65	7.1 ^{±0.36}	5.2 ^{±0.24}	6.6 ^{±0.17}	10.12	37	27.0
Oxford	8330	6583	79	6.4 ^{±0.26}	4.8 ^{±0.18}	7.8 ^{±0.15}	13.17	58	42.3
AF8	6660	4625	69	6.9 ^{±0.22}	5.5 ^{±0.22}	6.9 ^{±0.12}	11.10	42	30.7
MAX-5	8330	6705	80	7.4 ^{±0.24}	5.9 ^{±0.14}	8.3 ^{±0.19}	18.12	83	60.6

It was found that two clones – MAX-4 and MAX-5 – have the highest survival rates. Almost the same high survival rate was observed in the Oxford clone. Two clones of Italian selection – AF2 and AF8 are characterized by the lowest survival (65 and 69 %, respectively).

The highest values for diameter and height were found in MAX-4 and MAX-5 clones (Fig. 1). While the diameter of the Oxford clone ranks last among the studied clones, the height of this clone is in the third position. The lowest height was observed in clones AF2 and AF8.

The variability in height within the studied clones is average (V = 14.8-18.2 %) with high accuracy of the experiment (P = 1.6-2.5). At the breast height diameter, the coefficient of variation indicates significant variability of characteristics (V = 23.8-34.9 %), however, the accuracy of the experiment remains fairly high (P = 2.6-4.8).

The MAX-4 clone is marked by the maximum volume of stem wood – more than 100 m³/ha. This figure can be

considered a record for a 3-year cycle of growth. Other clones fall 1.2-2.4 times behind this figure (Fig. 2).

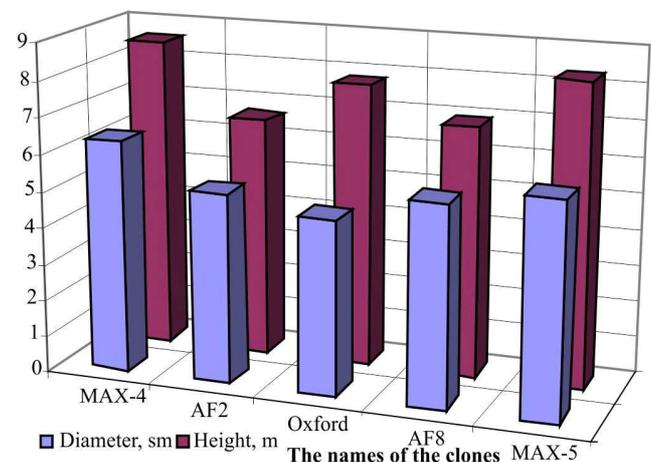


Figure 1. Height and diameters of the studied 3-year-old poplar clones under conditions of moist fertile site type (D₃)

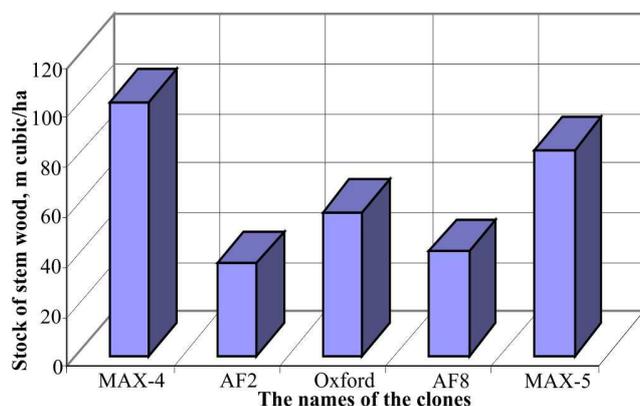


Figure 2. Stemwood volume of the studied 3-year-old poplar clones under conditions of moist fertile site (D₃)

Somewhat less volume of stem wood is accounted for the MAX-5 clone which falls 19 % behind the previous one due to lower survival rate and slightly weaker growth. Noticeably less volume of stem wood is accumulated by the Oxford clone.

Outsiders among the other poplar clones in terms of biomass supply are two Italian clones. The accumulated woody mass gap for clones AF2 and AF8 is due to their weaker growth and worse survival rate.

It should be noted that, probably, a higher initial density (e.g. 2.5×0.4 m, 10.0 thousand pcs/ha) could have affected the increase in the volume of phytomass per unit area. In addition, somewhat narrower spacing between rows would have contributed to the acceleration of the crown closure and the reduction in the intensity of the growth of herbaceous vegetation, which could have saved on agrotechnical treatment. The row spacing is mainly based on the availability of technical means for soil cultivation.

It is also necessary to notice the extremely intense growth of poplars. Thus, some 1-year-old shoots of the MAX-4 clone attained a height of about 8 m at the end of the growing season, that is, a height that some clones cannot reach at the age of 3 years.

Tentatively, it is possible to summarize that, in the studied conditions, the most suitable for further cultivation are two poplar clones – MAX-4 and MAX-5. The Oxford clone is intermediate, and the clones of AF2 and AF8 of Italian breeding showed the worst result. More reliable conclusions can be made after passing several three-year rotations of energy plantations in the investigated areas. The clone Oxford occupies an intermediate position, whereas clones AF2 and AF8 of Italian breeding showed the worst result. More reliable conclusions can be drawn after receiving several three-year rotations of energy plantations in the study areas.

Conclusions

The development of plantation-based forestry using fast-growing tree species should become one of the priorities of forest policy in Ukraine. Plantation forestry is an inevitable historical transition from extensive to intensive forest management. It is a logical consequence of a shortage of wood in conditions when it is impossible or economically inexpedient to obtain it in the required quantities using traditional methods of forestry. From this point of view, plantation forestry is a means to meet the needs of society in wood and other related needs both at present and in the future in general, and, therefore, it is a matter of national importance.

Transfer of a limited part of the Forest Fund (8-10 %) to plantation forestry and the establishment of bioenergy plantations of willow and poplar in wet and very wet forest site types will make it possible to obtain significant amounts of wood in a relatively short period of time, partially optimize the energy balance of the country, reduce the felling volume in primary stands, gradually restore the optimal age structure of forests in the territory of various regions of the country, increase forest cover percentage of the territories, significantly increase the amount of deposited carbon by fast-growing forest plantations, ensure balanced (sustainable) development of forestry in Ukraine.

Along with this, the effective introduction of plantation forestry in Ukraine is associated with a number of significant problems. First of all, this is a long-term attraction of capital due to a long cycle of wood production; cyclical nature of profit generation along with annual investments to maintain the operation of plantations; potential danger from using strong chemicals; the danger of using modified organisms; the lack of special equipment; the absence of the established timber market, etc.

Therefore, despite the significant prospects, effective development of plantation forestry in Ukraine is impossible without state support, first of all, at the legislative level, where priority should be given to plantation forestry with the primary aim of using woody biomass as a source of energy for domestic and industrial needs, support of international cooperation in the field of bioenergy, promotion of the use of biofuels as an energy product. It is also necessary to fund research work, first of all, breeding of tree plants and testing new promising species and varieties, economic evaluation of products obtained in forest plantations.

The use of relatively clean bioenergy-producing material will improve the state of the natural ecosystems in general, prevent the development of the greenhouse effect, reduce CO₂ emissions into the atmosphere, increase the amount of deposited carbon from the atmosphere, contributing to mitigating climate change.

Ukraine, compared to other European countries, is only at the initial stage in terms of production and use of renewable energy, but the country's forestry potential is capable of making a major step forward in this direction in a short term. Technologies that do not cause damage to nature are, at the same time, fully beneficial to humans.

It is important to expand the area of energy plantations, strengthen the positions in the production of woody biomass as a renewable energy source, take leading positions in the market of wood as energy raw material. This approach is an important step towards sustainable development and a responsible attitude towards the use of new energy sources and new technologies.

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ПЛАНТАЦІЙНІ ЛІСОВІ НАСАДЖЕННЯ ТА ЕНЕРГЕТИЧНІ ПЛАНТАЦІЇ В УКРАЇНІ: РЕСУРСНИЙ ПОТЕНЦІАЛ ТА ПЕРСПЕКТИВИ РОЗВИТКУ

Плантаційне лісовирощування на теперішньому етапі і на перспективу є найважливішим чинником збільшення деревного ресурсу в Україні. Тому актуальним дослідженням є розроблення спеціальних програм вирощування насаджень з коротким оборотом рубання та їх широкого впровадження у лісгосподарське виробництво для забезпечення промислових потреб у деревині, а також як відновлюваного джерела енергії. Переведення частини площ лісового фонду (8-10%) під плантаційне лісовирощування дасть змогу отримати значні обсяги деревини (1,2-1,7 тис. м³/га) промислового спрямування за відносно короткий період часу, зменшити обсяги рубань корінних лісостанів, оптимізувати енергетичний баланс держави за рахунок продукування деревини на енергетичних плантаціях, частково замінити викопні види палива на дешевшу і відновлювану деревну сировину. Розглянуто практичні аспекти запровадження плантаційних лісових насаджень та енергетичних плантацій за участю швидкорослих видів на території Західного регіону України. Встановлено місце плантаційних насаджень у загальному циклі лісовирощування на принципах породозміни.

Ключові слова: плантаційне лісовирощування; плантаційні лісові насадження; швидкорослі деревні види; енергетичні плантації, породозміна.

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ПЛАНТАЦИОННЫЕ ЛЕСНЫЕ НАСАЖДЕНИЯ И ЭНЕРГЕТИЧЕСКИЕ ПЛАНТАЦИИ В УКРАИНЕ: РЕСУРСНЫЙ ПОТЕНЦИАЛ И ПЕРСПЕКТИВЫ РАЗВИТИЯ

Плантационное лесовыращивание на сегодняшнем этапе и на перспективу является важнейшим фактором увеличения древесного ресурса в Украине. Поэтому актуальным исследованием является разработка специальных программ выращивания насаждений с кратким оборотом рубки и их широкого внедрения в лесохозяйственное производство для обеспечения промышленных нужд в древесине, а также как возобновляемого источника энергии. Перевод части площадей лесного фонда (8-10%) под плантационное лесовыращивание позволит получить значительные объемы древесины (1,2-1,7 тис. м³/га) промышленного направления за относительно короткий период времени, уменьшить объемы рубок коренных древостоев, оптимизировать энергетический баланс государства за счет выработки древесины на энергетических плантациях, частично заменить ископаемые виды топлива на более дешевое и возобновляемое сырье. Рассмотрены практические особенности внедрения плантационных лесных насаждений и энергетических плантаций с участием быстрорастущих видов на территории Западного региона Украины. Установлено место плантационных насаждений в общем цикле лесовыращивания на принципах породозамещения.

Ключевые слова: плантационное лесовыращивание; плантационные лесные насаждения; быстрорастущие древесные виды; энергетические плантации; породозамещение.