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The Distribution of Cash Expenses for the Creation of Bioenergy Willow Plantations in Ukraine

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***Abstract*. The economic cost analysis of creating energy willow plantations in Ukraine is provided in the present paper. The experience of creating bioenergy willow plantations at scientific and industrial institutions in Ukraine has been used in the paper. The purpose of this scientific work is to conduct an analysis of the structure of cash expenses for the creation of bioenergy willow plantations based on the experience of various institutions of Ukraine. The analysis is based on a technological map created during the study on drained peat lands at Panfyly Research Station. Analyzing the cost structure by category, the data obtained during the creation of bioenergy willow plantations of Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet were also taken into account. After analyzing all the technology stages of growing bioenergy willow, it was revealed that the most expensive is the second stage associated with the preparation for planting and planting willow cuttings in the context of the pricing policy in Ukraine. In general, more than 60% of all expenses fall upon the first year of cultivation. According to the experience of Ukrainian institutions, the cost structure will have a significant shift towards planting material - 55-60%. The remaining costs are distributed during the use of equipment in the field, which constitute 26-30% and transportation costs respectively are 12-19%.**

***Keywords:** biofuels, willow, renewable fuels, economic efficiency, energy willow, bioenergy plantation.*

I. Introduction

To gain positive results in becoming an energy-independent country Ukraine should develop alternative energy sources. Reducing the level of Ukraine's energy dependence on the traditional fuel export countries and the transition to environmentally friendly alternative energy sources is validated in the Energy Strategy of Ukraine for the period until 2030 [1]. This strategy declares indicators of the growth rate of alternative energy sectors and the field of biomass energy as the most economically attractive renewable energy source. Therefore, the issue of its effective sustainable production is extremely relevant.

It is known that the theoretically expedient potential for growing woody biomass to meet energy needs in Ukraine is one of the largest in Europe, but the level of use of these opportunities remains insufficient. Thus, the volume of planting and use of plantations of woody energy crops in real conditions underperforms the potential production volumes declared in the strategy. In addition to external facts that today affect life in Ukraine as a whole, one of the main reasons for this is the low investment attractiveness of such projects, which is due to the high level of initial costs and the long term of obtaining the first income (it is 3-4 years for energy willow) [3, 4].

Taking into account the national course towards European integration, it should be noted that according to the European Union Directive No. 2009/28/EC (Promotion of the use of energy from renewable sources), plantations of fast-growing energy plantations should be located on the lands that are not used for growing crops [5]. Using the existing potential for the creation of bioenergy willow plantations in unproductive and cultivated lands could help

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solve energy problems at the local level and would significantly reduce the volume of natural gas imports. To ensure the positive dynamics in the development of this sector, it is necessary to use modern approaches to the development of technological maps, taking into account the current situation in the capital markets and the abilities of national producers.

Research on the economic efficiency of growing perennial bioenergy crops in Ukraine was carried out in many scientific institutions, for example, based on experimental plantations of Research and Breeding Centers in Yaltushkivtsi, Uladovo-Liulyntsi, Bila Tserkva, Ivanivtsi, Veselyi Podil and DPDG «Salyvinkivske» of the Institute of Bioenergy Crops and Sugar Beet [6-7].

Fundamental scientific and practical research on using biomass energy for energy needs in Ukraine, the creation of willow plantations and the study of economic efficiency were carried out by V. Sinchenko, H. Kaletnik, M. Roik, H. Heletukha, I. Sliusar, I. Hnap and others [8-16]. However, the issue of the cost-effective use of bioenergy potential of drained peat lands requires further research.

The research work is carried out in the joint Ukrainian-Polish educational and scientific laboratory "DAK GPS" of Higher Education Institution "Podillia State University" within the framework of the scientific topic "Agrobiomass of Ukraine as the energy potential of Central and Eastern Europe" (registration number 0119U103056). The laboratory studies are focused on the development, justification and economic evaluation of the technological processes of energy willow and the designing of an automated machine for its planting [17-19]. Employees of the laboratory are also working on finding opportunities to optimize technologies for growing various agricultural and energy crops and evaluating the energy potential of plantations [20-22].

The purpose of this scientific work is to conduct an analysis of the structure of cash expenses for the creation of bioenergy willow plantations based on the experience of various institutions of Ukraine.

II. MATERIALS AND METHODS

The article material is based on the processing of data from the study on the cultivation of bioenergy willow, that was conducted at Panfyly Research Station of the NSC "Institute of Agriculture of the NAAS" (Panfyly, Yahotynskyi district, Kyiv region) on drained peat lands withdrawn from cultivation. More than 20 species, hybrids and forms of willow were selected for the analysis. Scientists have found that almond-leaved willow (Salix triandra L) and rod-shaped willow (Salix viminalis L) are the most appropriate for a given soil and climatic conditions. The use of these species provides a yield of up to 54.1 tons of absolutely dry biomass per hectare once every two years [23].

The traditional methods were used in the present study. Economic characteristics were calculated using technological schemes and methodological approaches developed at the Institute of Bioenergy Crops and Sugar Beets of the National Academy of Sciences of Ukraine [6, 25].

The whole process of creating a bioenergy plantation was divided into four technological stages:

- Preparation of the site for the plantation
- Soil preparation and planting shoots
- Plantation care
- Harvesting on an industrial basis

The main emphasis in the choice of agricultural machinery is on its accessibility in the Ukrainian market and minimization of initial investments. The calculations were carried out taking into account the minimization of the use of any chemical agents in the production process due to the environmental characteristics of drained peat lands and the legislation relating to the protection of the water bodies of Ukraine. The technological map of the bioenergy plantation creation process at Panfyly Research Station is presented in Table 1.

TABLE 1 COST STRUCTURE AT THE FIRST STAGE OF CREATING A BIOENERGY PLANTATION (1 HA) ON DRAINED PEAT LANDS

№	Technological operations	Time frame, quarter	Units of measure	Scope of work	The composition of the unit: Tractors	The composition of the unit: Agricultural machines	Total, $	Note
The 1st year								
STAGE 1 – Preparation of the site for the plantation								
1	Area preparation (mulching)	II	ha	1	MTZ -892	Mulcher RKR-1, 5M	20,15	
2	Peeling (two-time treatment)	II	ha	2	MTZ -892	AG-2.4	19,79	The depth of tillage is 10-12 cm.
3	Ploughing	III	ha	1	MTZ -892	PLN-3-35	19,55	to a depth of 20-25 cm
4	Continuous tillage	III	ha	2	MTZ -892	ZPG-15	5,47	
Total for the first stage							**64,96**	
STAGE 2 – Soil preparation and planting shoots								
5	Presowing tillage	IV	ha	1	MTZ -892	Europack AP-3	11,14	to a depth of 5-6 cm.
6	Loading packs of cuttings	IV	pack	600	By hand		305,21	25 cuttings per pack
7	Transportation to the place of planting	IV	pack	600	MTZ -892	2PTS-4	12,93	
8	Planting shoots	IV	ha	1	John Deer 8295 R	2-row EGEDAL Energy Planter	21,60	depth 18-19 cm, planting density 15000 pcs/ha)
Total for the second stage							**350,87**	
Total for the year							**415,83**	
The 2nd year								
STAGE 3 – Plantation Care								
9	Continuous tillage	II	ha	2	MTZ -892	LNG-15	5,47	(harrowing) when weeds appear

№	Technolo-gical operations	Time frame, quarter	Units of measure	Scope of work	The composition of the unit		Total, $	Note
					Trac tors	Agricult ural machines		
10	Planting cuttings	II	pcs.	2250	By hand	Kolesov sword	84,06	in places, not sprouted, if less than 85% of those planted remain
11	Loosening the soil between the rows twice	II	ha	2	MTZ -892	LSD-3.1	9,74	
12	Technological cut	IV	ha	1	John Deer 8295 R	Ny Vraa JF Z200-HYDRO/E	38,07	
13	Transportation of bio-raw materials to the place of preservation or use	IV	mt	10	MTZ -892	TSP-10	13,53	(10 km)
Total for the second year							**150,88**	
The 3rd year								
14	Loosening the soil between the rows twice	II	ha	2	MTZ -892	LSD-3.1	16,23	
Total for the third year							**16,23**	
Total for the third stage							**167,11**	
The 4th year								
STAGE 4 – Harvesting willow on an industrial basis								
15	Willow harvesting with chopping into chips	IV	ha	1	John Deer 8295 R	Ny Vraa JF Z200-HYDRO/E	36,07	
16	Transportation of bio-raw materials to the place of preservation or use	IV	mt	70	MTZ -892	TSP-10	80,70	(10 km)
Total for the fourth year and stage							**116,77**	
Total at the time of receiving the first harvest							**699,71**	

A site with soil and climatic conditions typical for drained peatlands was chosen for the cultivation of Salix willow at Panfyly Research Station.

Stage I. Preparation of the site for the plantation.

The preparation of the site consisted of the following technological operations: mulching, peeling (2-times), ploughing, and continuous cultivation. The available general-purpose tillage machines can be used for the cultivation of the site for the plantation. In the present study, mulching was carried out with the help of an RKR-1.5M rotary mulcher, since there were young trees and dense herbage on the site. Although, the specialists of the Educational and Scientific Center of "The Institute of Agriculture of the NAAS" note that its need in most cases can be considered as 25% of the total area of the site. To trim rhizomes, and destroy wheatgrass and other weeds, a two-time peeling was carried out to a depth of 10-12 cm with an AG-2.4 tillage disk unit. The next technological operation was ploughing to a depth of 20-25 cm with PLN-3-35 general-purpose plough. After that, two-time continuous tillage was carried out using the ZPG-15 harrow. This enabled us to destroy sprouted weeds and level the surface of the field.

It should be noted that high-quality preparation of the field is fundamentally important since the life of the plantation is usually 8-12 two or three-year harvest cycles [16]. The preparation of the field for planting energy willow is generally similar to the technologies for growing traditional crops, so there is a similar cost structure at this stage.

Stage II. Soil preparation and planting shoots.

Soil cultivation before planting is an integral part of a single process of growing energy willow and should be carried out without a gap in time and outpace planting by two-four aisles of the planting unit. Such cultivation is aimed at maximizing the preservation of moisture, warming up the soil, creating optimal conditions for engraftment and further growth of cuttings, and ensuring a finely lumpy top layer of soil [24].

Europack AP-3 unit was used for pre-sowing tillage and it ensured high-quality loosening of the soil, improved aeration, reduced the number of weeds and created optimal conditions for engraftment and growth of willow cuttings. The plantations were laid in strips of 2 rows. The Egedal Energy Planter was used for the mechanized planting of bioenergy willow. The cuttings were planted to a depth of 18-19 cm, the distance between the cuttings in the row is 0.60 m, and the distance between the rows is 0.70 m. The Europack AP-3 unit was used for pre-sowing tillage, which ensured high-quality loosening of the soil, improved aeration, reduced the number of weeds and created optimal conditions for engraftment and growth of willow cuttings. The plantations were laid in strips of 2 rows. For the mechanized planting of bioenergy willow, the Egedal Energy Planter was used. The cuttings were planted to a depth of 18-19 cm, the distance between the cuttings in the row is 0.60 m, and the distance between the rows is 0.70 m. According to this scheme, the density of plantings was 15000 pcs/ha [23].

Stage III. Plantation care.

In the case of laying bioenergy plantations on drained peat lands, the care of the sites is of decisive importance. Weeds pose the greatest danger to the first cycle of growing willow since the planted shoots themselves cannot effectively resist them. If you do not carry out adequate control in the first cycle, then in the future the plant will not be able to provide the planned yield.

In early spring, continuous tillage was carried out with ZPG-15 (MTZ-892) harrow before germination of cuttings to control the number of weeds. The cuttings were planted manually with the help of a Kolesov sword to avoid omissions, due to the death of cuttings. Such an operation is recommended if less than 85% of plants are rooted.

Loosening of the soil between the rows is carried out to improve the water-air regime and the conditions for the growth and development of plants. The need, frequency and depth are determined by taking into account the following factors: the state of plant development, the amount of precipitation, soil density and the presence of weeds.

During the first year of the growing season, the planted cuttings produced 1-3 shoots with a maximum height of up to 3m. At this stage, a technological cut was made to stimulate willow to better

noting that in recent years there has been a discussion in the scientific community regarding the need for technological cutting. Therefore, it is advisable to conduct such research in the future for specific soil-climatic and hydrological conditions.

The complex agrotechnical means should provide reliable control of the number of weeds (especially in the first harvest cycle), soil aeration and moisture level control. It is worth noting that the costs of planting cuttings in different fields can vary significantly even within the same farm. The main factors affecting their size are the consignments of planting materials, compliance with planting technology and weather conditions.

Technological cutting is performed by the same technique as harvesting.

Stage IV. Harvesting willow on an industrial basis.

Harvesting of bioenergy willow begins after the end of sap flow in the 3rd year of the growing season. Cutting is carried out at a height of 5-10 cm from the surface of the soil.

Mechanized harvesting with grinding into chips was carried out using Ny Vraa JF Z200-HYDRO/E mounted unit to John Deer 8295R tractor. The resulting biomass was transported to the place of storage by the TSP-10 dump trailer (tractor MTZ-892). The same technique was used for technological cutting in the third stage. The method of harvesting and transporting biomass may vary depending on the capabilities and needs of the farm. If necessary, natural drying is carried out at the edge of the field in piles. However, it is generally accepted practice to transport wet biomass to an energy-generating facility immediately after harvesting [25].

The analysis results of this technological map were compared with the data obtained during the laying of bioenergy willow plantations of Salix Energy by LLC and the Institute of Bioenergy Crops and Sugar Beet.

III. Results and Discussion

The data of the technological map of energy willow cultivation developed at Panfyly Research Station (Table 1.) allow us to analyze costs in terms of the course of individual technological operations and in the time dimension in general, which will afford to plan the need for future investments when laying a bioenergy willow plantation. It will also be important to analyze the cost structure, which involves assessing the prospects for choosing optimal economically sound decisions.

The costs of individual technological operations are presented in Figure 1. The cost diagram shows that operations 6 and 10 require the largest peak expenditures of funds, which are associated with the purchase and preparation of planting material, as well as operations related to the collection (12, 15) and transportation (13, 16) of the collected products.

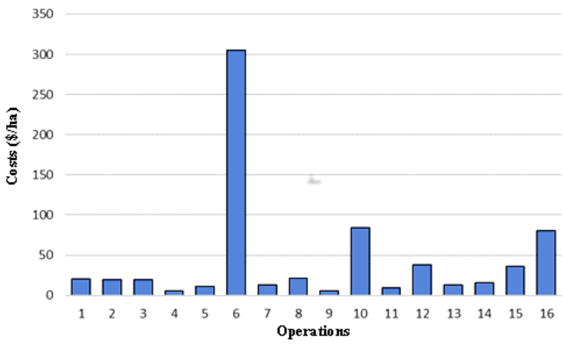


Fig. 1. Distribution of costs for individual operations in the cultivation of bioenergy willow.

Also, the cost structure over time should be analyzed to assess peak investment needs. Figure 2 demonstrates the costs required by the technology of planting a bioenergy willow plantation per quarter of each of the four years of the first growing cycle. As can be seen from the schedule of quarterly expenses, the main financial burden falls on the first two years of cultivation with a clear peak in the fourth quarter of the first year. This is correlated with the previous schedule of transaction costs (Fig. 1), where this peak falls on the operation associated with the acquisition of planting material. In addition, this graph shows that after the second year of planting the plantation, costs for some time are practically minimized, followed by a peak at the end of the cycle during harvest.

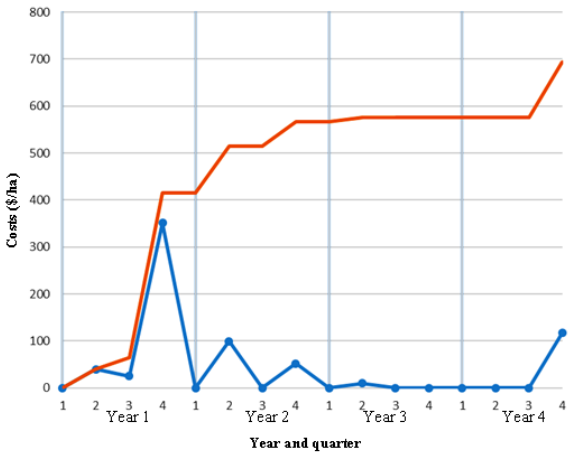


Fig. 2. Cost dynamics during the first cycle of creating an energy willow plantation at Panfyly Research Station: blue – expenses by quarters of the year, red – total accumulated costs for the entire four-year cycle.

More generally, such data demonstrate the size of costs for growing energy willow for the years of the first cycle (Fig. 3a) and the main stages of technology (Fig. 3b)

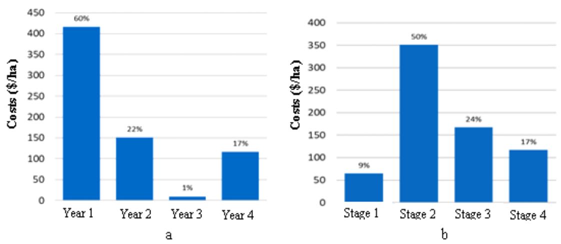


Fig. 3. Distribution of costs for growing bioenergy willow: a) by years of the first cycle; b) by the main stages of cultivation.

Peaks can be clearly distinguished during the first year of cultivation and the second stage of technology in these diagrams. The largest part of the costs at this stage is formed by the cost of planting material (laid down in point No. 2 – a load of packs of shoots). That is, these costs can be influenced by the search for more or less costly sources of obtaining cuttings of energy willow, the price of which varies widely depending on the type of willow and the nature of its origin. in this technology, The cost of planting material was 0.02 USD / pcs under mentioned above technology according to the reports of Panfyly Research Station, which is also specialized in the selection of willows.

There are three main categories of costs based on the data in Table 1:

- the cost of planting material
- the cost of using equipment
- transportation costs

To determine the cost structure by category, a grouping of technological processes from Table 1 into certain categories was carried out (Table 2).

TABLE 2 COST STRUCTURE AT THE FIRST STAGE OF CREATING A BIOENERGY PLANTATION BY COST CATEGORIES

№	Cost category	Expenses, $/ha	Note
1-4	Tillage	64,96	mulching, peeling, ploughing, harrowing
5	Tillage	11,14	presowing treatment
6	Planting material	305,21	600x25pcs
7	Transportation	12,93	
8	Planting	21,60	
9	Tillage	5,47	harrowing
10	Planting material	84,06	2250 pcs
11	Tillage	9,74	inter-row processing
12	Technological cut	38,07	10mt; 10km
13	Transportation	13,53	10mt
14	Tillage	16.23	inter-row processing
15	Harvesting	36,07	70mt
16	Transportation	80,70	70mt; 10km
Total for the use of agricultural machinery (tillage, planting, harvesting)		**203.28**	Operations: 1-4; 5; 8-9; 11-12; 14-15
Total for transportation		**107,16**	Operations: 7; 13; 16
Total for planting material		**389,27**	Operations: 6; 10
Total		**699,71**	

Figure 4 shows the share of each of these categories. About 56% of all costs fall upon the purchase of planting material. Such a high percentage focuses our attention on this component of the technology.

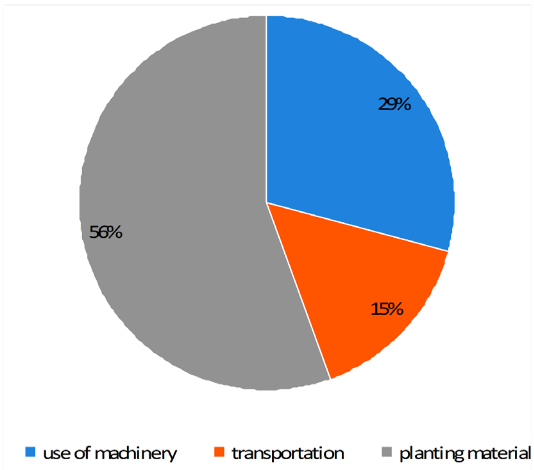
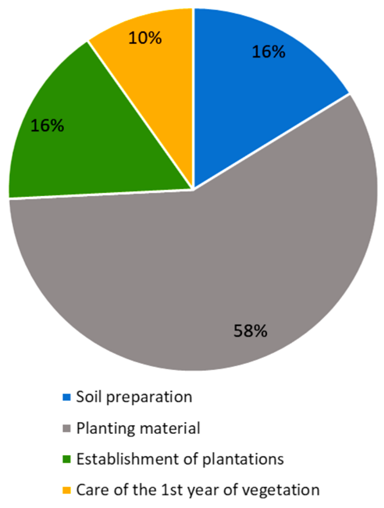
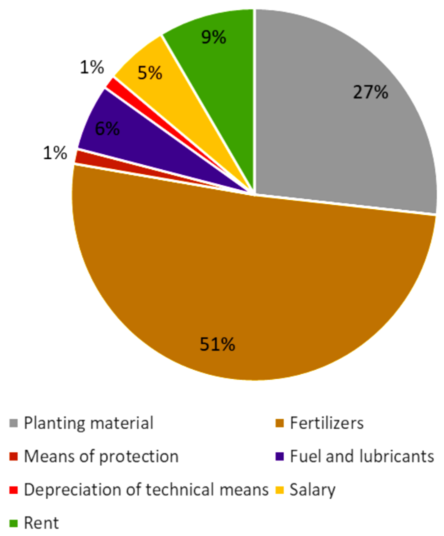


Fig. 4. Cost structure for the first cycle of creating a bioenergy plantation at the Panfyly Research Station.

Comparing these cost structures in the studies of Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet (Fig. 5) with the previously analyzed data (Fig. 4), it can be noted that they also take into account such components as land lease, which also generates significant expense. In addition, the costs of fuel-lubricating materials, depreciation of technical means and wages (Fig. 5b) are separately taken into account, which in other cases are included in the costs of soil preparation, planting, care and other operations for the use of equipment.



a



b

Fig. 5. Cost structure: a) for laying an energy willow plantation in Salix Energy LLC [27]; b) in the first year of rod-shaped willow (Salix viminalis L) cultivation at unproductive lands according to data of the Institute of Bioenergy Crops and Sugar Beet data [7].

The costs of fertilizers and plant protection products (about 51%) are the main difference in the research of the Institute of Bioenergy Crops (Fig. 5b). As noted above, during the study at drained peat lands of Panfyly Research Station, the need for mineral fertilizers and herbicides was not established. Whereas the costs presented in Fig. 5b relate to the cultivation of willow on unproductive lands. If we hypothetically discard these costs, we see that the cost structure for the main categories for all three studies remains approximately the same. That is, if in the cost structure we leave only those that are obligatory for all technologies, then the cost of planting material is 55-60%, and the rest of the costs are distributed during the use of equipment in the field, which is 26-30% and transportation is 12-19%.

IV. Conclusions

The theoretically relevant potential of growing wood biomass for energy needs in Ukraine is one of the greatest in Europe. Using the existing potential for the creation of bioenergy willow plantations on unproductive and cultivated lands could help solve energy problems at the local level and would significantly reduce the volume of imports of fossil energy sources. The present study uses the experience of creating bioenergy plantations of willow at scientific and industrial institutions. The analysis is based on a technological map created during the study on drained peat lands at Panfyly Research Station. The total costs at the time of receiving the first harvest from the bioenergy plantation amounted to 699,71 USD / ha. The period shows the heterogeneity of investment in the process during the four-year cycle before the first harvest. The technology was divided into 4 stages. After analyzing all the technology stages of growing bioenergy willow, we can conclude that the most expensive is the second stage, where the price of planting material plays the greatest role. In general, the first year of cultivation accounted for 60% of all expenses.

Analyzing the cost structure by category, the data obtained during the creation of bioenergy willow plantations at Salix Energy LLC and the Institute of Bioenergy Crops and Sugar Beet were also taken into account. Each approach and individual technologies have its characteristics, however, when considering specific natural climatic and production conditions, additional costs may incur, but if they are not taken into account, then according to the experience of Ukrainian institutions, the cost structure will have a significant shift towards planting material - 55-60%, the rest of the costs are distributed during the use of equipment in the field, which is 26-30% and transportation is 12-19%, respectively.

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