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TECHNOLOGICAL RESEARCH OF MECHANIZED SITE PREPARATION FOR AFFORESTATION OF FOREST LANDS

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ABSTRACT

The establishment of forest plantations on rocky and eroded soils and slopes requires adequate soil preparation. Depending on the peculiarities of the terrain, requirements of the culture for afforestation, and according to the available technical means and organization of the work, different technological schemes can be applied for soil preparation. In this paper is conducted a study over the work of bulldozer and scarifying units for soil preparation of forest land for afforestation. Time study based on video records of all the operational processes for a working day was performed. These operational processes include aligning and clearing areas for afforestation, terracing slopes and primary tillage. Basic operational and economic indicators of the studied machines in certain operating conditions were established. Operational productivity, fuel consumption and the average cost per hectare of soil preparation with bulldozer, and uprooter, and ripping aggregate were finding. The average price per one hectare cleaning operation from shrubs with simultaneous alignment of the terrain, with frontal bulldozer DZ-27 and crawler T-170, with operational productivity 0.183 ha/hour, was defined on 332.9 €/ha. The average price per one hectare primary deep soil tillage by ripper D – 513 and crawler T–170, with operational productivity 0,076 ha/hour, was defined on 839,7 €/ha. The average price per one hectare machine terraces on terrains up to 28 °, constructed by universal bulldozer DZ-38 and crawler T–170 with operational productivity 0.064 ha/hour, was defined on 966.7 €/ha. It was performed an evaluation of the researched technological schemes. The results can serve for regulation of labor and fuel costs for the studied aggregates for soil preparation for afforestation of forest land.

Key words: bulldozers, rippers, operating indicators, performance.

INTRODUCTION

Sustainable management of forest areas in Bulgaria requires the conduct of activities for restoration of non-regenerated timbering land. In many cases this can be achieved only by planning appropriate afforestation activities. Such activities are necessary after the occurrence of forest fires, natural disasters, etc. According the strategy for development of the Forestry sector, afforestation of such objects is the main method of work (Ministry of Agriculture, Food and Forestry, Executive Forests Agency). Along with the recovery and increase the timber resources this afforestation will help to prevent the erosion, to improve the ecological environment, to facilitate the tourism development, etc.

Soil preparation is a process that includes various technological operations related to the site preparation for afforestation and primary tillage (Gönna and Marc 1992, Marinov 2013). This is the most labor-intensive and power consumption activity in the process of creating and growing plantations (Dimitrov and Panov1982, Marinov 2014). This applies to the greatest extent for soil preparation of woodland sloping and rocky terrain, which are a significant part of forest areas in the country (Milev and Mari-

nov 1992). The introduction of appropriate technologies and equipment will increase productivity, reduce labor costs and improve working conditions (Vasilev and Dimitrov 1978). The mechanized methods for soil preparation are prerequisites for better treatment and creation of more favorable conditions for the development of the cultures (Hallbrook et al. 2006, Löfat al.2012). The application of mechanized technologies for soil preparation is a precondition for the mechanization of the subsequent technological operations – planting and cultivation of the cultures. Thus are created conditions for an overall rising of the level of mechanization for the afforestation. This process will lead to better working conditions in forestry, to increase productivity and quality of work, to reduce the total production costs and to provide more favorable conditions for increasing the productivity of forest plantations.

The purpose of this study is to explore the technological properties of machine-tractor units for soil preparation of forest land for afforestation. These aggregates will perform the following operations: cleaning bushes, earthworks, tillage furrows, and building trench-mound terraces.

The subjects of the study are the technological capabilities and performance of bulldozer and scarifying units.

2. METHODS AND OBJECTS

Objectives of the study. For the purpose of the experimental study and for the establishing technology capabilities and performance of bulldozer and scarifying units it is needed to solve the following tasks:

1. To determine the operating productivity per hour and per shift;
2. To determine time efficiency;
3. To establish operational fuel consumption;
4. To establish the average price for land preparation per 1 ha forest area.

To solve the above objectives, the following methods are used:

- Timing of the technological operations;
- Preparation of motion pictures of the working day;
- Establishment of fuel consumption for land preparation per area unit.

Objects of the study. For objects of the study are selected machine-tractor units that are not specialized for soil preparation for forest areas but have a widespread application and market in Bulgaria. They appear to be cheaper to operate with and for maintenance in comparison with specialized machines. Bulldozer aggregates are machines widely used in construction, industry, agriculture, and land improvement. In forestry they are used for construction of forest roads and perform other forestry activities. Tooth eradicators, except for eradicating of stumps, can be used for deep soil loosening. They are relatively widespread in our country, despite that they have less productivity than specialized ripping aggregates, they have a low price, and easy low cost maintenance.

Objects of the study are frontal and universal bulldozer, and frontal tooth eradicator, which are aggregated with crawler tractors of pulling power 100 kN (Figure 1).

Figure 1: Site preparation picture: 1 – Ripping aggregate – D-513A uprooter-ripper with T-170 crawler tractor; 2 – Bulldozer aggregate – DZ-27 dozer with crawler tractor T-170

The main characteristics of the studied machine-tractor units, as representative objects in this research are:

1. Bulldozer aggregate for cutting shrubs, cleaning and aligning the land, consisting of a crawler T-170 and frontal bulldozer DZ-27 with 3.30 m operational width;
2. Subsoiling aggregate for construction of tillage furrows by deep soil loosening, consisting of frontal tooth uprooter-ripper– D-513A and crawler T-170 with operational width of 1.50m;
3. Bulldozer aggregate for building trench-mound stepped terraces, consisting of universal bulldozer DZ-38 and crawler T-170 with a working width of 3.50 m.

Input parameters of the study. For input parameters are selected factors that characterize the terrain and the operating conditions:

1. Slope, [%];
2. Depth of processing, [cm];
3. Width of terraces and belts, [cm].

Output parameters of the study. The parameters that can be measured and with which it would be possible solve the objectives of the study are:

1. The duration for the operations, [s];
2. The size of the treated area, [ha];
3. The fuel consumption, [l].

The conditions of the study: The land for afforestation is a south facing mountain area with altitude of 200 m. The soil is cinnamon forest, sandy loam, heavy weight. The slopes of the afforestation area range from a minimum value 8^{o} to maximum – 29^{o}. The depth of the plow horizon varies from 20 cm to 55 cm. The habitat type is T-I-2, B1. The main vegetation is Jerusalem thorn with height up to 3.5 m, occupying almost 80% of the total area.

The place of the study: The study was located in State Forestry of Elhovo, within the territory of village Lesovo, compartment 474, subcompartments 2 and 4. The experimental site in subsection 2 occupies 5.5 ha, and in subcompartment 4 occupies 54.1 ha.

Methods and equipment of the measurement: Timings of the three technological operations are conducted. The operations include: cutting shrubs and aligning the terrain; construction of belts by deep loosening; and construction of trench-mound terraces. The operational strokes of the aggre-

gates in the experimental sites have set length of 100 m. The fuel consumption is measured in volumetric units, based on the spent fuel at the end of every operation. The motion pictures of the working day are established in accordance with the approved methodology for regulation of silviculture in Bulgaria (Stoyanov 1994). For every technological operation and for all three days were produced motion pictures of the work. The equipment of the study include: stopwatch, accurate to 1 s; tape measure with accuracy up to 1 cm; GPRS system for determining the size of the treated area; Laser declinator to determine the slope; volumetric measuring jug to calculate the fuel consumption with an accuracy of 0.1 liter.

Methods of processing and analysis of the results: For statistical treatment of results is used software program "Statistica 7". For comparing the results is used comparative method, which measures the impact of various factors on the performance of the machines.

The study was conducted in three experimental sites within the State Forestry of Elhovo, in section 474, nearby village Lesovo.

- In the first experimental site a full felling are performed and the land is completely cleared. For the purpose the existing shrubs and grass are cut, and pushed out of the site, while at the same time the top soil is aligned. In this experimental site is examined the work of the bulldozer unit – frontal bulldozer DZ-27 and crawler T-170.
- The second experimental area is located at the top of the hill and is characterized by average slope of 12^{o}. The area in this site is precleaned of vegetation and is aligned with the frontal bulldozer DZ-27. Deep subsoiling on a depth of 40 cm, into tillage furrows, without turning the plow layer of soil, is performed. In this site, it is examined the work of subsoiling unit – uprooter-ripper D-513A and crawlerT-170.
- The third experimental site is with average slope 22^{0}, and the area is pre-cleaned. In the section are built stepped trench-mound terraces with width of the lanes of 3,5 m. Here is examined the work of the bulldozer unit consisting of universal bulldozer DZ-38 and crawlerT-170. After building the terraces is performed primary tillage of the soil in the excavation part of the lanes by deep loosening to the unit.

3. RESULTS AND DISCUSSION

The technology of the work in all three experimental sites includes preliminary cutting of trees and shrubs by the frontal bulldozer DZ-27. Simultaneously, the cut vegetation is pushed out of the area and the terrain is aligned. To improve the sustainability and safety of the unit on sloping terrain and to reduce working resistance, the working stroke is carried downwards in the direction of the slope.

To limit the erosion over lands with a slope between 8^{o} and 15^{o}, the primary tillage of the soil is performed by deep subsoiling into wide tillage furrows along the horizontal terrain. Simultaneously with the treatment of soil are removed the existing roots in the cultivated layer. The tillage furrows in the second forest site are made with uprooter-ripper D-513A, with working width of 1.50 m. Between the belts it is important to left untreated strip with a width of about 0.50 m. When the unit is moving forward in front of the machine shield is accumulating

a certain amount of earth that forms soil shaft. This shaft hinders the movement of the unit and this requires technological disruption of the working stroke and lifting the working body. Thus, the average length of the operational strokes is limited to 50÷70 m. On the other hand, these earth shafts have a positive side, by retaining water swelling on the slopes, and reduce water and wind erosion. By anti-erosion standpoint, sites which are prone to erosion, it is desirable to have such shafts. For an operational stroke is desirable the earth shafts to have height of 0.8 m, length of 1.6 m, and a width not more than 1.0 m. For this purpose, the unit will perform not operational strokes in reverse, which will be twice longer than the operational strokes (Figure 2).

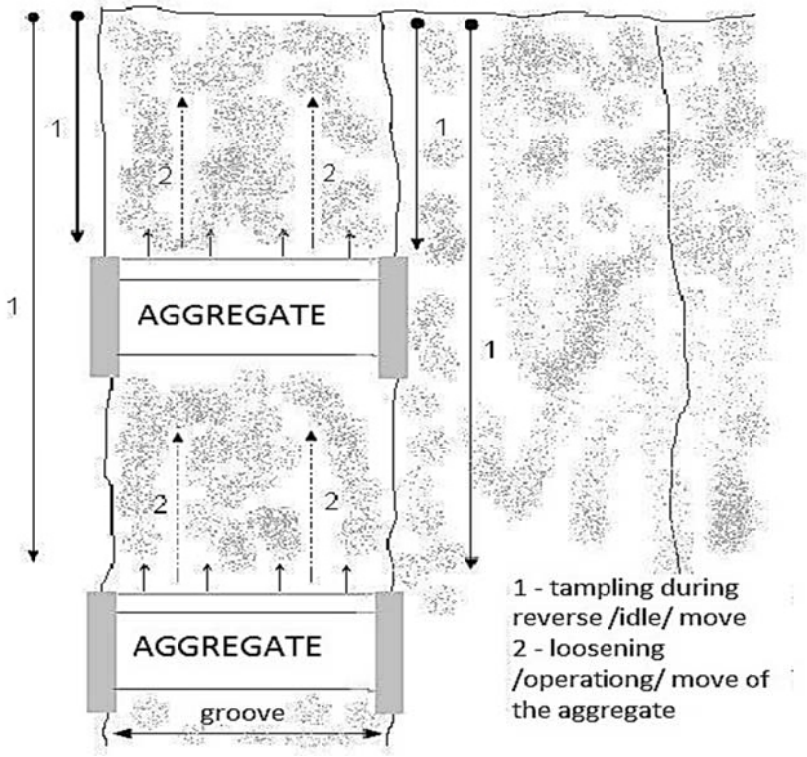

Figure2: Scheme of the movement of an uprooter-ripper aggregate D-513A and crawlerT-170 for deep subsoiling of tillage furrows (groove)

These non-operational and extended moves will reduce the productivity of the unit, but on the other hand such a technological scheme will help to restrict the erosion. Moreover, this compromise with the performance will provide better conditions for water retention and moisture preservation of the topsoil and will create conditions for better development of the forest cultures. Another positive effect is to expand the technological capabilities of machine-tractor units powered by tractors. Operating this way and with the existing water swelling, the unit will operate under a certain angle to the contour of the terrain – up to 15÷30°. Thus, crawler tractors can be used on terrains with a slope up to 20÷25°.

Mechanized land preparation on areas with slope from 15÷20° to 30÷35° can be accomplished by construction of stepped terraces. The third experimental site has an average slope of 22°. In this site the soil preparation includes construction of trench-mound terraces by horizontals of the terrain with universal bulldozer DZ-38 and primary soil tilling in trench terraced paths with uprooter-ripper D-513A (Figure 3).

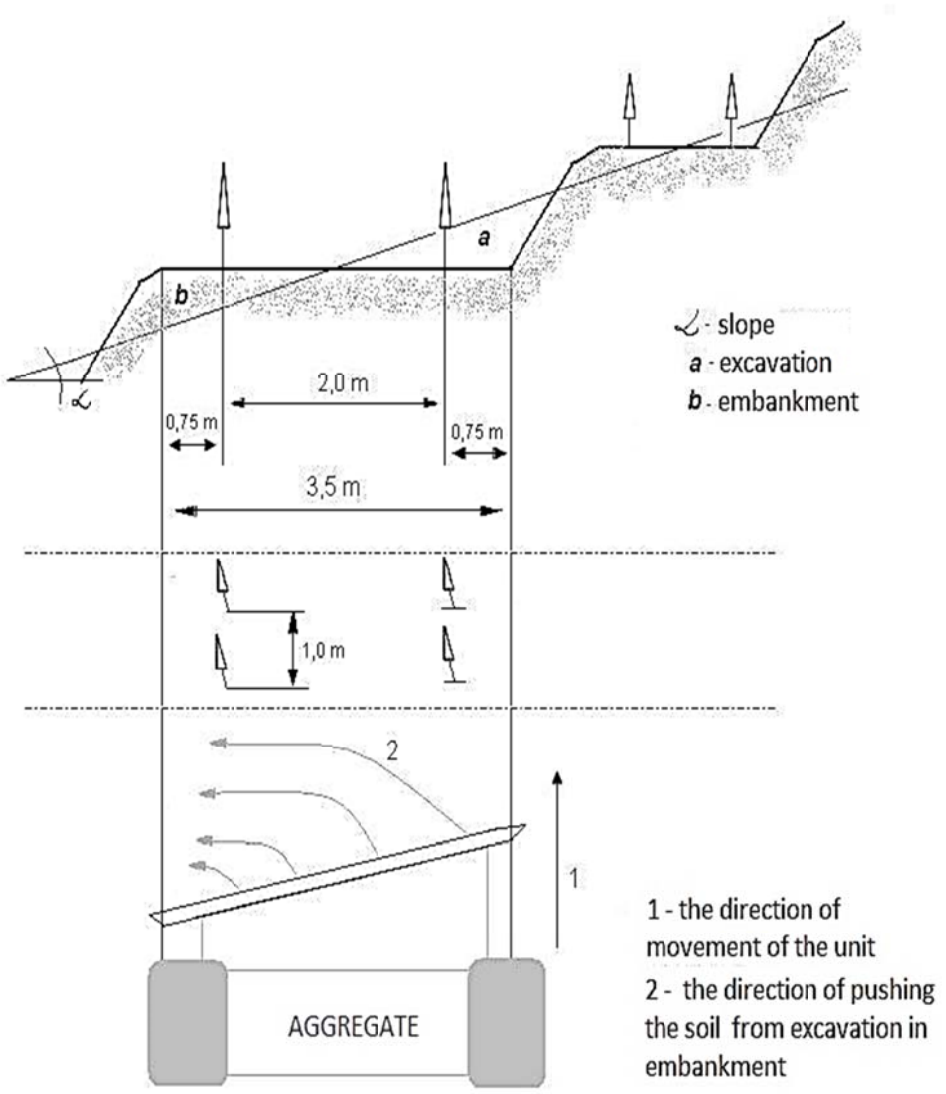

Figure3: Scheme of the movement of terracing aggregate bulldozer DZ-38 with crawler T-170, and parameters of the trench-mound terraces

Depending on the slope, the profile of the terraced lanes is forming with 2 to 4 strokes of the unit. Compared to manual, mechanized terraces are more expensive, but they are significantly better with erosion control. The mechanized terraces are an important factor to restrict the erosion, to increase moisture retention and to improve the development of forest plantations. Besides, they are a prerequisite for full mechanization of subsequent operations as tillage, planting and cultivation, especially for forest cultures, afforested on sloped terrains. The main tillage is performed by deep loosening up to 40 cm in the trench-part of the terraced lane with uprooter-ripper D-513A.

After statistical processing of the obtained data, the average timing values of the picture of the workday are presented in Table 1.

Table 1: Photo of workday operations of the studied operations and aggregates

Observed times [min]	Clearing and alignment with bulldozer unit DZ-27	Tillage furrows with uproot-ripping unit D-513A	Terracing with bulldozer unit DZ-27

$\mathbf{T_{stroke}}$ – Time for stroke	323.4	308.1	316.3
$\mathbf{T_{idle}}$ – Time for idling and maneuver	75.3	108.1	88.1
$\mathbf{T_{pco}}$ – Time for preparatory-concluding operates	38.2	35.2	30.1
$\mathbf{T_s}$ – Service time of the machine	23.3	9.6	20.9
$\mathbf{T_{rest}}$- Time for rest and physiological needs	19.8	19.0	24.6
$\mathbf{T_{sh}}$ – Time for 1 work shift	480.0	480.0	480.0
$\tau_{см}$ – coefficient of using working time at one work shift	0.673	0.642	0.658

From the conducted study of mechanized land preparation of forest areas for planting with black locust with non-specialized machine-tractor aggregates technological capabilities and performance were established. Operational performance, fuel consumption, coefficient of time efficiency, and average price of per one hectare mechanized soil preparation of these machine-tractor units are presented below:

1. Cleaning the area of shrubs with height up to 3.50 and density over 80% of the total area with simultaneous alignment of the terrain with bulldozers unit – Frontal bulldozer DZ-27 and tractor T-170:

- Operating performance per hour – 0.183 ha/h;
- Operating performance per shift – 0.981 ha/work shift;
- Operational fuel consumption – 138.3 l/dka;
- Coefficient of working time efficiency – 0.673;
- Average price of one hectare soil preparation – 332.9 €/ha.

2. Primary soil cultivation by deep loosening up to 40 cm on belts, simultaneously with eradicating the roots of shrubs, with an average slope 12°, average length of the work site 190 m and width belts of 1.50 m, by subsoiling unit – uprooter-ripper D-513A and tractor T-170:

- Operating performance per hour – 0.076 ha/h;
- Operating performance per shift – 0.389 ha/work shift;
- Operational fuel consumption– 333 l/ha;
- Coefficient of working time efficiency– 0.642;
- Average price of one hectare soil preparation– 839.7 €/ha.

3. Construction of trench-mound machine terraces on terrains with a slope up to 28°, with an average length of the site and the terraces – 220 m and width of the lane – 3.5 m, with bulldozers unit – universal bulldozer DZ-38 and tractor T-170:

- Operating performance per hour – 0.064 ha/h;
- Operating performance per shift – 0.338 ha/work shift;
- Operational fuel consumption– 395 l/ha;
- Coefficient of working time efficiency– 0.658;
- Average price of one hectare soil preparation – 966.7 €/ha.

The cost of soil preparation with a bulldozer and subsoiling units per hectare is made on the basis of the average price of a machine shift with tractor T-170. During the research this price was 325 Euro (VAT included). It includes all costs associated with the productivity of the machine and maintenance of the staff – depreciation, materials, repairs, fuel, salaries, insurance, etc.

From the conducted study, it is found that there is some possibility for increasing the degree of time efficiency and productivity per shift, which can reduce the cost for soil preparation. When operating with a bulldozer units for cleaning areas, the opti-

mum coefficient for time efficiency can reach τ_{sh} = 0.74÷0.78, and building machine terraces – to τ_{sh} = 0.70÷0.73. From the performed observation it is found that it can be achieved by limiting non-operating moves and reducing machine idle time due to technical and organizational reasons. To make a soil preparation on wide tillage harrow, with tooth uprooter-rippers and to construct anti-erosion shafts every 50÷70 m, is needed more time to carry out the longer non-operating moves. In this case, the working time efficiency can be improved by reducing the idle time of the unit due to organizational and technical reasons. Then the optimal values may reach τ_{sh} = 0.67÷0.69.

CONCLUSION

The implementation of mechanized technologies for site preparation is among the main factors for increasing productivity and quality of work, for reducing labor costs, shortening the deadlines for afforestation and improving working conditions in forestry. Lately, the volume of mechanized site preparation for a reforestation in our country has decreased significantly. As a main reason for this, could be argued the lower volume of total afforestation for the country. According to the reported data of the Executive Forest Agency (Annual Reports, 2005/2015) for the last ten years, the volume of afforestation is reduced more than 20 times. Today, the mechanized land preparation, including those in this study, is applied primarily for afforestation of large areas and with various measures and programs supported by European funds.

The construction of trench-mound machine terraces and tilled harrows on sloped sites contributes to more effectively limitation of the erosion, to reduce weeds, for better aeration and water preservation of the soil. The high quality of soil preparation conducted in this study is indicative by the result of the autumn inventory of the cultures–almost 97% survival rate.

Conducted technological research of mechanized land preparation on sloping, rocky and partially eroded terrains have the following main contributions:

- There are developed photos of the working day by the operations of machine cleaning of shrubs, construction of arable belts by deep loosening and building trench-mound terraces on sloping sites.
- There have been determined the technological capabilities of bulldozer and uprooter-ripping machine-tractor units powered by tractors with pulling power up to 100 kN – model T-170, for site preparation of forest sloped areas;
- There have been determined the technical and economic indicators of the frontal and universal bulldozers D3-27 and D3-38, and uprooter-ripper D-513A site preparation for forest areas:
  - Operating performance machines;
  - Coefficient of time efficiency;
  - Operational fuel consumption;
  - Average price per one acre of soil preparation.

The results can be used for regulation of labor costs, shift performance and fuel consumption when using the examined machine-tractor units and for determining the necessary funds for site preparation.

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CONTENTS