Sustainable Technology for Establishment and Management of a Field-Protective Forest Belt with Accompanying Agricultural Crops and Soil Microbiological Assesment in the State Forestry Enterprise "Dobrich", Northeastern Bulgaria

Pavlina Naskova[1], Dragomir Plamenov[1], Anna Bakalova[1]

1 - Technical University - Varna, Department of Plant Production, 1 Studentska Str., Varna, Bulgaria

Corresponding Author: Pavlina Naskova, e-mail: pnaskova@abv.bg
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Abstract

The establishment and sustainable management of field-protective forest belts represent a key component of ecological infrastructure in agricultural landscapes. This study aims to develop a sustainable technological scheme for the establishment and management of a field-protective forest belt combined with accompanying agricultural crops in the area of the Dobrich State Forest Enterprise, Northeastern Bulgaria, integrating soil microbiological indicators as an assessment tool for ecological functionality.

The proposed technology is based on site-specific environmental conditions and prioritizes Turkey oak (*Quercus cerris* L.) as the main forest species due to its high drought tolerance, wind resistance and long-term vitality under the conditions of Dobrudzha. Watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai) and sweet cherry (*Prunus avium* L.) are selected as accompanying agricultural crops within an agroforestry framework, providing ecological and economic benefits. The technological plan includes mechanized soil preparation and planting, followed by a five-year tending period combining mechanized and manual operations.

Soil microbiological analyses conducted in spring under *Quercus cerris* (L.), *Citrullus lanatus* (Thunb.) Matsum. & Nakai and *Prunus avium* (L.) revealed a higher relative abundance of non-spore-forming bacteria, actinomycetes and filamentous fungi in forest soils, while agricultural soils were dominated by spore-forming bacteria. The results indicate that integrating field-protective forest belts with agricultural crops will enhance soil biogenicity, stabilize agrolandscapes and supports sustainable land management. Continuous monitoring of soil microbiological indicators is recommended to assess long-term ecological sustainability.

Keywords: forest belt; agroforestry systems; *Quercus cerris*; soil microorganisms; Dobrudzha region

Introduction

A fundamental prerequisite for establishing shelterbelts is their ability to exert a beneficial influence on wind erosion, the soil water regime, the even distribution of snow cover, and the increase in crop yields from adjacent lands. These are linear forest plantations whose creation is particularly essential in regions with prolonged summer droughts and destructive northern, northwestern, and northeastern winds, such as Northern Bulgaria and, more specifically, the Dobruja region. The greatest protective effect is achieved when the belts are interconnected in a network, forming inter-belt cells.

The full development of agriculture, forestry, and other economic sectors that rely on natural resources is linked to the intensification of production and the use of various chemical fertilizers, biostimulators, and other inputs. Alongside their positive effect - namely, increased productivity - these inputs disrupt natural cycles of matter and energy turnover. They negatively affect the morphological structure of the environment and its ability to maintain its natural qualities and to regenerate exploited resources. Consequently, the capacity for continued existence and sufficient regeneration of vegetation and fauna is substantially diminished due to constantly changing natural conditions (Peev, 1989).

Shelterbelts are an integral part of the ecological infrastructure of agricultural landscapes in Bulgaria. They perform essential functions in protecting against wind erosion, retaining soil moisture, improving the microclimate, increasing agricultural crop yields, and creating resilient ecosystems. In the Dobruja region, their significance is particularly high due to the predominantly flat terrain, intensive agriculture, and frequent occurrences of drought and wind erosion. This calls for the development of technological solutions for the establishment and cultivation of shelterbelts under conditions of climate change and intensive land use. In their study of shelterbelts in Northeastern Bulgaria, Dodev et al. (2023a) report that Turkey oak and Sessile oak demonstrate resilience, while mass dieback has been observed in ash belts, and phased reconstruction is deemed necessary for belts of black locust, green ash, and field elm. The effectiveness of shelterbelts in Dobruja is considerable, and thanks to them farmers report higher yields. Shelterbelts and agricultural lands together form an agroforestry system and represent biodiversity oases within the otherwise uniform landscape of Dobruja.

Sustainable land management, including the stabilization of landslides and erosion processes, requires a combination of engineering and biotechnical methods that minimize environmental impacts. Biotechnical approaches rely on vegetation that improves the soil water regime and enhances soil stability. Mountainous and erosion-prone terrains must be viewed as integrated systems in which vegetation plays a key stabilizing role. When establishing shelterbelts, vegetation not only protects against wind erosion but also stabilizes soil structure and microclimatic conditions. Landslides in the Varna region remain a significant problem that requires continuous attention, funding, and complex engineering solutions to ensure public and infrastructural safety (Tsekova, 2025a). Recommendations for strengthening slope stability must be followed, both for Varna landslides and for the "Smolyan Lakes" landslide (Tsekova & Trizlova, 2025). All interventions in the land base or landscape must be evaluated for the risk of secondary negative processes such as erosion, landslides, and disruption of the water balance. The construction of shelterbelts must also be assessed with regard to fire risk in the area. Human activities such as deforestation and land-

use change for agriculture and urban development not only cause ignition events but also alter landscape susceptibility to wildfire, creating a dangerous feedback loop (Tsekova, 2025b). Therefore, the establishment of shelterbelts requires ecological assessment and careful spatial planning in the selection of species and belt locations.

The ecological approach to construction and landscape modeling requires minimal disturbance of natural ecosystem linkages. This principle is equally applicable to combining agricultural crops with protective forest plantations, where ecological compatibility is a leading criterion. Any intervention in the natural environment must be evaluated in advance in terms of ecological compatibility and potential risks. For example, wind farms can alter the landscape and be perceived as visual pollution; their construction may also lead to soil erosion and water contamination (Trizlova et al., 2025). This approach is highly relevant for shelterbelt design, particularly when integrating them with agricultural crops, where achieving a balance between ecological sustainability and economic efficiency is crucial. As the authors emphasize, environmental protection should remain a fundamental principle in all infrastructural and eco-engineering design. This standpoint reinforces the need for integrating engineering, biological, and landscape-ecological solutions when planning sustainable forest and agricultural systems.

A major component of soil microbial communities, both in forested and agricultural areas, is represented by non-spore-forming bacteria, followed by bacilli, with actinomycetes and mold fungi being less abundant (Bogdanov et al., 2015; Malcheva et al., 2015; Naskova, 2016; Plamenov et al., 2016; Yankova et al., 2016; Malcheva et al., 2018; Malcheva et al., 2019; Malcheva, 2020; Malcheva et al., 2020; Malcheva, 2021; Grigorova-Pesheva et al., 2022).. All these main groups of microorganisms are sensitive indicators and should be monitored during the establishment and development of shelterbelts, including under conditions of wind erosion.

The main objective of this study is to develop a sustainable technology for the establishment and cultivation of a shelterbelt with accompanying agricultural crops in the area of the Dobrich State Forest Enterprise (DSFE Dobrich), with a particular emphasis on soil microbiological indicators as sensitive tools for assessing soil biological activity and functional changes. The scientific hypothesis of this study is that the assessment of soil microbiological indicators provides valuable information for evaluating and supporting the sustainable establishment and management of field-protective forest belts combined with accompanying agricultural crops. It is assumed that the combined forest belt–crop system induces measurable changes in soil microbiological indicators, reflecting enhanced soil biological activity and functional stability as a result of altered microclimatic conditions, increased organic inputs, and modified plant–soil–microorganism interactions.

Materials and Methods

Historical Development and International Experience in the Establishment of Shelterbelts

Russia is considered the birthplace of shelterbelts, with protective afforestation reaching a significant scale in the southern Russian steppes at the end of the 18th and the beginning of the 19th century (Melekhov, 1948).

During the 1930s, when severe dust storms threatened the grain-producing regions of the U.S. Midwest, President Franklin D. Roosevelt initiated the ambitious Great Plains Shelterbelt Project. Between 1935 and 1942, an unprecedented 220 million trees were planted across a vast protective belt zone approximately 100 miles wide and stretching 1,150 miles from the Canadian border to northern Texas (Droze, 1977). The program was discontinued after the United States entered World War II. Perhaps because shelterbelts no longer occupy a central place in U.S. political discourse, the long-term effects of the program have never been fully assessed, despite the availability of extensive documentation (Tianshu, 2021). Since the mid-20th century, China has implemented large-scale national programs to combat desertification, within which various types of protective forest plantations, including shelterbelts in agricultural and steppe regions, have been established (FAO, 2002; Kong et al., 2021).

Field-protective forest belts (FPFBs) have a significant role in protecting soils from wind erosion and degradation, as well as in regulating the microclimate and improving agricultural crop yields (Georgiev, 1960; Kort, 1988; Peev, 1990a,b). The first attempts to establish field-protective forest belts in Bulgaria began as early as the 1920s in the region of Southern Dobrudzha, while the large-scale and systematic creation of shelterbelts in Bulgaria started after Council of Ministers Decree No. 236 of 8 March 1951, known as the *"Plan for the Transformation of Dobrudzha"* (Dodev et al., 2023a). At present, a serious problem is the widespread dieback of ash shelterbelts established in Dobrudzha, which creates the need for reconstruction of large areas of various types of degraded shelterbelts (Dodev et al., 2023b, c). The first measures aimed at restoring good condition and ensuring proper management of field-protective forest belts in Bulgaria were implemented during the period 1960–1965 (Marinov et al., 2003).

To fulfill their function, shelterbelts in arable lands must meet a number of specific requirements. Areas with unfavorable climatic conditions, such as those in Dobrudzha, should be considered a priority for implementing this type of agroforestry activity in terms of timing, scale, investment, and production resources. The guiding principle for afforestation in lowland regions should be "afforestation wherever possible." In addition, the supplementation, restoration, or complete reconstruction of many existing shelterbelt systems is necessary. This is required due to their reduced agricultural efficiency in Dobrudzha, which, because of their suboptimal characteristics, is 5–15% below the potential. Some belts even demonstrate a negative agro-productive effect, which is unacceptable (Peev & Hinkov, 2000, 2002).

Furthermore, the destruction of forest shelterbelts in some regions over the past three decades has led to the reoccurrence of adverse phenomena and processes, such as reduced agricultural production and crop failure (Hinkov & Kachova, 2023). Positive trends are identified in the Report on the Implementation of the National Strategy for the Development of the Forest Sector in the Republic of Bulgaria 2013–2020, which states that 24.5 ha of shelterbelts have been restored and 5.4 ha of new forest shelterbelts have been established (https://www.mzh.government.bg/media/filer_public/2018/03/02/nacionalna-strategiya-razvitie-gorski-sektor-2013-2020.pdf).

Selection of Tree Species and Ecological Requirements for Afforestation in Dobrudzha

For the establishment of field-protective forest belts, the selection of appropriate tree and shrub species - those that correspond to the natural conditions of the region - is of exceptional importance. The effectiveness and long-term stability of the belts depend on making the right species choice.

Based on the natural conditions of the Danube Plain and Dobrudzha, the selected species should meet the following key ecological and biological requirements:

• successfully grow and develop under the specific environmental conditions of the region, particularly within the forest-steppe zone;

• exhibit wind resistance and form a deep and strong root system;

• be drought-tolerant in order to withstand prolonged periods of aridity;

• be resistant to cold and snow loads;

• demonstrate rapid height and diameter growth;

• possess relative longevity, which ensures an extended functional lifespan of the belts.

The climatic and soil conditions in Dobrudzha are favorable for the cultivation of the following species: oaks, ash, honey locust, walnut, small-leaved elm, and black locust, with pedunculate oak expected to occupy a leading position in shelterbelt afforestation, followed by Turkey oak and red oak, while companion species may include silver lime, field maple, Tatar maple, manna ash, wild pear, and others (Georgiev, 1960). When selecting tree species, their resistance to glaze ice events characteristic of Dobrudzha should also be considered, with walnut and Turkey oak identified as the most ice-resistant species.

The composition of field-protective forest belts in Northeastern Bulgaria has been shaped by long-term practice aimed at mitigating wind erosion, improving the microclimate, and stabilizing the agrolandscape. According to Dodev et al. (2023a), a relatively wide range of tree species has been used in the existing shelterbelts in the region, with dominant participation of Turkey oak (*Quercus cerris* L.), honey locust (*Gleditsia triacanthos* L.), black locust (*Robinia pseudoacacia* L.), ash (*Fraxinus* spp.), and common walnut (*Juglans regia* L.).

Oak species, and particularly Turkey oak, occupy a leading position in the belts due to their high drought tolerance, good wind resistance, and ability to form a stable shelterbelt structure. An analysis of the health status of the belts indicates that Turkey oak is among the species best adapted to the climatic conditions of Dobrudzha and exhibits relatively high vitality in older stands (Dodev et al., 2023b).

As fast-growing and functionally important species in shelterbelt systems, honey locust and black locust have been widely used, contributing to a more rapid development of the protective effect, especially in the initial stages after establishment. Nevertheless, a deteriorated condition of some black locust and ash stands has been reported, necessitating gradual reconstruction measures (Dodev et al., 2023a,b,c).

The studies further show that ash belts are among the most severely affected by processes of dieback and degradation, whereas Turkey oak and common walnut are distinguished by greater resilience and a longer functional lifespan. Consequently, the need to prioritize resilient oak species and to carefully select companion species in future reconstructions and new afforestation initiatives is emphasized (Hinkov & Kachova, 2023; Dodev et al., 2023b).

In historical forestry practice, the use of fast-growing poplar species as auxiliary components in protective plantings has been reported, due to their rapid biomass production and adaptability to continental and relatively dry conditions. *Populus* spp. has been described as a drought-tolerant and fast-growing species used in shelterbelt systems (Isebrands & Richardson, 2014; Zhang et al., 2006).

In addition, other broadleaved species with supplementary functions occur within the belts, contributing to structural diversity and ecological stability of the agrolandscape. However, the authors note that the lack of timely silvicultural treatments at an early age has led to a deterioration of the initial permeability of many shelterbelts and a reduction in their overall effectiveness (Dodev et al., 2023a).

Microbiological analyses

Soil microbiological analyses included plating on meat peptone agar for non-spore-forming bacteria and bacilli, Czapek–Dox agar for micromycetes (filamentous fungi), and Actinomycetes Isolation Agar for actinomycetes and mineral-nitrogen-assimilating bacteria, each in three replicates. Incubation was carried out in a thermostat under aerobic mesophilic conditions, followed by enumeration of colony-forming units per 1 g of absolutely dry soil (CFU g^{-1}) (Gushterov et al., 1977; Mishustin and Emtsev, 1989; Malcheva and Naskova, 2018; Nustorova and Malcheva, 2020). The total cultivable microbial community and the mineralization coefficient (MC) (ratio of bacteria assimilating mineral nitrogen to the sum of non-spore-forming bacteria and bacilli) were calculated (Mishustin and Runov, 1957; Malcheva and Naskova, 2018; Nustorova and Malcheva, 2020).

Results and Discussion

Table 1. *Participation of Plant Species in Shelterbelts*

Plant Species	Area	
	[ha]	%
Turkey oak (*Quercus cerris* L.)	624.4	33.4
Honey locust (*Gleditsia triacanthos* L.)	399.9	21.4
Black locust (*Robinia pseudoacacia* L.)	318.7	17.1
Manna ash (*Fraxinus excelsior* L.)	307.5	16.5
American ash (*Fraxinus americana* L.)	64.1	3.4
Common walnut (*Juglans regia* L.)	62.9	3.4
Silver lime (*Tilia tomentosa* Moench)	33.7	1.8
Field elm (*Ulmus minor* Mill.)	24.4	1.3
Northern red oak (*Quercus rubra* L.)	16.4	0.9
White mulberry (*Morus alba* L.)	6.9	0.4
Pedunculate oak (*Quercus robur* L.)	4.9	0.3
St. Lucie cherry (*Prunus mahaleb* L.)	1.9	0.1
European hackberry (*Celtis australis* L.)	0.9	0.05
Field maple (*Acer campestre* L.)	0.9	0.05
Common pear (*Pyrus communis* L.)	0.4	0.02
Hungarian oak (*Quercus frainetto* Ten.)	0.2	0.01
Tatar maple (*Acer tataricum* L.)	single trees	
Cherry plum (*Prunus cerasifera* Ehrh.)	single trees	
Blackthorn (*Prunus spinosa* L.)	single trees	
Smoke tree (*Cotinus coggygria* Scop.)	single trees	
Total:	1868.1	100.0

In the area of the DSFE, the shelterbelts occupy a total area of 1868.1 ha. According to the data presented in Table 1, the belts include a relatively large number of tree and shrub species, with the highest representation of Turkey oak, honey locust, black locust, and manna ash.

Selection of the Operational Technology

The selection of a specific technological option for establishing and tending a forest plantation - and in particular a FPFB combined with accompanying agricultural crops - is the most critical stage in the design process. One and the same technology may be implemented in several technological variations depending on the machine accessibility of the area, the purpose of the plantation, the duration and intensity of tending operations, the available tractor - machine fleet, or the possibility of hiring additional machinery.

The most rational option is the one that ensures lower labour and financial costs.

Each technology is divided into four main parts (major operations), arranged according to their sequence:

• Preliminary site preparation - preceding the establishment of the belts and consisting of clearing the area from harvest residues (branches, tops, cut shrubs).

• Primary soil preparation - the slope of the terrain determines the appropriate method of soil cultivation.

• Establishment of the belts - marking planting spots, opening planting pits, and planting the seedlings.

• Tending of the plantations - typically, shelterbelts are tended until the age of 4, or up to 5 years if located within Natura 2000 forest territories.

Initial Data

Table 6 shows that most of the forest enterprise's territory has a low terrain slope. Very steep terrain accounts for only 0.3%. The largest share of the area - about 52.3% - consists of land with a slope up to 5°, which allows for extensive use of mechanization in silvicultural operations. A second major share - approximately 24.2% - belongs to gently sloping areas. The third group - around 18.4% - includes moderately sloping areas, where appropriate machinery and equipment for mechanized soil preparation need to be introduced. From a technological perspective, this does not pose significant difficulties due to the availability of various technologies for afforestation on sloping terrains - terracing, strip planting, etc.

Soil Type and Productivity

Leached Chernozems occupy the largest share - 92.9% of the productive forest area. These soils have formed in places where forest vegetation has been present for long periods. The parent material is loess. Such soils are characterized by great depth, significant accumulation of organic matter (humus) in the upper horizons, and highly favourable conditions for the establishment and growth of shelterbelts. Their soil reaction is nearly neutral, and the water regime is comparatively favourable. The soil texture - sandy-clay - facilitates the use of mechanized technologies.

Size and Shape of the Areas

This factor is of particular importance. The larger the areas, the more rational the use of machinery becomes. It eliminates the need for frequent transportation of tractor-machine units, and in general, efficiency is significantly higher on straight and wide terrains.

Relief and Accessibility

Overall, the relief of the region is flat. From this perspective, there are no obstacles to the implementation of full mechanization.

Selection of the Forest Species

The main forest species selected for the shelterbelt is *Quercus cerris* L. (Turkey oak). *Quercus cerris* L. is a tall tree (up to 35 m) with a massive, spreading crown. The bark is thick, grey-black, coarse, and deeply fissured. The twigs exhibit dense cracks and reddish bark. Young shoots are covered with fine hairs and have a grey-green colour. Leaves are 5–14 cm long, dark green, deeply lobed, and rough, with triangular lobes. The underside is sparsely pubescent, and in autumn the leaves remain green until the first frosts. Acorns mature in two years and reach 3–4 cm in length. The cupule is covered with long, linear-curved scales. In Bulgaria, the species is distributed up to 1200 m a.s.l.

Ecological Requirements of Turkey Oak

This is a light-demanding and drought-resistant species, tolerant of various soil conditions but growing best on deep and fertile soils. It tolerates calcareous substrates and polluted air. Very low winter temperatures may cause frost damage, which weakens tree vitality. Its longevity is relatively short (around 200 years). Due to its fast growth and tolerance to polluted air, it is widely used in parks and mixed stands under drier conditions. It participates extensively in landscape forest plantations, and due to its high drought resistance, its use in shelterbelts should be increased (Vakarelov & Gencheva, 2005).

Selection of Accompanying Agricultural Crops

As accompanying species, watermelon (*Citrullus lanatus (Thunb.) Matsum. & Nakai*) and sweet cherry (*Prunus avium* L.) are selected. According to the accepted classification, watermelon is a fruit vegetable belonging to the Cucurbitaceae family, while cherry is a stone fruit species from the Rosaceae family.

Ecological Requirements of Watermelon

The growth, development, fruiting, and longevity of watermelon depend on climatic and soil conditions. Light, water, and temperature are essential factors for all living organisms. These factors largely depend on latitude, altitude, relief, site exposure, and soil properties. In the present case, the conditions are optimal for watermelon.

Light

Watermelon requires high light intensity; insufficient light results in poor development, longer vegetation period, reduced sugar content, and lower yield.

Temperature

Watermelon is a thermophilic and heat-resistant plant. Seeds germinate at 15–17°C. Optimal growth occurs at 30–45°C. A drop to 15°C slows development, and 5–10°C may kill the plant. Successful pollination requires temperatures above 18°C. At the early growth stages, the plant tolerates low temperatures better. Under high humidity in low tunnels, young plants endure a wide temperature range (2–50°C).

Water and Irrigation

Watermelon has a strong root system, contributing to high drought resistance. To produce 5 kg per 1 m², about 160 litres of water are required. Excessive irrigation before fruit formation results in poor root development and low yields. If irrigation is needed, it should begin at the onset of fruit ripening. Optimal soil moisture is 75–80% of field capacity.

Soil Types

Watermelon is not demanding regarding soil fertility; it grows on poor sandy soils, heavy stony soils, and fertile Chernozems. Cold, clayey, and waterlogged soils should be avoided. Best results occur at pH 6–6.5.

Ecological Requirements of Sweet Cherry

Sweet cherry trees reach heights of 12–15 m, making them suitable as accompanying species. They form sparse, wide-pyramidal to rounded crowns with characteristically tiered branching. At a young age, they have strong vegetative growth and a well-defined leader. With proper care, they bear regularly and abundantly and can live 40–50 years in plantations.

Light

Cherry is highly light-demanding and develops best in open, well-illuminated locations protected from adverse weather. Insufficient light shortens lifespan, reduces yield, and lowers fruit quality. Poor light conditions may result from unsuitable site selection, dense planting, improper crown formation, or shading by trees/buildings.

Temperature

Cherry is a temperate-climate crop with high temperature requirements. It does not tolerate very hot and dry sites; fruits remain small and of poor quality. In hot and dry summers, especially on shallow soils, tree growth is weak and winter frost resistance declines. Fruit buds withstand –24 to –25°C under normal conditions.

Water and Irrigation

Cherry is relatively drought-tolerant and is usually grown under rainfed conditions. Drought tolerance is best expressed on deep, well-drained soils where a strong root system can develop. Cherry does not tolerate waterlogging, frequent irrigation, high groundwater levels, or heavy rainfall during fruit ripening.

Soil Types

Cherry can grow on a variety of soils: slightly podzolic, dark grey and leached cinnamonic forest soils, brown and grey forest soils, carbonate chernozems, alluvial and deluvial meadow deposits, and moderately moist soils.

Description of the Technologies Used for Establishing a Shelterbelt with Accompanying Agricultural Crops

One-year-old *Quercus cerris* (L.) seedlings will be planted. The soil is ordinary (leached) chernozem, with a sandy-clay texture, non-stony, very deep, and formed on loess. The soil depth reaches up to 120 cm, allowing for deep soil preparation. The terrain is flat and has a regular shape.

The main technological variants depend on site conditions - density of stumps, shrubs, and low woody vegetation. Other important factors include agro-technical deadlines and silvicultural requirements for belt establishment. Site machine suitability will be assessed using established criteria.

The site has flat relief and a slope of up to 2°. The soil is non-stony and deep. The mechanical composition is heavy. The site is large, with a regular shape and free access. Based on these characteristics, the site is highly suitable for mechanization, allowing full mechanization of silvicultural operations.

Technological operations will follow this sequence:

• Complete preliminary site preparation

Shrubs are mulched and the terrain is levelled using rotary tillers.

• Planting of seedlings

A two-row planting machine will be used. This method prevents two major problems: root folding during insertion and air pockets at the base of the planting slit. The planting scheme will be 3 × 0.5 m. Watermelons (*Citrullus lanatus (Thunb.) Matsum. & Nakai*) will be sown between the rows by direct seeding, while the two outer rows will be planted with cherries (*Prunus avium* L.) at 6 m spacing.

• Tending of shelterbelts

Due to frequent droughts in Dobrudzha, manual hoeing within rows will continue for five years, especially since much of the enterprise falls within Natura 2000.

Mulching of Existing Shrub and Woody Vegetation Using a FENDT 926 VARIO TMS Tractor and an AHWI M550 Forestry Mulcher

Mulching will be carried out using a unit consisting of a FENDT 926 VARIO TMS tractor and an AHWI M550 forestry mulcher (Fig. 1) designed for shredding shrub and woody vegetation, as well as logging residues in forest stands and plantations. The vegetation will be shredded into chips and left on the soil to decompose over an area of 34 dka.



Fig. 1. *Photograph of a FENDT 926 VARIO TMS mulching unit and an AHWI M 550 forestry mulcher*

Primary Soil Preparation and Stump Shredding (Deep Mulching) – 40 cm, and Terrain Leveling

Primary soil preparation and using a unit consisting of a FENDT 926 VARIO TMS tractor and a FAE SSM/HP- stump shredding (deep mulching) to a depth of 40 cm, as well as terrain leveling, will be carried out 250 soil mulcher (Fig. 2). This operation will be performed on an area of 34 dka.



Fig. 2. *Photograph of a FENDT 926 VARIO TMS mulching unit and an FAE SSM/HP-250 soil mulcher*

Establishment of the Shelterbelt and Sowing of the Accompanying Agricultural Crop

Afforestation will be performed mechanically using a two-row planting machine. To create suitable conditions for mechanization, provide adequate light, and maximize seedling growth, the planting scheme will consist of six rows for the main field-protective forest belt, with a spacing of 3 m between rows and 0.5 m within the row.

The accompanying agricultural crop is watermelon, which will be established by hill (nest) sowing. Each hill will be sown with 3–4 treated seeds at a depth of 4–5 cm. The spacing between hills within the row will be 60 cm, and the spacing between rows will be 120 cm. After emergence, at the 2–3 leaf stage, the plants will be thinned to 2 plants per hill.

Tending of the Plantation

Five years of tending are planned after planting. Each year, prior to sowing the agricultural crop in the interrows, deep mulching (rotary tilling) will be performed.

The scheme for establishing a field-protective forest belt with an accompanying agricultural crop is presented in Figure 3. The main shelterbelt consists of six rows of *Quercus cerris* L., planted at 3 m between rows and 0.5 m within the row. Watermelon (*Citrullus lanatus (Thunb.) Matsum. & Nakai*) is sown by hill planting in the interrows (1.2 m between rows; 0.6 m between hills). The outer rows are planted with *Prunus avium* at 6 m spacing.

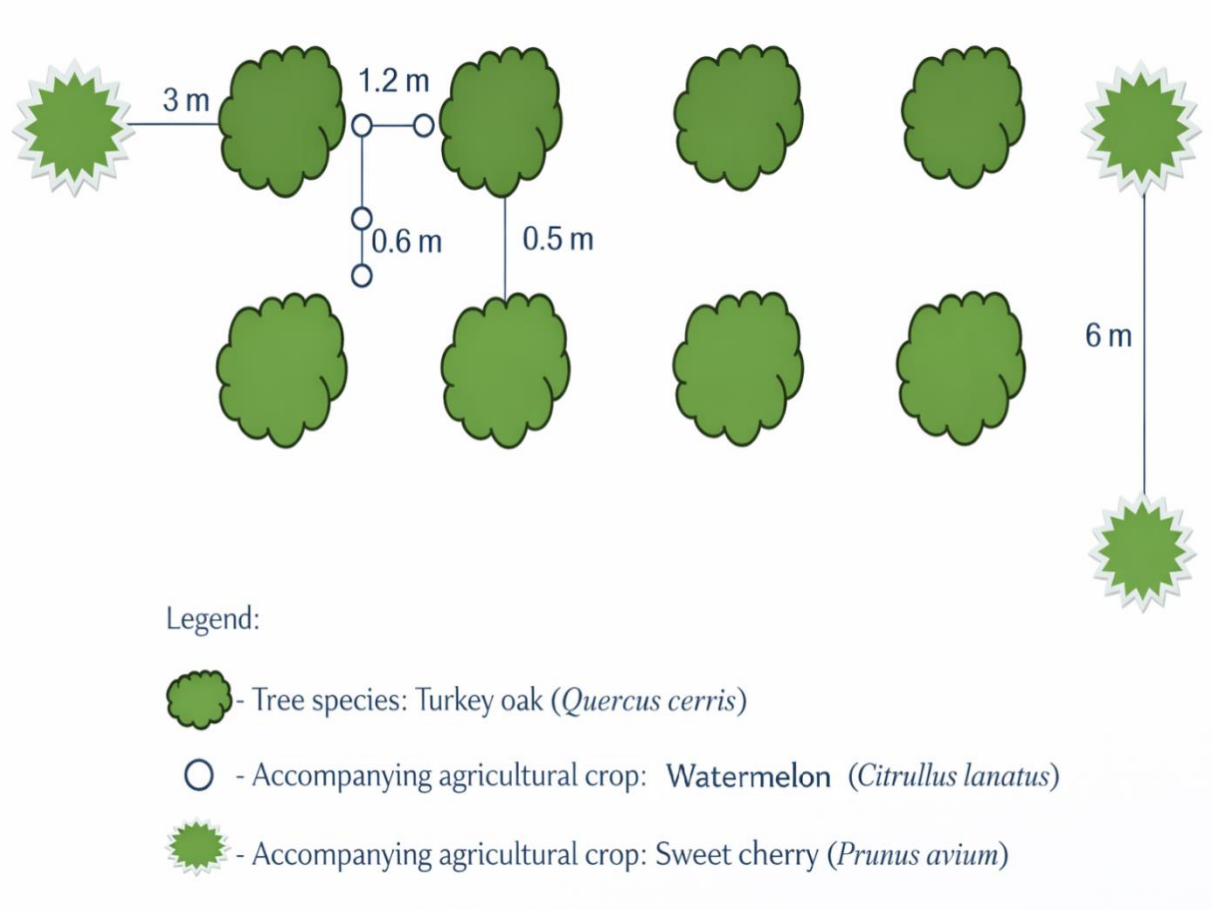


Fig. 3. *Scheme for establishing a field-protective forest belt with an accompanying agricultural crop*

Table 2 presents the technological plan for establishing a field-protective forest belt.

Table 2. *Technological plan for the establishment of shelterbelts*

Year	No	Technological operation	Unit	Work vo-lume	Planned period (from–to)	Wor-king days	Machine unit		Shift productivity Wsh [dka/shift]	Machine -shift days (n)	Required personnel (r)	Man-shift days (m)	Machine-shift cost		Man-shift cost	
							Power unit (model)	Working machine (model)					per 1 dka (Hm)	Total (Hm)	per 1dka (Hc)	Total (Hc)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
I	1	Mulching of woody–shrub vegetation and logging residues.	dka	34	04.III-04.III	1	Fend 926 VARIO	AHWI M 550	31.17	1	1	1	0.032	1.091	0.032	1.091
	2	Deep rotary tillage and stump shredding – 40 cm.	dka	34	05.III-07.III	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	3	Planting of the crop.	dka	34	08.III-08.III	1	Fend 926 VARIO	SLCH - 2	36	1	5	5	0.028	0.944	0.139	4.722
	4	Inter-row rotary tillage.	dka	24	4.V-6.V	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	5	Watermelon sowing.	lm	8100	7.V-9.V	3	-	manual	3300	-	-	10	-	-	1.513	51
	6	Inter-row weeding.	lm	18000	30.V-.6.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	7	Inter-row weeding.	lm	18000	25.VI-.31.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	8	Inter-row weeding.	lm	18000	10.VII-.15.VII	6	-	manual	3300	-	-	10	-	-	1.513	51
	9	Harvesting	dka	24	03.VIII-20.VIII	17	Fend 926 VARIO	Trailer	-	-	-	-	-	-	-	-
	10	Disc harrowing	dka	24	7.IX	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
II	11	Disc harrowing	dka	24	01.VI	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	12	Inter-row weeding.	lm	9900	01.VI-03.VI	3	-	manual	3300	-	-	10	-	-	1.513	51
	13	Inter-row rotary tillage.	dka	24	4.V-6.V	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	14	Watermelon sowing.	lm	8100	7.V-9.V	3	-	manual	3300	-	-	10	-	-	1.513	51
	15	Inter-row weeding.	lm	18000	30.V-.6.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	16	Inter-row weeding.	lm	18000	25.VI-.31.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	17	Inter-row weeding.	lm	18000	10.VII-.15.VII	6	-	manual	3300	-	-	10	-	-	1.513	51
	18	Harvesting	dka	24	03.VIII-20.VIII	17	Fend 926 VARIO	Trailer	-	-	-	-	-	-	-	-
	19	Disc harrowing	dka	24	7.IX	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
III	20	Disc harrowing	dka	24	01.VI	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	21	Inter-row weeding.	lm	9900	01.VI-03.VI	3	-	manual	3300	-	-	10	-	-	1.513	51
	22	Inter-row rotary tillage.	dka	24	4.V-6.V	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	23	Watermelon sowing.	lm	8100	7.V-9.V	3	-	manual	3300	-	-	10	-	-	1.513	51

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	24	Inter-row weeding.	lm	18000	30.V-.6.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	25	Inter-row weeding.	lm	18000	25.VI-.31.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	26	Inter-row weeding.	lm	18000	10.VII-.15.VII	6	-	manual	3300	-	-	10	-	-	1.513	51
III	27	Harvesting	dka	24	03.VIII-20.VIII	17	Fend 926 VARIO	Trailer	-	-	-	-	-	-	-	-
	28	Disc harrowing	dka	24	7.IX	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	29	Disc harrowing	dka	24	01.VI	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	30	Inter-row weeding.	lm	9900	01.VI-03.VI	3	-	manual	3300	-	-	10	-	-	1.513	51
	31	Inter-row rotary tillage.	dka	24	4.V-6.V	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	32	Watermelon sowing.	lm	8100	7.V-9.V	3	-	manual	3300	-	-	10	-	-	1.513	51
	33	Inter-row weeding.	lm	18000	30.V-.6.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	34	Inter-row weeding.	lm	18000	25.VI-.31.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	35	Inter-row weeding.	lm	18000	10.VII-.15.VII	6	-	manual	3300	-	-	10	-	-	1.513	51
	36	Harvesting	dka	24	03.VIII-20.VIII	17	Fend 926 VARIO	Trailer	-	-	-	-	-	-	-	-
IV	37	Disc harrowing	dka	24	7.IX	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	38	Disc harrowing	dka	24	01.VI	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176
	39	Inter-row weeding.	lm	9900	01.VI-03.VI	3	-	manual	3300	-	-	10	-	-	1.513	51

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
V	40	Inter-row rotary tillage.	dka	24	4.V-6.V	3	Fend 926 VARIO	FAE SSM/HP-250	11.76	1	1	1	0.085	2.891	0.085	2.891
	41	Watermelon sowing.	lm	8100	7.V-9.V	3	-	manual	3300	-	-	10	-	-	1.513	51
	42	Inter-row weeding.	lm	18000	30.V-.6.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	43	Inter-row weeding.	lm	18000	25.VI-.31.VI	6	-	manual	3300	-	-	10	-	-	1.513	51
	44	Inter-row weeding.	lm	18000	10.VII-.15.VII	6	-	manual	3300	-	-	10	-	-	1.513	51
	45	Harvesting	dka	24	03.VIII-20.VIII	17	Fend 926 VARIO	Trailer	-	-	-	-	-	-	-	-
	46	Disc harrowing	dka	24	7.IX	0.18	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	160	1	1	1	0.006	0.176	0.006	0.176

After determining the technological operations and the required number of machine-shifts and man-shifts, the composition of the machine–tractor fleet for the designed afforestation technology (Table 3) and the composition of the planned labor resources (Table 4) are presented in tabular form.

Table 3. *Composition of the planned machine–tractor fleet*

No	Name and brand of the tractor and technological machine	Required number for individual months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
First year													
1	FENDT 926 VARIO TMS	-	-	1	-	-	-	-	-	-	-	-	-
2	FAE SSM/HP-250	-	-	1	-	-	-	-	-	-	-	-	-
3	AHWI M550	-	-	1	-	-	-	-	-	-	-	-	-
4	AHWI SF 1000	-	-	1	-	-	-	-	-	-	-	-	-
5	Disc harrow Alpler – 2.5 m	-	-	-	1	1	1	-	-	-	-	-	-
6	SLCH - 2	-	-	1	-	-	-	-	-	-	-	-	-
Second year													
7	FENDT 926 VARIO TMS	-	-	-	1	-	-	-	-	1	-	-	-
8	FAE SSM/HP-250	-	-	-	1	-	-	-	-	1	-	-	-
9	Disc harrowAlpler – 2.5 m	-	-	-	1	-	-	-	-	1	-	-	-
Third year													
10	FENDT 926 VARIO TMS	-	-	-	1	-	-	-	-	1	-	-	-
11	FAE SSM/HP-250	-	-	-	1	-	-	-	-	1	-	-	-
12	Disc harrowAlpler – 2.5 m	-	-	-	1	-	-	-	-	1	-	-	-
Fourth year													
13	FENDT 926VARIO TMS	-	-	-	1	-	-	-	-	1	-	-	-
14	FAE SSM/HP-250	-	-	-	1	-	-	-	-	1	-	-	-
15	Disc harrowAlpler – 2.5 m	-	-	-	1	-	-	-	-	1	-	-	-
Fifth year													
16	FENDT 926VARIO TMS	-	-	-	1	-	-	-	-	1	-	-	-
17	FAE SSM/HP-250	-	-	-	1	-	-	-	-	1	-	-	-
18	Disc harrow Alpler – 2.5 m	-	-	-	1	-	-	-	-	1	-	-	-

Table 4. *Composition of the planned labor resources*

No.	Name and brand of the tractor and technological machine	Required number for individual months											
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
First year													
1	Tractor operator	-	1	1	1	1	1	-	-	-	-	-	-
2	Planters	-	-	4	-	-	-	-	-	-	-	-	-
3	Hoeing workers	-	-	-	10	10	10	10	10	-	-	-	-
Second year													
4	Tractor operator	-	-	-	1	1	1	1	1	1	-	-	-
5	Hoeing workers	-	-	-	10	10	10	10	10	-	-	-	-
Third year													
6	Tractor operator	-	-	-	1	1	1	1	1	1	-	-	-
7	Hoeing workers	-	-	-	10	10	10	10	10	-	-	-	-
Fourth year													
8	Tractor operator	-	-	-	1	1	1	1	1	1	-	-	-
9	Hoeing workers	-	-	-	10	10	10	10	10	-	-	-	-
Fifth year													
10	Tractor operator	-	-	-	1	1	1	1	1	1	-	-	-
11	Hoeing workers	-	-	-	10	10	10	10	10	-	-	-	-

As can be seen from the tables above, two tractors will be used, and only for a relatively short period - approximately 2–3 months. The funds required for renting the machinery will therefore have to be secured and invested within a short time frame.

The composition of the labor resources is also economically inefficient.

The technological plan shows that soil preparation and afforestation will be carried out in a mechanized manner. The tending operations will be conducted over a period of five calendar years.

Determination of the degree of mechanization

The degree of mechanization is determined for aggregated operations and for the technology as a whole. It is calculated using the following formula:

$$C = \frac{V_m}{V_o} \times 100\%$$

where V is the volume of work performed mechanized (dka), and V_o is the total volume of work performed (dka).

The degree of mechanization by aggregated operations and for the entire technology at the site is as follows:

- soil preparation - C = 100.00%;
- afforestation - C = 100.00%;
- tending - C = 84.0%;
- average – C = 87.00%.

Occupational safety when working with machinery

Due to the relatively harsh conditions of production activities, occupational safety is of crucial importance in forestry operations. Therefore, compliance with the statutory occupational health and safety regulations is strongly recommended.

Economic indicators

There are several basic rules for determining technological operations. It is important not only to reduce labor costs and increase productivity, but also to improve working conditions, reduce labor intensity, and comply with the fundamental silvicultural requirements (Table 5).

Table 5. *Evaluation of the technological project per dka*

No.	Technological operation	Machine unit		Unit price, BGN
		Power unit (model)	Working machine (model)	
1	2	3	4	5
1	Mulching of existing woody–shrub vegetation and logging residues.	Fend 926 VARIO	AHWI M 550	-70
2	Primary soil preparation (deep rotary tillage) and stump shredding – 40 cm.	Fend 926 VARIO	FAE SSM/HP-250	-400
3	One-year-old seedling plants + transport and handling			-58
4	Planting of the crop	Fend 926 VARIO	SLCH - 2	-50
5	Inter-row disc harrowing	Fend 926 VARIO	Disc harrow Alpler – 2,5 m	-15
6	Watermelon sowing	-	manual	-56
8	Watermelon seeds			-30
9	Weeding	-	manual	-46
10	Estimated watermelon yield per dka – 3,000 kg			+ 1000

According to the proposed scheme (Fig. 3) for establishing a field-protective forest belt with an accompanying agricultural crop, preliminary microbiological analyses were conducted on forest soils (Chernozems) under Turkey oak (*Quercus cerris* L.) and cultivated soils (Chernozems) under watermelon (*Citrullus lanatus (Thunb.) Matsum. & Nakai*) and sweet cherry (*Prunus avium* L.) in spring, at a depth of 0–20 cm. Although forest soils often exhibit lower overall microbial activity and slower mineralization of organic matter due to the accumulation of stable humus, recalcitrant compounds, and the absence of mechanical aeration and fertilization, the structure of the microbial community differs to some extent from that of agricultural soils. Forest soils are characterized by a higher relative contribution of non-spore-forming bacteria, actinomycetes, and filamentous fungi, whereas agricultural soils are dominated by spore-forming bacteria (*Bacillus* spp.), adapted to frequent mechanical disturbance, stress conditions, and fertilization with microbial fertilizers (Fig. 4). Mineralization activity is highest under *Citrullus lanatus* (Thunb.) Matsum. & Nakai. Soil microbiological indicators are sensitive parameters and should be monitored both before the establishment of shelterbelts and thereafter, considering their seasonal and annual dynamics. We consider that the establishment of a field-protective forest belt with accompanying agricultural crops will increase soil biogenicity.

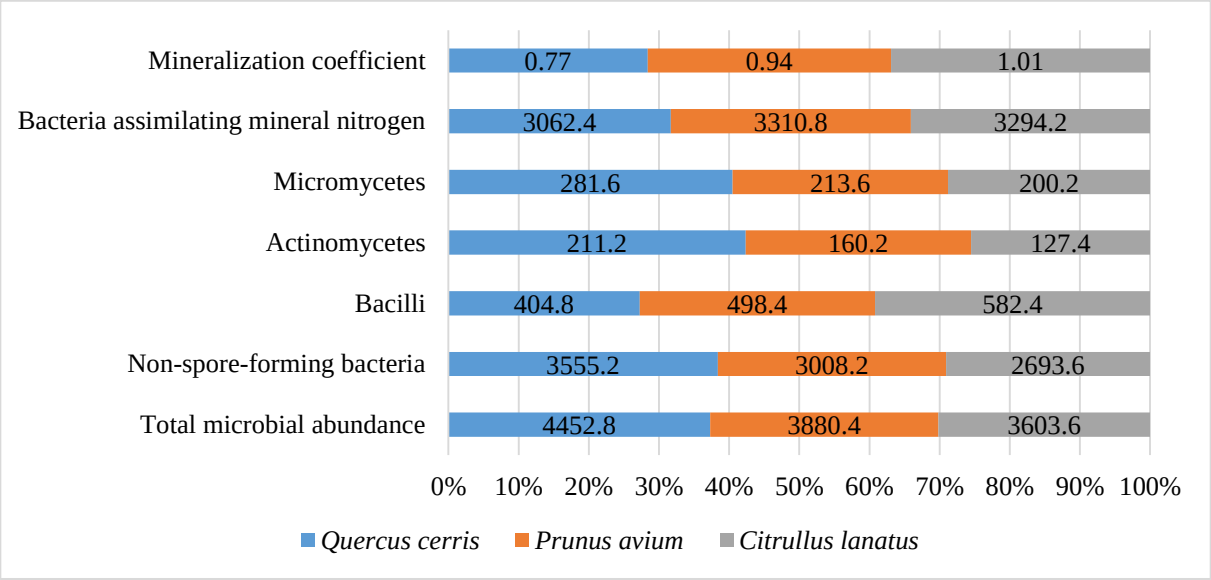


Fig. 4. *Abundance (×10³ CFU g⁻¹), composition, and activity (MC) of soil microorganisms*

Similar trends, with a predominance of non-spore-forming bacteria, followed by spore-forming bacteria (bacilli) and a lower contribution of mycelial forms - actinomycetes and filamentous fungi have also been reported by other authors in studies of forest and agricultural soils. These studies further indicate that the mineralization and enzymatic activities of microorganisms depend not only on their abundance but also on a complex of factors, including soil temperature and moisture, soil pH (forest soils are more often acidic, which favors the development of filamentous fungi), nutrient availability (mineral and organic fertilization at appropriate rates increases soil biogenicity), vegetation type (the decomposition of coniferous litter is more constrained compared to the decomposition of dead forest litter from broadleaved tree species), soil texture, altitude, and other factors (Susyan et al., 2006; Bogdanov et al., 2015; Malcheva et al., 2015; Naskova, 2016; Naskova et al., 2016;

Plamenov et al., 2016; Qi et al., 2016; Yankova et al., 2016; Malcheva et al., 2018; Malcheva et al., 2019; Malcheva, 2020; Malcheva et al., 2020; Malcheva, 2021; Grigorova-Pesheva et al., 2022; Malcheva et al., 2023; Malcheva et al., 2024; Malcheva, 2025).

Conclusion

The area of shelterbelt forest belts within the territory of the Dobrich State Forestry Enterprise amounts to 1,868.1 ha. Approximately 52% of them are over 50 years old. Among the tree species used in the existing shelterbelts, the highest proportions are represented by Turkey oak (*Quercus cerris* L.), honey locust (*Gleditsia triacanthos* L.), manna ash (*Fraxinus ornus* L.), black locust (*Robinia pseudoacacia* L.), and common walnut (*Juglans regia* L.). The belts were originally established with a permeable structure; however, due to the lack of silvicultural treatments at early developmental stages and the encroachment of shrub species, most of them are currently non-permeable, which hinders their proper functioning. A technological scheme is proposed, including full soil preparation, followed by planting of forest seedlings and sowing of an accompanying agricultural crop.The advantages of the proposed technological scheme include shortened agrotechnical periods for soil preparation, a significant reduction in labor costs, and the creation of prerequisites for additional income.

Forest soils under Turkey oak are characterized by a higher total abundance of microorganisms and a greater relative proportion of non-spore-forming bacteria, actinomycetes, and microscopic fungi, whereas cultivated soils under cherry and especially under watermelon exhibit a higher proportion of spore-forming bacteria and more intensive mineralization processes.

Microbiological indicators should be studied dynamically before and during the establishment of field-protective forest belts. We consider that their combination with accompanying agricultural crops will enhance soil biogenicity and soil fertility.

References

Bogdanov, S. B., Noustorova, M. L., & Malcheva, B. Z. (2015). Long-lasting effect of fertilization on soil microflora of brown forest soils (Distric-Eutric Cambisols) from the Western Rhodope region. *Ecology and Future*, 14(1–2), 23. (in Bulgarian).

Dodev, Y., Georgiev, G., Georgieva, M., Madzhov, S., Belilov, S., Ivanov, V., Marinkov, V., & Georgieva, L. (2023a). Main characteristics of shelterbelt forest belts in Northeastern Bulgaria. *Forest Science* (special issue), 17–31. (in Bulgarian).

Dodev, Y., Georgiev, G., Belilov, S., Ivanov, V., Georgieva, M., Madzhov, S., & Georgieva, L. (2023b). Health status of the field protective forest belts in Dobrudzha – results from the monitoring carried out in 2022. Silva Balcanica, 24(3), 17–26.

Dodev, Y., Georgiev, G., Belilov, S., Ivanov, V., Georgieva, M., & Madzhov, S. (2023c). Creation and management of field-protective forest belts in Northeastern Bulgaria – history, problems and gained experience. *Ecologia Balkanica*, 15(2), 154–161.

Droze, W. H. (1977). *Trees, prairies, and people: A history of tree planting in the Plains States*. Denton, TX: Texas Woman's University Press.

Food and Agriculture Organization of the United Nations (FAO). (2002). Tackling desertification in the Korqin Sandy Lands: Three-North Shelterbelt Programme overview. FAO. Retrieved from https://www.fao.org/4/AD115E/AD115E00.htm

Georgiev, D. (1960). *Field-protective forest belts in Bulgaria*. State Publishing House, Varna, 206 pp. (in Bulgarian).

Grigorova-Pesheva, B. B., Hristov, B. E., & Petrova, K. G. (2022). Analysis of the microbiological characteristics of different soil horizons of forest soils from Vitosha Nature Park. In *Proceedings of the 22nd International Multidisciplinary Scientific GeoConference SGEM*, 02 – 11 July, 333–340.

Gushterov, G., Andonov, P., Todorov, Ts., Kominkov, L., Gincheva-Starcheva, M. (1977). *Microbiology practicum with virology*. Science and Art Publishing House Sofia, 393 pp. (in Bulgarian).

Hinkov, G., & Kachova, V. (2023). The contribution of Professor Boris Peev to the study of field-protective forest belts in Bulgaria. *Forest Science*, No. 2, 123–132 (in Bulgarian).

Isebrands, J. G., & Richardson, J. (Eds.). (2014). *Poplars and willows: Trees for society and the environment.* Food and Agriculture Organization of the United Nations & CABI. https://doi.org/10.1079/9781780641089.0000.

Kong, Z.-H., Stringer, L. C., Paavola, J., & Lu, Q. (2021). Situating China in the global effort to combat desertification. *Land*, 10, 702. https://doi.org/10.3390/land10070702.

Kort, J. (1988). Benefits of windbreaks to field and forage crops. *Agriculture, Ecosystems & Environment*, 22–23, 165–190.

Malcheva, B., Naskova, P., Plamenov, D. and Iliev, Y. (2018). Study on impact of mineral fertilizers on biogenicity and enzymatic activity of soils with common wheat. *International Journal of Advanced Research*, 6, 137-144.

Malcheva, B., Naskova, P. and Plamenov, D. (2019). Investigation of the influence of mineral nitrogen fertilizers on the microbiological and enzymic activity of soils with rapeseed. *New Knowledge Journal of Science*, 8-4, 80-90, (in Bulgarian).

Malcheva, B. Z. (2020). Microbial diversity and enzyme activity of soils in coniferous forest ecosystems. *Soil Science, Agrochemistry and Ecology*, 54 (4), 43-54.

Malcheva, B., Naskova, P. (2018). *Guide for laboratory exercises of microbiology*. University Publishing House at TU-Varna, Varna, Bulgaria, 70 p. (in Bulgarian)

Malcheva, B., Petrova, V., Yordanova, M., Naskova, P. and Plamenov, D. (2020). Influence of biochar and manure fertilization on the microbiological activity of agricultural soil, *International Conference of the University of Agronomic Science and Veterinary Medicine of Bucharest, June 4-6 2020, Bucharest, Romania, Scientific papers, series B-Horticulture*, LXIV, 2, 191-198.

Malcheva, B. (2021). Influence of microbial fertilizers on microbiological and enzymatic decomposition of carbohydrates in agrogenic soil. Bulgarian Journal of Crop Science, 58, 95-103. (in Bulgarian).

Malcheva, B., Hristov, B., Gushterova, A., Malinova, L., Pavlov, P., Petrova, K. (2023). Response of catalase activity of soil microorganisms according to microbial biomass carbon in forest ecosystems from natural park "Vitosha". *Journal of Environmental Protection and Ecology*, (24)2, 446–458.

Malcheva, B., Grigorova-Pesheva, B., Hristov, B. (2024). Microbial diversity and cellulase activity of forest soils and litters. *Edelweiss Applied Science and Technology*, Vol. 8, No. 5, 568-577. DOI:10.55214/25768484.v8i5.1718.

Malcheva, B. (2025). Microbiological soil activity after application of combined nitrogen fertilizers and Bacillus subtilis. Agricultural Science and Technology, 17(3), 76-83. DOI: 10.15547/ast.2025.03.35.

Marinov, I., Stiptsov, V., & Genova, F. (2003). *Agroforestry: past, present and future*. BPS, Sofia, 63 pp. (in Bulgarian).

Melekhov, I. S. (1948). *Steppe afforestation and forest reclamation*. Moscow–Leningrad: Goslesbumizdat. (in Russian).

Mishustin, F., Emtsev, N. (1989). *Microbiology*, Moscow, Kolos: RUS, 367 pp. (in Russian).

Mishustin, E. Runov, E. (1957). The success of the development of principles for microbiological diagnosis of soil conditions. *Advances in Modern Biology*, 44, 256-268, 1957 (in Russian).

Naskova, P. (2016). Seasonal and annual dynamics of microbial activity in soils from natural, agro and urboecosystem. In: *Proceedings of University of Ruse*, 55 (1.2), 249-257 (in Bulgarian).

Naskova, P., Malcheva, B., Yankova, P. and Plamenov, D. (2016). Impact of the biological fertilizers on chemical indexes and enzyme activities of soils at cucumbers. *International Research Journal of Natural and Applied Sciences*, 3, 120-131.

Nustorova, M., Malcheva, B. (2020). Guide for laboratory exercises of microbiology. Gea Print, Varna, Bulgaria, 118 pp. (in Bulgarian).

Peev, B. (1989). *Wind-protective and microclimatic effectiveness of shelterbelt forest belts*. Habilitation thesis, Higher Institute of Forestry, Sofia, 296 pp. (in Bulgarian).

Peev, B. (1990a). Wind erosion. *Forestry*, No. 5, 15–18. (in Bulgarian).

Peev, B. (1990b). On the necessity of establishing field-protective forest belts. In: *Proceedings "The role of field-protective forest belts in increasing agricultural crop yields and protecting the natural environment"*. Sofia, 1-18 (in Bulgarian).

Peev, B., & Hinkov, G. (2000). Agro-productive efficiency of field-protective forest belts. In: *Proceedings of the Jubilee Collection of Scientific Papers "75 Years of Higher Forestry Education in Bulgaria"*. University of Forestry, Sofia, Section Forestry, 447–457.

Peev, B., & Hinkov, G. (2002). Ecologization of agricultural territories through field-protective forest belts. *Ecology and Future*, I(2–4), 96–99 (in Bulgarian).

Plamenov, D., Naskova, P., Malcheva, B. and Iliev, Y. (2016). Chemical and microbiological studies for determination the influence of fertilizers produced by "Agropolychim" AD on winter common wheat and oilseed rape. *International Journal of Science and Research*, 5, 1481-1486.

Susyan, B. A., Rybyanets, D. S., Ananyeva, N. D. (2006). Microbial activity in the profiles of gray forest soil and chernozems. *Eurasian Soil Science*, 39(8), 859-867.

Tianshu, L. (2021). Protecting the Breadbasket with Trees? The Effect of the Great Plains Shelterbelt Project on Agriculture. *Land Economics*, 97(2), 321-344. https://doi.org/10.3368/le.97.2.321.

Trizlova, N., Tsekova, M., & Chakyr, A. (2025). Impact of wind turbines on the environment. In: *Proceedings of ArCivE*. Varna Free University "Chernorizets Hrabar", 237–244.

Tsekova, M. (2025a). Landslides in the Varna region – main characteristics, monitoring, and stabilization. *Scientific Atlas*, 12, 92–96.

Tsekova, M. (2025b). Factors influencing the vulnerability of road infrastructure to forest fires. *Electronic Journal of Varna Free University "Chernorizets Hrabar"*, 23, 41–47.

Tsekova, M., & Trizlova, N. (2025). The "Smolyan Lakes" landslide – recommendations for improving terrain stability. In: *Proceedings of ArCivE.* Varna Free University "Chernorizets Hrabar", 527–535.

Qi, R., Li, J., Lin, Z., Li, Z., Li, Y., Yang, X., Zhang, J., Zhao, B. (2016). Temperature effects on soil organic carbon, soil labile organic carbon fractions, and soil enzyme activities under long-term fertilization regimes. *Applied Soil Ecology*, 102, 36-45.

Vakarelov, I., & Gencheva, S. (2005). *Ornamental dendrology*. Matkom, Sofia, 383 pp. (in Bulgarian).

Yankova, P., Naskova, P., Malcheva, B. and Plamenov, D. (2016). Impact of the biological fertilizers on the microorganisms and the nutrient elements in the soil. *International Journal of Current Research*, 5, 39681-39686.

Zhang, H., Wang, X., & Li, J. (2006). Shelterbelt systems and their role in controlling wind erosion in arid and semi-arid regions of northern China. *Journal of Arid Environments, 65*(3), 395–412. https://doi.org/10.1016/j.jaridenv.2005.08.010.

Ministry of Agriculture and Food of the Republic of Bulgaria. *National Strategy for Development of the Forestry Sector in the Republic of Bulgaria for the Period 2013 – 2020.* https://www.iag.bg/news/lang/1/id/19034/display

Ministry of Agriculture and Food, November 2013, 207 pages. https://www.mzh.government.bg/media/filer_public/2018/03/02/nacionalna-strategiya-razvitie-gorski-sektor-2013-2020.pdf