THE CURRENT ENVIRONMENTAL STATE OF THE FIELD PROTECTIVE FOREST BELTS OF THE FOREST STEPPE OF UKRAINE

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ABSTRACT

The vast majority of field protective forest plantations in Ukraine were created in the 1950s and 1970s. Today, most of them are reaching a critical age and need reconstruction. However, the first stage should be an assessment of their current ecological state, on the basis of which the following measures for their reconstruction can be developed. Field observations were conducted during 2021-2022 in the right-bank forest-steppe natural zone in the central part of Ukraine, Vinnytsia region, Vinnytsia district. The total survey area was 400 km2. In total, 70 main field protective forest belts and 40 auxiliary field protective forest belts in the zone of intensive agricultural production were surveyed.The main field protective forest belts perform much more environmental protection functions than the auxiliary forest belts, in particular, they slow down the wind speed, optimize the microclimate of the surface layer of the atmosphere, stop the development of soil erosion processes, and others. Their more intensive performance of defensive functions causes them to be more suppressed, compared to the auxiliary ones. In particular, in the main field protective forest belts, the share of felled trees was 6.6% higher than in the auxiliary ones, the share of dry trees was 1.2% higher, drying trees were 0.9% higher, the share of trampled vegetation was 2.3% higher, which in aggregate increased the fire danger in the main field protective forest belts by 4.1% compared to the auxiliary ones. Also, all the main field protective forest belts were littered with solid household waste. That's why, the main field protective forest belts need priority protection measures.

Key words: field protective forest belts, forest-steppe, Ukraine, ecological state.

INTRODUCTION

Field protective forest plantations are an important component of agroforestry landscapes, one of the most effective, long-term and relatively inexpensive measures to prevent wind and water erosion of soils. They have a positive effect on the microclimate of the surrounding areas and are able to significantly increase the yield of agricultural crops (Mazur et al., 2021; Didur et al., 2021; Monaldo et al., 2014).
Ukraine belongs to the countries with a well-developed agricultural sector of the economy, therefore the preservation and protection of arable land is one of the priorities of our state and is an important condition for ensuring the balanced development of agricultural landscapes and increasing the yield of agricultural crops. The

problems of modern agricultural landscapes of Ukraine are primarily related to excessive plowing of land, inefficient land use, which ignores the optimal parameters of the ecological and socio-economic functions of the territories, and reclamation and anti-erosion measures are unsatisfactory carried out (Razanov et al., 2020; Mykolaiko et al., 2020; Onea et al., 2014).

The ecological basis of agricultural landscapes is created by field protective forest belts. But today their number and sanitary condition do not meet modern requirements. The average field protective forest coverage in Ukraine is 1.3-1.5%, and the optimal one should be 3-4.5% depending on the natural and climatic zone. Based on this, for the effective protection of agricultural landscapes, the area of field protective forest belts should be increased by 2-3 times. At the same time, it is important to preserve all existing field protective forest belts. And for this, it is necessary to conduct their inventory and assess the current ecological state. However, statistics indicates the opposite: the area of existing field protective forest belts has decreased by 90% compared to 1990 (Petrovych, 2014; Yamazava et al., 1989; Razanov et al., 2022).

In Ukraine, the main share of field protective forest belts was created in the 1950s and 1970s. Today, these forest belts have reached the age of 50-70 years. During the times of the existence of the USSR, they were on the balance sheet of collective farms and state farms and they received depreciation deductions, for which these farms paid for the services of specialists in the creation and maintenance of forest belts (Hladun, 2005; Winterfeldt et al., 2009; Razanov et al., 2022) .

During the process of transformation of land ownership in the 1990s, 28 million hectares of agricultural lands were transferred to private ownership, and the lands planted under field protection forest strips were owned by collective agricultural enterprises formed on the basis of former collective farms and state farms. As the forest belts and other field protective plantations belong to non-agricultural lands, they were classified as lands that were not subject to resoldering and in the future could be the part of reserve lands, reserve fund, common use lands or still be collectively owned. However, field protective plantations are potentially agricultural lands but are not farm grounds (Piddubna, 2016; Lukish, 2013; Tkachuk et al., 2021).

By 2022, according to official statistical data, there is about 446,000 hectares of field protective forest belts in Ukraine. However, a number of scientists and specialists consider the official statistical data to be false, because due to the absence of a real owner of the field protective forest belts, these plantations are subject to deforestation, and a comprehensive state accounting of the field protective forest belts has not been carried out since 1976. Scientists and experts estimate the real area of field protective forest belts to be about 350,000 hectares. Based on these calculations, in order to achieve the normative indicators of maintaining the effective protection of agricultural crops by field protective forest belts, another 700,000 hectares need to be regenerated (Tkachuk et al., 2022; Mazur et al., 2021; Wilks, 2005).

As one hectare of field protective forest belt protects 20-30 hectares of arable land, today millions of hectares of arable land are under the protection of field protective forest belts in Ukraine, which ensures an increase in the efficiency of the use of these lands and reduces the cost of crop production. In order to stabilize the number of field protective forest belts and prevent their number and area from decreasing, approximately 6-7 thousand hectares of field protective forest belts should be created in Ukraine annually (Yukhnovskyyi et al., 2009; Furdychko et al., 2010; Wan et al., 2010) .

About 318,000 ha of field protective forest belts in Ukraine were not transferred to ownership and permanent use. Therefore, their protection, care and reproduction are not carried out within these protective plantations. As a result of the thinning of plantations by arbitrary felling, the processes of turfing and soil compaction develop in them, woody growth and shrub vegetation appear. Forest belts often become weed nurseries, a place for livestock grazing and garbage dumps. In addition, poorly maintained forest belts lose their aerodynamic and water-regulating properties due to their thickening (Lukish, 2013; Winterfeldt et al., 2009; Tkachuk et al., 2020).

For the effective functioning of field protective forest belts, care must be taken throughout the entire period of their existence, which consists of cutting down part of the bushes, trees and branches. The need for such felling is due to both economic and bioecological reasons. During felling, dry, weakened, low-growing, crooked trees are removed. The wind permeability of field protection forest belts is also regulated by felling. Trimming the lower branches on the trunks prevents the accumulation of snow in the forest belt. In the process of forming the blowing structure, all tall bushes are cut down and the so-called rejuvenation is done every 4-6 years. Medium and low-growing bushes rejuvenate, as a rule, after 10-12 years. In forest belts of older age and mixed composition, the maintenance fellings support the appropriate structure. Cutting down trees should be moderate in order to prevent excessive thinning of forest belts and the appearance of herbaceous vegetation (primarily cereals). The maintenance felling in forest belts is preferably carried out in autumn and winter - before the start of sap flow (Kalinin, 1994; Sharp et al., 2015; Mazur et al., 2021).

Taking into account the fact that most of the field protective plantations were created in the 50-70s of the 20th century, today some of them are reaching a critical age and need reconstruction. However, the first stage should be an assessment of their current ecological state, on the basis of which the following measures for their reconstruction can be developed.

MATERIALS AND METHODS

Field observations were conducted during 2021-2022 in the right-bank forest-steppe natural zone in the central part of Ukraine, Vinnytsia region, Vinnytsia district. The total survey area was 400 km^2. In total, 70 main field protective forest belts and 40 auxiliary field protective forest belts in the zone of intensive agricultural production were surveyed.
The research was conducted at the end of August, allocating 100 m long test plots within each forest belt starting from the edge of the forest belt, located closer to the population centers in four repetitions. The division of forest belts into main and additional ones was carried out according to their location relative to the prevailing winds in relation to the sides of the world and their width. The main field protective forest belts are located perpendicular to the main winds and have 5-7 rows of trees. Auxiliary field protective forest belts are located perpendicular to the main field protective forest belts and have 2-4 rows of trees. Within Vinnytsia district of Vinnytsia region, western and northwestern winds predominate with a frequency of recurrence during the year of 17.0% and 16.5%, respectively (Table 1.) (Oshurok, 2020; Makarovskiy et al., 2014).

Table 1. The frequency of recurrence of winds by the directions within Vinnytsia district of Vinnytsia region (according to the data of Vinnytsia Regional Hydrometeorological Center), %.

Rumba of winds							
North	North-East	East	South-East	South	South-West	West	North-West
11,5	5,0	11,0	12,0	13,0	12,5	17,0	16,5

The research was conducted in two stages. At the first stage, the field protectivel forest belts identified for observation were analyzed according to the ecological conditions of their location. In particular, the types of soils, within which the field protective forest belts were placed and the degree of the development of erosion processes on them caused by water erosion by the degree of their washing away, were determined on the basis of cartograms of agrochemical and soil survey of agricultural enterprises of Vinnytsia district, developed by Vinnytsia branch of the State Enterprise Institute of Soil Protection (Tsytsiura et al., 2017; Miglietta et al., 2017).
The relief of the studied territories, as well as the angle of inclination of the soil surface in the locations of the field protective forest belts and the distance of the forest belts to the nearest settlement were determined using topographic maps of Vinnytsia district (Kim et al., 2015; Olauson et al., 2015).
The climatic zone within the location of the field protective forest belts was determined according to the data of Vinnytsia Regional Hydrometeorological Center (Siuta et al., 2017; Staffell et al., 2016). The types of agricultural land adjacent to the field protective forest belts on both sides were determined visually according to the nature of the intended use of the land: with annual cultivation of the soil, its sowing with annual crops - it was defined as arable land; in the case of long-term cultivation of herbaceous plants with domestic animals (cows) grazing on them - it was defined as pasture.
The second stage of our observations foresee the determination of the current ecological condition of field protective forest belts based on a set of the following indicators: the share of felled trees in forest belts - by counting the number of tree stumps from the total number of trees within the test ranges; the share of dry trees in forest belts – by counting the number of completely dry trees that had only trunks and branches without leaves from the total number of trees within the test plots; the share of drying trees in forest strips - by counting the number of trees that started to dry, i.e. had a minimum of one branch without leaves, but a maximum of one branch with leaves, from the total number of trees within the test plots.
The presence of grass cover in forest belts and the proportion of trampled vegetation were determined on test plots measuring 1 м^2 in six replicates within the test sites. If grassy vegetation forming a grassy layer was found in three or more test sites within the test site, then the forest strips belonged to those with a grassy cover.

The presence of household waste in the forest belts was determined visually within the limits of the test sites by their presence in the form of clusters occupying the area of one massif with a size of at least 1 м^2. Fire danger in forest belts was determined by the share of the surface that was covered with dry grass, shrubs, bushes, cut and left dry trees, branches, and dry and drying trees that have not yet been cut. All studied indicators were calculated for the total length of forest belts.

RESULTS AND DISCUSSION

Depending on the location of the field protective forest belts relative to the prevailing winds, they are divided into main ones, which are placed perpendicular to the prevailing winds, and auxiliary ones, which are placed perpendicular to the direction of the main forest belts. The main forest belts help to slow down the wind speed and optimize the microclimate of field agro-ecosystems. The role of auxiliary forest belts is somewhat smaller, but they also improve the microclimate of agroecosystems, and their influence on wind speed is much lower than that of main forest belts. As a rule, the main forest belts are much wider due to more rows of trees than the auxiliary ones.
The assessment of the ecological conditions of the placement of field protective forest belts showed that most of the field protective forest belts are located on leaching chernozems: 42.9% of the main and 75.0% of the auxiliary forest belts. The podzolized chernozem takes the second place in terms of the placement of field-protective forest belts. It forms 28.6% of all the studied main forest belts and 25.0% of all the auxiliary ones. 14.3% of all main field protective forest belts were placed on typical chernozems and dark gray podzolized soils. Our research shows that main field protective forest belts are located on a much wider range of soil types than auxiliary field protective forest belts. This is explained by the greater agro-ecological value of the main field protective forest belts compared to the auxiliary ones. All studied field protective forest belts are located on highly fertile soils (Table 2).

Table 2. Ecological conditions of the placement of field protective forest belts.

Indicator	Type of forest belts			
	Main		Auxiliary	
	Parameter of the indicator	Share, %	Parameter of the indicator	Share, %
Type of soil	Leaching black soil	42,9	Leaching black soil	75,0
	Podzolized black soil	28,6	Podzolized black soil	25,0
	Typical black soil	14,3		
	Podzolized dark gray	14,3		
The degree of development of the soil erosion processes	Unwashed	85,7	Unwashed	100
	Weakly washed	14,3		
Relief	Plain	100	Plain	100
Slope of the soil surface, °	0	71,4	0	33,3
	1	14,3	1	33,3
	3	14,3	2	33,3
Climatic zone	Moderately continental / sharply continental	100	Moderately continental / sharply continental	100
Agricultural lands adjacent to the forest belts on both sides	Arable land / Arable land	85,7	Arable land / Arable land	100
	Pasture / Arable land	14,3		

All studied field protective forest belts were located on flat relief with a slight slope of the soil surface: 0-3 °. In 71.4% of the main field protective forest belts, zero surface slope angle prevailed, 14.3% of the main field protective forest belts were located in areas with surface slope angles of 1° and 3°. Auxiliary forest belts were evenly distributed depending on the angle of the surface slope - 33.3% of all field protective forest belts were located with soil surface slope angles of 0 °, 1 °, 2 °. As all the researched field protective forest belts are located on a relatively flat surface of the relief, they mainly perform a wind-reducing and microclimate-forming function, since our research was conducted within a moderately continental climate with a transition to a sharply continental climate.

This statement is supported by the degree of the development of erosion processes of the soils on which the researched field protective forest belts are located. In particular, 85.7% of all main field protective forest belts are located on unwashed soils and only 14.3% of forest belts are located on weakly washed soils. This part of the main field protective forest belts is located perpendicular to the slopes with a steepness of 3 ° and is intended to stop water erosion of the soil. At the same time, 100% of all auxiliary field protective forest belts are placed on unwashed soils. Thus, it was established that the main field protective forest belts, in addition to the wind protection function, also partially perform an erosion-stopping function in terms of slowing down water erosion of soils on slopes with a steepness of 3 °. At the same time, the researched auxiliary field protective forest belts do not perform such a function. However, it should be noted that the presence of both main and auxiliary field protective forest belts on the soil surface with a steepness of more than 0.5 ° does not allow the soil layer to move due to water washing. Therefore, the presence of such field protective forest belts does not allow soil erosion processes to develop.

All field protective forest belts are located within the boundaries of agricultural lands of various types. In particular, 85.7% of all main field protective forest belts were located on both sides of arable land (tillage), and only 14.3% of main field protective forest belts were located between arable land on one side and pasture on the other. At the same time, 100% of all auxiliary field protective forest belts were located between arable lands on both sides. It is on arable field lands that the main food crops are grown. Placing field-protective forest belts between them contributes to the highest increase in their productivity, compared to pastures where domestic animals graze. That's why, such distribution of field protective forest belts relative to arable land and pastures is justified. Also, on arable lands, due to their constant mechanical cultivation and loosening, the danger of water erosion of the soil may increase, in contrast to pastures, where a perennial grass cover has been created that protects the soil from erosion.

The effectiveness of the environmental protection functions of field protective forest belts largely depends on their ecological state, which can change due to means of intensification during the cultivation of agricultural crops on field lands next to forest belts, due to climatic and weather processes, natural phenomena, the spread of pests and tree diseases, industrial and automobile pollution air, household clutter with solid waste, unauthorized felling of trees, as well as accidental and targeted anthropogenic damage.

The average share of felled trees in all studied main field protective forest belts was 15.6%, but it varied depending on the forest belt from 3 to 40%. In auxiliary forest belts, the share of felled trees was 6.6% lower and amounted to 9.0% and had a range of 2-23%. Trees were cut down in field protective forest belts due to their drying, damage by pests, damage by diseases, fractures, and also due to unauthorized felling. The higher proportion of felled trees in the main field protective forest belts is explained by their higher density, compared to the auxiliary forest belts, due to a larger number of tree rows and a smaller distance between trees in a row, which increases the competition between trees for survival. Also, the main forest belts are depleted more due to a much higher nature protection function, compared to the auxiliary forest belts. Due to the greater number of rows and denser placement of trees in the main forest belts, it is easier to camouflage and hide felled trees in them than in auxiliary forest belts with unauthorized felling (Table 3).

Table 3. Ecological state of field protective forest belts.

Indicator	Type of forest belt	
	Main	Auxiliary
Share of felled trees in forest belts, %	15,6* / 3,0-40,0	9,0 / 2,0-23,0
Share of dry trees in forest belts,	2,9 / 0-7,0	1,7 / 1,0-2,0
Share of drying trees in forest belts, %	4,6 / 2,0-7,0	3,7 / 3,0-4,0
Presence of grass cover in forest belts, % of forest belts	57,1	66,6
Presence of household waste in forest belts	are present	absent
Distance from the forest belt to the nearest settlement, m	971 / 400-2000	333 / 30-500
Share of trampled vegetation in forest belts, %	4,3 / 2,0-9,0	2,0 / 1,0-3,0
Fire danger in forest belts, %	16,4 / 7,0-30,0	12,3 / 7,0-20,0

**NOTE: the numerator is the average value; the denominator is a range of values.*

As a rule, dry trees in field protective forest belts almost do not fulfill their environmental protection functions because they completely or almost completely lose their leaf apparatus. They are breeding grounds for diseases and pests that can spread from dry to healthy trees. However, trees can be dry out due to adverse climatic and weather factors. In this case, they will not cause the spread of drying processes to other trees. However, for any reason of drying, such trees should be cut down.

The share of dry trees in the studied main field protective forest belts was 2.9% with a range of 0-7.0%. So, there were observed forest belts in which no dry trees were found at all. In auxiliary forest strips, the average share of drying trees was 1.2% lower and amounted to 1.7% with a range of 1.0-2.0%. There is a trend of existence of more dry trees in the main field protective forest belts compared to the auxiliary forest belts. The drying process of trees can last several years. During this time, they continue to perform their environmental protection functions, although after a few years they will need to be cut down. The average share of drying trees in the main field protective forest belts was 4.6% with a range from 2.0 to 7.0%. In auxiliary forest belts, drying trees were 0.9% less - 3.7% with an amplitude of 3.0-4.0%. Grass cover in field protective forest belts can be present with a sparse placement of trees, because in dense forest belts with bushes, shrubs and undergrowth, grass does not germinate due to significant shading of the soil surface. Grass cover was present in 57.1% of all studied primary field protective forest belts, which was 9.5% less than in auxiliary field protective forest belts. This is explained by the much rarer tree stand in auxiliary forest belts and the absence of bushes in them.

An important ecological problem of the functioning of field protective forest belts in Ukraine is their cluttering with household waste of residents of surrounding settlements. The conducted studies showed that solid household waste was found in all the main field protective forest belts, and there was a lot of waste in 28.6% of the forest protection forest belts. At the same time, no household waste was found in the auxiliary field protective forest belts. This is explained by the fact that the main field protective forest belts are much wider and denser, which allows for better masking of solid household waste in them, compared to the auxiliary forest belts, despite the fact that the auxiliary field protective forest belts are located at a distance of 30-500 m from the nearest settlements, in that while the main field protective forest belts are at a distance of 400-2000 m. As a rule, solid household waste within the forest belt is concentrated at a distance of 0 to 50 m from the edge of the forest belt, mainly on the side of the roads perpendicular to them.

Grass, shrub and bush cover may be trampled within the field protective forest belts by domestic or wild animals or anthropogenic factors during unauthorized felling, recreation, harvesting of medicinal plants, fruits, and berries. However, any trampling of the cover of the forest belt violates its stability and impairs the performance of field protection functions. An average of 4.3% of grass cover with a range of 2.0-9.0% was trampled in the studied main field protective forest belts, and 2.3% less in auxiliary forest belts, with a range of 2.0%. A potential danger within the field protective forest belts is the possibility of fires occurring in them. Dry grass, bushes, shrubs, cut tree branches, flammable household waste cause the risk of self-ignition. The more specified components of forest belts, the higher is the probability of fire occurrence in forest belts.The analysis showed that in the studied main field protective forest belts, the fire hazard is 16.4% with a range of 7.0-30.0% depending on individual forest belts. In auxiliary field protective forest belts, the fire hazard was 4.1% lower and amounted to 12.3% in the range of 7.0-20.0%.

In terms of all studied ecological parameters of stability, the main field-protective forest belts were inferior to the auxiliary ones. In particular, they are characterized by a greater share of felled, dry, drying trees, trampled vegetation, a higher fire hazard and are significantly cluttered with solid household waste. At the same time, the analysis of the ecological conditions of the placement of the main and auxiliary field protective forest belts did not reveal significant differences.

In particular, the main field protective forest belts are located on four types of soil, of which three types are highly fertile chernozems of various types, and only 14.3% of the main field protective crop rotations are located on less fertile dark gray podzolized soils. All investigated auxiliary field protective crop rotations are placed on chernozems. Also, 14.3% of the main field protective forest belts are located on slightly washed soils with a slope angle of 3 °, while all auxiliary field protective forest belts are located on unwashed plain soils. It is these auxiliary factors that partly influence the higher percentage of suppression of the main field protective forest belts compared to the auxiliary ones.

CONCLUSIONS

The main field protective forest belts perform much more environmental protection functions than the auxiliary forest belts, in particular, they slow down the wind speed, optimize the microclimate of the surface layer of the atmosphere, stop the development of soil erosion processes, and others.Their more intensive performance of field protective functions causes them to be more suppressed, compared to the auxiliary ones. In particular, in the main field protective forest belts, the share of felled trees was 6.6% higher than in the auxiliary ones, the share of dry trees was 1.2% higher, drying trees were 0.9% higher, the share of trampled vegetation was 2.3% higher, which in aggregate increased the fire danger in the main field protective forest belts by 4.1% compared to the auxiliary ones.Also, all the main field protective forest belts were littered with solid household waste. So, it is the main field protective forest belts that need priority protection measures.

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