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METHODOLOGY FOR DETERMINING THE SUITABILITY OF SOILS FOR AFFORESTATION IN PLAIN PART OF UKRAINE

Purpose. To develop a methodology for assessing forest suitability for certain varieties of unproductive soils.

Methods. There are used the classical methods of soil science, agrochemistry, forest science, forest management, typology and mathematical statistics.

Results. The principles of forest typology are the basis for determining the suitability of soils for forestation. Its essence lies in a comprehensive study of soil properties (soil morphometry, chemical composition) and forestry characteristics of forest stands, as well as an analysis of the grass-shrub layer by ecomorphs. The results of studies of the combined study of the productivity of forest stands and the properties of the main varieties of unproductive soils (sandy, eroded and skeletal) in different natural zones of the plain part of Ukraine are presented. Determination of the suitability of soils for forestation was assessed according to three categories: 1) unsuitable for forestation and conditionally suitable for forestation (very dry, very poor, toxic, with a limited rhizosphere zone, inaccessible or hardly accessible for cultivation); 2) limited suitability for forestation (dry and poor soils); 3) suitable for forestation. Packages of markers have been developed, on the basis of which it is possible to assess both their forest suitability and determine the type of forest growth conditions of non-forest lands. When compiling markers, preference was given to such soil indicators, which, along with informativeness in relation to soil quality, did not require complex methods of determination. The composition of markers includes morphological, physical, agrochemical parameters and depends on the type of soil.

Conclusions. The developed packages of markers are the basis for the scientifically based creation of forests on unproductive lands, on which forest vegetation did not grow before. Their use in afforestation increases its efficiency and makes forests more resistant to adverse environmental factors. The Methodology is intended for forestry specialists, it can be used at enterprises, institutions of the forest sector, forest design organizations, as well as in related industries concerned with the protection and rational use of natural resources. The methodological developments can be included in the curricula of secondary and higher forestry-oriented education institutions.

KEY WORDS: *unproductive soils, forest growth potential, afforestation*

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Introduction

The forest cover percent of the territory of Ukraine is currently lower than it is necessary to achieve a landscape-ecological balance, meet the needs of the economy and the functioning of developed forestry, agriculture and industry. The science-based level of optimal forest cover percent for Ukraine is 20%, and, in order to realize this, it is necessary to additionally afforest about 2 million hectares of land [1] The implementation of optimal forest cover in Ukraine is one of the priority tasks fixed in a number of laws, decrees and resolutions of various branches of executive power, in particular, the State Forest Management Strategy of Ukraine up to 2035 [1]. In order to increase the forest cover, it is planned to create protective forest plantations, field shelterbelts by forestation of new lands, primarily low-productive, degraded and contaminated lands, which are removed from the categories of agricultural lands and transferred to the forest fund.

Considering the low level of productivity and the non-forest nature of these lands, forestation should be preceded by work on determining the level of their forest growth potential and general forestation suitability, and, therefore, by forest typological assessment.

The assessment of the forest soil productivity has its own specifics and differs from the assessment of agrocenosis [2 – 4]. This is primarily due to the fact, that the forest is a complex multicomponent and multifunctional ecosystem with a practically closed circulation of substances, functioning for a hundred years or more. Therefore, mobile forms of nutrients are used to assess the fertility of agricultural land on which the crops is forming during one growing season, while the total forms of nutrients are often used to assess the productivity of forest soils [2 – 4]. In addition, the productivity of forest stands depends not only on the presence of nutrients in the soil, but also largely determined by the granulometric composition of the soil.

The author's own experience and analysis of numerous literary materials showed that among the soil properties, one of the leading markers of soil suitability for forestation is the particle size distribution of the soil, which determines its composition, porosity, water permeability and moisture capacity, nutrient status, regimes of soil processes, the volume of the rhizosphere zone, etc [2 – 10]. Also very important, and in some cases decisive (soils on dense rocks), is the thickness of the rhizosphere and humus part of the soil profile [3, 4]. It should be noted that the values of the particle size distribution and other indicators of forest productivity of soils can by no means be considered in isolation from other factors (soils buried by sands, sandy-loamy interlayers in the profile of sandy soils, the presence of perched water-table, topography, etc.).

Forestation based on theoretical developments that take into account the potential of land as much as possible acquires a science-based level, which ensures high survival and viability of forest crops and maximum adaptation of created forests to environmental factors.

Methods

The studies were carried out by synthesizing two methodological approaches - forest typological, as the leading method in Ukraine for assessing the quality of forest lands, and direct study of soils (field and analytical). The forest typological approach is based on the phytoindication method, i.e., the forest fertility of the soil is assessed by the composition and productivity of forest vegetation (primarily the forest stand) growing on this soil. On certain types of unproductive forest soils, trial plots were laid, on which the productivity of forest stands (height, quality class) and the main soil indicators that form its fertility were studied. There were at least 30 trees on the sample plot. A total of 170 sample plots were established. On the each sample plot, the soil profiles were laid and described (the depth depended on the type of soil and varied from 0.5 m to 2 m) and the samples were taken for the chemical analysis.

Further under laboratory conditions the following soil indicators were determined according to generally accepted methods: granulometric composition (pipette method in modification of N.A. Kachinskiy); humus content (method of Tjurin in Kononova and Belchikova's updating); content of total forms K (in concentrated sulfate extract, Ginzburg's method).

At the final stage, a correlation analysis of the dependence between the values of soil indicators and the height of the forest stand were carried out. Thus, those soil characteristics that have the greatest influence on the height of the stand were determined. The studies covered all natural zones of Ukraine and the most common varieties of low-productive soils: sod-podzolic soils on fluvioglacial (glacial) sands, soddy podzolized soils on ancient alluvial sands, southern calcareous short-profile chernozems, technozems on eluvium of dense limestones after shell rock mining.

Results and Discussion

Degraded and low-productive lands are now being transferred to forestry enterprises for forestation. Degraded land includes: a) land plots whose surface is disturbed as a result of earthquakes, landslides, karst formation, floods, mining, etc.; b) land plots whose soils are eroded, waterlogged, with high acidity or salinity, soils contaminated with chemicals, and others, while to low-productive ones belong - agricultural lands, the soils of which are characterized by negative natural properties, low fertility, and their intended commercial use is economically ineffective (Article 171 of the Land Code of Ukraine).

The most common degraded and low-productive lands are now being transferred to for afforestation are: sandy, eroded, saline, stony, hydromorphic lands. This article presents the results of the assessment of the forest growth potential and general suitability of sandy, short-profiled and eroded soils for forestation.

Sandy soils are common in all natural zones of Ukraine. Despite the different conditions of their formation and different origins, the forest growth potential of these soils has more similarities than differences. The soils of sandy massifs can be combined into the following groups [7]:

I. Soddy podzolized clayey-sandy and sandy-loamy soils which were not subjected to eolian redeposition, on sands of different genesis (ancient alluvial, fluvioglacial). They combine a large group of soils formed under well-illuminated forests with a developed grass cover. These soils are characterized by: uneven-grained particle-size distribution, shallow bedding of loamy interlayers (pseudofibers), which serve as drainage for perched water table, and a sufficiently developed profile. They are distributed in all natural zones of Ukraine.

II. The type of sod-podzolic soils on fluvioglacial, moraine and ancient alluvial sands of Polissia. The thickness of the humic layer ranges from 8 to 15 cm. According to the degree of manifestation of the podzolic process, the following is distinguished:

1) Sod low-podzolic (concealed podzolic) soils. The podzol content is expressed in the form of grey and whitish spots, sometimes merging into a strip not exceeding 1-2 cm between the humus and illuvial brownish horizons. They are typical of less moistened areas - wide hilltops, gentle slopes and elevated flat or gently rolling areas.

2) Sod medium-podzolic soils. They are formed on sands and sandy loam of uneven-grained particle-size distribution with the presence of clayed interlayers. The podzol content is expressed in the form of a grey-whitish strip 2-5 cm wide between the humic layer and illuvial horizon. They are found in the lower parts of the slopes and on flat, gently rolling sands with a deep level of groundwater.

III. The type of soddy soils on the sands of the Steppe zone. This type includes soils formed according to the steppe type of soil formation on sands with a deep level of groundwater. The degree of their clay content and profile development can differ significantly: from pure quartz modern eolian underdeveloped sands (non-humificated and low-humificated – all non-overgrown and slightly overgrown sands), in which the humic layer is absent (pale yellow-colored, fine- or medium-grained sands occur from the surface), or it is at the initial stage of formation (sand with some signs of humus formation is underlain with a deep layer of alluvial pale-yellow sands) up to chornozem-like clayey-sandy and sandy loam on ancient alluvial (multiphase) of sands, colored darkish-grey or grey pale-yellow.

IV. Saline sandy soils. They are found mainly in the Steppe, primarily on the sands of the coasts of the Black sea and the sea of Azov, on their islands and spits, as well as on the ancient river sands adjacent to them, and in the Forest-Steppe - on the left tributaries of the middle course of the Dnipro river. They are found in low areas and small depressions where the capillary layer of groundwater is located near the surface for most of the year.

The largest by area (> 200 thousand hectares) massifs of sand deposits (quartz sands) in Ukraine are the Lower Dnipro (Oleshkiv) sands, located in its southern part and confined to the ancient Dnipro riverbed. The vast areas of the lower Dnipro region represent group III of sandy soils. These soils were subjected to intense deflation, as a result of which their properties differ from sandy soils of northerly regions (Polissia, Forest-Steppe). The suitability of the lower Dnieper region sands for forestation was studied in detail, systematized [6].

When determining the forest growth potential and the suitability of saline sandy lands for forestation, these lands make up group IV of sandy soils, as well as for determination of other saline lands, it is necessary to be guided by the "Methodological instructions for the soil and forest typology survey of saline lands" [8].

The main edificator of sandy sites is common pine**.** The most productive pine forests are formed in the Polissya zone, that is, in the conditions of their natural distribution area, on soddy low- or medium-podzolic soils on sandy and sandy-loam deposits. The dominant types of growth sites are fresh fairly infertile pine site types (B_2), moist fairly infertile pine site types (B_3), and fresh infertile pine site types (A_2).

In the Forest-Steppe and the Northern Steppe, sandy growth sites are confined to the second above-floodplain (pine forest) river terraces covered with a thick layer of ancient alluvial well-washed sands, on which soddy podzolized (pine forest) clayey-sandy soils are formed. Pine forests of the Forest-Steppe zone are almost everywhere of artificial origin and are represented by B_2 conditions, and some areas (insignificant in size) of gently rolling pine-forest terraces are A_2 conditions. Even less common are dry fairly infertile pine site type (B_1), they occupy the tops of sandy hills of pine forest terraces, as well as fresh fairly fertile site types (C_2), which are confined to sandy loam massifs or clayey sands with pseudofibers or buried soils.

The Steppe zone is characterized by a significant complexity of the types of growth conditions, consisting of zonal upland and intrazonal types (floodplains, bottoms of ravines, sandy terrace) and a number of disturbed growth sites. The system of the left-bank terraces of the Northern Steppe is composed of low-humus and non-humus sands, which are the main background for the creation of pine forests. In this zone, dry infertile pine site type (A_1) and dry fairly infertile pine site type (B_1) are mainly formed. However, the gradient of soil moisture content, depending on the topography of the site, can vary from very dry to dry, fresh and moist. Forestation is primarily limited by severe shortage of soil moisture.

Thus, the vast majority of sandy growth areas of Polissya, the Forest-Steppe and the Northern Steppe zones (sandy soil groups I-II) are quite suitable for forestation. The cultivation of forest plantations in the Southern Steppe zone, which is primarily limited by a severe moisture deficit, requires a differentiated approach.

To assess the forest growth potential of soils of non-saline sandy sites, it is sufficient to determine their most informative indicators: particle-size distribution; thickness of the humus horizon and the content of the total K_2O form (Table 1). The Table presents the parameters of indicators that can be used to assess the forest growth potential of sandy lands in a number of

Table 1

Diagnostic indicators [1)] to determine the level of nutrient status of sandy lands of Ukraine (Polissia, Forest-Steppe, Northern Steppe)

Trophotope (nutrient status)	Parameters of soil diagnostic indicators for determining nutrient status of Ukraine's lands						
	Physical clay (silt-and-clay),%	The thickness of humus part[2)] of the profile, cm			K_2O, %[3)]		
		Polissya	Forest-Steppe, Northern Steppe	average	Polissya	Forest-Steppe, Northern Steppe	average
A	<5	<15	<15	<15	≤0.03	0.03–0.04	≤0.03
AB	*≈5*	*10–15*	*10–15*	*10–15*			
B	5–7	15–20	15–30	15–30	0.03–0.05	0.04–0.08	0.03–0.06
BC	*≈7*	*20–25*	*25–30*	*25–30*			
C	7–12	25–30	30–50	30–50	0.05–0.06	0.08–0.15	0.06–0.15

Note:
1) – the reliability level of values is 95%.
2) – the thickness of the humus part of the profile includes horizons – He+Hp (PH).
3) – the K_2O content is determined in the sulfuric acid extract.

site types: infertile pine site type (A) – fairly infertile pine site type (B) - fairly fertile hardwood site type (C), as well as their transitional variants.

It should be noted that while the content of physical clay and total potassium requires analytical methods for determining, the thickness of the humus part of the profile is determined already at the first stage of soil studies. The sim plicity and speed of determination makes this parameter a particularly valuable indicator of the forest growth potential of sandy soils. In general, soil humus content is an integral indicator of many factors closely related to natural-climatic, geomorphological, orographic conditions, therefore the value of this indicator differs quite significantly in the zonal aspect, increaseing from Polissia to the Forest-Steppe and the Northern Steppe. Taking into account the high indicator significance of the thickness of the humus part of the profile in determining the forest-growth potential of sandy soils, its parameters were differentiated by natural zones (Table 2). Thus, using the data presented in Table 2 already during field survey of non-forest sandy lands set aside for forestation, it is possible to assess them by forest typology and determine forest productivity at the regional level.

Based on the results of the author's own numerous factual materials, the author developed a forestry classification of sandy soils of Ukraine according to indicators of their forest growth potential (for the conditions of Polissya, the Forest-Steppe of the Northern Steppe) (Table 3).

The presented classification does not apply to the vast areas of the Lower Dnipro sands, the forest-growth properties of which are quite specific and differ from most sandy lands of Ukraine. The developed soil indicators, which make up the forestry classification, can be used for the quantitative description of the pine series of growth sites (within trophotopes A, B, C) of the Alekseev-Pogrebniak edaphic grid.

In the steppe regions of Ukraine, soils with a shortened profile (short-profiled soils) on dense limestones are set aside for afforestation. Their main natural variants are southern calcareous chornozems on dense limestones and sod-calcareous soils on dense limestones, and disturbed ones – reclaimed soils after the extraction of shell limestone. These soils have a tendency to limestone outcrops and are common in the Donbass, Mykolaiv, and Odesa regions, and in the Crimea. Their main characteristics are as follows: high carbonate content and carbonate effervescence from the surface, the particle-size distribution is mainly medium- and heavy clay loam, the depth of the soil profile varies from 15 (or less) to 65 (85) cm.

The soils designated for forestation are characterized by a very small depth of the soil profile, which in the vast majority does not exceed 25 cm. Short-profiled soils are characterized by a low level of potential fertility due to the shortened rhi-

Table 2

Parameters of the humus part depth of the profile for forest typological assessment of sandy growth sites according to natural zones of Ukraine

Trophotope (nutrient status)	The humus profile depth*, cm	
	Polissya	**Forest-Steppe, Northern Steppe**
A	<10 (15)	<15
AB	*10-15*	*15-20*
B	15-25	15-40
BC	*20-25*	*35-40*
C	25-35	40-90

Note: *the depth of the humus part of the profile includes horizons – He+Hp (PH).

Table 3

Forestry classification of sandy soils of Ukraine (for conditions of Polissia, the Forest-Steppe, the Northern Steppe)

Trophotope (nutrient status)	Physical clay content,%	The humus profile depth[1)], cm	K_2O, %[2)]
A	<5	<15	<0.03
B	5-7	*15-35*	0.03-0.06
C	7-12	>35	0.06-0.15

Note:

[1)] - the depth of the humus part of the profile includes horizons – He+Hp (PH).

[2)] - the K_2O content was determined in the sulfuric acid extract (Ginzburg's method).

zosphere zone and significant dryness. The level of their moisture content during the growing season remains consistently low and corresponds to a dry and very dry gradient. The dryness of the growth sites is caused not only by the climatic conditions of the Steppe zone (high radiation balance, small amounts of precipitation with significant evaporation), but also by the occurrence of dense carbonate rocks close to the earth's surface.

The main diagnostic indicator for determining the level of forestation suitability of soils with a shortened profile on dense carbonate rocks (Pontic limestone), in particular, ordinary calcareous chornozems, southern calcareous chornozems, sod-calcareous soils, reclaimed soils, outcrops of limestone eluvium to the soil surface, is the depth of dense rock. Methods of phytoindication (by grass cover) in this case are of secondary importance, since they only indicate the nutrient status and moisture content of the topsoil (5-25 cm), which is absolutely insufficient for the formation of woody vegetation.

Dry growth sites of the Steppe zone of Ukraine on dense limestone deposits with a soil profile depth of up to 30 cm, which are not threatened by erosion processes, should be classified as "unsuitable for forestation" (α). It should be noted that the unsuitability of sites for forestation refers to the inefficiency and inexpediency (in the absence of an erosion threat) of their forestation, both by tree and shrub species, without applying special agrotechnical techniques, in particular, deep plowing. Land plots on which dense carbonate rock is deposited at a depth of 30 to 45 (50) cm are limited suitable for forests (within dry fairly fertile ultracalciophilic site types (C_1). The limitation of forestation suitability is primarily caused by their considerable dryness). They require the use of special techniques aimed at preserving and retaining moisture, special preparation of planting material and soil for planting forest crops, as well as careful selection of tree and shrub species adapted to the alkalinity of the soil solution, long-term dry conditions, and exposure to high daily air temperatures.

In general, the soil depth of < 30 cm (the beginning of dense rock occurrence from the surface) is the limit to forestation suitability for short-profiled soils on dense both carbonate and non-carbonate rocks. Such soils without their reclamation (deep plowing with the destruction of dense rock, filling soil layer, etc.) are unsuitable for forestation. The depth of the soil over 30 cm can be considered as the beginning of an increase in the level of its forestation suitability.

Soil erosion is the process of capturing soil particles and their removal by water or wind, the result of which is the destruction of the upper, most fertile soil layers. The actual erosion level of lands in Ukraine is 57%, of which 32% of the areas are subject to wind erosion, 22% – to water erosion, and 3.4% – to a combined effect of both types of erosion [11]. The largest areas of eroded soils are concentrated in Luhansk, Odesa, Donetsk, Mykolaiv, and Dnipro regions, that is, in the Steppe zone, where erosion covers 37.2% of the total land area. In the Forest-Steppe, 23.4% of the territory has been damaged by erosion (mostly in Kharkiv, Vinnytsia, Khmelnytskyi, Ternopil and Cherkasy regions). The eroded lands of Polissia are mostly distributed in the forest patch areas of Ivano-Frankivsk, the Transcarpathian, and Rivne regions and occupy 7.2% of its territory.

Forest reclamation is one of the most effective measures to combat soil erosion. However, its effectiveness will largely depend on the quality of forest typological assessment of the eroded areas. The degree of soil erosion must be assessed exclusively on a zonal-regional and typological basis, that is, within a specific physical-geographical and forest-typological area. The forest-growth potential of eroded lands depends not only on the degree of erosion of the surface soils, but also on the nature of the parent rocks on which they are formed.

Forest typological assessment of eroded soils assumes that all types of eroded soils (except halogenic ones) are included in a certain type of forest growth conditions (trophotope or edatope) when assessing the level of their forestation suitability. With this model, the forestry classification of eroded soils clearly reflects a gradual decline in their forest productivity as the degree of erosion increases. Very heterogeneous forest growth conditions are formed in eroded areas, which significantly complicates their forest growth assessment. Forest growth conditions are best in the upper part of ravines, then they gradually deteriorate towards the mouth and especially on the slopes of southern exposures.

Schemes for forest typological assessment of eroded growth sites differentiated by soil types and characteristics of soil-forming rocks are presented below: on loamy-clay parent rocks (Table 4); on sandy rocks (Table 5), on dense carbonate, and on non-carbonate rocks (Table 6).

Table 4

Nutrient status of eroded soils on heavy (loamy, clayey) rocks based on their zonal-morphological diagnostics

Soils	Natural zone, Forest typological region	DE[1)]	Truncatable horizon		Horizon emerging on the earth's surface		Nutrient status
			Sb[2)]	level of truncating	Sb	morphological features	
Chornosems (typical, podzolized, leached, ordinary, southern) on loess rocks; dark-chestnut non-saline on loess rocks	Forest Steppe, Steppe 2 d, 1e	0	untruncated		H	black, dark-grey, cloddy	D
		I	H	<1/2	H	black, dark-grey, rill erosion on the surface	D
		II	H	>1/2	H (HP)	grey with brownish tint	D
		III	HP	partially	Ph	brown, cloddy, prone to crust formation, carbonate effervescence	D-C
		IV	HP, Pk	HP- completely	Pk	brown, cloddy, carbonate effervescence	C
Dark-grey on loess rocks	Forest Steppe 2 d	0	untruncated		He	grey, cloddy	D
		I	He	<1/2	He	grey, cloddy	D
		II	He	>1/2	HI	brownish-grey, rill erosion on the surface, bean-shaped structure	D
		III	HI	partially or completely	I	brown, prismatic- cloddy, viscous, very dense, crusting is possible	C
		IV	I	completely	Pik, P	yellowish-brown, prism-shaped, dense, carbonate effervescence	C (D-C)
Grey on loess rocks (blanket loams)	Forest-steppe, Southern Polissia 2 d, 3d	0	untruncated		HE	dark grey, possible brownish tint	D
		I	HE	<1/2	HE	grey with brownish tint	D
		II	HE	>1/2 or completely	Ih	brownish-grey, prism-shaped, dense, prone to crust formation	C
		III	Ih	partially or completely	PI	brown, prism-shaped, cloddy, dense, viscous, crusting is possible	C
		IV	PI, Pk	PI- completely	Pk	yellowish-brown, prism-shaped, somewhat dense, carbonate effervescence	C
Light-grey on loess rocks (blanket loams)	Western Forest-Steppe, Southern Polissia 2 d, 3d	0	untruncated		HE	light-grey, cloddy	D (D-C)
		I	HE, E	<1/2	E	light-grey, rill erosion on the surface	D-C
		II	E	>1/2 or completely	Ih	brownish-grey, bean-shaped platy structure, dense, prone to crust formation	C
		III	Ih, I	partially or completely	PI, I	brown, prism-shaped, cloddy, dense, viscous, crusting is possible	C (C-B)
		IV	PI, Pk	PI- completely	Pk	yellowish-brown, prism-shaped, somewhat dense, carbonate effervescence	C

Note: DE[1)] – Degree of erosion
Sb[2)] – Soil genetic horizon symbol

Table 5

Nutrient status of eroded soils on sandy rocks based on their zonal and morphological diagnostics

Soils	**Natural zone, Forest typological region**	**DE[1)]**	**Truncatable horizon**		**Horizon emerging on the earth's surface**		**Nutrient status (content of physical clay, % depth of H horizon, cm)**		
			Sb[2)]	level of truncating	Sb	morphological features	A (<5; 5-15)	B (5-7; 15-35)	C (7-20; 35-70)
Sod low-podzolic, Sod medium-podzolic on fluvioglacial sands	Polissya 3d	0	untruncated		HE	light-grey, fragile, cloddy	A	B	C
		I	HE, E	<1/2	E	light-grey, rill erosion on the surface	A	B	C
		II	E	>1/2 or completely	I	whitish, fragile, bean-shaped platy structure	A	B (B-A)	C (C-B)
		III	I	partially or completely	PI, I	yellowish-brown, fragile, prism-shaped	A	A-B (A)	B (B-A)
		IV	PI, P	PI- completely	P	yellowish, steel-blue	A	A	A-B
Soddy podzolized (soddy infertile pine site type) on ancient alluvial sands	Forest-Steppe, Steppe, Polissia 2 d, 1e, 3d	0	untruncated		He	light-grey, cloddy	A	B	C
		I	He	<1/2	He	grey, rill erosion on the surface	A	B	C
		II	He	>1/2 or completely	HP, Ph	brownish-grey	A	B (B-A)	C (C-B)
		III	HP, (Ph)	partially or completely	HP, Ph	yellowish-brown	A	A-B (A)	B (B-A)
		IV	Ph	completely	P	yellow, steel-blue	A	A	A-B

Note: DE[1)] – Degree of erosion
Sb[2)] – Soil genetic horizon symbol

The main and often the only indicator of the degree of soil erosion on loose parent rocks of heavy (loamy-clay) composition is the depth of genetic horizons, primarily humic layer, as well as other available parts of the soil. To determine the level of forest growth potential of eroded soils, the depth of horizons of the eroded soil is compared with a reference, that is, with the same, but undamaged with erosion, soil unit. The reference soils are typically modal upland soils.

To provide a forest typological assessment of eroded soils formed on loamy / clayey parent rocks, it is necessary to determine: typical soil affiliation; the degree of destruction of genetic horizons relative to the modal soil (determined by the morphological features of the horizons emerging on the earth's surface). In this way, the trophotope of eroded growth sites is determined, and their hygrotope is determined by being confined to a certain forest typological area [12] (Table 4).

For forest typological assessment of eroded soils formed on light (sandy, sandy loam) parent rocks, it is necessary to determine: the degree of destruction of genetic horizons relative to the modal soil (determined by the morphological features of the horizons emerging on the earth's surface); physical clay content (Table 5). Thus, each individual type of eroded soil, depending on the degree of their disturbance, is given a forestry assessment or they are defined as unsuitable for forestation. The trophotopes or edatopes shown in the diagrams within natural zones and forest ty-

Table 6

Forest typological diagnostics of eroded lithogenic soils

Soils	**Natural zone, Forest typological region**	**Beginning of dense rock occurrence, cm**	**Type of forest growth conditions**
Southern carbonate chornozem underdeveloped on dense limestones and limestone eluvium; soddy-carbonate on dense limestones and eluvium of limestone; Reclaimed land after limestone mining; eluvium of limestone	Southern Steppe Oe, Of	<30	unsuitable for forestation *(α)
Short-profiled southern carbonate chornozem on dense limestones		30-60	C_0, C_1
Southern carbonate thin (thick) chornozem on dense limestones		>60	D_0, D_1
Ordinary underdeveloped chornozem on chalky-marl rocks; sod primitive on chalk-marl rocks; eluvium of chalk	Northern Steppe 1e	<20	A_{0-1} (slope <12°) A_{0-1}, α (slope >12°)
Ordinary short-profiled chornozem on chalk-marl rocks		20-40	B_{0-1} – on chalk C_{0-1} – on marl
Ordinary thin chornozem on chalk-marl rocks		>40	C_{0-1}
Soddy-skeletal short-profiled on dense non-carbonate carbonic rocks or on eluvium of non-carbonate rocks		<20	unsuitable for forestation *(α)
Soddy-skeletal short-profiled on dense non-carbonate carboniferous rocks or on eluvium of non-carbonate rocks		20-40	AB_{0-1}
Ordinary thin (thick) chornozem on dense non-carbonate carboniferous rocks or on eluvium of non-carbonate rocks		40-100	$CD_{1\,(2)}$
Ordinary thick short-profiled chornozem on dense non-carbonate carboniferous rocks or on eluvium of non-carbonate rocks		>100	D_{1-2}
Soddy-primitive (raw) on massive-crystalline rocks and on eluvium of massive-crystalline rocks	Polissya 3d	<10	Unsuitable for forestation *(α)
Soddy-skeletal underdeveloped on massive-crystalline rocks		10-30	A_1 (AB_{1-2})
Soddy-skeletal short-profiled on massive-crystalline rocks or on eluvium of massive-crystalline rocks		30-60	B_{1-2}
Soddy-skeletal podzolized on massive-crystalline rocks or on eluvium of massive-crystalline rocks		>60	C_{2-3}

Note. * - in this case, "unsuitability" means the impossibility of creating forest plantations by conventional methods without significant capital investments in the preparation of the forestry area for planting (fill soil, destruction of dense rock, drip irrigation systems).

pological regions usually represent their predominant types, however, it should be noted that due to the significant complexity of eroded growth sites, they can be represented by other, although similar in terms of productivity, types.

Soils formed on dense rocks, as a rule, are characterized by an underdeveloped soil profile, therefore in practice it is quite difficult to determine the degree of their erosion. This is due to the fact that the shortened depth of the humus horizon can be considered, on the one hand, as a result of erosion effect, on the other hand – as a consequence of the natural course of soil formation, as well as a combined effect of both factors. At the same time, it should be noted that the underdevelopment of the soil profile, regardless of its nature (erosive influence or the degree of soil development under the influence of the soil-forming process), is, in most cases, the main factor limiting the land forestation. Thus, for practical purposes, in the silvicultural development of lithogenic soils of eroded growth sites, one can completely ignore the cause of the underdevelopment of the soil profile, that is, not differentiate them by the degree of eroded. Note that for steep slopes, a very important indicator, which will determine the degree of their forest-cultural development, is the steepness of the slope [4].

Thus, to assess the degree of forestation suitability of eroded soils on dense rocks, it is necessary to determine: depth of the dense rock and genesis of the parent rock (Table 6).

The genesis of the parent rock (igneous, sandstone, shale, chalk-marl, limestone, etc.) determines the differentiation of growth sites into acidophilic and calciphilic variants, according to which agricultural techniques of creation and types of forest crops are determined.

Conclusions

The use of the methodology generally accepted in the forestry of Ukraine methodology for assessing the quality of forest soils by the phytoindication method (according to the composition and productivity of the forest stands) is not suitable for soils where there is no and never was forest vegetation. For this purpose, a comprehensive study of soil properties and forestry characteristics of forest stands was carried out, which made it possible to develop a methodology for assessing the forest suitability of non-forest unproductive (sandy, eroded and skeletal) soils of the plain part of Ukraine. It has been determined that the afforestation of unproductive lands should be preceded by an objective and qualitative assessment of the type of their forest growth conditions according to the following soil indicators: moisture content (the association with the forest typological area and the level of groundwater occurrence is determined); salinity with readily soluble salts; the depth of humus and total soil profile; nutrient status; chemical and mineralogical composition of the parent rocks with mandatory consideration: specifics, duration and intensity of previous use; the presence or potential threat of erosion processes. The effectiveness and overall expediency of creating forest plantations will largely depend on these factors. The chosen methodological approach made it possible to determine the indicators of the forest-growing potential of soils, as well as quantitatively characterize various types of habitats (infertile pine site type – Bir (A), fairly infertile pine site type – Subir (B), fairly fertile hardwood site type – Sugrud (C), fertile hardwood site type – Grud (D)).

Afforestation of low-productive lands of the Steppe zone requires a special, differentiated approach, which is dictated not only by the climatic conditions critical for the development of forest plantations, but also by the significant variety of its soil mantles. It should be noted that the creation of forest plantations on low-productive lands and barren lands requires strict compliance with technological processes at all stages of the creation of forest plantations, including protection from diseases and pests, as well as taking into account their future purpose. When creating of commercial forests, the main role is assigned to the economically valuable native species, while when creating protective forests, it is necessary, to select species that fully ensure the performance of various protective functions by future forests (soil protection, water and climate regulation, field protection, reclamation, etc.), and at the same time show resistance to certain negative environmental conditions.

Conflict of interest

The author declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the author fully complied with ethical standards, including plagiarism, data falsification, and double publication.

References

1. State strategy of forest management of Ukraine up to 2035. (2021). Decree of the Cabinet of Ministers of Ukraine No. 1777-r dated December 29, 2021. Retrieved from https://zakon.rada.gov.ua/laws/show/1777-2021-%D1%80#Text

2. Hansson, K., Laclau, J.-P., Saint-André, L., Mareschal, L., Heijden, G., Nys, C. …Legout, A. (2020). Chemical fertility of forest ecosystems. Part 1: Common soil chemical analyses were poor predictors of stand productivity across a wide range of acidic forest soils. *Forest Ecology and Management*, *461*. https://doi.org/10.1016/j.foreco.2019.117843
3. Raspopina, S. P. (2017). *Scientific basis of assessment of forest growth potential and forestation suitability of soils of the flat part of Ukraine*. Extended abstract of D.Sc. thesis. 42. (In Ukrainian).
4. Teleshek, Yu. K.; Zamlelyi, V. V.; Orlov, A.N., & Olkhovskyi, A.F. (1982). *Methodological guidelines on the technology of creating forest-reclamation plantations on steep rocky banks of the hydrographic network in the flat areas of the Ukrainian SSR.* 31. (In Ukrainian).
5. Chornyi S.G., & Vilna (Poliashenko) N.V. (2019). Updating of "The Index Productivity of Peirce» and its application for an estimation of chernozem soils quality in the Right-bank Steppe of Ukraine. (88), 31-39. https://doi.org/10.31073/acss88-04 (In Ukrainian).
6. Gladkyi, O.S. (1960). Soil and forest-growth conditions of the Lower Dnieper (Oleshkiv) sands. *Scientific works of UkrNDILGA*. *20,* 68-79. (In Ukrainian).
7. Raspopina, S., Degtyarjov, V., & Chekar, O. (2021). *Comparative Evaluation of the Sandy Soils of Pine Forests in Ukraine: Soils Under Stress.*Springer, Cham. https://doi.org/10.1007/978-3-030-68394-8_15
8. Migunova, O.S. (1974). *Methodological guidelines for soil survey of saline lands.* 33. (In Ukrainian).
9. Ponette Q., Bispo A., Brethes A., Dupouey J-L., Feix I, Gégout J.-C. … Rangeet J. Fertility indicators in temperate forest soils: issues, approaches and prospects. (2014). *Hal science ouverte.* https://doi.org/10.4267/2042/56269
10. Zhao W., Cao X., Li J., Xie Z, Sun Y., Peng Y. Novel weighting method for evaluating forest soil fertility index: a structural equation model. *Plants (Basel, Switzerland)*, *12*(2), 410. https://doi.org/10.3390/plants12020410
11. Baliuk S., Medvedev V., Miroshnichenko M., Skrylnik Ye., Timchenko D., Fatieev A… Tsapko Yu. (2012). Environmental state of soils in Ukraine. *Ukrainian Geographical Journal*, *2*, 38-42. Retrieved from http://nbuv.gov.ua/UJRN/UGJ_2012_2_9 (In Ukrainian).
12. Ostapenko B.F. & Tkach V.P. (2002). *Forest typology*. 204 (in Ukrainian).

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МЕТОДИКА ВИЗНАЧЕННЯ ПРИДАТНОСТІ ҐРУНТІВ ДЛЯ ЗАЛІСНЕННЯ РІВНИННОЇ ЧАСТИНИ УКРАЇНИ

Мета. Розробка методики оцінки лісопридатності для окремих різновидів малопродуктивних ґрунтів.

Методи. Класичні методи ґрунтознавства, агрохімії, лісознавства, лісовпорядкування, типології та математичної статистики.

Результати. Основою визначення придатності ґрунтів для лісорозведення є принципи лісової типології. Їхня сутність полягає у комплексному вивченні властивостей ґрунту (морфометрії, хімічного складу ґрунту) та лісівничих характеристик лісових насаджень, а також аналізі трав'яно-чагарникового ярусу за екоморфами. Наведено результати комплексного вивчення продуктивності деревостанів та властивостей основних різновидів малопродуктивних ґрунтів (піщаних, еродованих та скелетних) у різних природних зонах рівнинної частини України. Визначення придатності ґрунтів для лісорозведення оцінювали за трьома категоріями: 1) непридатні для лісорозведення та умовно придатні для лісорозведення (дуже сухі, дуже бідні, токсичні, з обмеженою ризосферною зоною, недоступні або важкодоступні для обробітку); 2) обмежено придатні для лісорозведення (сухі та бідні ґрунти); 3) придатні для лісорозведення. Розроблено пакети маркерів, на підставі яких, можна оцінювати як їхню лісопридатність, так і визначати тип лісорослинних умов нелісових земель. При комплектуванні маркерів перевагу надавали таким показникам грунту, які поряд з інформативністю щодо його якості, не вимагають

надскладних методів визначення. Склад маркерів включає морфологічні, фізичні, агрохімічні показники та залежить від типу ґрунту.

Висновки. Розроблені пакети маркерів є основою для науково обґрунтованого створення лісів на малопродуктивних землях, де раніше не виростала лісова рослинність. Їх використання у лісорозведенні підвищує його ефективність і робить ліси стійкішими до несприятливих факторів довкілля. Методика призначена для фахівців лісового господарства, може бути використана на підприємствах, установах лісового господарства, лісопроєктних організаціях, а також у суміжних галузях, пов'язаних з охороною та раціональним використанням природних ресурсів. Методичні розробки можуть бути включені до навчальних програм середніх та вищих навчальних закладів лісового профілю.

КЛЮЧОВІ СЛОВА: *малопродуктивні ґрунти, лісорослинний потенціал, лісонасадження*

Список використаної літератури

1. Про схвалення Державної стратегії управління лісами України до 2035 року. Розпорядження Кабінету Міністрів України від 29 грудня 2021 р. № 1777-р. 2021. Київ. URL: https://zakon.rada.gov.ua/laws/show/1777-2021-%D1%80#Text (дата доступу 1.05.2023).
2. Hansson, K., Laclau, J.-P., Saint-André, L., Mareschal, L., Heijden, G., Nys, C. …Legout, A. Chemical fertility of forest ecosystems. Part 1: Common soil chemical analyses were poor predictors of stand productivity across a wide range of acidic forest soils. *Forest Ecology and Management*. 2020. Vol. 461. DOI: https://doi.org/10.1016/j.foreco.2019.117843
3. Распопіна С. П. Наукові основи оцінки лісоростового потенціалу та лісопридатності ґрунтів рівнинної частини України : автореферат дис.д-ра агр. наук. 2017. 42с.
4. Телешек, Ю. К., Замлілий В. В., Орлов А.Н.; Ольховський А. Ф. Методичні вказівки з технології створення лісомеліоративних насаджень на крутих скелястих берегах гідрографічної мережі в рівнинних районах УРСР. 1982. 31с.
5. Чорний С. Г., Вільна (Поляшенко) Н.В. Модифікація «Індексу продуктивності Пірса» та його використання для оцінки якості чорноземних ґрунтів Правобережного Степу України. *Агрохімія і ґрунтознавство*. 2019. Вип. 88. С. 31-39. DOI: https://doi.org/10.31073 /acss88-04
6. Гладкий О.С. Грунтово-лісоростові умови Нижньодніпровських (Олешківських) пісків. *Наукові праці УкрНДІЛГА*. 1960. Т. 20, 68-79.
7. Raspopina, S., Degtyarjov, V., Chekar, O. *Comparative Evaluation of the Sandy Soils of Pine Forests in Ukraine: Soils Under Stress.*Springer, 2021. Cham. https://doi.org/10.1007/978-3-030-68394-8_15
8. Мігунова, О.С. Методичні вказівки до ґрунтового обстеження засолених земель. 1974. 33с.
9. Ponette Q., Bispo A., Brethes A., Dupouey J-L., Feix I, Gégout J.-C. … Rangeet J. Fertility indicators in temperate forest soils: issues, approaches and prospects. 2014. *Hal science ouverte.* DOI: https://doi.org/10.4267/2042/56269
10. Zhao W., Cao X., Li J., Xie Z, Sun Y., Peng Y. Novel weighting method for evaluating forest soil fertility index: a structural equation model. *Plants (Basel, Switzerland)*. Vol. *12. N* 2. DOI: https://doi.org/10.3390/plants12020410
11. Балюк С., Медведєв В., Мірошніченко М., Скрильник Є., Тимченко Д., Фатєєв А… Цапко Ю. Екологічний стан ґрунтів України. *Український географічний журнал*. 2012. № 2. С. 38-42. DOI: http://nbuv.gov.ua/UJRN/UGJ_2012_2_9
12. Остапенко Б.Ф., Ткач В.П. Лісова типологія. 2002. 204с.

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