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FORMATION OF EROSION RESISTANCE OF GRAY FOREST SOILS IN THE CONDITIONS OF CARPATHIAN REGION

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Aim. To study the impact of perennial grasses mixtures on the formation of erosion resistance of gray forest soils of different degradation degree and their unmodified analogues in conditions of long-term permanent experiment. **Methods.** Field, laboratory, assessment and comparison. **Results.** It was established that lupine-cereal grass mixtures increased erosion resistance of slope soils considerably within fifteen years. The sum of soil structural aggregates was improved from satisfactory into good category. There were positive changes in the number of water-resistant aggregates as well. The studies confirmed a positive impact of legume-grasses on the density and porosity of soil. Soil density was the lowest when the slope was laid down in perennial lupine and its mixture with cereal grasses. The intensification of soil erosion and the approximation of the illuvial horizon level to the surface resulted in the compaction of upper soil layers to 1.29–1.44 g/cc. General porosity of soil correlated with its density which did not exceed optimal values in poorly eroded soils in upper layers. The studies proved the impact of the ways of laying down the slope in grass and the level of soil degradation on its humidity and water permeability. In the experiment conditions, the increase in soil degradation led to the decrease in its moisture. The decrease in the content of humidity in crop field took place at the expense of higher intensity of the growth and water consumption of lupine-cereal grasses in comparison with natural mixed herbs, especially in the periods with a small amount of precipitation. The difference in the upper soil layers was in the range of 0.2–0.5 %. It was established that the highest values of soil water permeability were formed on lupine-cereal grass mixtures in all the variants of degraded soils. **Conclusions.** Laying down slope lands in perennial lupine in combination with cereal grasses promotes the formation of their higher resistance to erosion processes and restoration of fertility. Perennial legume-cereal mixtures ensure the improvement of structural-aggregate state, total density and porosity of soil, enhance its water supply and water permeability.

Keywords: gray forest soils, degradation, erosion resistance.

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INTRODUCTION

The degradation processes, caused by the impact of water erosion, are widely spread on the slope lands of the Carpathian region. The inconsistence of the land use structure and crop rotation, the non-compliance of soil-protecting technologies of cultivating agricultural crops, the violation of zonal norms of general and field-protecting forest cover lead to the decrease in soil erosion resistance and enhance erosion processes. In particular, in conditions of Lviv region in the zone of small (Lviv) Polissia on the agricultural land, the development of water erosion processes of different intensity takes place on the area of 47,446 ha, wind erosion – 25,091 ha, in the zone of west Forest-Steppe – 146,055 and 15,790 ha respectively. In the Subcarpathian region, 50,314 ha and in the Carpathians – 56,790 ha of lands are subjected to destructive impact of water. According to the results of studies of the Institute of Agriculture of the Carpathian Region NAAS, the highest index of erosion-ecological tension of agricultural lands (the ratio of lands, subjected to the impact of erosion processes, to the total area of agricultural lands) was noted on the arable land in all soil-climatic zones of the region. It was 0.26 in Polissia, 0.37 – in the Forest-Steppe, 0.24 – in the Subcarpathian region, 0.49 – in the Carpathians. The lowest values were recordedon hayfields and meadows [1, 2]. It conditions a considerable aggravation of ecologic situation and a sharp decrease in ecologic restoration and productive functions of soils. Along with the loss of humus layer and nutrients there is a considerable change in physical-chemical and water-physical properties of soils and its heat regime [1, 2].

Taking into consideration economic aspects, the introduction of meadow in the system of soil-protecting agriculture is a cheap and reliable method of protecting soils, enhancing their erosion resistance and restoring the soil fertility [1, 3–6]. Perennial grasses and grass mixtures enhance the performance of ecosystem, stabilize its functioning, improve physical properties, enrich soil with nitrogen, phosphorus, and calcium [2, 7].

MATERIALS AND METHODS

The studies were conducted in conditions of long-term permanent experiment of the Institute of Agriculture of the Carpathian Region.

The experiment was started in 2003 on the slope of the southern-western exposition, its length was 100 m and the steepness – 11°. There were two factors under investigation. The variants of the first factor were the areas of different degrees of degradation – heavily, medium and poorly eroded soils and their unmodified analogues, the variants of the second factor– perennial grasses: perennial lupine (pure sowing); clover-cereal grass mixture; lupine-cereal grass mixture; perennial cereal grasses (pure sowing); natural overgrowth. The cereal component consists of the following perennial grasses: awnless bromegrass, meadow brome, timothy grass.

The location of variants was sequential, there were three repeats, the area of the experimental plot was 320 sq.m., that of the registration plot – 160 sq.m., the total area under the experiment – 1,20 ha.

The arable soil layer of different degradation degree was characterized by the following agrochemical indices: content of humus (according to Turin) – 1.4–1.7 %, mobile phosphorus and potassium – 125–205 and 50–112 mg per 1 kg of soil respectively, pH (KCl) – 5.2–6.0, hydrolytic acidity – 2.3–2.5 mg-eq per 100 g of soil, the sum of absorbed alkali – 4.4–5.3 mg-eq per 100 g of soil, the content of base-hydrolyzed nitrogen is 60–85 mg/kg of air-dry soil.

RESULTS AND DISCUSSION

The aim of our studies was to investigate the impact of meadow-reclamation events on the erosion resistance of gray forest soils in conditions of sufficient humidity.

It was proven that the fields of perennial grasses on erosion-hazardous and eroded soils decrease the surface runoff, promote its diffusion due to the formation of dense turf, ensure the formation of water-resistant

Table 1. Structural-aggregate composition of gray forest surface-clay soil (2015)

Way of laying down with grass	Size of structural aggregates in mm, content in %									Sum of macroaggregates	C_{str} $C_{water\ resistance}$	Estimation of structural state of soil
	>10	10..7	7..5	5..3	3..2	2..1	1..0.5	0.5..0.25	<0.25			
Poorly eroded												
Lupine-cereal mixture	16.4	6.0	6.8	12.2	9.8	17.7	4.4	6.4	20.3	63.2	1.72	Good
			3.2	2.1	4.4	16.7	7.4	7.1		40.9	0.65	Satisfactory
Natural overgrowth	20.5	6.6	6.8	14.6	10.6	14.2	3.7	5.0	17.9	61.6	1.60	Good
			4.1	5.4	3.8	12.8	5.9	5.5		37.5	0.61	Unsatisfactory
Heavily eroded												
Lupine-cereal mixture	17.2	7.6	7.6	12.3	8.4	14.4	3.2	6.0	23.3	59.5	1.47	Satisfactory
			3.3	3.7	4.0	11.1	6.8	5.9		34.8	0.58	Unsatisfactory
Natural overgrowth	27.4	7.3	7.5	12.4	8.4	14.6	3.0	5.0	14.3	58.3	1.40	Satisfactory
			6.1	6.9	2.5	10.8	4.2	5.3		35.8	0.61	Unsatisfactory

Note. The numerator – structural-aggregate state, denominator – water resistance of soil aggregates.

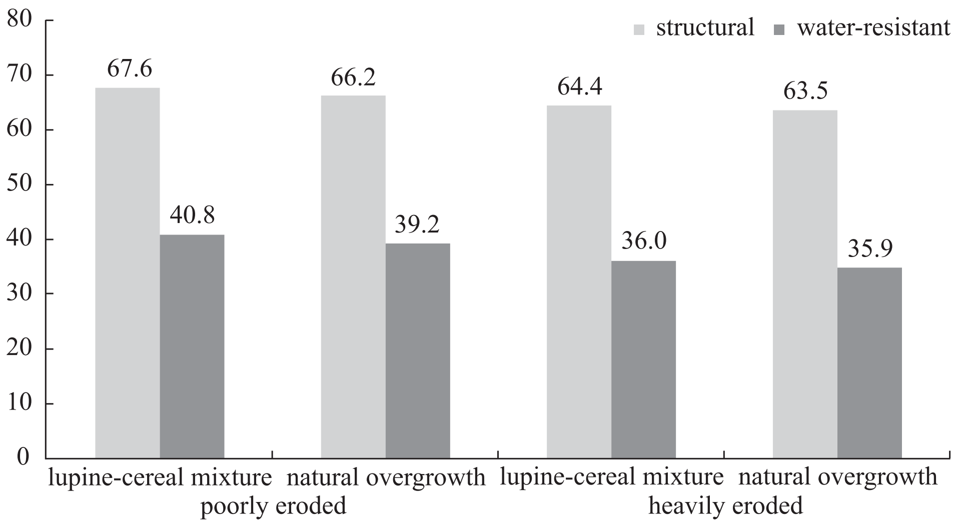

Fig. 1. The content of structural and water-resistant aggregates depending on the meadow-reclamationevents and the degree of slope erosion, % for 2015

structure, enhance water permeability of soil and protect the surface from the destructive action of rain drops [2, 7].

In our studies, the analysis of experimental data as of 2015 demonstrated a considerable positive impact of perennial grasses on the structural-aggregate state and water resistance of soil aggregates (Table 1). It was established that, depending on the erosion degree, the sum of soil structural aggregates in the variants of lupine-cereal grass mixture was in the range of 63.3–59.5 % and exceeded the variant of natural overgrowth by 1.6 and 1.2 %. There were 3.6 and 3.3 % less structural aggregates on heavily eroded soil compared to poorly eroded soils. There was domination of structures with the size of 1...2 mm – 14.2–17.7 % and 3...5 mm, the content of which was at the level of 12.2–14.6 %. The fraction of aggregates of 0.5...1 mm was the least – 3.0–4.4 %. Under natural overgrowth of eroded lands, the content of structure-free soil aggregates (under 0.25 mm) was 2.4 and 9.0 % less compared to the fields of the mixture of lupine and cereal grasses.

Water resistance of aggregates is a relevant characteristic of erosion resistance of soil [8]. In our studies the content of water-resistant aggregates under grasses was 34.8–35.8 % on heavily eroded soils, and 37.5–40.9 % on poorly eroded analogues.

The calculations demonstrated that the coefficient of structuredness ($C_{str.}$) for the poorly eroded soil was 1.60–1.72, and that for heavily eroded soil – 1.40–1.47. The coefficient of water resistance ($C_{water\ resistance}$) of soil aggregates was 0.61–0.65 and 0.58–0.61 respectively.

The estimation of structural state demonstrated that good structural state of soil aggregates is formed on the fifteenth year after the start of the experiment (0.25–10 mm) in the range of 63.5–67.6 %. This shows a clear tendency towards its improvement.

The changes in the number of water-resistant aggregates were less evident. Water-resistant structure was satisfactory only on lupine-cereal grass mixture in conditions of poorly eroded soil (Fig. 1).

Soil density is a relevant index of erosion resistance of soils. Optimal indices of the density promote a favorable ratio between solid, liquid and gas phases of soil, ensuring the most efficient consumption and use of moisture, with the formation of good conditions for the development of the root system of plants.

Our studies confirm a positive impact of grass mixtures on soil density (Table 2). In all the experiment variants, the root system of perennial grasses and the absence of impact of the movement of agricultural equipment promotes the optimization of this index. It was also promoted by the plant cover of grasses which created a barrier for soil compaction by rain drops.

The density of poorly eroded surface clay soil was 1.22–1.36 g/cc. The lowest soil density was found in the upper layers in the variants of the fields of lupine-cereal mixture – 1.22–1.27 g/cc.

The intensification of soil erosion and the approximation of the illuvial horizon level to the surface resulted in the compaction of upper soil layers to 1.29–1.44 g/cc. Soil density was lower when the slope was laid down in perennial lupine and its mixture with cereal grasses.

Table 2. Physical properties of soil of different erosion degree under grasses (2015)*

Soil layer, cm	Density of soil structure, g/cc*			Soil porosity, %		
	Way of laying down with grass					
	perennial lupine	lupine-cereal mixture	natural overgrowth	perennial lupine	lupine-cereal mixture	natural overgrowth
Poorly eroded soils						
0–10	1.25	1.22	1.23	51.2	52.0	52.0
10–20	1.30	1.27	1.31	50.0	51.2	49.6
20–30	1.31	1.30	1.36	50.0	50.4	48.1
0–30	1.29	1.27	1.30	50.4	51.2	49.9
Heavily eroded soils						
0–10	1.30	1.29	1.31	50.0	50.4	49.6
10–20	1.37	1.35	1.40	48.1	48.9	47.0
20–30	1.40	1.37	1.44	47.2	48.3	45.7
0–30	1.36	1.34	1.38	48.4	49.2	47.4

* The density of soil structure was defined prior to the second cutting.

Table 3. The level of humidity in crop field depending on the slope erosion and its laying down with grasses, 2015, %

Soil layer, cm	Way of laying down with grass			
	Poorly eroded		Heavily eroded	
	lupine-cereal grasses	natural overgrowth	lupine-cereal grasses	natural overgrowth
Prior to the first cut				
0–10	19.2	19.6	18.9	19.8
10–20	19.6	19.9	19.2	19.3
20–30	18.0	18.8	17.8	17.8
30–40	18.7	19.2	18.1	18.7
40–60	19.0	19.3	18.7	19.0
60–80	19.6	20.4	19.0	19.1
80–100	20.0	20.9	19.5	19.5
0–30	18.9	19.4	18.6	19.0
0–100	19.2	19.7	18.7	19.0
Prior to the second cut				
0–10	6.6	6.9	5.8	6.3
10–20	5.9	6.1	5.2	5.6
20–30	5.4	5.5	5.0	5.2
30–40	5.2	5.2	5.1	5.2
40–60	6.1	5.9	5.3	5.7
60–80	13.5	13.8	13.1	13.0
80–100	15.3	15.0	14.8	14.8
0–30	6.0	6.2	5.3	5.7
0–100	8.3	8.3	7.8	8.0

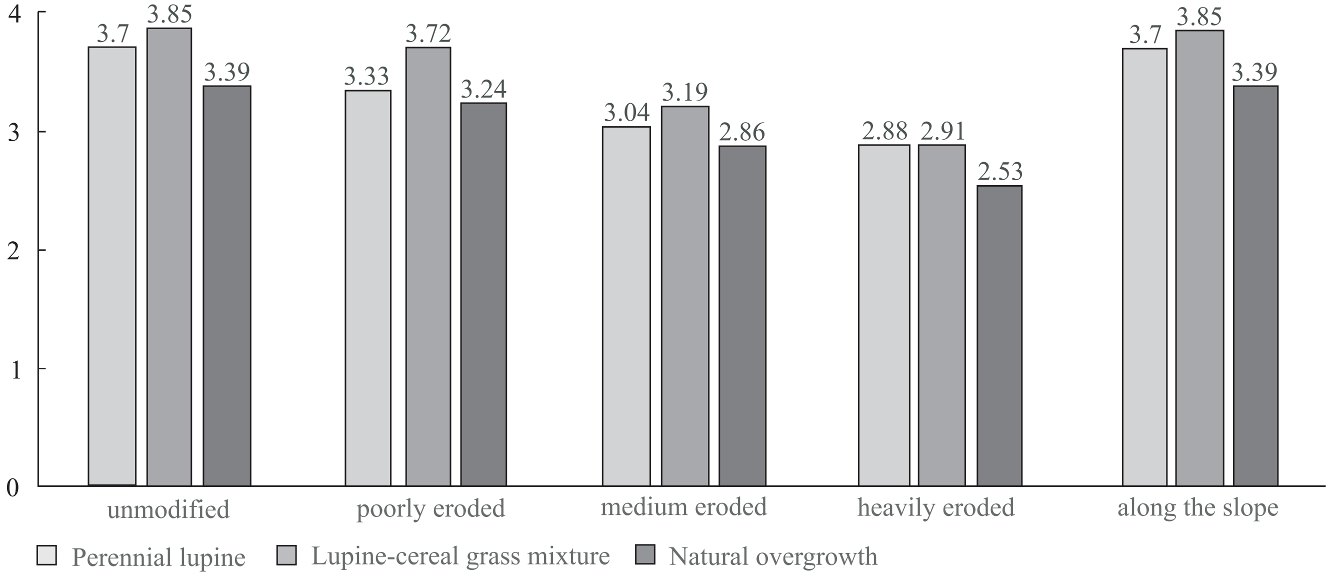

Fig. 2. The estimation was performed prior to the second cutting. Water permeability of soil, mm/min during the first hour

General porosity of soil correlated with its density which did not exceed optimal values in poorly eroded soils in upper layers – less than 50 % (Table 2). In conditions of heavy erosion in the 0–10-cm soil layer, it was 49.6–50.4 % and in the 0–30 cm layer it was 47.4–49.2 %. Porosity was 2–4 % higher in poorly eroded soil.

Soil moisture has a considerable impact on soil structure and thus on their erosion resistance. Plant cover promotes interception of precipitation, even accumulation of snow which ensures the improvement of water indices of fertility and decrease in erosion progress.

Humidity in crop field was determined prior to the first and second cutting of grasses. The results of the studies demonstrated (Table 3) which way of laying down the slope with grass and the degree of soil erosion had impact on humidity in crop field. In conditions of 2015, the enhanced development of lupine-cereal grass mixture promoted increased water consumption and decrease in soil moisture compared to the grasses in the variants of natural overgrowth which was 18.6–19.4 % in the 0–30 cm soil layer and 18.7–19.7 % in the 0–100 cm layer depending on the erosion degree.

In general, as of the time of the first cutting of grasses, the moisture of eroded soil was sufficient for the formation of their high performance. A considerable amount of precipitation promoted the latter.

The number of precipitations after the first cutting of grass, which was not high compared to perennial grasses, conditioned a sharp decrease in soil moisture (Table 3). For instance, its content in the layers down to 60 cm did not exceed 6.9 %. Higher intensity of the growth of lupine-cereal grasses compared to natural overgrowth conditioned a decrease in the content of humidity in crop field. The difference in the upper layers was in the range of 0.2–0.5 %.

Starting with the depth of 60 cm, the content of moisture in creased and was 13.0–15.3 %. Soil moisture of a one-meter-deep layer was at the level of 7.8–8.3 %.

Water permeability of soil determines the completeness of absorbing water of atmospheric precipitation and impacts the degree of water supply of soil and the development of erosion processes. Waters, flowing from the field surface, cause ablation and erosion of soil.

Drought conditions in summer of 2015 impacted water permeability of soil. It was 3.39–3.85 mm/min on average on the slope depending on the grass. The highest values were formed on lupine-cereal grass mixtures in all the variants of degraded soils. The analysis of changes in this index by degradation variants demonstrated its decrease in all the areas of perennial grasses from unmodified analogues to heavily eroded soil, amounting to 3.70–2.88 in the fields of perennial grasses, 3.85–2.91 – for lupine-cereal grass mixture, and 3.39–2.53 in the natural state during the first hour (Fig. 2).

The decrease in water permeability in conditions of enhanced soil ablation occurs due to the deterioration of water resistance of its structure, which conditions fast colmatati on of soil pores by dispersed particles. In heavily eroded soils water permeability decreased by 22–24 % compared to unmodified analogues.

CONCLUSIONS

Laying down slope lands in perennial lupine in combination with cereal grasses promotes the formation of their higher resistance to erosion processes and restoration of fertility. In these conditions, a good structural state of aggregates (0.25–10 mm) is formed on poorly eroded soil in the range of 63.5–67.6 % and there is a clear tendency towards its improvement on heavily eroded analogues. Perennial legume-cereal mixtures ensure the improvement of general density and porosity of soil, its water supply and permeability.

Формування протиерозійної стійкості сірих лісових ґрунтів в умовах Карпатського регіону

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Мета. В умовах довготривалого стаціонарного досліду дослідити вплив комплексів багаторічних трав на формування протиерозійної стійкості сірих лісових ґрунтів різного ступеня деградованості та їх незмитих аналогів. **Методи.** Польовий, лабораторний, розрахунково-порівняльний. **Результати.** Встановлено, що люпино-злакові травосумішки за п’ятнадцятирічний період істотно підвищували протиерозійну стійкість схилових ґрунтів. Покращувалась сума структурних агрегатів і, згідно градації оцінювання структурного стану, на варіантах досліду переходила з категорії задовільної в добру. Проявлялись позитивні зміни й кількості водостійких агрегатів. Проведеними визначеннями підтверджено позитивний вплив бобово-злакових трав на щільність та шпаруватість ґрунту. Щільність ґрунту була найменшою при залуженні схилу люпином багаторічним та його сумішкою із злаковими травами. Посилення змитості ґрунту та підвищення до поверхні рівня ілювіального горизонту спричинювало ущільнення верхніх пластів ґрунту до 1,29–1,44 г/см^3. Загальна шпаруватість ґрунту корелювала з його щільністю, яка на слабозмитих ґрунтах у верхніх шарах не виходила за оптимальні значення. Дослідженнями доведено вплив способів залуження схилу та рівня деградованості ґрунту на його вологість та водопроникність. В умовах досліду зростання деградованості ґрунтів призводило до зниження їх вологості. Зменшення вмісту польової вологи відбувалось і за рахунок вищої інтенсивності росту та водоспоживання люпино-злакових трав в порівнянні до природного різнотрав’я, особливо в періоди з невеликою кількістю опадів. Різниця у верхніх шарах була в межах 0,2–0,5 %. Встановлено, що найвищі значення водопроникності формувались на люпино-злакових травосумішках по всіх варіантах деградованих ґрунтів. **Висновки.** Залуження схилових земель багаторічним люпином у сумішці зі злаковими травами сприяє формуванню їх високої стійкості до ерозійних процесів і відновленню родючості. Багаторічні бобово-злакові комплекси забезпечують покращення структурно-агрегатного стану, загальної щільності та шпаруватості ґрунту, поліпшують його вологозабезпеченість та водопроникність.

Ключові слова: сірі лісові ґрунти, деградація, протиерозійна стійкість.

Формирование противоэрозионной устойчивости серых лесных почв в условиях Карпатского региона

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Цель. В условиях длительного стационарного опыта исследовать влияние комплексов многолетних трав на формирование противоэрозионной устойчивости серых лесных почв разной степени деградованости и их незмитих аналогов. **Методы.** Полевой, лабораторный, расчетно-сравнительный. **Результаты.** Установлено, что люпино-злаковые травосмеси по пятнадцатилетний период существенно повышали противоэрозийную устойчивость склоновых почв. Улучшалась сумма структурных агрегатов и, согласно градации оценки структурного состояния, на вариантах опыта переходила из категории удовлетворительного в хорошую. Проявлялись положительные изменения и количества водостойких агрегатов. Проведенными определениями подтверждено положительное влияние бобово-злаковых трав на плотность и скважность почвы. Плотность почвы была наименьшей при заложенные склона люпина многолетним и его смеси со злаковыми травами. Усиление змитости почвы и повышения к поверхности уровня илювиального горизонта вызывало уплотнения верхних слоев почвы к 1,29–1,44 г/см^3. Общая скважность почвы коррелировала с его плотностью, на слабозмитих почвах в верхних слоях не выходила за оптимальные значения. Исследованиями доказано влияние способов заложенные склона и уровня деградованости почвы на его влажность и водопроницаемость. В условиях опыта рост деградованости почв приводило к снижению их влажности. Уменьшение содержания поле-вой влаги происходило и за счет более высокой интенсивности роста и водопотребления люпино-злаковых

трав в сравнении с природного разнотравья, особенно в периоды с небольшим количеством осадков. Разница в верхних слоях была в пределах 0,2–0,5 %. Установлено, что высокие значения водопроницаемости формировались на люпино-злаковых травосмеси по всем вариантам деградированных почв. **Выводы.** Заложенные склоновых земель многолетним люпином в сумищци со злаковыми травами способствует формированию их высокой устойчивости к эрозионных процессов и восстановлению плодородия. Многолетние бобово-злаковые комплексы обеспечивают улучшение структурно-агрегатного состояния, общей плотности и скважности почвы, улучшают его влагообеспеченность и водопроницаемость.

Ключевые слова: серые лесные почвы, деградация, про-тивоэрозионная устойчивость.

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