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COMPARING AN EFFICIENCY OF ERODED SOILS RESTORATION IN NORTH-WESTERN UKRAINIAN POLISSYA

Valerii KOLIADA[1], Olga KOLIADA[2], Serhii CHUHAIEV[2], Liubov KORCHASHKINA[2]

[1]National Scientific Center "Institute for soil science and agrochemistry research named after O. N. Sokolovsky" NAAS, 4 Chaikovska Str., Kharkiv, 61024, Ukraine,
Phone/Fax:057/7041669; E-mail: koliadavalerii@gmail.com
[2]Lugansk National Agrarian University, 44 Alchevskyh str., 61002, Kharkiv, Ukraine, Phone/Fax: 057/7523766; Email: olyapovh@gmail.com, agro.chugayev@gmail.com horadotus684@gmail.com

Corresponding author: koliadavalerii@gmail.com

Abstract

Presented prospects about restoration of sod-podsolic and sod-carbonate soils possessing light granulometric composition (texture) regarding local processes of wind erosion. Agricultural efficiency of crops growing in conditions of Polissya (West forest zone) has been determined. It has been investigated that growing of red clover («Trifolium pratense» Lat.) on such territories in spite of fertilizers input creates stable crops cover, decreases the deflation processes spread and results in obtaining seeds and harvesting green biomass in nearest future. It has been found that after 5 years of perennial growing these territories regain profitable qualities. Comparing different plans of agro technical activities on such areas showed that one of the most viable and practically proved variants is to harvest crop together with mineral and organic fertilizers input in first years of restoration. As the particular example the components of farming practices in the form of mineral fertilizer input and overseeding grasses payback are used to obtain both the environmental and economic benefits of applied operations.

Key words: *efficiency, restoration, fertilizer, perennial, calculation.*

INTRODUCTION

Wind erosion processes occur in Ukraine in different ways - both in quantitative terms and forms, depending on the nature of local climatic conditions, soil types, etc. Thus, in case of Polissya conditions (forest region in north-western part of country) structureless sandy loam or sandy clay soils particles provoke moving as a part of air-dust flow that cripple a surface of drained organic soils and incorporate them in process of saltation. Moreover, dust storms in Polissya occur at speeds of 6-10 m/s, recurring often up to 3-4 times in decade – that is fleeting and aggravating the situation with significant soil deterioration and air dusting [3]. For Polissya with the same probability the occurrence of dust storms at speeds matching 5-10 m/s coincides with the data for the southern steppes of Ukraine [6]. During the last 20-30 years in the Polissya region local centers of recurring manifestation for deflationary processes were observed and characterized by a small size of eroded areas but with tendency to develop and spread further due to the tree belts remoteness and erosion control measures lack on these lands. Until recently the study on manifestation of wind erosion processes in the Polissya had been considered controversial because some scientists described this region as historically inherent with excess moisture, excessive rainfall and distribution of natural herbaceous vegetation and forests [10]. The gradual reduction of forest areas of Polissya together with the involvement of large areas of land into agricultural production as well as widespread usage of drainage reclamation in the 1970s - all caused prerequisites for additional impact on soil and accelerated the occurrence of degradation processes in the region, the endemic example of which may be the dust storm in the Volyn Highlands in 1969 [4]. After the former USSR drainage reclamation and development program in 1991 these areas are no longer appropriate for such operations because of their short-lived effect, lack of control and funding. Regulation of water regime at very uneven distribution of moisture and the presence of close hydrological relationship between different combinations of soil from ground water level significantly complicates an optimal water regime in the territory, and the negative consequences from misbalanced drainage reclamation predictably emerged in organic and mineral soils, including areas at a considerable distance (3-12 km) outside of reclamation facilities [9]. The solutions to the proliferation of soils dusting in the long term perspective are the following: practices to restore drainage systems; bilateral water regime of soil instead of gravity-flowing; changes in the nature of soil organic origin with simultaneous fertility increase; restoration of vegetation and leveling blow plots by erosion-protective techniques [7].

The purpose of this work is to assess efficiency of locally implemented erosion preventive measures in combination with other methods of operational management, on example of Kopayivska soil drainage system lands in Shatsky district, Polissya region to protect these lands from the spread of deflationary processes in future.

MATERIALS AND METHODS

The study of erosion control measures with aim to suspend local deflationary processes occurrences was carried out during 2009-2015 years within Kopayivska drainage network near the village Pishcha, Shatsky region (until 2005 – a former part of Lyubomlsky region), Polissya, Ukraine (Fig. 1).

This area with extraordinarily mosaic and multivariate mineral compositions of soils having varying degrees of podzolization, gleyefication and with presence of overdried organic soil types is not resistant to wind. The main soil types with local deflation processes are soddy gley podzolized and soddy carbonate soils on a territory with GIS-coordinates between 51, 60147 and 51, 60274 of N-north latitude, and between 23,82486 and 23,82733 of E-east longitude in Western part of Polissya Region. During research on soddy gley and soddy carbonate soils the potentially possible annual soil loss was calculated on a base of measured in-site pins data on an area of 5 ha for a period of 5 years.

Fig. 1. Location of experiment area near the village Pishcha (Shatsky region, Polissya, Ukraine).
Source: Own materials of soil erosion control lab., NSC-ISSAR

Following data with direct observation of the removed soil material carried out from 2009 to 2015 pointed on a 1.5 cm layer of soil carried beyond the land area of 5,030 hectares. According to installed pins of 10 cm height above the soil surface for a period of 5 years investigation, equivalent to the entire area - 750 m^3. After taking into account the average value of soil density for soddy gley and soddy carbonate soils within 1.5 g/cm^3 we calculated the total loss from research area amounted to 45 tons of soil from 1 hectare per year. Taking into account a fact about limiting level of losses to these soils is 10 times smaller [2], we intend to conduct research that relates to the regulatory enabling erosional processes in such agriculture landscape. In order to restore the adjustments in the composition of soil nutrients and to suspend local deflationary processes the studies were planned to compare efficiency of different scenarios of erosion preventive activities at that site and select the most appropriate one [1].

Among the appropriate scenarios for action were the following:

(i) organic fertilizer input in the form of litter manure with such nutrient content characteristics: Soil Organic Matter (SOM) – 20%, Nitrogen – 0.5%, Phosphorus – 0.2%, Potassium – 0.6%;

(ii) mineral fertilizers input in the form of: (i) Ammophos® ($NH_4H_2PO_4$ + $(NH_4)_2HPO_4$)

including: 10-12% of Nitrogen and 52% Phosphorus,
(ii)Kalimag-30® ($K_2SO_4 \cdot MgSO_4$), include: K_2O — 24-26%; MgO — 11-18% of Potassium;
(iii) shift the direction of intensive land usage expressed by extensive-grazing termination of the established grasslands by perennial grasses (in the form of red clover «*Trifolium Pratense » lat.)(*Fig. 2).

Fig. 2. General view of red clover "*Trifolium pratense*" Lat.
Source: Illustration from Thome, O. V., 1905 [12].

To determine the cost-effectiveness of erosion preventive activities for each scenario it was planned to employ the set of indicators that would fully reflect the feasibility of activities application. These equations 1-3 included: avoided soil losses, productivity of the different entities, costs of materials and financial means per 1 ha of crops, the cost of 1 kg of product profitability and income [5].
Calculation for avoided soil losses was determined by the formula:

$$\Delta L = L_1 - L_2 \qquad (1)$$

where L_1 - loss of soil on eroded lands in the actual structure of sown areas, t / ha; L_2 - loss of soil on eroded lands after the implementation of protective measures, t / ha.
The content of organic matter and nutrients in the soil were set by agrochemical survey results and included in research data.
For determining the profit from the introduction of erosion preventive measures (P_c) the following formula was used:

$$P_c = (C_1 + C_2) - C_p \qquad (2)$$

where P_c - conditional profit, UAH; C_1 - cost of seeds, UAH; C_2 - cost of hay, UAH; C_p - production costs, UAH.

The level of profitability was assessed by comparing the conditional profits with production costs as follows:

$$P = \frac{P_c}{C_p} 100 \qquad (3)$$

where P - profitability of farming practices,%;
P_c - conditional profit, UAH; C_p - production costs, UAH.

RESULTS AND DISCUSSIONS

This section presents the evolution of variation coefficients calculated on the basis of the methodology presented above. Price variation is very important in the production decision as well as in the calculation of vegetable farmers' incomes. Table 1 presents the values of variation coefficients of the monthly procurement prices by development regions and by types of vegetables. During efficiency evaluation of soil measures the comparison of three different scenarios (mineral fertilizers use (input), organic fertilizers use (input) and growing of perennial grasses in traditional technologies of farming) was performed.
The economic effect was determined by conventional profit from 1 hectare of implementing farming practices and environmental effect – as a result of obtained measures to reduce losses of soil and by a reduction of soil degradation degree, expressed in the prevented quantity of removed soil material. In determining the value of humus and nutrients losses, averted from the implemented deflation preventive measures, the appropriate recalculation of manure and fertilizers were made using their acquisition price or average implementation fertilizer prices considering cost of their introduction into the soil.
After taking into account a nutrition content of removed soil surface layer for soddy gley soil, the quantity were on a level: P (Phosphorus) – 117.0 mg/kg per hectare (or 26.3 kg/ha), K (Potassium) – 78.0 mg/kg per hectare (or 17.55 kg/ha); for soddy carbonate soil: P – 27.5 mg/kg per hectare (or 6.19 kg/ha), K –

44.0 mg/kg per hectare (or 9.9 kg/ha). After multiplying these values by 0.3 (constant factor to convert kg/ha) we converted them in mg/100 g of soil. The amounts of phosphorus and potassium for soddy gley and for soddy carbonate soils were on a level: 35.1 and 8.25 kg/ha for phosphorus; 23.4 kg/ha and 13.2 kg/ha for potassium.

Total amount of removed soil from investigation area as it presented above reached 45 tonnes of soil. The percentage of soil organic matter (SOM) in removed soddy gley soil – 5.22%, that converted in losses of 235 kg of SOM per hectare, and for soddy carbonate soil – 1.67%, that converted in losses of 75 kg of SOM per hectare.

Three scenarios to compensate soil losses from eroded research area presented below:

Organic fertilizers. To compensate the losses of organic matter on the investigation area is urgent to make organic fertilizer input in amount of 66 t/ha in the form of litter manure during five years, the same quantity of 50 t/ha on soddy gley soils and 16 t/ha on soddy carbonate. Given that with input of 50 t/ha manure for the entire period a soddy gley soils get on a 250 kg of Nitrogen, 125 kg/ga of Phosphorus, 300 kg of Potassium in form of active substance; so as soddy carbonate - 80 kg of Nitrogen, 40 kg and 96 kg of Phosphorus and Potassium resp. Furthermore, fertilizers input will fully compensate the loss of elements provoked by wind erosion. The market price of manure adopted in our calculations as 80 UAH per ton, and the cost for fertilizer application were on a level as 10% of the fertilizer cost. Under such conditions the cost of restoring the SOM content to a previous level were for soddy gley soil – 4,400.00 UAH/ha and for soddy-carbonate – 1,408.00 UAH/ha in period of 5 years. The cost of fertilizer application as well were on a level of 10% of the fertilizer cost, which was a 495.81 UAH/ha on soddy gley soils, and 167.46 UAH/ha on soddy carbonate. Before the input of organic manure to compensate the removed content of SOM due to the rapid change in the price of fuel and oil lubricants, the costs for purchasing, transportation, storage and application of soil organic and mineral fertilizers were taken into account as a 15% of additional costs.

Mineral fertilizers. Such measures to improve soil fertility of deflated soils and protect soil from deflation in future are presented by implication and increasing of soil nutrients content till the recommended level by means of mineral fertilizers Ammophos® and Kalimag-30® [8]. To restore a losses of elements the quantity of needed mineral fertilizers input included Ammophos® [$Ca (H_2PO_4) \cdot 2H_2O + 2CaSO_4$] (19% of Phosphorus in active substance) to restore the contents of Phosphorus and Kalimag-30® granulated bulk ($K_2SO_4 \cdot MgSO_4 \cdot 6H_2O$ (with 26% of Potassium in active substance) - to restore the losses of Potassium. The costs of fertilizers input were on a level of 10% of the fertilizer costs and for soddy gley soils they were 45.07 UAH/ha, so as for soddy carbonate – 15.22 UAH/ha.

Considering that Ammophos® contains a 10% of Nitrogen in active substance, we assume that soddy gley soil received additionally 5.26 kg/ha of this element so as soddy carbonate received additionally 1.24 kg/ha but losses of SOM in this way were not compensated at all. Total costs of mineral fertilizers usage to restore a level of fertility were 495.81 UAH/ha and 167.46 UAH/ha for different types of soils as reflected in Table 1.

Table 1. Calculation of costs to compensate nutrient losses with mineral fertilizers input, Pishcha Shatsky district, Volyn region, 2013-2018

Type of mineral fertilizer	Prices for 1 ton of fertilizer, UAH	Content of nutrients, %	Needed portion and cost of fertilizers for a period of five years			
			For soddy gley soil		For soddy carbonate soil	
			Kg	UAH per ha	Kg	UAH per ha
Amophos	5,900	50	52.6	310.34	12.38	73.04
Kalimag-30	2,400	30	58.5	140.40	33.00	79.20
Costs for input of mineral fertilizers			-	45.07	-	15.22
Total	-	-	-	495.81	-	167.46

Source: Own calculation on the basis of prices data for experiment beginning in 2013, NAAS

Perennial grasses. The shift of the intensive land use direction expressed by extensive-grazing termination of the established grasslands by perennial grasses in the form of red clover proved to be a non-profit scenario even with seeds sales in a first year.

To make it profitable from second year of growing we arranged a realization of seeds and hay according to their actual market prices and received conditional profit – 607.1 UAH/ha for system with mineral fertilizer input and 425.0 UAH/ha without fertilizer input. In any of these cases the level of profitability is definitely high with numbers from 48% to 57.5%, comparing with a production costs from 2,125.65 UAH/ha to 2,649.6 UAH/ha after 5 years of grasses seeding application.

The cost of the eroded soil restoration is shown as a result of expected wind erosion losses in terms of the quantity and prices of organic and mineral fertilizers required to compensate the loss of deflation after taking into account the costs of purchasing, transporting, storing and application.

The evaluation of soil deflation preventive measures proved a faster efficiency of the mineral fertilizer input version than involving only perennial grass growing. In this case the extra economic effect (from the sale of seeds and hay grasses) and direct environmental effect in the form of prevented soil losses were obtained from second year of implementation as reflected in Table 2.

Type of deflation preventive variations presented with: 1. The use of organic fertilizers; 2. The use of mineral fertilizers; 3. The growing of perennial grasses.

On an area of 5 ha the seed cost 2.51 UAH/kg resulted in the amount spent of 200.8 UAH in actual prices [11]. The full economic effect on the cultivation of perennial grasses option was 1524 UAH/ha per 2016 year. Furthermore, it should be noted that if in calculation this year were used market prices of 2017-2018 for the seeds of clover at least, the potential economic impact of this measure would have been much higher. After the calculations of specified environmental and economic performance, we have adjusted the increase in deflationary stability of soils after changing the direction of the economic use of land by the termination of grazing plot, creating meadows of perennial grasses like clover with the prospect of obtaining seed in the early years (the recommended frequency - every five years).

After implication of these farming activities on the deflated areas of the local drainage network as a result – some of parameters returned to a level before erosion processes appeared (among such parameters are: soil stability and connectivity of soil particles).

Table 2. Comparison of ecological and economic efficiency of seeding grasses in the conditions of mineral fertilizers and absence of fertilizer

<table>
<tr><th rowspan="3">Number and typ of deflation preventive variations</th><th rowspan="3">Costs for remediation for 5 years, Hr, UAH per ha</th><th colspan="3">Conditional profit (loss) for the 5 years, hr per ha</th></tr>
<tr><th rowspan="2">Economical, hr per ha</th><th colspan="2">Ecological, (Prevented soil losses)</th></tr>
<tr><th>Soddy gley soils</th><th>Soddy carbonate soils</th></tr>
<tr><td>1. Organic fertilizers</td><td>5,808.0</td><td>-</td><td>SOM – 11.5 t/ha; N – 250 kg/ha; P – 125 kg/ha; K – 300 kg/ha</td><td>SOM– 3.76 t/ha; N – 80 kg/ha; P – 40 к kg/ha; K – 96 kg/ha</td></tr>
<tr><td>2. Mineral fertilizers</td><td>663.3</td><td>-</td><td>N – 5.26 kg/ha; P – 26.3 kg/ha; K – 17.55 kg/ha</td><td>N – 1.24 kg/ha; P – 6.19 kg/ha; K – 9.9 kg/ha</td></tr>
<tr><td rowspan="2">3. Perennial grasses</td><td rowspan="2">2,649.6</td><td rowspan="2">1523.9 UAH per ha from products realization on market</td><td colspan="2">Reduce of deflation processes (225 t/ha of soil); additional creation of 15.9 cwt/ ha of biological nitrogen annually.</td></tr>
<tr><td>SOM– 11.5 t/ha; P – 26.3 kg/ha; K-17.55 kg/ha</td><td>SOM – 3.76 t/ha ; P – 6.19 kg/ha; K – 9.9 kg/ha</td></tr>
</table>

Source: Own calculation on the basis of prices data for experiment beginning in 2013, NAAS

It was found that the potential soil loss gradually reduced to 70-75% in the first year and reached 50-55% in the 5th year as a result of some farming practices and changing the purpose of land usage, reduction and regulation of grazing. Implementation of soil-based agriculture as part of deflation preventive activities on these lands enabled to avert the loss of humus from 0.025 to 0.5 t/ha, which indicates their significant environmental effects.

The comparison of characteristics efficiency of preventive deflation measures as use of organic fertilizers, use of mineral fertilizers and growing of perennial grasses presented in Table 3.

In the short term it is advisable to assess the actual extent of deflationary processes in order to determine their causes, furtherly intensify and hold a series of urgent preventive actions in the form of compensation nutrients and annual surveillance of eroded areas.

Table 3. Comparison of characteristics efficiency of preventive deflation measures for soils, Pishcha Shatsky district, Polissya region, 2013-2018.

Parameters	Growing "Red clover" as perennial grasses («Trifolium Pratense» Lat.)	
	with mineral fertilizer input	without mineral fertilizer input
1 year of implementation		
Production costs, UAH per ha	1,656.0	1,430.0
Yield of clover seeds, 100 kg per ha Constant price in 2010, UAH/kg	1.5	
for seeds for hay	500.99 17.11	
The cost of seeds, UAH per ha	751.5	
Conditional income (loss) from sale of seeds, UAH/ha	-904.5	-678.5
2-5 years of implementation		
Production costs for the year, UAH/ha	248.4	173.9
Yields of clover for hay, t/ha	5.0	3.5
The cost of hay, UAH per ha	855.5	598.9
Conditional profit for the year, UAH per ha	607.1	425.0
5 and more years of implementation		
Production costs, UAH per ha	2,649.6	2,125.6
Production value, UAH per ha	4,173.1	3,146.9
Conditional income, UAH per ha	1,523.9	1,021.3
Level of profitability, %	57.5	48.0

Source: Own calculation on the basis of prices data for experiment beginning in 2013, NAAS

CONCLUSIONS

Creation of protective cover using perennial grasses with incorporation of a certain amount of organic or mineral fertilizers is one of optimal ways to restore eroded lands with further selling products in the form of seeds and hay. The implementation of such activities can profit on the 5th year. Such farming practices as changing the direction of land usage from tillage to creating meadows by growing perennial grasses, showed their efficiency due to the relatively small value - 2,650 UAH/ha for the entire period of obtaining conditional income - 1,524 UAH/ha in five years implementation – obtaining clover seeds in the first year and hay for the next four years.

Perennial grasses due to a strong root system are binding the soil particles and reduce the soil remove by wind speed in the surface layer. More optimal in this case is not to cultivate them in the field rotation but in soil protective or fodder crop rotations. By developing a strong root system the soil is well sealed, combined with the Nitrogen fixing bacteria features contributing additional nitrogen annually and clover yield – all of this is enough to stop and prevent deflation processes. The best solution to the issue of deflation, preventive deterioration on agricultural lands and local dusting due to light soil particle size distribution is minimal tilling along with fertilizers application in combination with perennial grasses sowing every 5th year.

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