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Estimating Ecological and Economic Efficiency of Crop Rotation and Pasture Rotation

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***Abstract*—Based on the data of multi-year research (1964 - 2018), the article gives ecological and economic estimation of crop rotation and pasture rotation affected by agrotechnical and agroforestal activities in the steppe and dry steppe of the Volga region. The agrotechnical technique of soil-slotting with mulching increased the profitability of crop and pasture rotation by 22.2%, compared with controlling. Conducting the complex of anti-erosion measures restores the functions of the soil cover, which results in the increased productivity of agricultural crops and grasses, and consequently, in the increased profitability of the applied agrotechnical and agroforestal techniques. According to regression and correlation analysis, profitability is by 48% related to the productivity of agricultural land and costs of crop and grasses production. Soil-slotting with mulching increases soil fertility, land productivity and profitability.**

Keywords—ecology; economy; profitability; crop rotation; pasture; agrotechnology; agroforestal amelioration; regression; correlation

I. INTRODUCTION

The growing global dangers to civilization, along with the modern society progress, instability and the increasing diversity of economic, social and environmental components of development urgently require a national security strategy that will associate the country's political, economic, defence and other needs with a comprehensive environmental rehabilitation. Apparently, the development of the theory and practice of systems security is acquiring not only theoretical, but also practical significance. The most important national interests of Russia include economic and environmental security of the state and its regions that make up the components of national security of the society in general. The national security system should be supplemented by a new security type - economic and environmental security, which will integrate the system of economic and environmental security and will become a tool for achieving the goals of sustainable development.

The problem of drought, soil erosion and anti-erosion conservation remains one of the greatest challenges in Russia. The most remarkable attempts to resolve this problem include V. Dokuchaev's expeditions (1892 - 1899) and sand-ravine expeditions (1908 - 1918), conducted by the Tsar's government, as well as the implementation of plans for nature transformation, adopted in the Soviet period, up to the year 1991 (in 1921, 1948, 1966, 1967, and 1989) [1].

Over 160-year history of protective afforestation in Russia, 5.2 million hectares of protective forest planting were created, 4.35 million hectares of which (84%) - during the Soviet times. As of 2008, approximately 2.5 million hectares (48%) were preserved, with 130 thousand hectares being located in Saratov region [9]. According to the strategy of protective afforestation development, in order to reach 3.8% of agricultural land covered with forests, 2.5% of plough land covered with forests, and 7-9% of slope land covered with forests, it is necessary to have about 7 million hectares of forests in the Russian Federation, with about 300 thousand hectares in Saratov region [9]. Nowadays, 65% of plough land, 28% of hay land and 50% of pastures in the Russian Federation are subject to soil-destroying processes with annual losses of humus of 0.62 t/ha. The problem of linear soil erosion that resulted in over 1 million hectares of current ravine area, more than 8 million hectares of raviney lands and annual increase in the number of eroded lands up to 0.5 million hectares [1] has not been solved yet.

As multi-year research has shown, the acceptable indicators of soil erosion can be achieved due to taking the complex of anti-erosion measures: arranging the territory, agro-, phyto-, chemo-, forest- and hydro-amelioration. Linear erosion is terminated, and the surface wash is reduced due to the creation of anti-erosion barriers - a differentiated ecological net of protective forest planting and hydraulic structures, from the watershed to a hydrographic network. Further reducing of surface erosion in the inter-belt spaces to the acceptable value is possible by means of agromeliorative techniques: phytomelioration, soil-protecting crop rotation, contour strip cropping, and special methods of flow regulation (soil-slotting, mulching, etc.) [1].

Anti-erosion measures should be taken systematically and comprehensively and should be considered at all stages: research, design, creation (construction), and operation. Reconstruction of objects can follow some or all of the stages. Ecological passport projects and anti-erosion objects should undergo environmental expertise [1].

II. OBJECTIVES AND METHODS

With a system-based approach to solving the problem of anti-erosion soil protection, we have designed and laid down research and production experiments on the implementation of anti-erosion conservation complexes in the steppe and dry steppe zones of the Volga region [3]. Ecological and economic assessment of agrotechnical and agroforestal techniques in crop rotation and pastures, is provided based on the productivity of cultures and natural grasses in feed units, t/ha [3]. The calculations on the profitability of agricultural land affected by agrotechnical and agroforestal anti-erosion activities were performed taking into account the prevented damage from erosion, according to the methodology of Russian Research Institute of Agricultural Amelioration [3] and Russian Research Institute of Agriculture and Soil Protection from Erosion [4] [5].

III. RESULTS AND DISCUSSION

In transition to sustainable environmentally-oriented development of the economy of the state and its regions, an improved model of managing natural resources based on ecological, economic and social principles should be implemented. It may guarantee a balanced interaction of people and the environment, including the natural resource potential and environmental factor in the economic activity, and to create a modern, environmentally friendly mechanism of managing the economy.

The profitability of pastures with the use of forest belts and belts of bushes is the highest, due to the low costs of harvesting and transporting grass to the place of feeding - from 204.6% to 390.5% ("Table I" "Table II"). Cultivating cultures in crop rotation and applying agrotechnical techniques (mulching with soil slotting) increases costs, which results in profitability decline to 45.2%, and to 65.0% together with forest belts ("Table I").

TABLE I. ECONOMIC ASSESSMENT OF CROP AND PASTURES ROTATIONS AFFECTED BY AGROTECHNICAL AND AGROFORESTAL TECHNIQUES ON THE SOUTHERN CHERNOZEM LANDS OF THE VOLGA STEPPE (1964-2018)

Crop rotation, pastures rotation	**Agrotechnical and agroforestal techniques**	**Soil erosion *, t/ha**	**Productivity, feed units, t/ha**	**Costs, RUB000's/ha**	**Product evaluation, RUB000's/ha**	**Profit, RUB000's/ha**	**Profitability, %**
Pastoral cropping (vegetative reclamation) (1964-1972)	Control (C)	0.99	0.88	2.26	3.70	1,44	63.7
	Soil-slotting (S) + Mulching (M)	0.61	1.14	3.30	4.79	1,49	45.2
	Forest Belts (FB)	0.46	1.23	2.49	5.17	2,68	107.6
	FB+M	0.18	1.48	3.63	6.22	2,59	71.3
Field crop rotation (1973-2001)	C	2.31	1.28	3.17	5.38	2,21	69.7
	M	1.01	1.77	5.05	7.43	2,38	47.1
	FB	0.88	1.86	3.48	7.81	4,33	124.4
	FB+M	0.30	2.18	5.55	9.16	3,61	65.0
Pastures rotation (2002-2018)	C	2.55	0.42	0.79	1.76	0,97	122.8
	M	0.91	0.58	1.29	2.44	1,15	89.1
	FB	0.34	0.63	0.87	2.65	1,78	204.6
	FB+M	0.08	0.76	1.42	3.19	1,77	124.5
Average for crop rotations and pastures rotation (1964- 2018)	C	1.95	0.86	2.07	3.61	1,54	74.4
	M	0.84	1.16	3.21	4.87	1,66	51.7
	FB	0.56	1.24	2.28	5.21	2,93	128.5
	FB+M	0.19	1.47	3.53	6.17	2,64	74.8

[a] Note. The price of oats: 4.2 RUB000's/t

[b] *Acceptable value of soil erosion – 0.3 t/ha

Product evaluation is calculated based on the oats price of 4.2 thousand roubles/t for the 4th quarter of 2018 [6] [7].

TABLE II. ECONOMIC EFFICIENCY OF AGRICULTURAL LAND AFFECTED BY FOREST BELTS AND BELTS OF BUSHES ON CHESTNUT SOILS OF THE DRY STEPPE OF THE VOLGA REGION

Crop rotation culture. Pasture	Forest belts. Belts of bushes	Productivity, feed units, t/ha	Costs, RUB000's/ha	Product evaluation, RUB000's/ha	Profit, RUB000's/ha	Profitability, %
Spring wheat (crop– 1.06 feed units; chaff – 0.22 feed units)	FB					
	Control	2.09	5.19	8.79	3.60	69.4
	5 H	2.62	5.70	11.00	5.30	93.0
	0-25 H	2.52	5.70	10.58	4.88	85.6
Sunflower (herbage – 0, 15 feed units)	FB					
	Control	2.89	8.73	12.14	3.41	39.1
	5 H	3.30	8.80	13.86	5.06	57.5
	0-25 H	3.15	8.80	13.23	4.43	50.3
Grass (hay – 0.52 feed units)	BoB 1 and GFB 2					
	Control	0.26	0.38	1.09	0.71	186.8
	5 H	0.42	0.42	1.76	1.34	319.0
	field centre	0.35	0.42	1.47	1.05	250.0
Grass (hay)	BoB 1 and BoB 2					
	Control	0.26	0.38	1.09	0.71	186.8
	5 H	0.39	0.42	1.64	1.22	290.5
	field centre	0.30	0.42	1.26	0.84	200.0
Grass (hay)	BoB 3 and FRFB 2					
	Control	0.26	0.38	1.09	0.71	186.8
	5 H	0.49	0.42	2.06	1.64	390.5
	field centre	0.44	0.42	1.85	1.43	340.5
Grass (hay)	On average for belts of bushes					
	Control	0.26	0.38	1.09	0.71	186.8
	5 H	0.43	0.42	1.82	1.40	333.3
	field centre	0.36	0.42	1.57	1.15	273.8

[a] Note: 1) GFB - gully forest belt, FRFB - flow regulating forest belt; BoB - belt of bushes; 2) H - forest belt height (9 m), belt of bushes height (1,4 m). 3) 0 - 25 H - on average, at the distance of 0 - 25 H from the forest belt (225 m).

Taking anti-erosion agro-, phyto-, forest-, hydro-amelioration measures on the existing eroded slopes contributes to the restoration of ecological functions of the soil cover. For this reason, along with calculating the predicted economic result, it is recommended to estimate the restoration of the ecological and energy potential of the soil (primarily humus), i.e. the prevented damage [8]. Within the system of forest belts and soil-slotting with mulching in inter-belt spaces, soil erosion may reach the acceptable level of 0.3 t/ha ("Table I").

Performing the activity of soil-slotting with mulching reduced profitability values by 22.7%, compared to control without forest belts, and increased by 0.4% with forest belts. The use of forest belts only, increases the profitability by 54.1%, but in this case the value of acceptable soil loss is not achieved (0.56 t/ha> 0.3 t/ha). Mulching the slots with shredding, increases profitability by means of improving the capacity of agricultural crops and pasture grasses due to the mineralization of mulch. The productivity of agricultural land under the influence of forest belts and belts of bushes is most profitable, it amounts for 390.5% due to the fact that the annual costs of planting maintenance are determined by depreciation costs (10% of plantings cost). These costs are much lower, compared to the cost arranging soil-slotting with mulching (2 times less), which is demonstrated in Tables 1 and 2. However, since soil erosion exceeds the acceptable values without agrotechnical and agroforestal techniques, in the nearest 5 - 10 years the productivity of agricultural crops and pasture grasses will be decreasing by 1.5 - 2 times, as a result of surface wash. Consequently, the land profitability will decrease [9].

The projected profitability of agricultural lands and pastures, calculated according to the methodology of the Russian Research Institute of Agricultural Amelioration [10] and the Russian Research Institute of Agriculture and Soil Protection from Erosion [4], can be found in "Table III".

However, the projected profitability without a taking complex of agrotechnical and forest amelioration activities will decrease by 50.6%, from 74.4% to 23.8%; but with creating the forest belts and mulching slots it will increase by 166.4%, from 74.8% to 241.2% ("Table III").

TABLE III. LAND PROFITABILITY FOR AVERAGE CROP AND PASTURE ROTATION FOR 1964-2018

Agrotechnical and agroforestal techniques	Soil erosion *, t/ha	Productivity, feed units,	Costs, RUB000's/ha	Product evaluation,	Profit, RUB000's/ha	Profitability, %
Control (C)	1.95	0.86 0.57	2.07 1.93	3.61 2.39	1.54 0.46	74.4 23.8
Soil-slotting (S) + Mulching (M)	0.84	1.16 1.74	3.21 3.31	4.87 7.31	1.66 4.00	51.7 120.8

Agrotechnical and agroforestal techniques	Soil erosion *, t/ha	Productivity, feed units, t/ha	Costs, RUB000's/ha	Product evaluation, RUB000's/ha	Profit, RUB000's/ha	Profitability, %
Forest Belts (FB)	0.56	1.24 1.86	2.28 2.33	5.21 7.81	2.93 5.48	128.5 235.2
FB+M	0.19	1.47 2.94	3.53 3.62	6.17 12.35	2.64 8.73	74.8 241.2
FB+ BoB (belts of bushes, pasture)	0.22	0.26 0.43	0.38 0.42	1.09 1.82	0.71 1.40	186.8 333.3

[a] Note. The numerator and denominator - the prevented environmental and economic damage from soil erosion not included and included, respectively.

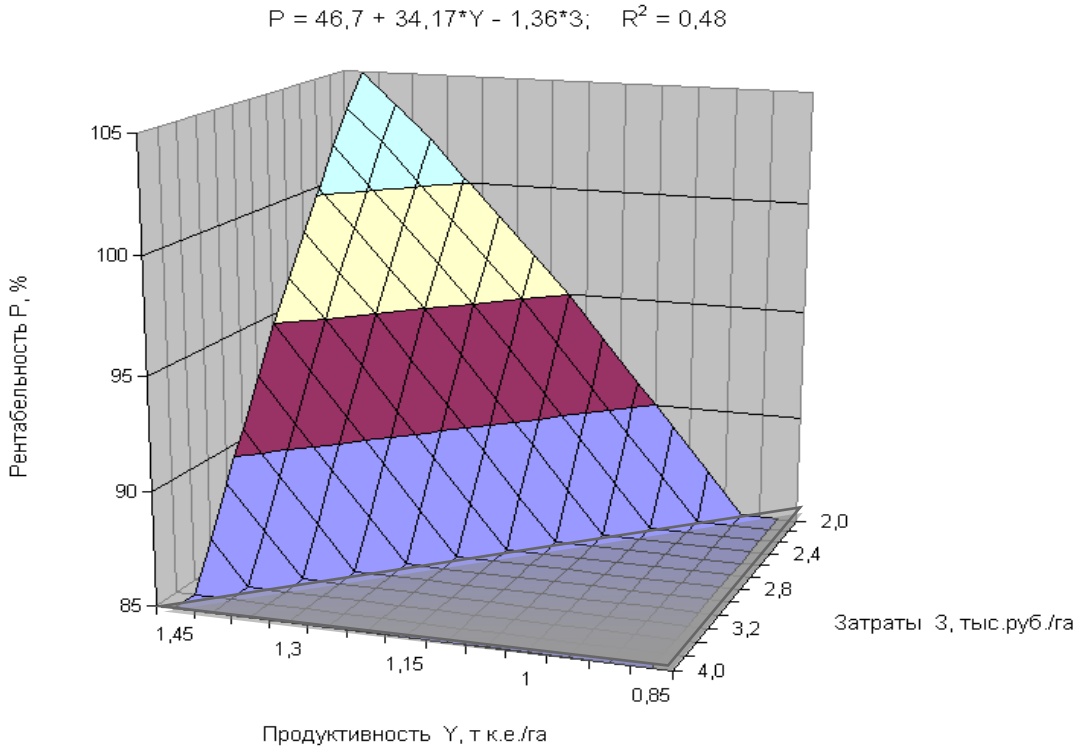

Fig. 1. Profitability of agrotechnical and agroforestal measures depending on the land productivity and production costs.

Regression and correlation analysis has proved that profitability is by 48% related to the productivity of agricultural land and costs of crop and grasses production (the correlation coefficient – 0.7).

IV. Conclusion

During the transition to sustainable development of state and regional economy, it is proposed to use the improved model of natural resources management based on social and socio-economic principles. The implementation of such a model will ensure a balanced interaction of people and the environment within human economic activity; the possibility of full integration of natural resources potential and the environmental factor into economic activity and creating a modern environment-oriented mechanism for managing the regional economy in general and the economy of its industry in particular [11].

Soil-slotting with mulching reduces the profitability of crop rotation cultures and pasture grasses by 22.7%, as compared with the results of land were no agrotechnical and agroforestal activities are performed. With no soil-slotting with mulching, soil erosion in inter-belt spaces does not reach an acceptable level of 0.3 t/ha, which leads to reduction of soil fertility and land productivity by 1.5 - 2 times, and consequently, to a decrease in profitability.

Profitability is by 48% related to the costs and productivity of agricultural land.

Recommendations may include the following:

- On the slopes of 3 - 50, between the 300 m forest belts create mulched slots at 1,4 m intervals;
- Use a mulch dose from shredding 5 t/ha;
- In the inter-belt space of 300 m alternatively create three or four double-row belts of bushes.

The crisis phenomena of the present time undoubtedly influence the state of the social-ecological-economic system, manifesting themselves in two ways. On the one hand, the environmental stress is reducing, as so are the production volumes. On the other hand, in times of crisis, all economic entities curtail their nature-protecting activities, which leads

to increased anthropogenic and technogenic pressure on the ecosystem [11].

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