Evaluation of the Effectiveness of Agroforestry in the South of Russia with the Assistance of an Information Product

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Abstract: In Russia, the era of initial capital accumulation for society has ended and the problems of sustainable development have become more urgent for government and business structures than the commercial profitability of the crop. The main trend in achieving sustainable land use in the country has been the inclusion of measures for forest reclamation of arable land not only at the regional, but also at the federal level. One of the main parameters for assessing forest reclamation complexes in the arid zone of Russia is the study of their ecological and economic efficiency based on the assessment of ecosystem services provided by trees to the agricultural sector. The article substantiates the advantage of agroforestry in providing environmental benefits to protect the soil from degradation in comparison with its agronomic benefits in the form of providing commercial income to farmers by increasing the yield of crop production in fields with elements of agroforestry. The interface of the developed software with input and output data "Economic evaluation of forest reclamation ecosystem services" is presented.

1 INTRODUCTION

The acute problem of increasing environmental pollution in the country, disruption of the functioning of natural ecosystems as a result of the depletion of biological resources requires the activation of all measures capable of forming a protective mechanism that counteracts the destruction of nature. Agroforestry occupies a worthy place among such events.

The positive role of agroforestry in increasing agricultural production in forested fields is well known. This is ensured by the creation of a special favorable microclimate by trees on inter-lane protected land plots. At the same time, the most modern and most important importance of agroforestry lies in its role in providing sustainable land use – preventing degradation of the agricultural sphere and improving the basic characteristics of the quality of the natural environment on adjacent lands. Systems of protective forest strips forming agroforest complexes on the territory of arid low-forest agricultural areas with frequent manifestations of negative natural anomalies perform exceptional climate-regulating, soil-protective and stabilizing functions. Agroforestry transforms open landscapes and provides many ecosystem services (Cialdella *at al*, 2023).

Protective forest plantations determine the physiognomy of the agricultural landscape and significantly affect agricultural production. In this regard, it remains relevant to quantify this impact by determining the economic value of ecosystem services of trees.

In the conditions of the digital economy, automation of evaluation procedures by writing source code for application development is of particular relevance.

2 RESEARCH METHODOLOGY

The assessment of ecosystem services of agroforestry was carried out using simulation modeling (the size of the model agroforestry landscape is 2000 x 2000 meters). Both the well-known standards for the design of protective forest plantations and the

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scientific achievements of recent years in the field of agroforestry were used (Manaenkov, 2018).

The benefits from the functioning of protective forest plantations were considered as ecosystem goods and services produced by agrocenoses and stands of forest plantations. The economic assessment of these benefits was carried out in accordance with its generally accepted methodology (Plottu, Plottu, 2007) and the CICES classification of ecosystem services (Haines-Young, Potschin, 2018).

The economics of environmental benefits consisted in assessing of the Regulation and maintenance ecosystem services produced by the forest components of the agroforest landscape and having an Indirect use Value. The main evaluation method is Replacement cost: fertilizers value.

The economics of agro-economic benefits consisted in the assessment of Provisioning ecosystem services produced by agrocenoses in forested fields and having Direct use Value. The main evaluation method is Market prices: grain crops.

The economic assessment was based on the calculation of the value of ecosystem services on an annual average, that is, for the entire lifetime of forest plantations. The discount rate is assumed to be 2% (Korneeva, 2022).

The research was carried out in relation to the natural and climatic conditions of the arid zone in the south of Russia. It is located within three zones – forest-steppe, steppe and dry-steppe. The geographical location of these zones determines the high continentality of the climate and its aridity, increasing from the northwest to the southeast of the region (Shashko, 1985).

All values have been standardized to USD in 2021 prices using an exchange rate adjusted for purchasing power parity (PPP, 2023). Unit values (ha of agroforest landscape/year) were obtained by dividing the area allocated for protective forest plantations by the total area of the agricultural landscape to be afforested.

The calculation apparatus (calculator) of the main economic indicators of ecosystem services of agroforestry is presented in the form of a console CLI application developed by writing source code in a compiled, statically typed general-purpose programming language C++.

3 RESULTS AND DISCUSSION

3.1 Assessment of Regulating and Maintenance of Ecosystem Services Produced by Forest Components of Agroforest Landscape

The ecological benefits of agroforestry are manifested, first of all, in a favorable soil-protective anti-erosion effect on the adjacent territory (Korneeva, 2020). Many of the world's leading researchers have confirmed and emphasized the exceptional importance of this ecosystem service for ensuring the sustainable development of the agricultural sector in many agricultural regions (Lund, 2001, Wilson, Lovell, 2016, Rulev, Pugachova, 2019). At the same time, the sustainable development of land use involves the placement of protective forest plantations in such a way that they completely block the negative anomalies of nature that destabilize agricultural production. With regard to protective forest plantations, this implies a reduction of typical inter-lane spaces by at least 2 times (Корнеева, 2021).

The positive soil protection effect of protective forest plantations in the adjacent territory in the form of regulation and maintenance of ecosystem services of agroforestry is estimated by the direct prevented damage to farmers resulting from soil degradation, the corresponding amount of nitrogen, phosphorus and potash fertilizers necessary to compensate for the loss of these trace elements in the soil layer, and the costs of their delivery.

Calculations show that the value equivalent of this ecosystem service increases with the increase in the improvement of soil and climatic conditions (Table 1). Thus, in the south of Russia, provided that trees fully protect agricultural land (reducing typical interband distances by 2 times from 30 to 15 heights (H) of the stand), the value of ecological Regulating and maintenance of ecosystem services when using long–lasting forest crops, it is USD 1932-USD 3381. The use of precocious species increases the value of this ecosystem service of trees on an average annual basis by 5-8%.

In the direction from the dry steppe to the forest steppe, the indicator of the value expression of ecosystem services increases almost 2 times together with the estimated height of the forest stands from 10 to 18 meters.

Table 1: Assessment of the ecological ecosystem service provided by agricultural landscapes with full forest protection, ha of agroforest landscape/ year (on average, over the lifetime of trees).

Natural zone	Regulation and maintenance services: soil nutrients

	compensation cost
Durable breeds	
Forest steppe	USD 3381
Steppe zone	USD 3036
Dry Steppe	USD 1932
Precocious breeds	
Forest steppe	USD 3664
Steppe zone	USD 3264
Dry Steppe	USD 2029

3.2 Assessment of the Provisioning Ecosystem Services Produced by Agrocenoses in Forested Fields

Ecosystem services of agroforestry in the form of commercial benefits from the sale of agricultural products provided by protective forest plantations are estimated through an increase in gross crop production in fields with full forest protection.

It is well known that crop increases reach 2.5-3.5 centner /ha, depending on the natural zone, which is 10-30% of the yield obtained in traditional agriculture (Tribunskaya, 1990). The increase in yield is also an indirect expression of the prevented damage from the destruction of the soil cover as a result of negative natural anomalies (Pugacheva, 2021).

The study of agro-economical efficiency of agroforestry showed that the monetary value of its Provisioning ecosystem services in the forest-steppe–dry steppe range is equal to USD 359-USD 455 (Table 2). This is 5.0-9.4 times less than the cost of environmental benefits of agroforestry with equal costs for planting and growing forest crops.

Table 2: Assessment of agronomical ecosystem services provided by agrocenoses on forest-reclaimed fields with full forest protection, ha of agroforest landscape/ year (on average, over the lifetime of trees).

Natural zone	Provisioning services: Market prices: grain crops
Durable breeds	
Forest steppe	USD 359
Steppe zone	USD 449
Dry Steppe	USD 380
Precocious breeds	
Forest steppe	USD 366
Steppe zone	USD 455
Dry Steppe	USD 386

3.3 A command-line interface (CLI) application «Economic evaluation of forest reclamation ecosystem services» in C++

Based on the mathematical apparatus developed by the author for calculating the value of ecosystem services of agroforestry, depending on zonal-spatial and temporal factors, a console CLI application in the C++ programming language was developed.

The computer program allows you to calculate the value of Regulation and maintenance and Provisioning ecosystem services depending on the protective forest cover (F, %), the natural zone, which is characterized by the design height of forest stands (H, meters) and operational life of trees (A, years).

The application input interface is shown in Figures 1 and 2.

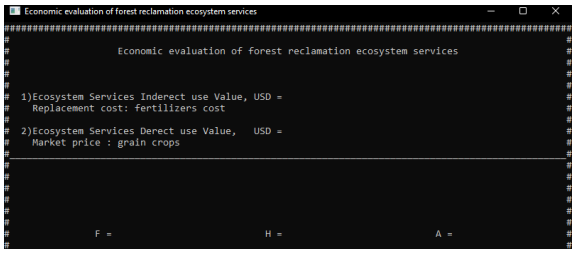

Figure 1: Application Interface «Economic evaluation of forest reclamation ecosystem services».

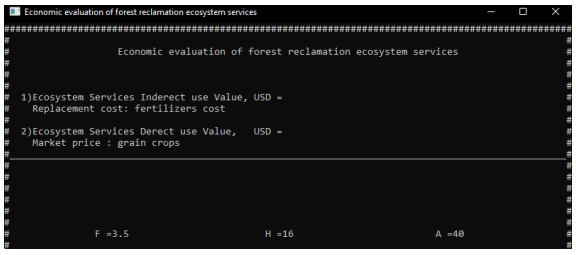

Figure 2: Application Input Data Interface «Economic evaluation of forest reclamation ecosystem services».

The output interface is shown in Figure 3.

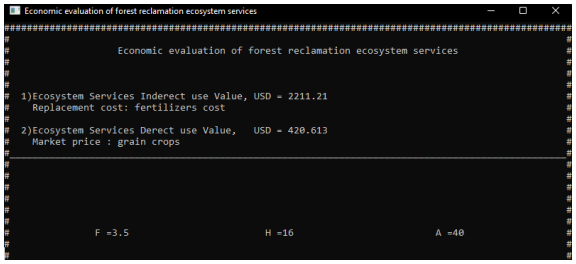

Figure 3: Application Output Interface «Economic evaluation of forest reclamation ecosystem services».

This is the monetary expression calculated by the program of the studied Regulation and maintenance and Provisioning ecosystem services of agroforestry in dollars at prices of 2021, adjusted to the local currency exchange rate by purchasing power parity (PPP, 2023).

4 CONCLUSIONS

Thus, it should be noted that the importance of agroforestry for agricultural regions is indisputable. At the same time, the value of benefits obtained through ecological ecosystem services of the forest component in the fields is several times higher than the value of material benefits of agrocenoses, due to which farmers in forested areas receive commercial income. This indicates that agroforestry should first of all be considered from the perspective of ensuring sustainable land use and all concepts for the development of agroforestry activities in regions subject to land degradation should be based on this conclusion.

When designing measures for forest land reclamation both at the regional and federal levels, it is advisable to use the software developed by the author to evaluate the effectiveness of these measures, installed on a PC in the form of an independent program and does not require a special compiler in the C++ programming language. Its use will make it possible to pre-estimate the value of Regulation and maintenance and Provisioning ecosystem services provided by trees to agricultural production, depending on different afforestation regimes of fields, both in the zonal-spatial and temporal vector of research.

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