Res. Crop. **24** (2): 373-377 (2023) DOI: 10.31830/2348-7542.2023.ROC-953
Printed in India

Role of agroforestry in increasing the economic fertility of arable lands in arid regions

E. A. KORNEEVA*

Federal Scientific Center of Agroecology
Complex Melioration and Protective Afforestation
Russian Academy of Sciences, 400062, Volgograd, 97, University Ave., Russia
**(e-mail: korneeva.eva@list.ru)*

(Received: March 29, 2023/Accepted: May 05, 2023)

ABSTRACT

The solution to the problem of agricultural producers' rational and effective use of land resources depends heavily on the economic evaluation of firms' resource potential. One of the main resources of enterprises in the production process is fixed capital or fixed production assets, of which protective forest stands are an integral part. Solving the tasks of increasing the economic fertility of arable lands in arid areas, provides a significant increase in agricultural production. In order to study this issue in more detail, a study was conducted during 2021 at the laboratory of Mathematical Modelling of the Federal Scientific Center for Agroecology, Integrated Melioration and Protective Afforestation of the Russian Academy of Sciences, located in the Volgograd region (Russia), to identify the role of protective forest plantations in increasing the economic fertility of arable land. To do this, we conducted a score assessment of its main indicators – yield and net income from the sale of wheat – for various variants of land objects with open and forested spaces within the main natural zones of the Volgograd region (Russia). The comparison showed that under all spatial-zonal scenarios, forested land has a much greater potential for improving the fertility of arable land than open land. At the same time, the benefits received from the forest reclamation of fields are many times higher than the costs of this event, which indicates the economic feasibility of measures in the region.

Key words: Agroforestry, arable land, economic fertility, net income, yield

INTRODUCTION

Agroforestry is an agricultural model combining food production of trees and plants with ecosystem services, such as carbon capture (Hanif *et al.*, 2015; Cialdella *at al.*, 2023). Variations in soil and climatic conditions, the diversity of the geological structure of the territory determine the diversity of types of protective forest plantations in different regions and countries (Immanuel and Rao, 2021). Regardless of the definitions of agroforestry and the specifics of its implementation in different countries, the World Bank and the Food and Agriculture Organization (FAO) have included this type of economic activity in their forest policy as an integral system of sustainable land use that produces private and public goods (Current *et al.*, 1995, Hillbrand *et al.*, 2017).

The main objectives of agroforestry are the provision, conservation and rational use of land resources, primarily arable land. The role of protective forest stands in preserving, increasing soil fertility, as well as increasing crop yields in forested fields is well known. Agroforestry also occupies a particularly important place in the fight against land desertification, which has become global in recent years. The fight against this natural and anthropogenic phenomenon is carried out in all developed countries of the world, consumes considerable resources and requires reliable scientifically based estimates and forecasts (Manaenkov and Korneeva, 2021).

Thus, foreign experience testifies to the high efficiency of agroforestry in protecting arable land from degradation, manifested in the form of wind and water erosion (van Noordwijk, 2021). In recent years, both in developed and developing countries of the world, there has been a tendency to increase the volume of agroforestry activities (Gosling *et al.*, 2020).

In Russia, until recently, despite the negative state of the soil cover similar to other countries, the problem of economic justification of the effectiveness of forest reclamation measures makes it difficult to implement them and is the reason for the low attractiveness for land users. Last but not least, this is caused by the features of the political system in the country.

Thus, in the pre-reform period (until 1990), agroforestry plantations were taken into account as part of the fixed production assets of agricultural enterprises along with perennial plantings and were formed at the expense of centralized capital investments. Their reproduction was ensured by depreciation charges, which were included in the cost of additional products obtained due to the positive impact on the soil and climatic complex.

After the reform of agricultural production, most collective and joint farms turned into peasant farms. At the same time, protective forest plantations ceased to be taken into account on the balance of farms, and thus turned out to be ownerless. This was the reason for the cessation of care for forest strips, their death from logging and fires. The lack of government support has led to a sharp decline in the volume of planting and forestry care measures.

Currently, the high demand in agriculture for ecological "green" agroforestry services actualizes this type of economic activity in Russia. Special attention was given to him relatively recently, when discussing issues of mitigation of the effects of global climate change and adaptation to them. The realization that protective forest plantation systems are suitable for diversifying farm incomes while providing environmental services and benefits for ecosystems (Korneeva, 2022) has also increased their susceptibility on the part of landowners. Thus, until recently, protective afforestation remained a little popular practice on the territory of Russia, including due to the imperfection of the methodology for evaluating its effectiveness.

In the article, in the context of the natural zones of the Lower Volga region, the effectiveness of agroforestry in increasing the economic fertility of lands is analyzed by means of a point assessment of arable land protected by forest plantations and open arable land plots using various methodologies for this assessment – crop yields and net income from the proceeds of its sale.

Thus, the purpose of the study was a comparative analysis of the zonal-spatial efficiency of agroforestry measures based on a score assessment of the fertility of forested and open arable land.

MATERIALS AND METHODS

The work was carried out in 2021 on the basis of the laboratory of Mathematical Modelling of the Federal Scientific Center of Agroecology, Complex Melioration and Protective Afforestation of the Russian Academy of Sciences, located in the Volgograd region (Russia).

The Volgograd region is located within three zones – steppe, dry-steppe and semi-desert. The geographical position 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).

The steppe zone (Novoanninsky district, Volgograd region) is characterized as semi-arid and arid, medium and above average provided with heat, with a predominance of medium-sized chernozems. The sum of active temperatures above +10°C is 2719°C. The average annual precipitation is 389 mm. The steppe zone belongs to the band of mid-late and late cultures. The main growing season is long (up to 160 days), the frost-free period is shorter than the main one.

The dry-steppe zone (Ilovlinsky district, Volgograd region) is characterized as very arid, above average and highly provided with heat, with a wide distribution of dark chestnut and chestnut soils. The sum of active temperatures above +10°C is 3090°C. The average annual precipitation is 355 mm. The dry-steppe zone belongs to the band of mid-late and late crops. The main growing season is long and very long (up to 170 days), the frost-free period is shorter by 10 days of the main one.

The semi-desert zone (Pallasovsky district, Volgograd region) is characterized as semi-dry, above average and highly provided with heat, with the dominance of light chestnut soils. The sum of active temperatures above +10°C is 3400°C. The average annual

precipitation is 180 mm. The dry-steppe zone belongs to the band of mid-late and late crops. The main growing season is long and very long (up to 175 days), the frost-free period is shorter by 10-20 days of the main one.

The main method of study was methodologies based on a score assessment of open and protected forest areas, as well as a systematic analysis of the data obtained.

The main criteria for assessing the economic fertility of land were the yield and net income from the sale (at equal costs) of the basic agricultural crop – wheat.

The average annual yields of this grain crop were obtained for the corresponding administrative districts included in the studied natural zones (Table 1). Biophysical quantitative data on yields were obtained in the Department of Agricultural and Environmental Statistics of the State Statistics Service for the Volgograd region for 2021.

Net income from the sale of wheat/ha ha of field was calculated as the difference between the three-year (2019-2021) average selling price for wheat of class 3 (Agrovestnik Portal, 2021) and the average cost of its cultivation, which is about 60% of total revenue. Income from agroforestry, expressed in the form of additional products, was reduced by the cost of creating and growing protective forest plantations. So, in arid plain conditions, they, respectively, amount to EUR 20.8 and EUR 2.7 (Korneeva and Belyaev, 2022). Translated into dollars, this is equivalent to USD 22.3 and USD 2.9. In addition, the cost of additional crop production included the cost of its cleaning and refinement (30% of the cost of production).

The assessment was made on a 100-point scale. The highest yield on the best soils was taken for 100 points. The score of the studied area (P) was based on the following formula (Mayorov *et al.*, 2006):

$$P = \frac{C_i \cdot 100}{C_0}$$

Where, Ci is the yield (or net USD income from the sale of agricultural products) on the studied plot in centners/ha, C_0 is the yield (or net USD income from the sale of agricultural products) on the reference plot, centners/ha.

All values have been standardized to USD ha/year in 2021 prices using an exchange rate adjusted for purchasing power parity (OECD, 2022).

RESULTS AND DISCUSSION

Usually, when it comes to the fertility of agricultural land, they always mean economic fertility, which is characterized as a special property of the soil, depending on the productive forces. In this sense, economic fertility is understood as an artificial increase in soil fertility, which gives an economic effect of varying degrees on different soils (Solovyova, 2009). Natural fertility is only the basis of economic fertility and is characterized by the genetic properties of the soil itself, as well as the climatic conditions of zonal soil formation (Pugacheva, 2021).

Thanks to the development of science and technology, the improvement of agrotechnical techniques, the use of machines, the introduction of fertilizers, land reclamation and other measures, the natural fertility of the soil increases and thus artificial fertility is created – this is the fertility of the soil created as a result of artificially produced improvements in the composition of the soil. Economic fertility is created solely as a result of human labour activity and expresses the unity of natural and artificial fertility (Mayorov *et al.*, 2006).

A set of measures aimed at improving

Table 1. The score of forested and open arable land of the Volgograd region according to the average annual yield of wheat/ha of sown area

Natural zone	Land object without agroforestry system		Land object with a system of agroforestry		Difference	
	Annual yield (kg/ha)	Points	Annual yield (kg/ha)	Points	Annual yield (kg/ha)	Points
Steppe zone	2090	77	2440	90	350	13
Dry steppe zone	1640	61	1970	73	330	12
Semi-desert zone	1500	55	1750	65	250	10
On an average in the Volgograd region	1810	67	2130	79	320	12

the water, physical regime of soils, increasing nutrients by applying fertilizers made it possible to progressively increase economic fertility. The lack of moisture in arid conditions, the presence of large areas of saline, eroded lands reduced this fertility. Therefore, the development of irrigation, agroforestry and other measures aimed at the accumulation of soil moisture are an effective method of increasing the fertility of the lands of the corresponding zone (Solovyova, 2009).

The study of the role of protective forest plantations in changing soil economic fertility, conducted using various methodologies – a point-based assessment of crop yields and a point-based assessment of net income from the sale of these crop products, showed the following results.

Calculations showed that when using the first methodology (Table 1) in all natural areas of the Volgograd region, on forested fields with a system of forest strips, the evaluation scores were much higher than in open spaces. Thus, the system of protective forest plantations increasesd the economic fertility of arable land, expressed in the form of an increase in the yield of crop production (wheat), depending on the natural zone from 21 to 24 centners/ha (steppe zone) and from 15 to 18 centners/ha (semi-desert zone), that is, by 10-13 points. In the whole region, this excess was 12 evaluation points.

The use of another methodology for scoring land fertility – by net income from the sale of crop products (Table 2) showed that despite certain costs required for agroforestry system, due to the creation of favourable microclimatic conditions by trees in forested fields and the production of additional crop production, the estimated scores of net incomes received from forested arable land also exceeded similar indicators for open arable land by 17-20%.

Thus, the amount of net income received from the sale of crop products (grade 3 wheat), with the traditional method of cultivation in the Volgograd region, was USD 1785 - USD 2487 (zonal vector: semi-desert zone-steppe zone) per one hectare of arable land. In terms of evaluation points, this, respectively, were 49-68 points. Land plots with elements of agroforestry were estimated by net income at 31-43 points higher than land without these elements. This significantly exceeded the indicators obtained using the first scoring methodology by 3.1-3.4 times.

Zonal dynamics according to two scoring methodologies (average annual wheat yield and net income from its sale) indicated that in the direction from the northwest to the southeast of the Volgograd region, these indicators decreased by almost 1.5 times. This was due to the harsh natural conditions that were formed under the influence of increasing aridity of the climate in this direction.

Thus, the economic fertility of land is an important indicator of the effectiveness of agroforestry measures. In the agricultural landscapes transformed with the help of protective forest plantations, permanent protection of the soil from loss of the fertile layer and obtaining sustainable yields will be ensured, especially in dry farming areas.

Despite the various methodologies used in the article (both in terms of yield and net income) for comparative assessment of forested and open arable lands, the estimated scores of forested land plots slightly exceeded similar indicators of open plots. This indicated the high profitability of agroforestry activities not only in the research region, but also in other arid regions, especially where there was a very high risk of land degradation and desertification.

The main motivating indicator of the creation of forest plantations for land users may

Table 2. The score of forested and open arable land in the Volgograd region based on net income from the sale of wheat/ha of sown area

Natural zone	Land object without agroforestry system		Land object with a system of agroforestry		Difference	
	Net income (US $)	Points	Net income (US $)	Points	Net income (US $)	Points
Steppe zone	2487	68	2904	111	417	43
Dry steppe zone	1952	53	2344	94	392	41
Semi-desert zone	1785	49	2083	80	298	31
On an average in the Volgograd region	2154	59	2535	98	381	39

be the opportunity presented in the article to see future economic benefits in the form of an average annual wheat yield and net income from its sale. At the same time, the difference in points when using the second scoring methodology was more significant than when using the first methodology, which indicated not only the ecological, but also the high commercial efficiency of agroforestry in arid regions.

CONCLUSION

Thus, the results of the study show that agroforestry is a highly effective measure to increase the economic fertility of agricultural land, which contributes to improving the efficiency of the agricultural sector and provides commercial income to farmers. This is a sufficient reason to increase the protective forest cover in sparsely wooded agricultural regions.

ACKNOWLEDGEMENT

The work was carried out within the framework of the topic of the state assignment of the Scientific Research Center of Agroecology of the Russian Academy of Sciences No. FNFE-2022-0015: "Management of desertification processes in arid territories based on monitoring data of soils, climate and lands subject to desertification by mathematical modelling methods".

REFERENCES

Agrovestnik Portal (2021). The trading platform of the Agrovestnik available online: https://agrovesti.net/news/indst/tseny-na-osnovnye-zernovye-kultury-na-01-10-2021-goda.html (accessed on 1 March 2023).

Cialdella, N., Jacobson, M. and Penot, E. (2023). Economics of agroforestry: Links between nature and society. *Agroforest Syst.* **97**: 273-77.

Current, D., Lutz, E. and Scherr, S. (1995). *Costs, Benefits and Farmer Adoption of Agroforestry: Project Experience in Central America and the Caribbean.* World Bank Group, Washington D. C., USA. pp. 212.

Gosling, E., Reith, E., Knoke, T., Gerique, A. and Paul, C. (2020). Exploring farmer perceptions of agroforestry via multi-objective optimization: A test application in Eastern Panama. *Agroforest Syst.* **94**: 2003-20.

Hanif, M. A., Bari, M. S. and Rahman, A. (2015). Potentiality of carbon sequestration by agroforestry species in Bangladesh. *Res. Crop.* **16**: 562-67.

Hillbrand, A., Borelli, S., Conigliaro M. and Olivier, A. (2017). *Agroforestry for Landscape Restoration: Exploring the Potential of Agroforestry to Enhance the Sustainability and Resilience of Degraded Landscapes*. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. pp. 22.

Immanuel, R. R. and Rao, G. B. S. (2021). Production potential of groundnut under palmyra (*Borassus flabellifer*) based agroforestry system in coastal red soils of Tamil Nadu. *Crop Res.* **56**: 105-10.

Korneeva, E. A. (2022). Economic assessment and management of agroforestry productivity from the perspective of sustainable land use in the south of the Russian plain. *Forests* **13**. *doi: org/ 10.3390/f13020172.*

Korneeva, E. A. and Belyaev, A. I. (2022). Assessment of ecological and economic efficiency of agroforestry systems in arid conditions of the lower Volga. *Forests* **13**. *doi.org/ 10.3390/ f13081248.*

Manaenkov, A. S. and Korneeva, E. A. (2021). Bio-geographic aspects of estimating the efficiency of arable lands protection with forest belts. *Vestnik Moskovskogo Universiteta, Seriya Geografiya* **5**: 48-54.

Mayorov, Y. I., Malakhov, A.V. and Aseeva, A. A. (2006). *Economic Analysis of the Economic Activity of Agricultural Enterprises.* Publishing House of the Kursk State Agricultural Academy, Kursk, Russia. pp. 296.

OECD (2022). Purchasing Power Parities (PPP) (Indicator). Available online: https://doi.org/10.1787/1290ee5a-en (accessed on 14 March 2023).

Pugacheva, A. M. (2021). The influence of homogeneous stands on the recovery of secondary virgin lands in agroforestry landscapes of dry steppes. *Biol. Bull.* **2**: 184-92.

Shashko, D. I. (1985). *Agro-climatic Resources of the USSR.* Hydrometeoizdat, Leningrad, Russia. pp. 248.

Solovyova, N. V. (2009). Substantiation of factors affecting the economic fertility of the soil. *Agroengineering* **8**: 69-71.

van Noordwijk, M. (2021). Agroforestry-based ecosystem services. *Land* ***10.*** *doi: org/ 10.3390/land10080770.*