

# Expanded Reproduction of Soil Fertility: Theoretical and Practical Aspects

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**Abstract** – The research aims at studying the expanded reproduction of soil fertility as the main factor of inclusive green economy adoption in agriculture. Ecological, economic, and social aspects of expanded reproduction of soil fertility are investigated from the viewpoint of the theory of reproduction, which shows a predominantly inverse correlation between capital reproduction and soil fertility reproduction in conventional agriculture. Organic agriculture, inherently characterized by low yields of agricultural crops at increased production costs, at the same time ensures an expanded reproduction of soil fertility. However, expanded reproduction of capital is possible only through the introduction of intensive innovative technologies allowed by national and international regulations for the production of organic food. Therefore, organic farming is of particular science intensity in terms of biological protection of plants, resource-saving regimes and irrigation technologies, the use of more efficient and environmentally friendly organic fertilizers as compared to manure. Scientific and industrial cooperation in the implementation of these end-to-end technologies will create the reverse effect of decoupling resulting in the loss of direct correlation between expanded reproduction of soil fertility and reduction in farmers' capitals. Due to this, the practice will be widely applicable in the sustainable development of organic farming and green economy.

**Keywords:** *soil fertility, organic farming, decoupling effect, end-to-end technologies, scientific and industrial cooperation in organic farming*

## I. INTRODUCTION

Agricultural production combines environmental, economic and social aspects, and therefore has special social importance and social responsibility, which makes it a key area for inclusive green economy development. In this context, according to the UN interpretation [1], inclusiveness implies ensuring equality of opportunities for the rural population to access social and economic benefits,

which creates the need for their involvement in generating new added value. As for social responsibility, it turns out to be closely linked to the need for sustainable development of agrobiocenoses for the benefit of future generations. In this regard, the expanded reproduction of soil fertility in general and organic farming, in particular, can be considered as a means of solving both environmental and socio-inclusive problems, since it is the developing organic agriculture that is able to provide effective market niches for farm households, while conventional agriculture becomes complicated for them due to the obviously unprofitable position in competition with agricultural corporations.

From the theoretical viewpoint, sustainable agriculture can exist only in the systemic unity of crop production and animal breeding. But in fact, animal breeding and crop production are controversial processes, since the latter is used to ensure the former. However, animal breeding still creates conditions for further development of crop production by producing manure as the basis for soil fertility reproduction. As early as in the 19th century, A.V. Engelhardt, one of the founders of Russian scientific agronomy, noted the key difference between the dynamics of fertility in landowner fields and peasant fields. Landowners having large-scale and advanced for their time production of grain crops, subjected agrobiocenoses to a steady decline in soil fertility through the removal of nutrients with the crops. Peasants, in their turn, mainly had small-scale or non-commodity livestock and used to annually apply manure to the fields, thus increasing their productivity [2].

Thus, anthropogenic factors of agrobiocenosis can both contribute to the growth of soil fertility and humus accumulation, and destroy the humus layer. With regard to the very concept of soil fertility, it should be noted that in the economic literature, many types of soil fertility have been distinguished: natural, effective, potential, economic.

The following typology has been used to unify the terminology: natural fertility as a result of soil formation in natural biogeocenoses; cultural (anthropogenic) fertility as a materialized result of lands' cultivation; and potential fertility, combining both these categories. Effective fertility reflects the realization of the potential one in a particular agrocenosis on the background of a certain technology. Its expression in value categories is a part of the theoretical apparatus of economics. Simple reproduction means relative stability of physical and chemical characteristics of soil, quantitative and qualitative indicators of humus layer over time in the process of agricultural use of agrobiocenosis for the selected period of time. In the process of expanded reproduction, all or particular indicators change towards the optimum, which creates objective prerequisites for increasing the productivity of agrocenoses and reducing production costs through the use of similar cultivation technologies. Narrowed reproduction of fertility implies the reverse processes of mainly anthropogenic origin.

With regard to the economic aspects of soil fertility reproduction, it should be noted that agricultural lands represent both an asset and a commodity, while soil fertility is the main property that ensures their value in these qualities. Physical, chemical, and biological processes that form narrowed reproduction of soil fertility reduce agrobiocenoses' value as a production asset, and a commodity due to reduced biological productivity.

At the same time, spoilage in the agricultural industry always leads to short-term and long-term risks, and, as a result, to direct financial losses, while in other industries it can be corrected. In the areas of risky agriculture covering up to 80% of Russian agricultural lands, the anthropogenic factor is associated with significant natural risks (droughts, dry winds, dust storms, early frosts, thaws, prolonged rains, etc.).

In this regard, farmer's work is characterized by an exceptionally high degree of self-exploitation without actually taking into account the cost of time and production rates. The final result is its only criterion, and its key feature that distinguishes it from labor in other industries is the absence of alienation and exploitation. Thus, farmer's work is closely related to their status as an owner, it is the work for the benefit of themselves and their families. Classical economist in agrarian sphere A.V. Chayanov notes that the scale effect inherent in industry, which leads to the ruin and disappearance of artisanal industries in the process of competition, manifests itself in agriculture to a much lesser extent, and in all countries of the world, labor agriculture not only did not go bankrupt, but also strengthened its position [3].

The very doctrine of A.V. Chayanov about the labor households has also strengthened its methodological positions over the last century, since the problem of small-scale agricultural production and farmer cooperation acquires new aspects of relevance in connection with the need for inclusive development of the agricultural economy. Chayanov's methodology continues to be supplemented and developed in modern studies of sustainable development of rural areas [4].

The reserve of stability and adaptability laid down in soil and plants by nature allowed making transition from

traditional, economically inefficient agriculture, at the same time providing simple or extended reproduction of soil fertility, to industrial methods of food production, in the development of which three stages could be distinguished: mechanization (1930–1950), chemicalization (1960–1970), biologization (1970 – up to present). Each of the three stages is associated with a qualitative jump in the economic efficiency of agriculture and an equally qualitative increase in the anthropogenic load on agrobiocenoses, disrupting the processes of natural reproduction of soil fertility. Grain and tilled crops, which by virtue of their profitability are the basis of modern conventional crop production, are characterized by particularly strong removal of nutrients from soil during harvesting. For example, up to 34 kg of nitrogen, up to 12 kg of phosphorus and up to 26 kg of potassium are taken from soil with 1 ton of winter wheat grain. Such significant losses of mineral elements for simple reproduction of soil fertility require the introduction of 20 to 80 tons of manure per 1 hectare of land and increased doses of mineral fertilizers, or even more increased application of concentrated fertilizers in the absence of organic matter, which is typical for the modern Russian agricultural economy due to the imbalance of animal breeding and crop production towards the latter. Therefore, increased soil chemicalization, in addition to environmental risks for agrobiocenoses, associated ecosystems and consumers of final agricultural products, creates economic problems, since soil acidity increases. Its neutralization requires additional chemical reclamation costs.

Besides, chemicalization of agriculture has a negative impact on biodiversity, which in addition to obvious environmental damage has less obvious economic losses caused by disruption of the life of bees and earthworms, that make major contribution to humus development [5].

The so-called rebound effect is an important factor of intensifying the conventional agriculture. It manifests the Jevons paradox in agriculture, i.e. the process when optimization of the use of resources as a result of technological innovations leads not to a reduction but to an increase in their consumption. This phenomenon manifests itself particularly negatively in the use of concentrated mineral fertilizers, pesticides [6] and in the reduction of efficiency of GMO crops cultivation due to the adaptation of harmful organisms to Roundup and other similar complex preparations, the use of which in agrobiocenoses with GMO plants theoretically should qualitatively simplify agricultural technology and reduce costs significantly [7].

## II. MATERIALS AND METHODS (MODEL)

The problem of food security for the world's population against the background of limited agricultural lands and the ongoing process of anthropogenic pollution of the environment becomes global. The foremost task facing human society is the issue of social responsibility for the environment, for the rational use of agricultural lands and soil fertility preservation. Economic and environmental aspects of this task, taken together, give it a social character. Economic and social phenomena often co-exist in organic unity, continuity and interdependence. Society functions as a living organism through production and economy. Social and economic aspects are intertwined to a very large extent. Analyzing the qualitative determination of production and

economy, economists proceed from the relations of property as their essential side. Property and appropriation are the categories that precede production. Production factors must be appropriated by someone before the actual process of production takes place. There is no production without appropriation. Appropriation of production factors is carried out in a certain form. Historically determined forms of appropriation include private, collective, and public forms of ownership depending on the subject of appropriation – individuals, groups of people or society as a whole.

Sociality as a category that expresses the relations arising in a holistic socio-economic organism between its agents –owners of natural resources (land, labor) aimed at preservation, rational and effective use, and reproduction, represents this determination.

Sociality has its own specific objects and subjects, as well as a special nature of the relations between the latter on the use of the former. The subjects of sociality are people acting on behalf of civil society as a whole, the state and business. The object of sociality is the natural resources of production – soil, subsoil assets, human resources. The state, as a subject of sociality, acts as a guarantor of civil society in terms of exercising its rights as the supreme owner of resources and factors of production for solving constantly emerging social and economic problems with all the ensuing consequences in the sphere of social responsibility [8].

Formation of a layer of environmentally motivated consumers willing to purchase organic products at an increased price creates an economic basis for a comprehensive solution of environmental and social problems through the production of organic food. At the same time, the crisis of Russian agriculture, associated with the not fully overcome consequences of its market transformation, makes it possible to turn one of its key problems into an opportunity. This is connected with the forced decrease in the chemicalization of agriculture and the withdrawal from agricultural circulation of vast arable lands, which, during 10-20 years have undergone natural detoxification processes and currently comply with Russian and international requirements for organic certification. It should be noted that the market niches of organic production are practically free of agricultural corporations, which generate more profit from extensive conventional agriculture.

Thus, development of organic agriculture is a way out of the socio-economic crisis for Russian rural areas and a means of financial flows formation for solving social problems of the village. In addition, creation of one job in the sectors of agricultural production provokes creation of 6-7 jobs in related industries, such as mechanic engineering, processing, transportation, storage of agricultural products.

Therefore, organic agricultural production is one of the promising areas of modern agriculture, which attracts attention of international organizations, producers and consumers, and in recent years, the Russian authorities, who have begun to form an institutional environment for its development. Organic agriculture is not a universal alternative to conventional, chemicalized agriculture due to a priori reduced biological productivity of the agrocenosis at other conditions being equal. Nevertheless, in Russian conditions this area has already found market niches for the

successful production of crops such as rice, soybeans, corn, vegetables of open and closed soil, melons, essential oil crops, medicinal herbs.

Organic farming is closely connected with the problems of expanded reproduction of soil fertility, sustainable development of the agricultural sector in rural areas, as well as with development of the green economy in general. The latter concept, despite its multidimensional nature, can be identified with the practical implementation in agriculture of the so-called decoupling effect, i.e. termination of the direct correlation between production growth and the increase in anthropogenic load on soils and agrobiocenoses.

Doctrinal definitions of organic agriculture are characterized by a variety of particular criteria relating mainly to the admissibility of certain elements of intensive farming technologies, including biological ones. Regulatory concepts, also varying in certain technological particulars, are generally close to the definition developed as early as in 1980 by the US Department of agriculture (USDA), where organic agriculture was presented as a production system that excludes the use of synthetic fertilizers, pesticides, as well as synthetic feed additives and artificial growth promoters in animal breeding. Permissible and desirable means of increasing the productivity of agrobiocenosis, in this case, are the cultivated crops rotation with a wide use of cover crops and green manure crops, biological protection of plants, application of manure, vermicompost and other organic fertilizers, as well as a limited number of mineral fertilizers in the form of natural agronomic ores.

Today, according to the International Federation of Organic Agriculture Movements (IFOAM), both large-scale and small-scale production of organic food is carried out in almost all countries of the world, and in 87 of them this industry is institutionally regulated through the adoption of appropriate regulations [9]. Since 2015, Russia has been one of these countries.

According to the Swiss-based Research Institute of Organic Agriculture (FiBL), the market volume of organic products in value terms amounts to 89.7 billion USD, and since 2000 its volume has increased by more than 5 times and demonstrated resistance to economic crises. Experts of the above institute predict the increase up to 250 billion USD by 2025. The number of internationally certified organic food producers in the world exceeds 2.7 million. The area of certified organic lands also continues to grow. As of 2018, in Australia their area amounted to 22.8 million hectares, and about 21 million hectares – in Argentina. However, it should be noted that these indicators have been achieved mainly due to extensive cattle breeding with the use of traditional for these countries free-range technologies corresponding to institutional innovations in the field of organic food. In the USA, the area of certified organic lands is more than 2 million hectares. As of 2018, in the European Union organic areas made 14.6 million hectares. The world area of organic arable lands is about 12.1 million hectares, which in relative terms makes 17 % of the world area of organic lands or 0.8 % of the total area of world arable lands [10].

With regard to Russian organic lands, it should be noted that, according to FiBL and the Ministry of agriculture of the Russian Federation, 290 thousand hectares of land have

been certified, which make Russia the 14th country in the world in terms of certified production occupying, however, only 0.2 %. At the same time, 84 agricultural producers have been certified, the average land area of which amounts to 3400 hectares [11]. Thus, this segment of Russian agricultural production is only at the very beginning of its development and will expand as the institutional environment improves. This can be achieved by partial subsidization of certification costs – the practice widely used in the US and the EU.

Steadily growing demand for organic food in Russian and foreign markets will also contribute to organic production development.

Developed countries of the West can not fully provide themselves with organic food due to the following reasons: lack of suitable lands and high demand for organic products conditioned by higher income levels and environmental motivation of the population. Thus, the volume of this market in Germany in value terms makes about 10 billion EUR, and only own production – less than 2 billion.

The Russian market also has prospects of slow but steady adherence to Western trends, since the sale of organic food is potentially beneficial not only to agricultural producers, but also to retail chains. Thus, according to the Economic Research Service of the US Department for Agriculture (ERS USDA) [12], the price premium for products demanded by the population and, accordingly, retailers, such as vegetables and root crops, including onion, carrot and potatoes, can reach 2-3 times with organic certification. Due to this premium, consciously paid by environmentally motivated consumers, the margin of producers on average exceeds the profitability of similar conventional products by up to 50 %. The rest of the premium is assigned to retailers, which forms a stable mutual interest in cooperation.

At the same time, it is the institutional ban on the use of pesticides and mineral fertilizers that sets both key problems of organic agriculture efficiency and key opportunities for increasing its science intensity and introducing agrotechnical and biotechnological innovations. Standards of organic farming allow for the use of a variety of biological fungicides and insecticides. More than 100 preparations of this kind are currently certified, and we can observe the constant development and introduction of new samples. Besides, organic farming development has increased the demand for the use of entomophage populations for pest control.

End-to-end technologies in the field of biological plant protection is carried out in St. Petersburg, Krasnodar, and Voronezh branches of the All-Russian Research Institute of Plant Protection: microbiological and biological plant protection, agricultural entomology, plant immunomodulation (St. Petersburg); phytosanitary monitoring, control of myco-diseases, mass breeding of insects (Krasnodar); complex biological and mechanical protection systems (Voronezh).

Biological systems of plant protection are based on the control of harmful populations by cultivation and introduction into the agrobiocenosis of populations of their natural opponents. Thus, immunostimulation of plants is

carried out by mass reproduction of entomophages and entomopathogens as well as by certain agrotechnical techniques. Natural suppressiveness of soil increases through its artificial saturation with various multifunctional fertilizers and preparations that have an antagonistic effect on pathogens or increase the immunity of plants due to phyto regulatory activity. Thus, methods and technologies of biological protection of plants, fully meeting the standards of organic production, create an effective alternative to pesticides.

An equally important science-intensive aspect of organic farming is the use of organic fertilizers, superior to manure in terms of nutrients and environmental safety. Such fertilizers are primarily represented with vermicompost and other products of organic bioconversion of soil by earthworms. They contain worm coprolites of different forms and concentrations, which in their turn contain soluble humus having an exceptionally high content of nutrients, on the one hand, and insoluble humus structuring the soil, improving its water permeability, preventing the processes of water and wind erosion, on the other hand [13]. Vermiculture itself, having significant potential in conventional agriculture, has a special significance for organic farming, since the introduction of a few tons of vermicompost per 1 hectare of arable land provides an average increase of 15-30 % of yield, which is comparable to applying dozens of tons of manure. Replacement of the latter with more advanced fertilizers contributes to solving the problem of the extensiveness of organic farming, which creates ground for criticizing the very area under study.

The essence of this problem lies in the fact that the need to introduce 60 or more tons of manure per 1 hectare of land for obtaining an acceptable level of yield has the following implications: firstly, it qualitatively limits the very potential of organic farming in practical terms due to the lack of livestock and, as a consequence, small amount of manure, and, secondly, in the theoretical aspect, it deprives organic farming of its ecological relevance, since the hypothetical presence of large herds, the need to cut down forests for pastures and forage crops would impose a great anthropogenic burden on nature. Bioconversion yields up to 0.6 tons of vermicompost of 1 ton of manure, and this proportion is even more advantageous in concentrated preparations. In addition, manure saturates the soil with pathogenic microflora and potentially germinating weed seeds, the number of which in 1 ton of manure can reach 5 million. During the processing of substrate into coprolites by worms, these seeds are swallowed, and the pathogenic microflora dies. Besides, the mucus secreted by worms, penetrates the soil together with coprolites, has an immunomodulatory effect on plants and promotes the development of beneficial microorganisms that process organic matter and further accelerate soil humification [14].

However, it should be mentioned that earthworms die in chemicalized agrobiocenoses due to pesticides, but continue their natural activity in organic agrobiocenoses, structure the soil, improve its granulometric composition and saturate it with coprolites without any additional costs for their production and application. Population of 50 worms per 1m<sup>2</sup> processes up to 50 tons of soil per 1 hectare during one season [15]. In organic agrobiocenoses, worm populations

are characterized by great biodiversity, which is especially useful in dry and arid climates [16].

Organic production also has a significant potential for the introduction of precision farming and precision irrigation technologies due to the need to interpret the increased volume of multi-factor information and increased requirements for the quality of agricultural activities. Combining precision farming with resource-saving, minimum, and zero soil treatment is especially relevant, since this allows increasing the moisture reserve in soil, reducing its acidity and improving physical properties [17].

Besides, conventional plowing causes soil degradation, prevents accumulation of carbon and nitrogen in the soil planted with cereals [18].

The use of effective microorganisms, such as cyanobacteria, fixing atmospheric nitrogen and water in the soil, reducing greenhouse gas emissions and promoting soil humification is an important technological aspect of expanded reproduction of soil fertility in organic farming [19]

Effectiveness of organic farming can also be provided by combining effective microorganisms and the introduction of supplements from plant residues both in a sterile form as a source of organic matter, and in a non-sterile one for the formation of populations of bacteria such as *Pseudomonas moraviensis*, *Bacillus cereus* and *Stenotrophomonas maltophilia*. T. Ul. Hassan and co-authors introduced *Cenchrusciliaris*L. root powder into wheat-planted soil and noted an increase in the content of protein in the grain and acceleration of its maturation. This allowed for the increase in economic efficiency of grain cultivation by 19 % [20].

Today, organic farming is predominantly rain-fed. Even in the USA, according to the ERS USDA data, 5% of organic soybeans, 15% of corn and 11% of wheat are cultivated using irrigation [12]. However, drip irrigation includes a qualitative reserve of organic crop yield growth, increasing the efficiency of water assimilation by about 2 times and reducing water losses in evaporation by a multiple. There are significant opportunities to expand the scale of drip irrigation in many agricultural industries, including the area of organic agriculture, which is due to the special demand for the production of vegetables and root crops on irrigation near large settlements with a maximum of market volumes and a minimum of logistics costs. Positive trends have been observed over recent years in the development of irrigation reclamation and state support for this direction in Russia. This creates broad prospects for import and import substitution of drip irrigation systems. Arrangement of drip irrigation systems in the Russian Federation required at least 3 thousand modular sets for land plots of 10 hectares each. In the future, at least 9 thousand such systems will be required if the existing trends continue [21].

Intense competition in this market will ensure the production of organic food through technological solutions affordable for farmers.

Relatively reduced mineral nutrition of plants in the conditions of organic production gives special relevance to environmentally efficient irrigation water use. Irrigation is optimally combined with the use of effective

microorganisms, vermicompost, and concentrated humic acid preparations [22].

For instance, for potatoes, high doses of organic fertilizers in combination with irrigation contribute to the growth of tubers and increase in their number (11-16 tubers vs. 8-15 at other conditions being equal). Potato yield of Russian and foreign selection increases by 20-25%, depending on the optimal water regime of the soil [23].

Increased application of mineral fertilizers reduces the consumption of irrigation water by plants [24]. Thus, the inverse correlation with a particularly high coefficient of water consumption of crops in organic agrobiocenoses is also accurate.

### III. CONCLUSION

Environmental aspects of irrigation in organic production form an additional system of environmental risks and innovative technological opportunities for their prevention. The need to increase irrigation standards entails the risk of secondary salinization and waterlogging of agrobiocenoses. At the same time, introduction of precision irrigation technologies, geoinformation systems with automated data collection based on the Internet of things allows using irrigation water with maximum efficiency, which creates new opportunities for cross-cutting scientific and industrial cooperation in the field of organic production, supplementing it with digital technologies and giving it an intensive character, without contradicting the criteria of organic certification of products. Realization of this potential will reduce organic farming costs to affordable level, while increasing the productivity of irrigated organic agrobiocenoses. This will allow forming a reverse manifestation of the decoupling effect, in which the environmentally responsible management is no longer correlated with the narrowed reproduction of farmers' capital as compared to conventional farming in a comparable set of factors.

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