Optimization of agricultural land use by impact on the climate

V I Kiryushin

Soil Institute named after V.V. Dokuchaev, 119017, Pyzhevsky lane, 7, unit 2, city of Moscow, Russia

*E-mail: vkiryushin@rambler.ru

Abstract. An assessment of the agrogenic transformation of the main ecological landscape functions affecting the greenhouse effect (bioproductive, destructive, organo-accumulative, biogeochemical) is given. It is shown that the tasks of optimizing agricultural environmental management under economic and agroecological conditions coincide with the tasks of maintaining a deficit-free carbon balance, reducing nitrogen gas losses and greenhouse gas emissions. The inexpediency of using emergency alarmist measures to reduce greenhouse gases is justified. The immediate tasks of optimizing nature management are associated with the development of adaptive landscape farming systems and ecological optimization of animal husbandry, which will ensure a deficit-free balance of carbon and biogenic elements, significantly stop the processes of soil and landscape degradation, and significantly reduce CO₂ emissions.

1. Introduction

The problem of climate warming has become an objective reality [1]. Its negative consequences (sudden weather fluctuations, droughts, crop failures, dust storms, forest and peat fires, floods, etc.) are widely discussed [2]. At the same time, there is an increase in yields in areas with a deficient temperature regime. [3]

The contribution of agricultural environmental management to climate warming is estimated at 20% or more of the total causes associated with an increase in the concentration of greenhouse gases in the atmosphere [4]. To reduce the emission and absorption of greenhouse gases, various measures are proposed [6], including those requiring special costs or extreme restrictions, such as reducing the consumption of livestock products, etc. Due to limited information, the adoption of alarmist measures involves risks of unjustified costs. Obviously, efforts should be directed to the implementation of preventive and adaptation measures that are associated with the optimization of agricultural production and that coincide with the requirements of reducing greenhouse gas emissions into the atmosphere [7]. To do this, it is necessary to know their sources and, accordingly, the biosphere functions, associated with climate change.

2. Research objectives and methodology

Since the problem of climate warming is insufficiently developed and, to a large extent, mythized, it is necessary, first, to determine geographical patterns and trends in the dynamics of thermal and hydrological regimes on a national scale. According to Russian meteorological service, the average warming rate in Russia over the past 40 years is 0.5⁰ per decade with significant variability in different regions. At the same time, another climate component is also important – moisture availability, the
assessment of which is not always given due attention. Meanwhile, in most cases, an increase in temperature is accompanied by an increase in annual precipitation amounts. Their growth varies from 5 to 25 mm or more per decade. As a result, territories with various trends are represented in a huge country such as heat and moisture availability, which, first, should be established. At the same time, it should be expected that the possibility of increasing agricultural production is expanding everywhere in the taiga and forest zones and, to a certain extent, in the forest-steppe zone, especially in Siberia. In the steppe zone, opposite expectations are more likely.

The methodology proposed by us for optimizing agricultural environmental management in terms of climate impact is to manage the biosphere ecological functions that directly or indirectly affect the climate, including those related to the formation and transformation of greenhouse gases. These include bioproductive, destructive, organo-accumulative, and biogeochemical functions. They change significantly under the effect of agricultural land use. The question is to what extent the optimization of these functions in terms of productivity and sustainability of agriculture coincides with the conditions for regulating greenhouse gases, or special measures will be required to prevent an increase in their concentration. To do this, it is necessary to imagine how various agriculture elements (crop rotations, tillage, fertilizers, pesticides, etc.) affect the productivity of agroecosystems and the greenhouse gas regime.

3. Results and their discussion

3.1. Bioproduction function

The banding of CO₂ into organic matter during photosynthesis is the basic biosphere function. It is measured by the value of net primary production, determined by the difference between the intensity of photosynthesis and the intensity of respiration of aboveground and underground plant organs per unit of time. The annual primary production of natural ecosystems varies significantly in zonal and provincial aspects. The change of natural biogeocenoses by agrocenoses leads mainly to its decrease. At the same time, the alienation of products with grain harvest and straw reduces the carbon input into the soil in grain agrocenoses (AGC) in traditional agricultural technologies by 3-4 times (Table 1). For many years, agriculture in Russia has been extensive with high CO₂ emissions and a very low level of carbon deposition. Modern agricultural technologies allow to increase the yield of agricultural crops by 1.5-2 times or more. In addition, carbon deposition can be significantly increased due to postharvest and mowing crops, reduction of net vapors, exclusion of badlands from active agricultural turnover.

A special role belongs to protective afforestation. It is necessary to overhaul many old-age protective forest strips, create water-regulating forest strips in erosive agricultural landscapes and, in the future, the formation of a territory ecological framework integrated with the field infrastructure of the agricultural landscape. The importance of forest phytocenoses in regulating the water regime of agroecosystems, protecting soils from water and wind erosion, and regulating the microclimate is complemented by their high deposition capacity relative to CO₂, which expands the assessment of their role in climate regulation.

| Table 1. Production and entry of plant residues into the soil in natural ecosystems and grain agrocenoses [9] |
|---|---|---|---|---|
| Indicator, t/ha per year dry matter | Primary products | Entry of residues |
| | Average Value | Limits of deviations | Average value | Limits of deviations |
| Southerrn Taiga | | | | |
| Forests | 10.0 | 8.0 | 16.0 | 10.0 | 8.0 | 16.0 |
| AGC with fertilizers | 9.6 | 7.8 | 12.3 | 3.6 | 2.9 | 6.2 |
The productive function of landscapes is closely related to the biodiversity function. They are largely interdependent. Climate change threatens biodiversity, but ecosystems with high biodiversity will suffer less from it. It creates complementarity and interchangeability of species in biocenoses, provides population control, self-healing abilities of ecosystems. Biodiversity directly or indirectly affects all ecological functions of the landscape. As for the practical regulation of biodiversity, one of the most effective adaptive means is the ecological restoration of disturbed landscapes, aimed at the formation of ecosystems close to the initial state [10]. Simultaneously with these tasks, a constructive biosphere approach should be developed, focused on the creation of new biological species and highly productive agroecosystems. At this stage, the task of creating plant varieties resistant to unfavorable agroecological conditions and knowledge-intensive agricultural technologies based on them is particularly relevant.

3.2. Destructive functions
These functions include the processes of plant death, the formation of dead phytomass (mortmass), humus substances, their decay to simple mineral compounds. The key link in this chain is the transformation of soil humus and its regulation. To this date, there has been a definite picture of changes in the humus state of various soils in the process of their agricultural use. It is shown that the loss of humus of the chernozems of the European part of Russia in the humus horizon reaches 20-30% on flat plains [9], which is associated with a several-fold decrease in the intake of its sources into the soil and an increase in organic matter mineralization. In complex landscapes, humus losses increase due to erosion. Our studies in the steppe and forest-steppe zones of the Trans-Urals, Siberia, and Northern Kazakhstan [9] have shown less significant losses of humus of chernozems compared to the European part of the country, due to lower mineralization of humus in a shorter warm period, less intensive tillage, a smaller proportion of arable crops. The humus content decreases most intensively in the first 10-15 years after plowing due to the rapid decomposition of labile forms of organic matter. Subsequently, this process slows down, being established at a new level of dynamic equilibrium, depending on the entry of organic matter into the soil and the conditions of its mineralization. For example, the average annual loss of humus in the arable layer of southern chernozem when used in grain-pair crop rotations without the use of fertilizers in the first decade was about 1 t/ha, in the second - 0.5, in the third - 0.4 t/ha. In the next 30 years, approximately the same loss of humus was observed - 0.3 t/ha per year [9]. Certain patterns of changes in the relative loss of humus in the geographical aspect have been established their increase to the south and north of the forest-steppe zone. If in leached chernozems there was a decrease in the humus content in the arable layer during the period of
their use in arable land for 50-300 years by only 3-14%, then in southern chernozems it was 10-21% over 10-60 years, and in podzolized soils – 14-19% relative to virgin land (Table 2).

Table 2. The effect of long-term agricultural use of soils of the chernozem zone of the Trans-Urals, Siberia and Kazakhstan on the content of humus in the arable layer

| Research objects                  | Humus content (%) to soil | Duration of arable land use, years | Humus loss, % to soil | Repetition | LSD 0.95 | Measuring error, % |
|-----------------------------------|--------------------------|-----------------------------------|----------------------|------------|----------|-------------------|
| Dark gray forest soil             | 5.45                     | 4.31                              | 60                   | 1.14       | 20.9     | 9                 |
| Podzolized chernozem              | 8.64                     | 7.0                               | 55                   | 1.64       | 19.0     | 7                 |
| Leached chernozem                 | 8.86                     | 8.18                              | 50                   | 0.68       | 7.8      | 7                 |
| Leached chernozem on the slope 3° | 9.51                     | 6.08                              | 60                   | 3.43       | 36.1     | 5                 |
| Ordinary chernozem                | 5.78                     | 5.20                              | 33                   | 0.58       | 10.0     | 9                 |
| Southern chernozem                | 4.64                     | 3.66                              | 60                   | 0.98       | 21.1     | 1                 |
| Meadow-chernozem soil             | 6.13                     | 5.07                              | 50                   | 1.06       | 17.3     | 7                 |
| Chernozem-meadow soil             | 9.42                     | 7.92                              | 50                   | 1.50       | 15.9     | 7                 |
| Meadow alkaline soil              | 9.46                     | 6.92                              | 45                   | 2.54       | 26.8     | 5                 |

In the intrazonal aspect, an increase in humus losses was revealed with an increase in hydro morphism and alkalinity of soils. In meadow-chernozem and meadow soils, the humus loss in the arable layer for 30-150 years is 15-25%, i.e., much more than in zonal chernozem soils. Humus losses are especially high in meadow alkaline soils. The increase in humus losses in the southern direction is associated with an increase in the processes of its mineralization and a relative decrease in the total production of agrocnoses compared with the production of natural phytocenoses. The intensive decrease in humus content in meadow and meadow-chernozem arable soils is explained by the mineralization of increased amounts of detritus, brown humic acids, and a significant increase in oxidative conditions. In meadow alkaline soils, intensive mineralization of humus is also associated with its high mobility.

It is almost impossible to restore the humus content in arable chernozems to the level of virgin ones due to the large difference in the number of incoming humus sources on virgin land and on arable land but ensuring a deficit-free carbon balance and maintaining an optimal amount of labile organic matter in the soil should be the immediate task.

In light gray, gray forest, and especially podzolic soils of the taiga-forest and forest zones, the conditions of humus formation are significantly improved due to the change of woody vegetation to herbaceous one and the introduction of fertilizers and meliorants. Oxidative processes are intensified, highly dispersed humic substances are decomposed, humic compounds are formed.

From the point of view of reducing carbon emissions in agriculture, minimizing tillage plays a decisive role. Our studies, in particular [9], have shown a decrease in the intensity of the processes of organic matter mineralization and CO2 isolation from the soil (leached chernozem) in a row: plowing – free loosening – shallow flat treatment - without basic tillage. A significant role in this regard is played by a reduction in the proportion of clean fallow. In fallow fields, the processes of organic matter and, in particular, humus mineralization are intensified due to an increase in the intensity of Nocardia and other humus-destroying microorganisms due to a decrease in the toxic effect of microflora metabolites that decompose labile organic substances. A special task is the preservation of peat soils and
3.3. Organo-accumulative function
It causes the organic matter accumulation because of the destructive process lag from the productive one. When the destructive process slows down, part of the carbon is removed from the biological cycle for different periods in the form of reserves of living organic matter, long-lived organisms, litter, humus, peat, coal, oil. Of the living systems, the most significant carbon accumulators are forest ones, due to the gigantism and durability of plant formations that hold reserves of organogen elements in a huge phytomass, and the wide spread of evergreen life forms. Afforestation is often recommended as an end in itself to deposit carbon and, accordingly, reduce the greenhouse effect. In agriculture, forest plantings have a multiple purpose. They play a soil-water protection and agronomic role. Their importance will increase with the development of adaptive landscape farming and the formation of an ecological framework of the territory integrated with the field infrastructure.

A large reserve for increasing carbon stock (accumulation in agricultural landscapes) both to reduce the greenhouse effect, and especially to increase the productivity of poor podzolic, sod-podzolic, and light gray forest soils is their cultivation, aimed at increasing the capacity of the arable horizon, increasing the humus content, improving physico-chemical and physical properties. Currently, most of these soils are poorly cultivated with a humus content of less than 2%, and a significant part of medium-cultivated soils are returning to their original state due to abandonment. The use of intensive and, moreover, high-intensity agricultural technologies is possible only on cultivated soils. The solution to this problem will be accompanied by a significant carbon stock, which will amount to significant values with an increase in humus content in the arable layer by 0.5-1.0% due to the use of organic fertilizers, green manure crops, plant residues of increasing yields, liming, and use of mineral fertilizers. This requires adequate development of animal husbandry and its rational placement, excluding excessive concentration in large livestock complexes.

In addition to the functions considered, some biogeochemical functions have a certain effect on the greenhouse effect, especially hydrocarbon functions associated with methane formation because of anaerobic decomposition of organic matter, as well as nitrogen functions in terms of nitrous oxide release as a result of denitrification. Water vapor plays a special role in heat exchange between the atmosphere and the earth surface. They are unevenly distributed in the atmosphere and partially concentrated in clouds. Hence their dual role is. By gas volume, water vapor is the predominant greenhouse gas, with the formation of clouds, the opposite effect is manifested, associated with high albedo and sunlight reflection.

3.4. Land use optimization systems by climate impact
The tasks of optimizing farming and land use are related to the regulation of the landscape ecological functions. Regarding the considered biocological functions, this means, at least, ensuring a deficit-free balance of carbon and plant nutrition elements. When the biological cycle is disrupted, soils are depleted, biological productivity and reserves of labile soil organic matter are reduced, followed by physical degradation of lands, especially marginal ones. In this regard, the primary task of biological cycle optimization and land use ecologization is the transition from extensive farming systems to adaptive landscape, differentiated in relation to various agroecological land groups. At the same time, the following tasks are being solved: territory organization; diversification of crop production; optimization of the structure of land, crops, the proportion of clean fallow, perennial grasses; complete disposal of animal husbandry waste; minimization of tillage; reconstruction of forest protection plantings; ordering of drainage and irrigation reclamations. At the same time, the use of mineral fertilizers plays a special role, considering their systemic interaction with agriculture elements and agrotechnologies. Exactly mineral fertilizers are the main condition for increasing the production of biological products and accordingly, carbon uptake. In this regard, manifestations of agrochemical nihilism in the form of declarations of farming systems without the use of mineral fertilizers (biological, ecological, energy-saving, etc.) pose a certain danger. Recently, the terms "carbon", "low-
emission", "carbon-saving agriculture" with similar declarations have appeared. As for the negative manifestations of the use of fertilizers in the form of nitrous oxide release, accumulation of heavy metals in the soil, it is a consequence of their unqualified use and is mainly excluded in high-tech technologies of adaptive landscape farming. The primary task is to master these technologies on irrigated and drained lands, especially peat lands, while simultaneously reconstructing and ordering the use of reclamation systems, which will at least double their productivity and significantly reduce CO₂ losses.

Further development of adaptive landscape farming is associated with the design of agricultural landscapes (cultivated lands, livestock, water management, forestry, etc.) by transforming part of the ecological functions of landscapes into socio-economic ones in the ecological frameworks of the territory integrated with field infrastructure. This means achieving a positive carbon balance in agriculture and, accordingly, the reduction of greenhouse gas reserves. The protective role of forests in the ecological frameworks of the territory, along with the absorption of greenhouse gases, should be particularly noted.

4. Conclusion
Climate warming and its negative consequences are considered because of irrational nature management. The tasks of agricultural environmental management optimization under economic and agroeocological conditions coincide with the tasks of maintaining a deficit-free carbon balance and reducing gaseous losses of nitrogen and other greenhouse gases. The immediate task of nature management is the rejection of nature-intensive extensive farming and the development of adaptive landscape farming systems. This will significantly increase agricultural productivity, including through the use of additional heat, ensure a deficit-free balance of carbon and nutrients, significantly stop the degradation of soils and landscapes and significantly reduce CO₂ emissions. Further improvement of agricultural nature management is associated with the restoration of degraded landscapes, the creation of ecosystems with a high biological potential that surpasses natural ecosystems, the creation of highly productive and sustainable agricultural landscapes in the system of the ecological framework of the territory integrated with field infrastructure. Thus, prerequisites will be created for a significant reduction in greenhouse gas emissions, optimization of moisture-heat exchange processes and other impaired functions of the biosphere. Obviously, their restoration is associated with the transition from an adaptive paradigm of agricultural nature management to a constructive biosphere [8].

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References
[1] 2009 Global climate change and the forecast of risks in agriculture in Russia Edited by Ivanova A L M.: Russian Agricultural Academy 518
[2] Zhemukhov R Sh and Mashukova F E 2016 Anthropogenic climate change and its consequences for agriculture at the regional level Successes of Modern Natural Science 7 118-122
[3] 2015 Adaptation of agriculture in Russia to global climate change Ed. by I G Ushacheva and A G Paptsova Research Institute of Economics of Agriculture Moscow 42
[4] UNFCCC 1992 United Nation Framework Convention on Climate Change UNEP/IUC 29
[5] Sorokin O G 2006 Adiabatic theory of the greenhouse effect In Col. Possibilities of preventing climate change and its negative consequences Moscow: Nauka 101-29
[6] Pachauri R et al. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva IPCC
[7] 2018 National report "Global climate and soil cover of Russia: assessment of risks and ecological and economic consequences of land degradation Ed. by A I Bedritsky M.: Soil Institute named after V.V. Dokuchaev GEOS 286

[8] Kiryushin V I 2018 *Ecological foundations of agricultural landscape design* St. Petersburg: LLC "Quadro" 568

[9] Kiryushin V I, Ganzhara N F, Kaurichev I S, Orlov D S, Titlyanova A A and Fokin A D 1993 *The concept of optimizing the regime of soil organic matter in agricultural landscapes* Moscow: Publishing House of MAA 99

[10] Tishkov A A 1996 *Ecological restoration of the disturbed ecosystems of the North* Moscow: Publishing House of UrAO 115

[11] Kiryushin V I 2011 *The theory of adaptive landscape farming and the design of agricultural landscapes* M.: KolosS 443