Possibility of balanced development of the Volga Federal District of Russia while maintaining the carbon cycle and transition to renewable energy

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Abstract. The article provides an assessment of the possibility of a balanced development of the regions of the Volga Federal District of the Russian Federation due to an increase in the share of renewable energy in the regional energy balance and subject to the preservation of the carbon cycle. Particular attention was paid to agricultural areas, which, in a case of irrational nature management, can significantly disrupt the carbon cycle. Thanks to the use of a special indicator, it was found that the Volga Federal District is in an unbalanced state. It is possible to correct the situation by increasing the share of alternative energy to 52-96 per cent in regional energy balances (77 per cent on average in the district). In eleven regions of the District, there is carbon dioxide emission from anthropogenically disturbed territories, covered mainly by agricultural areas. In order to preserve the carbon cycle in the Volga Federal District, it is necessary to bring 136,200 sq. km of territory into a special nature management regime, mainly steppe ecosystems and pastures, which cover 10.9 per cent of the total area of the district.

1 Introduction

The modern economic system is at the center of the global natural system, from which resources can be withdrawn indefinitely and where accumulated wastes can be stored back. There are some hopes that further technological progress will open up new opportunities in solving the problem of preserving the environment, but most experts evaluate them as illusory [1]. The reason for such a destructive approach to nature is a pragmatic attitude towards it, supported by technologies based on powerful energy sources. The concept of sustainable development was printed at the World Summit in Rio de Janeiro (1992), the main provisions of which are reflected in the document called "Agenda 21". Unfortunately, the scientific community soon moved away from the systemic content of the term "sustainable development". The idea of sustainable development began to be understood as exclusively a transition to environmental protection and just only as. Pity but sustainable

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development in a sense of a narrow branch of environmental protection only is formulated in the national programs of various countries. The main essence of these programs has remained intact, i.e. the maximum increase in production and the expansion of the use of scientific and technological progress in order to better meet the material needs of man. The decades that have passed since the Rio Conference show that the modern world has not changed its trajectory of development - achieving success by any means through the exploitation of nature. It is necessary to return to a systematic approach, to explore a multi-level, multi-parameter system of the relationship between nature and economy [2]. Prospects for further development will depend on various balances between its various components [3]. Consideration of the constituent parts of economic activity in the form of interrelated subsystems makes it possible to apply the apparatus of general systems theory, to formulate a multi-level model of the interaction between economy and nature, to substantiate methodological tools for formulating strategies for balanced development at various levels of territories if solving the problems set by the sustainable development goals.

2 Materials and methods

Previous studies have made it possible to form methodological tools that allow assessing the level of assimilation potential of the region's ecosystems according to the maximum allowable energy load [4]. When correlated with the energy intensity of economic activity in the region, this makes it possible to identify the level of balanced development [5]. At the same time, the balance increases significantly with an increase in the share of renewable energy in the regional energy balance [6], since renewable sources use material and energy sources already circulating in the biosphere, mainly associated with the transformation of solar energy [7]. This property of renewable energy, and not just the absence of greenhouse gas emissions, largely explains its rapid development in recent years, with the expectation of an "energy transition" in 2050-2060. However, even under such a scenario, the natural carbon cycle may be disrupted, and the emission of carbon dioxide into the atmosphere will continue. The reasons for this are the anthropogenic destruction of soils as a result of agricultural activities, which can lead to a significant violation of the existing carbon balance [8]. Unfortunately, not many researchers pay attention to this process, mainly focusing on the emission of carbon dioxide as a result of the activity of the energy industry running on fossil fuels. In this study, the authors tried to correct this situation by making some adjustments to the existing methodological tools and testing it on the example of one of the specific territories.

In order to initially determine the current state of the carbon cycle as a result of land use disturbances during agricultural activities, it is first necessary to determine the ability of the region's natural and anthropogenically modified ecosystems to assimilate or emit carbon dioxide. The results of a study of the emission / absorption of greenhouse gases by anthropogenically disturbed territories by Mozharova N.V., Kulachkova S.A. and Lebed-Sharlevich Y.I. [9] were used for this purpose, and the data obtained Krasutsky B.V. [10] and Mekush G.E. [11] according to the absorptive capacity of various forest ecosystems. The latest Guidelines for quantifying the amount of greenhouse gas absorption approved by the [Ministry of Natural Resources of Russia], formed on the basis of the methodology of the Regional Forest Carbon Budget Assessment (RFCBA) [8], verified by experts of the UN Framework Convention on Climate Change (FCCC) and the Intergovernmental Panel on Climate Change (IPCC) were used in addition. In general, the state of the carbon cycle depends significantly on the characteristics of the existing land use in the region, i.e. from the ratio of areas of natural ecosystems: coniferous, deciduous, other forests (shrubs), non-forest areas (steppes, tundra), water bodies (including swamps). And it also depends on the ratio with the areas of anthropogenically disturbed territories: land used in agriculture and residential areas occupied by settlements.

Calculation of the balanced development of the region, if it is necessary to maintain the carbon balance in the process of land use, and taking into account the development of renewable energy sources, was carried out according to the following formula:

$$K_c = \frac{E_{rt} - E_{ra}}{\sum_{i=1}^{6} S_i^C * p_i^C} \quad (1)$$

Where Kc is the final level of the region's balance, taking into account the preservation of the carbon balance, S_1^C is the territory of the region occupied by deciduous forests, S_2^C is the territory of the region occupied by coniferous forests, S_3^C is the territory of the region occupied by other forest ecosystems (shrubs), S_4^C is the territory of the region occupied by non-forest areas (steppes , tundra), S_5^C is the area of agricultural land in the region, S_6^C is the territory of the region occupied by water bodies (including swamps), is the coefficient of emission (absorption) of carbon dioxide by the i-th territory, E_{rt} is the emission of carbon dioxide by fossil fuel energy, E_{ra} is the predicted value of emission reduction carbon dioxide in the development of renewable energy in the region.

Provided that $K_C \leq 1$ the balance of development and the carbon cycle in the region should be recognized as corresponding to the norm, in the case when $K_C > 1$ regional development and the carbon cycle should be recognized as disturbed, the natural ecosystems of the region are not able to fully absorb the emitted carbon dioxide. This situation will require managerial decisions to correct the imbalances that have arisen in regional development.

3 Results

The study was carried out on the example of the Volga Federal District (VFD) of the Russian Federation. The Volga Federal District is located in the east of the European part of the country and includes fourteen regions: the Republic of Bashkortostan, the Republic of Mari El, the Republic of Mordovia, the Republic of Tatarstan, the Udmurt Republic, the Chuvash Republic, the Perm Territory, the Kirov Region, the Nizhny Novgorod Region, the Orenburg Region, the Penza Region, Samara region, Saratov region, Ulyanovsk region. The area of the district is relatively small, accounting for 6.06 per cent of the entire country. The population of the Volga Federal District is numerous - 28.9 million people. Most of the territory of the Volga Federal District is a well-defined plain and lowlands, only in the east are the low Ural Mountains, which largely favors agricultural activities. There are several natural zones on the territory of the district: there is a taiga zone in the north, which is replaced a little by mixed forests and forest-steppe to the south, the entire southern part is represented by steppes, which are now largely converted into agricultural land. The climate in the Volga Federal District is continental, temperate continental, summers are warm, sometimes hot, winters are cool. The District is well provided with water resources; the largest river in Europe, the Volga, flows via its territory. There is also a fairly significant number of small lakes, rivers and swamp ecosystems in the district. The district contains approximately a quarter of the industrial production of the Russian Federation. Mechanical engineering, oil and natural gas production, and the chemical industry are well developed. A feature of the district is developed agriculture. Volga Federal District ranks second in the country in terms of gross harvest of grain crops, sunflower seeds, potatoes, vegetables, fruits and berries. The quite significant are volumes of production of meat, milk, eggs, honey, sugar beet, rapeseed. This situation also predetermines a significant anthropogenic impact on the environment. Large areas of the District are allocated for agricultural land, in addition, high anthropogenic pressure is also exercised by residential areas where developed industry is represented.

On the basis of materials with statistical data, the areas of natural and anthropogenic ecosystems of the district were initially identified, which have a direct impact on the assimilation potential of the regions of the Volga Federal District and the state of the carbon cycle. It was revealed that agricultural land dominates in the structure of land use, they occupy 44.1 per cent of the total area of the district. True, it should be noted that this includes both lands occupied by arable land, and pastures, fallow lands, and a number of others occupied with agricultural production, which will affect the state of the carbon cycle in different ways, which was taken into account in further research. So, plowed lands, due to soil destruction, are sources of carbon emission in general, and carbon dioxide in particular, the amount of CO_2 emission can reach 746 kg/sq.km. At the same time, pastures, subject to rational nature management, are not significantly disturbed areas, and are closer to the state of natural steppes, which, according to a number of studies, are able to actively absorb carbon dioxide, up to 397 kg/sq.km, if soil destruction is not observed.

According to the data obtained (based on the use of formula 1), the assimilation potential of the ecosystems of the Volga Federal District amounted to 16.04 GW. For comparison: the assimilation capacity of the ecosystems of the Ural Federal District is 33.94 GW, the Siberian Federal District is 95.67 GW, and the Far Eastern Federal District is 145.81 GW.

Table 1. Indicators characterizing the balance of the regions of the Volga Federal District, taking into account the development of renewable energy and the preservation of the carbon cycle.

Region	Ecological capacity of ecosystems, GW	Energy consumed per unit of time (power), GW	Indicator of regional balance (K_c)	The share of renewable energy when the K_c is equal to one, per cent	Absorption (-) / emission (+) of greenhouse gases by ecosystems, million tons	Required areas (sq.km) with a special nature management regime (steppes / pastures)
Republic-of-Bashkortostan	1.84	9.77	5.30	81	+7.81	6900
Republic-of-Mari-El	0.44	0.91	2.07	52	-0.55	-
Republic-of-Mordovia	0.29	1.32	4.55	78	+4.6	4100
Republic-of-Tatarstan	0.60	9.73	16.27	94	+24.86	21800
Udmurt-Republic	0.81	2.32	2.86	65	+3.39	3000
Chuvash-Republic	0.23	1.56	6.72	85	+4.48	4000
Perm-Territory	4.65	9.94	2.14	53	-14.56	-
Kirov-region	3.00	1.85	0.62	-	-4.57	-
Nizhny-Novgorod-region	1.39	7.68	5.50	82	+5.15	4600
Orenburg-region	0.79	8.48	10.73	91	+31.15	27300
Penza-region	0.45	1.56	3.47	71	+12.68	11000
Samara-region	0.39	9.55	24.47	96	+20.34	17800
Saratov-region	0.67	4.30	6.37	84	+36.61	27500
Ulyanovsk-Region	0.45	1.83	4.04	75	+9.3	8200
Volga-Federal-District	16.04	70.8	4.41	77	+129.42	136200

Further, using statistical materials, the final indicator (K_C) of the balance of the regions of the Volga Federal District was calculated, taking into account the possibilities for developing renewable energy and preserving the carbon cycle, which is presented in Table 1.

The balance indicator exceeds one in all regions of the Volga Federal District, with the exception of the Kirov region. It is in these regions that in order to achieve a balance between the economy and ecosystems, it will be necessary to increase the share of alternative energy to 52-96 per cent in the regional energy balance. Emission of carbon dioxide from anthropogenically disturbed ecosystems is present in eleven regions of the Volga Federal District, in which it will be additionally necessary to increase the areas of ecosystems (with a special nature management regime) to maintain the carbon balance, which is shown in Figure 1. The total area of such territories in the district will be 136,200 sq.km, which reaches 10.9 per cent of the area of the Volga Federal District. Predominantly, steppe ecosystems and pastures, which are the most effective carbon sinks, should be introduced into such territories, based on the natural conditions of the district.

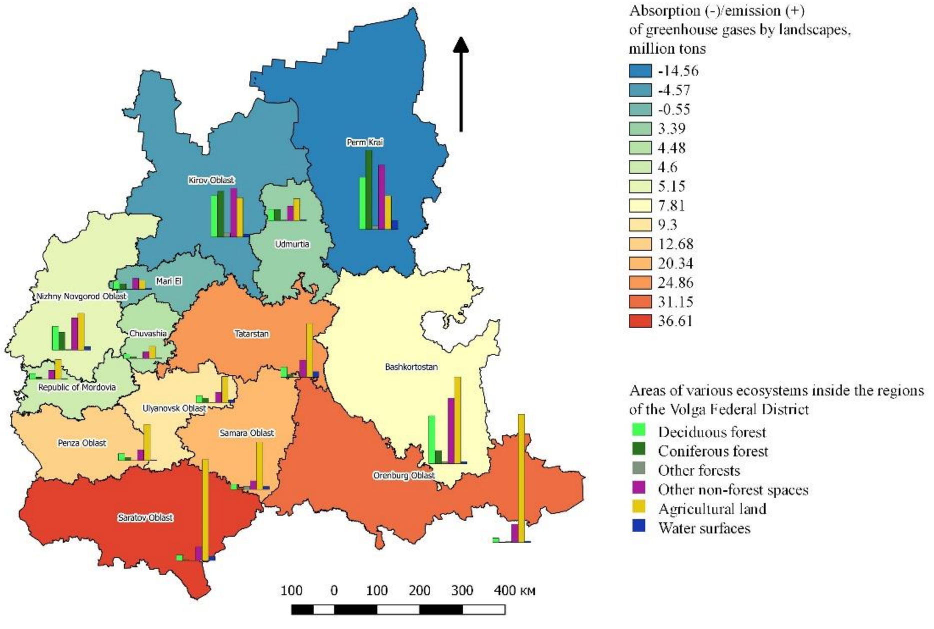

Fig. 1. Emission/absorption of carbon dioxide by the ecosystems of the regions of the Volga Federal District.

4 Discussion

It should be noted that many values associated with the emission or absorption of carbon dioxide by various ecosystems are currently estimated. There are still no systematically obtained data for a number of landscapes. The study used coefficients from the Methodological Guidelines for the Quantification of Greenhouse Gas Absorption (adopted by the Russian Ministry of Natural Resources), as well as data from other scientific publications. In particular, the results of studies of steppe ecosystems carried out at the Institute of Physical, Chemical and Biological Problems of Soil Science of the Russian Academy of Sciences were used, which confirm that the steppes are able to effectively absorb carbon dioxide. Based on the averaged data obtained by Lopez de Guerenu V.O. and Kurganova I.N. [12] obtained the following averaged data on the absorption of carbon dioxide by the steppes – 397 tons of CO_2. per sq.km, which is even higher than in forest ecosystems (65.3 t. CO_2. per sq.km for deciduous forests and 68.6 t. CO_2. per sq.km for coniferous forests). Grasslands with special management regimes will have comparable CO_2 uptake values, although more detailed data require additional carbon landfill studies. In further studies, the presented values can be adjusted.

5 Conclusions

The results obtained indicate that the Volga Federal District is in an unbalanced state, its balance index KC is significantly greater than one and amounts to 4.41. Of the fourteen regions of the district, only in one, in the Kirov region, this indicator is less than one, i.e. 0.62. To a large extent, this is due to the developed industrial activity, the energy complex using fossil energy sources, which has a serious negative impact on the environment. Due to the fact that renewable energy uses biospheric material and energy flows, it is possible to correct the situation by increasing its share in the regional energy balance. To do this, it will be necessary to increase its value from 52 per cent in the Republic of Mari El, to 96 per cent in the Samara region, on average for the district to 77 per cent. However, even if this scenario is implemented, the carbon cycle will be disrupted in eleven regions of the district. The reason for this is the developed agriculture of the district. Agricultural land occupies 44.1 per cent of the total territory, with irrational nature management, degradation of the soil cover occurs, leading to carbon emissions. Correcting the situation is possible due to the transfer of part of the territory, up to 10.9 per cent of the area of the district, mainly steppe areas and pastures, to a special nature management regime aimed at preserving the carbon cycle. Since this is difficult to do at the expense of residential areas, a significant transformation will be required from agricultural production, which should be further paid attention to by other researchers.

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