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Carbon Intensity of the Regional Economy as a Land Use Management Factor[1]

Abstract. As stated in the National Greenhouse Gas Inventory Report, CO_2 emissions and carbon balance vary significantly between Russia's regions. In this regard, estimations of regional capabilities to absorb GHG and CO_2 specifically are quite important. The analysis, undertaken in this study, made it possible to identify the territorial differentiation of the carbon capacity for the districts of the Republic of Tatarstan – one of the leaders of economic development in Russia. The author also considers the role of evaluating carbon intensity in the regulation of regional economy by optimizing land use structure.

Keywords: ecosystem service, land use, CO_2 balance, Tatarstan Republic

1. Introduction

The "Assessment Report on Climate Change and Its Consequences on the Territory of the Russian Federation," issued by the Federal Service for Hydrometeorology and Environmental Monitoring (Rosgidromet), states that the current climate change "has a serious impact on the socio-economic development of Russia" [Assessment Report… 2014]. That's why, according to many Russian researchers – ecologists and economists alike, the transition to a low-carbon

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economy in Russia has to be the key direction of development towards sustainability. As stated in international documents, a low-carbon economy is an innovative "socio-economic and technological system aimed to reduce GHG emissions without compromising the pace of socio-economic development" [Ecological footprint… 2016].

According to BP Statistical Review of World Energy, Russia is ranked 4th in carbon dioxide emissions after China, the US and India: in 2016, CO_2 emissions in Russia amounted to 1.5 billion tons. However, these calculations do not take into account the absorption of CO_2 by natural ecosystems. According to the National Greenhouse Gas Inventory Report, the rate of such absorption in Russia is estimated at about 500 million tons per year. However, CO_2 emissions and CO_2 balance vary significantly across Russia's regions. In this regard, estimations of regional capabilities to absorb GHG and specifically CO_2 are quite important: land use adaptation to climate change impacts can be quite an effective instrument to elaborate a mitigation policy and to create a new low-carbon economy.

The analysis, undertaken in this study, made it possible to identify the territorial differentiation of carbon intenisty in the districts of the Republic of Tatarstan, as well as the role of the regional land use policy to regulate carbon intensity of the regional economy for purposes of sustainable development.

2. The Republic of Tatarstan as a leader of economic development in the Volga region

The regional level of research activity is the most reliable way to evaluate the current situation. The methodical approach based on the calculation of the carbon absorption capacity of natural ecosystems and on a comparison with carbon intensity of the regional economy were analyzed for one of the most developed Volga regions – the Republic of Tatarstan.

The region was selected for a number of reasons: economic (high level of economic development and diversified structure of the economy), environmental (location in the highly significant environmental region of the Volga river basin) and social (an inequality in the standard of living of the local population).

The natural conditions of the region are determined by the fact that the territory spans two natural zones: the southern taiga and forest-steppe. Agriculture (both crop and livestock production) plays an important role thanks to favourable agro-climatic conditions and rich soils, such as sod podzolic soils and chernozems. The industry is mainly based on rich oil reserves, as well as knowledge-based manufacturing industry. As a result, in 2016 the Republic ranked 6th among

85 regions of the Russian Federation in terms of GRP, 4th and 5th in terms of agricultural and industrial production, respectively [Federal state statistics… 2016].

The evaluation of human development's sustainability is currently one of the topical issues for the world economy, given that a lot of resources – human, material and financial – are being consumed to reach sustainability. The current practice in sustainability assessment is based on a number of complex indicators, which are not without certain shortcomings. The most popular ones include the Human Development Index (HDI), the indicator of Adjusted Net Savings, indicators of Ecological Footprint (EF) and the Living Planet Index, both developed by WWF. In Russia, the Ecological-Economic Index (EEI) was suggested as an adaptation of the Adjusted Net Savings index to the Russian reality. To consider environmental and social aspects, in addition to economic ones, the Tatarstan Republic was compared to other Volga regions by complex indicators, based on [Bobylev et al. 2012; Ecological footprint… 2016; Bobylev & Grigor'ev 2016].

Table 1. Economic, ecological and social indicators of the Volga region's

Subject of the federation	GRP, bln. RR	HDI	EEI, %	EF, gha per capita
Mari El Republic	165.5	0.835	35.47	4.07
Republic of Tatarstan	1833.2	0.894	19.91	4.97
Chuvash Republic	250.4	0.839	33.94	3.95
Samara Region	1240.3	0.865	9.38	5.59
Ulyanovsk Region	301.4	0.843	39.79	4.46

Source: State report… 2016; Bobylev et al. 2012; Ecological footprint… 2016; Bobylev & Grigor'ev 2016.

The data presented in Table 1 show that Tatarstan has high levels of economic and social indicators (GRP and HDI) and lower levels of environmental indicators (EEI and EF) of development.

3. Data and methods

It is widely known that land use change is a key factor associated with carbon emissions and carbon dioxide absorption at the regional level [De Cara & Jayet 2011; EEA 2017; Kirillov et al. 2017; Lungarska & Chakir 2018], and carbon intensity of the regional economy can be considered as an indicator of the efficiency of economic activity. We evaluated carbon intensity of the regional economy taking into account carbon dioxide emissions from fuel combustion in the industrial, transport and housing sectors. The calculation is based on the approach proposed in the Recommendations on GHG Inventory developed by the Intergovernmental Panel on Climate Change (IPCC).

The basic formula used for calculating emissions from fuel combustion (1) is as follows:

$$E = M \times K_O \times TH3 \times K_B \times \frac{44}{12} \quad (1)$$

where:

E – total CO_2 emissions from fuel combustion, tons/year;
M – amount of fuel per year, thousand tons/year;
K_O – coefficient of carbon oxidation, tabular data;
K_B – carbon emission factor, tons/TJ, tabular data;
$TH3$ – net calorific value that allows to convert fuel to energy units TJ/thousand tons

The data on fuel consumption were taken from official statistical sources. Since the required data are provided by national statistical agencies for administrative territorial units only, our calculations were made at the level of municipal districts of Tatarstan.

Taking into account a high level of diversification of the regional economy, different sources were used to analyze the territorial structure of land use and the level of development: cartographic materials, space images, statistical compilations, state reports on environmental protection [State report… 2016; The Republic of Tatarstan… 2016] from the official web-sites of the regional and municipal administrations [The Republic of Tatarstan… 2016; The portal of municipalities… 2017], etc.

The amount of carbon dioxide absorbed by forest ecosystems and agricultural land was calculated at the level of forestry districts and arable lands respectively, because relevant statistical information is also available at the level of administrative territorial units. The calculations were made using data about the amount of carbon accumulated by different types of plant communities - for stands, litter and soils – according to the approach recommended by IPCC and adopted by the Russian Ministry of Natural Resources and Environment [The Order… 2017]. For example, the amount of carbon in a tree stand (growing stock) is calculated according to the formula (2):

$$C = V \times K_K \quad (2)$$

where:

C – quantity (stock) of carbon in the biomass of trees of a certain age and breed;
V – volume of stem wood of a certain age and breed;
K_K – conversion factor to calculate the amount of carbon in the volume of trees biomass for a certain age and group, tons/m^3, table value.

Calculations of carbon volumes, absorbed by other types of land, were made in a similar fashion, according to the guidelines [The Order… 2017]. The meth-

Table 2. Conversion factors for some tree species common in Tatarstan

Tree species	Age category			
	Sapling (1st and 2nd classes)	Middle-aged trees	Trees ripen	Overmature forest
Pine	0.435	0.352	0.329	0.356
Spruce	0.614	0.369	0.351	0.364
Larch	0.392	0.371	0.398	0.398
High-stem oak	0.616	0.491	0.418	0.478
Birch	0.437	0.396	0.367	0.367
Aspen, poplar	0.356	0.363	0.335	0.365

Source: National Greenhouse Gas… 2017.

odology includes adjustments for losses from forest fires, deforestation and forest cutting.

Since the region of interest belongs to the subzone of the southern taiga and forest-steppe, we used appropriate coefficients for tree species and other types of plant communities prevailing in the region. For each of forests and agricultural plant communities (including stands, litter and soils) the calculation was carried out in several stages: 1) the amount of carbon in biomass of every type of plant communities; 2) the absorbing capacity of biomass; 3) losses (emissions) of carbon in biomass; 4) the carbon balance in biomass.

The calculation follows a typical procedure for such estimations and takes into account such parameters of plant communities as the stock of carbon in the biomass of trees (accounting for different age and breed), grass cover or soil; the volume of stem wood and other types of vegetation; conversion factors to calculate the amount of carbon in the biomass of each group (Table 2).

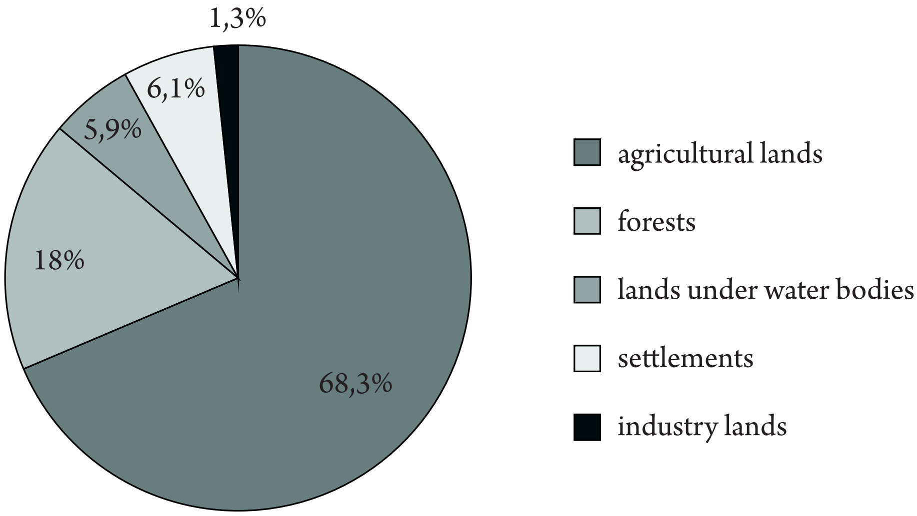
The total value of the absorbing capacity of forests, arable lands and pastures, and carbon deposits within the boundaries of the region were analysed using the MapInfo program, which can be used to determine areas of positive and negative balance of carbon dioxide.

4. Land use structure and carbon absorption capacity

The land use structure in the region is represented by a donut chart showing different industrial centers, including oil production and processing, agricultural lands, water bodies, etc. (Chart 1).

CO_2 emissions in the republic come mainly from industrial enterprises, which are located in the districts with a high share of transformed landscapes.

Chart 1. Land use structure in the Republic of Tatarstan (2016)



Source: State report… 2016.

They are usually deprived of forests and other forms of natural vegetation and their CO_2 absorption capacity is quite low. In contrast, in agricultural areas, CO_2 emissions are not significant, and agricultural lands have a high level of carbon absorption capacity.

As mentioned above (section 2), the data on fuel consumption were obtained on request from an official statistical source – the statistical service of the Republic of Tatarstan. Since the data are only available for administrative territorial units, all the calculations were made at the level of municipal districts of the republic, taking into account the coefficients for each fuel type given in the IPCC methodology. Unfortunately, information about fuel combustion in 5 of 45 Tatarstan's districts – Agryzsky, Apastovsky, Kaybitsky, Rybno-Slobodsky and Spassky – was unavailable, therefore calculations for these areas could not be performed. Emission values vary quite significantly in different administrative units: the highest volumes (8 538 780 t/year) were observed in the Nizhnekamsk district, 3,662,261 and 2,082,604 t/year in the towns of Kazan and Naberezhnye Chelny, respectively. The lowest volumes of carbon emissions (4,893 t/year) were recorded in the Muslyumovsky district. Thus, the highest rates exceed the lowest by more than 1.5 thousand times. The distribution of the main centers of CO_2 emissions in the Republic of Tatarstan is shown in Fig. 1.

The comparison of economic development indicators (GTP, gross territorial product) of the Tatarstan districts shows that they are not correlated with the emissions rates, which indicates different levels of carbon intensity across districts: thus, in the Nizhnekamsk district, which has the largest level of emissions, GTP is 180.5 billion RR, which is less than a third of the GTP of Kazan

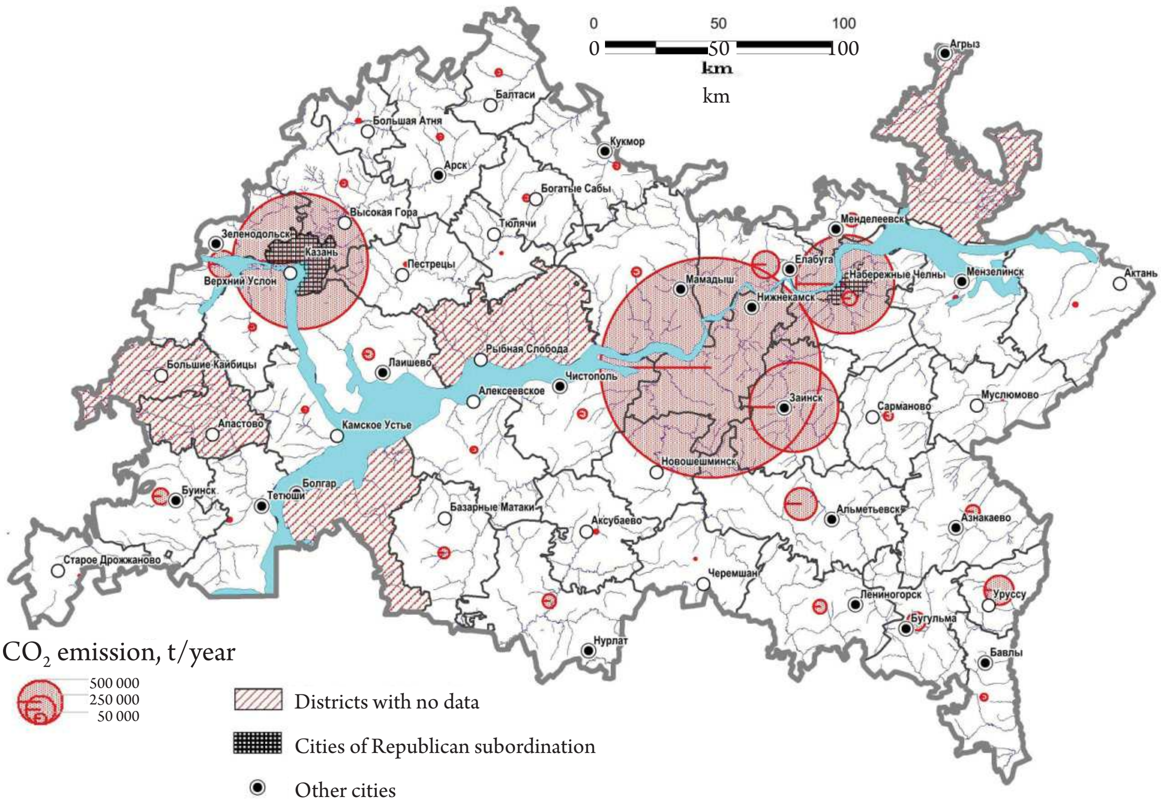


Figure 1. The main centers of CO_2 emissions in the Republic of Tatarstan

Source: own elaboration.

(605 billion RR). GTP of the town of Naberezhnye Chelny is also higher (187billion RR).

In order to evaluate the role of regional ecosystems in carbon absorption, its value was estimated for forest and agricultural lands (for forestry districts and administrative units respectively). Analysis of land use structure and its differences across the districts of Tatarstan shows a correlation between the carbon intensity of the regional economy and the carbon absorption capacity of the local ecosystems. According to our calculations, one hectare of agricultural crops in the Republic of Tatarstan absorbs from 13.4 to 14.5 tons of carbon dioxide per year, depending on the combination of agricultural crops. However, real figures ranged from 2.15 to 4.9 tons per year, taking into account the value of soil respiration. At the same time, one hectare of forest stands absorbs from 0.7 to 2.8 tons of CO_2 per year, depending on the combination of different tree species, their age and other characteristics taken into account in the assessment. It means that agricultural fields are more effective as absorbers of carbon dioxide. At the same time, forest communities are more efficient when it comes to carbon storage. Using the data on absolute values we compared relative carbon intensity and carbon capacity per GRP unit for the Tatarstan districts (Table 3).

Table 3. Carbon intensity and carbon absorption in some districts of the Tatarstan Republic

Carbon intensity and carbon capacity indicators	CO_2 emission, t/year	CO_2 absorption by forests and agricultural lands, t/year	Relative carbon intensity per GRP unit, t/RR	Relative carbon capacity per GRP unit, t/RR	Balance
Negative balance* (Nizhnekamsk district)	8 538 780.0	65 003.5	47.2	3.15	–44.05
Parity of emissions and absorption (Almetyevsk district)	290 266.5	49 722.7	1.06	2.27	1.21
A positive balance (Bugulma district)	110 467.5	42 263.7	2.30	9.04	6.74

* Negative balance – carbon intensity exceeds carbon absorption capacity; positive balance – carbon absorption capacity exceeds carbon intensity.

Source: own elaboration.

Thus, all districts of Tatarstan can be divided into three groups in terms of their capacity to absorb CO_2:

– districts exceeding the limit (Nizhnekamsk and Zainsky districts and towns of Naberezhnye Chelny and Kazan);

– districts close to the limit (Yutazinsky, Almetyevsky, Zelenodolsk, Elabuga);

– districts well under the limit (the remaining ones).

Our study allowed us to conclude that the transition to a low carbon economy can be carried out not only by using alternative energy sources but also by regulating land use patterns. The ratio of transformed to natural ecosystems plays a key role in regulating carbon intensity. Natural landscapes, such as forests, swamps and natural meadows, absorb greenhouse gas emissions, while reducing environmental impacts. However, economic incentives to manage the land use structure often face barriers. From this perspective all the issues considered in the article are highly relevant directions of ecological-economic research.

The expansion of arable land and the consequent reduction in forest areas in the region have caused a carbon imbalance in regional landscapes. The digital map of regional land use, based on space images and statistical data, made it possible to evaluate the predominant types of landscape in the region of interest. In other words, land use efficiency and sustainable regional development can be used as key criteria in the assessment of carbon balance in the industrial and agricultural production and for purposes of regulation by increasing natural areas, especially in regions of economic growth, such as the Republic of Tatarstan.

Further studies will contribute to land use management as an important tool for sustainable regional development policies aimed at achieving and harmonizing environmental, economic and social parameters.

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Intensywność zużycia węgla w gospodarce regionalnej jako czynnik zarządzania użytkowaniem gruntów

Streszczenie. Jak czytamy w krajowym raporcie inwentaryzacji, emisja gazów cieplarnianych, emisja CO_2 i bilans węglowy znacznie różnią się w poszczególnych regionach Rosji. W związku z tym bardzo ważne są oceny regionalnych możliwości pochłaniania gazów cieplarnianych i emisji CO_2. Przeprowadzona w wyniku badania analiza pozwoliła zidentyfikować terytorialne zróżnicowanie intensywności zużycia węgla w rejonie Republiki Tatarstanu – jednego z liderów rozwoju gospodarczego Rosji. Analizie poddan również rolę oceny intensywności zużycia węgla w regulacji gospodarki regionalnej poprzez optymalizację struktury użytkowania gruntów.

Słowa kluczowe: usługi ekosystemowe, użytkowanie gruntów, bilans CO_2, Republika Tatarstanu