CARBON POLYGONS AND THEIR IMPACT ON LOCAL ECOSYSTEMS: INTERACTIONS AND CONSEQUENCES

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Abstract

Carbon polygons are areas where data are collected and accumulated to assess the carbon balance of ecosystems, as well as to implement measures to reduce carbon emissions and increase the absorption of greenhouse gases (GHGs). They play an important role in the context of the global fight against climate change, providing important information for improving the management of carbon cycles. However, their impact on local ecosystems is complex and multifaceted. The interaction of carbon polygons with the surrounding nature can vary from positive (e.g. restoration of biodiversity, improvement of soil and water conditions) to negative (including changes in vegetation structure, disruption of usual animal migration routes and possible displacement of local species). This paper considers the key ecological aspects of the functioning of carbon polygons, their interactions with local ecosystems, as well as possible socio-ecological consequences, including both environmental benefits and potential threats to biodiversity and the resilience of natural systems.

Keywords: carbon polygons, carbon balance, climate change, local ecosystems, biodiversity, greenhouse gases, ecosystem restoration, ecosystem services

I. Introduction

More than 160 countries around the world have committed to achieving carbon neutrality by 2030-2070 in one form or another. 1 The goal of achieving carbon neutrality no later than 2060 is formulated in the Climate Doctrine of the Russian Federation. However, many decarbonization plans lack specificity. As a result, they are being implemented too slowly, faced with increasing protectionism, complicated geopolitical problems (security, reliability of supply chains), which prevents the necessary pace of progress towards carbon neutrality. 2 In order for decarbonization actions to be understandable, coordinated at all levels of decision-making and implementation, and to receive broad public support, a clear and understandable action plan is needed - a roadmap - to transform the current raw materials model of economic and socio-political development of Russia into a model of an inclusive and fair innovative low-carbon economy.

The pilot project to create a network of carbon polygons in the Russian Federation is aimed at fulfilling the tasks within the framework of the national action plan for adaptation to climate change and ensuring environmental safety. The main goal of the project is to study the processes of emission and absorption of greenhouse gases (GHG) and develop technologies that help reduce their concentration in the atmosphere. Carbon polygons are experimental territories where comprehensive studies are carried out aimed at assessing the carbon balance of ecosystems and implementing solutions to reduce GHG emissions and increase their absorption.

The main objectives of the project:

1. Monitoring greenhouse gas emissions and absorption:

One of the key functions of carbon polygons is to monitor emissions and absorption of GHGs (carbon dioxide, methane, and others). Ground-based and remote measurement methods are used,

such as installing sensors, detectors, and using satellite data. This helps to monitor the dynamics of carbon flows and identify sources and sinks of GHGs in different types of ecosystems.

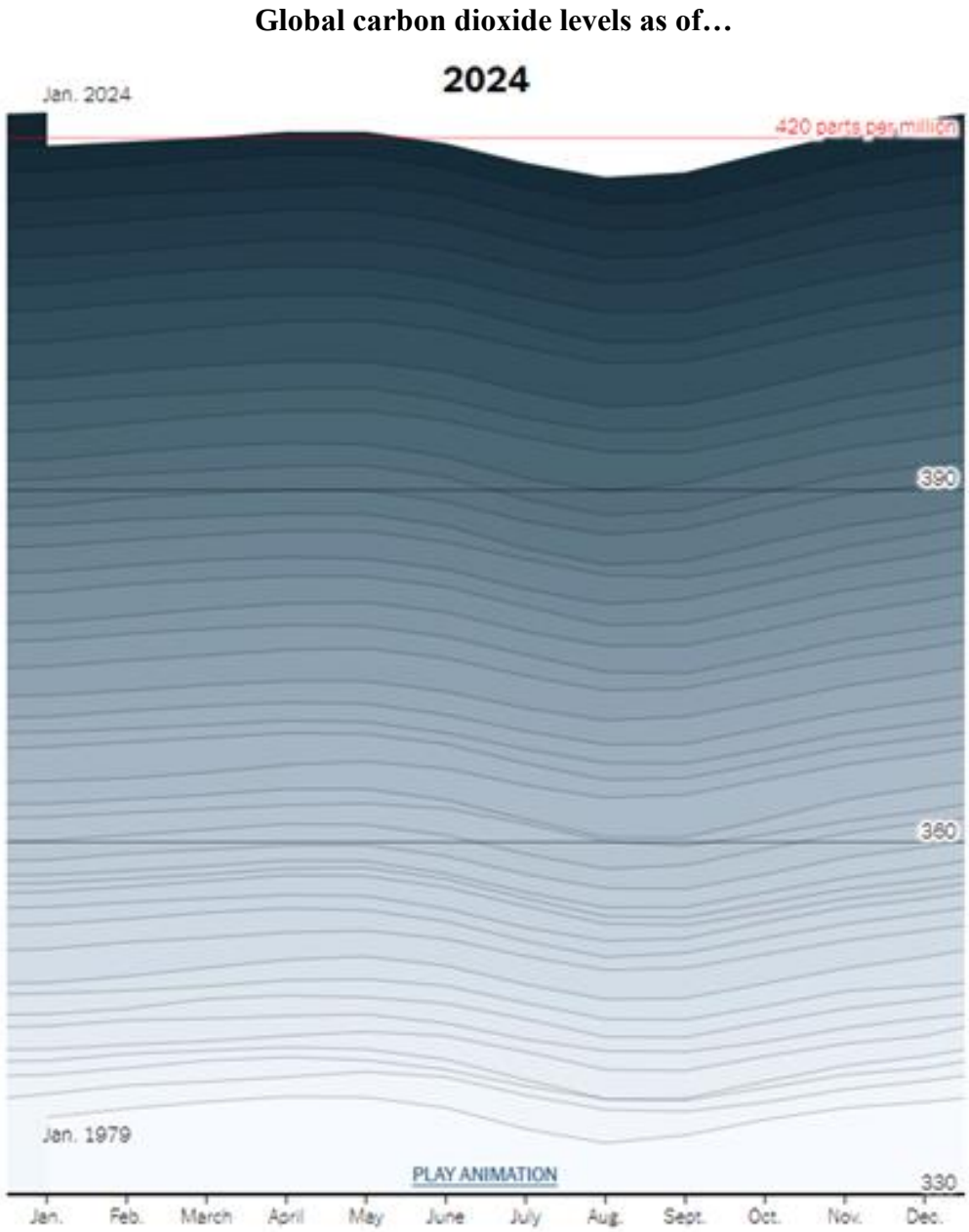

Figure 1: *The chart shows monthly numbers of carbon dioxide molecules per million molecules of dry air. Because of seasonal differences, levels are higher in May than in August.*

2. Assessment of spatial and temporal variability of carbon fluxes:

Regular measurements are taken at landfills to determine the spatial and temporal dynamics of carbon emissions and absorption. These data allow the creation of integrated carbon balance models, assessing how these flows change depending on the season, time of year, weather conditions and landscape features. As a result, conclusions can be drawn about how differences in climate and geography can affect the carbon balance of various ecosystems.

3. Development of technological solutions to reduce emissions and increase absorption of greenhouse gases:

One of the project's priorities is testing and verification of technologies aimed at reducing emissions and increasing absorption of GHGs by natural ecosystems. Such technologies include

forest restoration, regulation of agricultural practices (e.g. minimizing the use of fertilizers and improving agricultural practices), water and soil management. In addition, polygons are used to test these technologies under conditions close to real ones and verify their effectiveness in different climate zones and ecosystems.

4. Development of technologies for remote monitoring of ecosystems:

To manage carbon flows, it is necessary to develop technologies for remote monitoring of the structure and condition of ecosystems (vegetation and soil cover, soil moisture, biomass). This is achieved by synthesizing ground-based measurement data with the results of satellite observations and mathematical modeling. The use of such technologies will allow for prompt assessment of the condition of ecosystems and forecasting changes in the carbon balance.

The carbon landfill project proposed by Ctrl2Go is a key initiative to address Russia's unsustainable production and reduce greenhouse gas emissions. With limited government resources to develop their own solutions, business participation is becoming a strategically important step. Ctrl2Go has provided a technology that can not only reduce Russia's gap in the green economy, but also make it one of the leaders in this field. With the European Union introducing a carbon tax from 2023, Russia faces additional challenges amid an economic crisis exacerbated by the COVID-19 pandemic. The carbon landfill project provides an opportunity to minimize risks to the economy and avoid a protracted crisis that could arise due to the complication of trade relations with the EU.

The authors of the project emphasize that carbon landfills are the only fast and effective way for Russian enterprises to reduce greenhouse gas emissions. This is a preferable way compared to the proposal to introduce taxes on excess carbon dioxide emissions, which, according to the authors, will not solve the problem of polluting industries, but will only increase the burden on them. The technology developed by Ctrl2Go is capable of providing real mechanisms for monitoring and reducing emissions, which makes this project a viable alternative to tax measures.

The scientific component of the project also plays an important role. Russia, which has long relied on traditional fuels such as oil and gas, risks falling behind in the field of new energy sources, which will negatively affect its industry and energy sector. Carbon polygons allow not only to implement emission control technologies, but also to create a scientific complex for automated measurement of the level of carbon dioxide absorption in various natural zones of the country. This is especially important in the context of international climate agreements and requirements. The European Union uses closed methods for calculating the carbon footprint, which take into account only the level of emissions, but do not take into account the absorption of carbon dioxide by nature. The carbon polygon project will allow Russia to develop an alternative system for assessing the carbon balance and propose its own adjustments to the international practice of calculating carbon duties, which will strengthen its position in international negotiations.

II. Methods

Carbon landfills are currently being considered as a possible tool to combat the effects of climate change. Their main advantage is that they can improve air quality by capturing and storing carbon dioxide emitted by industrial plants, which is especially important near large emission sources. These landfills also have the potential to reduce the amount of carbon dioxide released into the atmosphere, which helps slow global warming. In addition, the development of this technology can stimulate economic growth and create new jobs.

However, carbon landfills also have their drawbacks. Their implementation requires significant financial costs, which can become a serious barrier to large-scale use. It is also worth considering that the technology is still in the development stage, and there are many technical problems that need to be solved. In addition, the ability of carbon landfills to capture carbon dioxide is limited, and their effectiveness on a global scale remains questionable. Overall, despite

the existing difficulties, carbon landfills play an important role in studying the mechanisms of CO_2 absorption by natural ecosystems and can become a significant element in the fight against climate change.

III. Results

The need to combat climate change remains important at the global level, and Russia continues to actively develop climate policy. Data on greenhouse gas (GHG) emissions and absorption play a key role, as they are used to formulate climate goals, compile country and company reports, implement climate projects, and develop carbon markets. However, the quality of this data is still far from ideal. According to the IEA, the uncertainty in estimates of global carbon dioxide emissions is 10%, methane - 25%, nitrous oxide - 30%, and fluorinated gases - 20%. Also difficult is the assessment of the ability of forests and other ecosystems to absorb carbon, which is of particular importance for the Russian climate strategy.

Russia's climate goal for 2030 is to reduce GHG emissions to 70% of 1990 levels, taking into account the maximum absorption capacity of forests and other ecosystems, subject to sustainable socio-economic development. Currently, absorption compensates for about 30% of GHG emissions in the country. The assessment methodology is based on recommendations from the Intergovernmental Panel on Climate Change, but discussions about the accuracy continue.

In February 2022, Russia approved the Federal Program for Environmental Development and Combating Climate Change until 2030, which includes the creation of a system for monitoring GHG flows and the carbon cycle. The law on limiting GHG emissions adopted in 2021 obliged large emitting companies to submit emissions reports and opened up opportunities for climate projects.

The report analyzes the role and current state of the carbon landfill network in Russia, including goals, objectives, regional characteristics, results, scientific research, technologies, educational programs and international cooperation.

IV. Discussion

Global averaged concentrations of carbon dioxide (CO2), the most important greenhouse gas, in 2022 were a full 50% above the pre-industrial era for the first time. They continued to grow in 2023.

The rate of growth in CO2 concentrations was slightly lower than the previous year and the average for the decade, according to WMO's Greenhouse Gas Bulletin. But he said this was most likely due to natural, short-term variations in the carbon cycle and that new emissions as a result of industrial activities continued to rise.

Methane concentrations also grew, and levels of nitrous oxide, the third main gas, saw the highest year-on-year increase on record from 2021 to 2022, according to the Greenhouse Bulletin, which is published to inform the United Nations Climate Change negotiations, or COP28, in Dubai.

“Despite decades of warnings from the scientific community, thousands of pages of reports and dozens of climate conferences, we are still heading in the wrong direction,” said WMO Secretary-General Prof. Petteri Taalas. “The current level of greenhouse gas concentrations puts us on the pathway of an increase in temperatures well above the Paris Agreement targets by the end of this century. This will be accompanied by more extreme weather, including intense heat and rainfall, ice melt, sea-level rise and ocean heat and acidification. The socioeconomic and environmental costs will soar.. We must reduce the consumption of fossil fuels as a matter of urgency,” said Prof. Taalas .

Just under half of CO2 emissions remain in the atmosphere. Just over one quarter are absorbed by the ocean and just under 30% by land ecosystems like forests – although there is significant year-to-year variability in this. As long as emissions continue, CO2 will continue accumulating in the atmosphere leading to global temperature rise. Given the long life of CO2, the temperature level already observed will persist for several decades even if emissions are rapidly reduced to net zero.

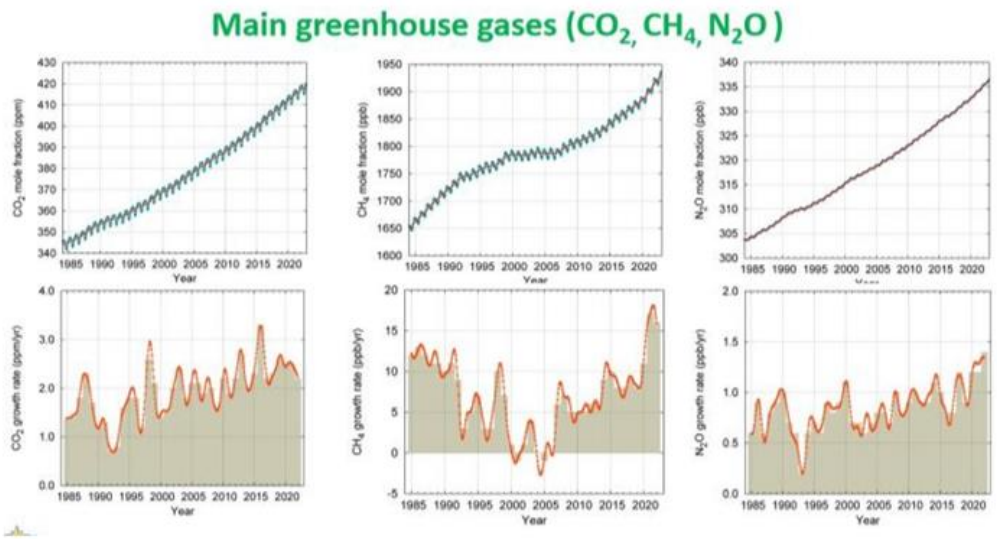

Figure 3: *Graphs - Main greenhouse gases*

The last time the Earth experienced a comparable concentration of CO2 was 3-5 million years ago, when the temperature was 2-3°C warmer and sea level was 10-20 meters higher than now.

The carbon measurement supersite at Kadyrov Chechen State University is distinguished for its scientific research aimed at developing regenerative animal husbandry technologies in mountainous and foothill regions. Regenerative grazing management, especially adaptive grazing across multiple pastures, helps to reduce soil degradation compared to continuous grazing, thereby potentially lowering carbon emissions from the soil. The integration of crop rotation and maintaining perennial cover crops with controlled grazing also contributes to the accumulation of organic carbon in the soil.

This work is being carried out as part of a project to develop a pasture management tool. To achieve these goals effectively, the university collaborates with climate and carbon experts from the Peoples' Friendship University of Russia, the Voronezh State Forestry University, the National Research University Higher School of Economics, the Institute of Geography of the Russian Academy of Sciences, and the Yu.A. Israel Institute of Global Climate and Ecology.

The project aims to identify the most efficient methods of regenerative animal husbandry to enhance carbon sequestration in pastures and study the effects of climate on ecosystems in mountain and foothill landscapes. The planned service will rely on a digital model of pasture sites, enabling the analysis of pasture conditions, degradation, forage production volume, and the detection of soil and grass cover damage, wind and water erosion, and signs of salinization. At each site (reference, intensive grazing, and average grazing sites), aboveground herbaceous vegetation is sampled to evaluate biomass volume and quality. The dominant plant species in each ecosystem are identified. In total, 62 species of vascular plants from 31 families have been cataloged on the southern slope of the Makazhoy Basin.

A mathematical model has been employed as part of the project to account for the physical stabilization mechanisms of soil organic matter. Parameter identification for this model is currently underway at regenerative animal husbandry test sites. The project aims to restore soil quality,

increase soil carbon content, improve production profitability by increasing livestock density in the same areas, and reduce production costs through natural pasture restoration.

Figure 4: Carbon Polygon Territories of Kadyrov Chechen State University

Figure 5: *Carbon polygon Way Carbon*

The polygon is unique due to the diversity of landscapes on its territory, including steppe zones, forests and subalpine meadows. This allows for research to be conducted in various natural conditions, making climate research more comprehensive. Each of these zones conducts its own climate research aimed at understanding how different ecosystems respond to changes in the environment.

The key goal of the research is to create conditions for carbon neutrality. This means that scientists aim to ensure that the environment absorbs more carbon than it emits. To do this, strategies are being developed to reduce carbon dioxide emissions and increase its absorption by natural ecosystems such as forests, meadows and soils. Ultimately, this will help combat global climate change and preserve ecosystems.

This excerpt talks about carbon sequestration as one way to achieve carbon neutrality. Carbon neutrality means a balance between the emission of carbon dioxide into the atmosphere and its absorption by natural processes. One effective way to absorb CO_2 is to plant plants with high sequestration potential, i.e. the ability to actively accumulate carbon dioxide from the atmosphere.

Sequestration in this context means the absorption of carbon by plants or soil, which helps to offset CO_2 emissions, and carbon dioxide emissions and absorption are monitored at special landfills to determine how effectively this helps to achieve a carbon balance.

Carbon farms are plots of land where plants with a high potential for carbon sequestration are planted. For example, paulownia and poplar are mentioned as tree species that can actively sequester carbon because they grow quickly and effectively absorb CO_2 from the atmosphere.

Thus, with the help of such projects aimed at increasing the absorption of carbon dioxide, it is possible to offset carbon emissions and get closer to achieving carbon neutrality.

Carbon polygons are an important and promising area in Russia's climate policy. They not only contribute to the creation of a reliable system for monitoring carbon flows in the country's ecosystems, but also increase confidence in Russian climate initiatives, since foreign carbon farms face problems with the reliability of their results. According to the Center for Strategic Research (CSR), the polygons, sharing the goals and objectives of the Ministry of Education and Science of Russia, focus on the practical aspects of their work, including the search for optimal solutions for decarbonization. The presence of industrial partners enhances the practical focus of their activities. Although most Russian carbon polygons are in the initial stages of implementation, by September 2022 they have already achieved some success, especially in the field of education and scientific research.

Most of the current research at the sites is related to the development of scientific and methodological tools for climate monitoring, such as geographic information systems (GIS). The sites emphasize the importance of timely delivery of equipment to intensify scientific work, but most of the necessary equipment in Russia is imported, mainly from the United States. In the context of increasing geopolitical tensions, this creates risks for supplies. According to the Russian Ministry of Education and Science, deliveries continue, but the deadlines have increased, and prices have increased by 20-30%.

The educational activities of carbon polygons are also developing successfully. In 2021–2022, at least seven new educational programs for bachelors and masters were created, existing programs were updated, and new courses were introduced. More than 15 advanced training programs and courses were also prepared. In addition, the polygons actively conduct educational and outreach events.

The most challenging situation at present is international cooperation of carbon polygons, which is extremely important for the recognition of Russian research abroad. There is a breakdown in traditional ties with the West, a transition to more active cooperation within the EAEU and a reorientation towards Asian countries. The Russian Ministry of Education and Science is making efforts to support international cooperation by inviting foreign experts from friendly countries to the Expert Council. The survey showed that polygons almost unanimously recognize the potential for further development in all areas: scientific research, education and international cooperation, and plan to commercialize and scale up best practices in the future. However, they also note the existence of barriers, such as access to technology, funding, infrastructure and administrative difficulties, including difficulties with permitting procedures, lack of standards and unified methods. Among the potential barriers, access to funding and uncertainty with the verification of the obtained data are most often mentioned.

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