Drebot, Oksana; Zinovchuk, Natalia; Vysochanska, Mariya et al.

**Article**

# Analysis of existing models of climate change and identification of zones which are suitable for agricultural production in the context of rural territories

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**Oksana Drebot,**
**Natalia Zinovchuk,**
**Mariya Vysochanska,**
**Lyudmyla Sakharnatska**

# ANALYSIS OF EXISTING MODELS OF CLIMATE CHANGE AND IDENTIFICATION OF ZONES WHICH ARE SUITABLE FOR AGRICULTURAL PRODUCTION IN THE CONTEXT OF RURAL TERRITORIES

*The object of research is the methodology of existing models of climate change and the identification of areas that are suitable for agricultural production.*

*The consequences of natural disasters (floods, tornadoes, tornadoes, earthquakes, volcanic eruptions etc.) are the destruction of local ecosystems and the local economy, the emergence of threats to food and water supply, the creation of social conflicts, internal and external migration. Damage from natural disasters is estimated at billions of dollars. The economies of countries in which natural disasters are being synchronized cannot recover on their own and need international assistance, especially the placement of climate refugees in other countries. An analysis of recent research and publications shows that its authors do not even pose such a problem. In the period from 2011 to 2020 alone, the number of natural disasters in the world increased 7 times, in particular in Europe – 41 times.*

*The study shows that the concept of anthropogenic impact on climate change, sustainable development and possible adaptation through environmental and energy and resource conservation measures must be considered erroneous. International spending on climate change adaptation programs around the world is inefficient. The theoretical basis on which these concepts have been built so far needs to be revised, and the environmental policy of all countries of the world is subject to radical transformation.*

*The practical significance of research is to improve the model of climate change, which is used to develop forecast scenarios for world events, based on the dependence of $CO_2$ emissions. from anthropogenic human activity. Since the results of any mathematical model depend on the input data and the correlation of the relationships embedded in such a model, the percentage of reliability and probability of implementation of such a model is also estimated. Therefore, climate models developed at the initiative of the International Group of Experts on Climate Change cannot be used as a basis for substantiating recommendations for the transformation of agriculture in accordance with climate change.*

**Keywords:** *agrosphere, agroecosystems, climate change, adapting agriculture, agricultural production, rural development, rural areas.*

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## 1. Introduction

A number of international organizations and leading universities in the world are dealing with the impact of global warming and climate change on the emergence of climate migrants. In particular, the International Organization for Migration investigates this issue and presents the results of its research in its reports. Among the scholars is the author of the paper [1], which examines the policies and programs of the United Nations Migration Agency (IOM) related to migration, environment and climate change, and coordinates IOM's contribution to political processes, such as negotiations on climate change.

In recent years, more and more research has emerged recognizing that climate change poses an unacceptably high and potentially catastrophic risk to our planet, and that

preventing the effects of climate change may be the biggest dilemma of the 21st century. Climate change caused by anthropogenic and natural factors has adverse effects on the environment through numerous direct (e. g. heat waves, sea level rise, frequency and intense storms) and indirect pathways (e. g. food and water shortages, social and environmental instability).

The relevance of this study today is debatable and calls for a detailed study, in particular, the root causes of climate change and their impact on migration, as well as contribute to the development of basic approaches to solving the problem of climate migrants.

Therefore, the development of scenario forecasts of agricultural production depending on climate change is real and urgently needed.

Thus, *the object of research* is the methodology of existing models of climate change and the identification of areas that are suitable for agricultural production. And *the purpose of the work* is to develop a methodological basis for the analysis of climate change and opportunities for adaptation to it. Particular attention was paid to: characteristics of the manifestations and consequences of climate change; analysis of existing climate models.

## 2. Research methodology

In modern science, there are two diametrically opposed views on the causes of global climate change. According to the first approach, global climate change is caused by anthropogenic factors, and the second approach interprets these changes as cycles occurring in nature. The approaches are reflected in Article 1 of the UN Framework Convention on Climate Change (UNFCCC). Article 1 defines climate change as: «directly or indirectly caused by human activities that cause changes in the global atmosphere and are superimposed on natural climate fluctuations observed during comparative periods of time» [2]. The Intergovernmental Panel on Climate Change (IPCC) emphasizes the dominance of the human factor: «Human impact on the climate system is obvious, and modern anthropogenic greenhouse gas emissions are the largest in history» [3]. Opponents of this concept, and we support them, argue that global climate change is not caused by long-term anthropogenic changes in the atmosphere or land use, but by natural internal processes or external influences such as solar cycle regulation or volcanic eruptions.

## 3. Research results and discussion

Climate change has been found to be a significant and lasting change in the statistical distribution of weather conditions over long periods of time. Climate change includes changes in average weather conditions as well as extreme weather events, which can be frequent or rare. Climate change is determined over a period of decades to millions of years [4]. A sign of change in climate is the change in the average values and/or variability of its parameters, which persist for a long period [5]. Climate change can be local and global. Global climate change is commonly referred to as global climate change. Global climate change has a direct impact on the transformation of local climate systems.

The climate system combines the atmosphere, hydrosphere, lithosphere, cryosphere and biosphere. The components of the climate system are interconnected and complex, characterized by direct and indirect connections. The complexity and ambiguity of connections in the climate system, the constant evolution of its components with different inertia is the cause of many climate changes on the planet. Since under the same external conditions on Earth there can be several types of climate, the state of the climate system is determined not only by external influences, but also by the interaction between its components.

Physical mechanisms that affect the climate system, as well as the main interactions between its components are called climate-forming factors. They are divided into: external, which determine the energy impact on the climate system, and internal, which characterize the properties of the climate system itself. Climate change means the restructuring of all geosystems on the planet [5, 6].

The manifestations of climate change include:

– increase in air temperature;
– appearance of abnormal weather phenomena (tsunamis, typhoons, floods, tornadoes, fires in regions for which these phenomena were uncharacteristic);
– melting glaciers;
– raising the level of the world's oceans;
– change of population and habitats of animals, etc. [6].

Due to the limitations of modern tools in the study of the relationship between the components of the climate system and climate-forming factors, scientists often consider the same manifestations of climate change as their causes and consequences. An important methodological problem is the establishment of causal relationships between different manifestations of climate change. Certain controversial and controversial points have been made on this issue since the emergence and spread of the concept of global warming. It should be emphasized that the history of attracting the attention of the general public to climate change dates back to 1979, when the World Climate Conference was held at the initiative of the World Meteorological Organization and the United Nations Environment Program (UNEP). The most important result of the conference was the decision to create a World Climate Program. In 1985, an International Conference was held to assess the role of carbon dioxide and other greenhouse gases in climate fluctuations and related impacts. The decisions of this conference were the basis for the establishment in 1988 of the Intergovernmental Panel on Climate Change (IPCC).

The result of the Intergovernmental Panel on Climate Change from 1988 to the present is the preparation of: 6 Assessment Reports; methodological reports; Special Reports [7]. An analysis of the content of the reports of the Intergovernmental Panel on Climate Change suggests that most of the research was conducted in support of the concept of global warming. Its content was that increasing emissions of $CO_2$ and other gases into the atmosphere through the development of economic activities and human activities leads to the greenhouse effect, which causes global warming, which in turn provokes climate change and disasters. Global climate change is associated with human activities that produce so-called greenhouse gases, which absorb the spectrum of infrared radiation and cause global warming.

The spread of the concept of global warming has led to the emergence of two opposing views in the current international political and scientific community on the causes

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of global climate change. Many scientists and politicians still believe that the cause of global warming and other climate change is the rise in atmospheric temperature, which is due to human economic activity.

However, today there are other opinions about the causes of climate change. Representatives of natural sciences consider biotic processes, fluctuations of solar radiation, movement of tectonic plates, volcanic eruptions as factors of climate change. Some scientists argue that the main cause of climate change is not so much human activity, but cyclical natural phenomena. Geosensors record the expansion of the planet along the equator, which causes earthquakes, energy and frequency of which increases every year. The most powerful fires occur at the fault of tectonic plates due to increased emissions from the middle of the lithosphere. The glaciers of Antarctica and Greenland are melting from the bottom to the top, primarily because magma and the accompanying heat fluxes are rising from the Earth's interior. The increase in neutrino and $CO_2$ emissions occurs from the middle of the lithosphere, not from its surface. Geophysicists claim that in 2020 climate change has reached a new level, characterized by the synchronization of natural disasters. Changes on planet Earth are identical to changes on other planets in the solar system.

Thus, it should be noted that climate change is a natural process of development of the planet Earth and does not depend on the existence of people and their activities. This is more realistic and should be the basis of a methodology for adapting agriculture to climate change.

The consequences of global climate change are an increase in the number of natural disasters and the synchronization of their manifestations. Natural disasters are natural or anthropogenic phenomena, or large-scale processes, which may or may not endanger human life and health, destroy or destroy material values and components of the environment. Natural disasters can occur independently of each other or in relation to each other. They always have a significant scale, but differ in the duration of manifestations, which can be from a few seconds to several hours, days, months.

Analysis of the dynamics of natural disasters for the period from January 2011 to October 2020 shows, that their number, strength and scale increase exponentially (Table 1).

During this period, the number of countries in which a disaster occurred increased 4.5 times. The total number of disasters increased 7 times. And only in 2019–2020 the number of natural disasters has doubled. The greatest growth rates are floods, tornadoes, landslides and mudslides. During the study period, the number of floods increased 8 times, tornadoes – 5 times, landslides and mudslides – 22 times. Since 2017, the manifestations of all natural disasters have been synchronized and the area and scale of their destructive force has been increasing.

Analysis of natural disasters in Europe shows that their share in the total number of countries affected by natural disasters ranges from 7.7 % (2011) to 29.6 % (2014) and 29.3 % (2020). Beginning in 2017, there is a tendency to increase this share, which indicates that Europe is becoming a dangerous area for living. The total number of manifestations of natural disasters for the period 2011–2020 increased 41 times. Among the most common manifestations are floods, tornadoes, forest fires. Since 2017, there have been earthquakes, volcanic eruptions, storms, faults, landslides and villages, and abnormal hail in Europe. The most dangerous countries include Italy, Spain, Greece and Portugal. For example, in Ukraine in the period 2011–2020 there were only 11 cases of natural disasters, including floods (1 case), tornadoes (5 cases), tornadoes (2 cases), landslides and villages (2 cases), anomalous hail (1 case). Therefore, these data give grounds to consider Ukraine a safer country than most European countries.

**Table 1**

Dynamics of manifestations of natural disasters in the world, 2011–2020

| Characteristics of manifestations | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of countries in which the disaster occurred | 13 | 26 | 21 | 27 | 29 | 35 | 35 | 34 | 40 | 58 |
| The total number of manifestations of natural disasters, including: | 19 | 32 | 38 | 34 | 41 | 46 | 51 | 48 | 73 | 135 |
| – floods | 6 | 14 | 15 | 15 | 17 | 12 | 11 | 10 | 24 | 49 |
| – water tornadoes | – | – | – | – | – | – | 1 | – | 1 | 7 |
| – tsunami | – | – | – | – | – | – | – | 1 | – | – |
| – storms | – | – | – | – | – | – | 1 | – | – | 4 |
| – cyclones, hurricanes | 1 | 2 | – | – | 1 | 2 | 3 | 4 | 3 | 3 |
| – typhoons | 3 | 1 | 5 | 2 | 2 | 4 | 3 | 4 | 4 | 1 |
| – tornado | – | 5 | 5 | 1 | 2 | 7 | 3 | 2 | 11 | 24 |
| – earthquakes | 4 | 4 | 4 | 2 | 3 | 9 | 9 | 5 | 5 | 5 |
| – volcanic eruptions | 2 | 2 | 3 | 6 | 5 | 4 | 4 | 6 | 6 | 7 |
| – faults of the earth's crust | – | – | – | – | – | – | – | 5 | – | – |
| – landslides, villages | 1 | – | 2 | 7 | 5 | 1 | 11 | 7 | 8 | 22 |
| – sandstorms | – | – | – | – | – | – | – | – | – | 2 |
| – forest fires | 2 | 4 | 4 | 1 | 4 | 6 | 5 | 2 | 6 | 5 |
| – abnormal snow, hail | – | – | – | – | 2 | 1 | – | 2 | 5 | 5 |

**Note:** formed and calculated according to [8]

Among the most recognized climate models are:
– EUROPA-MODELL (numerical model of weather forecast for calculations of thermodynamic characteristics);
– ECHAM4 (block of the global climate model, which calculates the processes of cloud and precipitation, the passage of solar radiation in the atmosphere, the impact of the underlying surface on heat fluxes, taking into account albedo and surface type);
– REMO (combines EUROPA-MODELL and ECHAM4 models and allows modeling of past and future regional climate);
– RegCM3 (is a hydrostatic version of the 5th version of the mesoscale model MM5, which is based on solving equations for a compressible atmosphere in the σ-coordinate system);
– HIRLAM (weather forecast model);
– RCA3 (allows to take into account the underlying surface within one coordinate cell, the scheme of solar radiation transfer, turbulence and parameterization of cloud and precipitation);
– IPCC-2007 (Global Climate Change Model) [9].

Predictive variables in all models are pressure, temperature, horizontal projections of wind speed, absolute humidity and water content of clouds. Baseline and boundary data for models can be analysis data from, for example, the European Center for Medium-Range Weather Forecasts (ECMWF), reanalysis, or most global climate models. On the basis of climate models, variant forecasts of reduction (or increase) of $CO_2$ emissions are developed. At the initiative of the International Climate Change Expert Group, standards and scenarios for climate forecasting were set within the Climate Comparison Projects of the World Climate Research Program (CMIP5, CMIP6). More than twenty climate centers around the world have developed about thirty climate models. In the most pessimistic scenario (SSP5 8.5 – rapid economic growth due to fossil fuels), the increase in average global temperature will reach 6–7 °C by 2100, which is 1 °C higher than in previous estimates. Only one of the socio-economic scenarios (SSP11.9 – marked by strong international cooperation and prioritization of sustainable development) allows to maintain temperatures below the global warming target by 2 °C at the cost of very significant mitigation efforts [10].

It is important for the analysis of climate models and forecast scenarios developed on the basis of such models to understand that the results of any mathematical model depend on the input data and the correlation of the relationships embedded in such a model. The percentage of reliability or probability of implementation of such a model is also estimated. Therefore, climate change models developed at the initiative of the International Panel on Climate Change, which are based on the dependence of $CO_2$ emissions on human anthropogenic activities, cannot be used as a basis for developing recommendations for adapting agriculture to climate change.

Climate change is destroying the environment, destroying many sectors of the economy, encouraging people to relocate to other places or countries. Migration, which is associated with rescue from emerging climatic disasters, such as floods, landslides and tsunamis, volcanic eruptions, faults, is inevitable and requires a rapid response. Migration, which is associated with the inability to adapt to abnormal weather conditions, droughts, tornadoes, storms, forest fires, tornadoes over a period of time, is prolonged over time, but also irreversible. Thus, in the period from 2008 to 2018, 87 % of internal movements around the world were caused by disasters related to weather factors, rather than political, economic, social and other conflicts [11, 12].

Tens of thousands of people face threats to food security, forced migration, disease and death. Climate change has a direct impact on ecosystem biota. Many natural systems are particularly sensitive to climate change because they have limited adaptability. Many of these systems are destroyed forever. To a large extent, this applies to many species of living organisms that live in the natural environment under normal living conditions. Individual species may increase their numbers or habitats in the new environment, but climate change will increase the existing risks of extinction of some of the more vulnerable species and significantly increase the threat of biodiversity loss.

It is important to understand that global climate change has direct and indirect effects on the industrial sector. Direct impacts are associated with direct changes in climatic conditions due to changes in energy consumption and availability of natural resources, difficult access to minerals, increased risk of man-made emergencies, insufficient water resources of appropriate quality, etc. Indirect impacts are due to changes that occur in related industries and are changes in economic conditions due to the dependence of processing enterprises on management schemes in agriculture and forestry [12].

It has been found that the effects of climate change in rural and urban areas in the same region may be different. Large and medium-sized cities are more dangerous to survive. It is believed that the combination of the negative effects of urbanization and climate change poses a direct threat to environmental, economic and social security. Climate change can cause direct risks (flooding, abnormal heat, exacerbated by urban microclimatic features, etc.) and indirect – disruption of the functioning of certain urban systems and difficulties in providing basic services to the population (water, public transport, energy, etc.).

Until now, countries with low adaptive capacity, i. e. limited economic resources, low technology, poor information network, weak infrastructure, unstable or underdeveloped institutions, unfair access to resources, were considered to be more vulnerable to climate change. On the contrary, developed countries have a high adaptive potential and therefore have a better ability to adapt to climate impacts than developing countries or countries with emerging markets. However, natural disasters between 2011 and 2021 have shown that volcanic eruptions, earthquakes, floods, tornadoes, fires, etc. destroy the economy and pose a threat to human health, regardless of the level of economic development of the countries where such events unfold.

It is established that today the world community has declared global climate change as the most serious problem of the world economy, which poses threats to energy, food, drinking water and risks to the existence of ecosystems and people [13]. The world's elite has called on humanity to adapt all areas of the economy and human activities to global climate change. The attention of the world community, focused on global climate change, could be considered a positive phenomenon if it was based on an understanding of the true causes of climate change and

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the manifestations of natural disasters. However, in reality there has been a shift in emphasis from the severity of climate challenges and threats to the gradual solution of certain environmental problems. Such as increasing emissions of $CO_2$ and other gases into the atmosphere through the development of economic activity, which leads to the greenhouse effect, which causes global warming, which in turn provokes climate change and disasters. After all, the concept of anthropogenic impact on climate change turned out to be wrong and impossible to implement in the format of a consumer society. The main drawback was that in many countries around the world to study and improve this issue was directed scientific potential, the priority of which was environmental, economic and social security.

Another concept that also shifts the emphasis from the need to inform all mankind about the devastating future cataclysms to the possibility of gradual adaptation to them is the concept of adaptation to climate change. Adaptation to global climate change is defined as the process of adaptation in natural or human systems in response to actual or expected climate impacts, which will reduce their negative effects and take advantage of opportunities. Adaptation policy is defined as activities and decisions made by public and private stakeholders at different levels of government that purposefully take into account the consequences. They also aim to have a significant impact on stakeholders, sectors and geographical areas in terms of vulnerability to climate change [12]. In anthropogenic systems, the purpose of adaptation is to reduce the potential harm or use of favorable opportunities, in natural – human intervention as a way to adapt to the expected climate and its effects. Mitigation (of climate change) involves human intervention to reduce emissions or increase the absorption of greenhouse gases [14, 15].

A number of scientists believe that adaptation to climate change includes a wide range of measures aimed at reducing economic, environmental and social vulnerability to climate factors. However, given the true cause of climate change – space cycles, the concept of adaptation of society and economy to natural disasters in its modern interpretation seems utopian. Therefore, it can be argued that the existing environmental policy of the states, in the framework of which climate change measures are implemented, needs a radical transformation.

Adaptation to climate change in the city requires an integrated approach and implementation of measures at various levels. For some of the negative effects of climate change, it is important to develop a system of monitoring/early warning/risk management – this will at least partially minimize the damage caused by meteorological factors. And when formulating a citywide plan for adapting to climate change, it should be noted that there are measures that help mitigate several negative effects of climate change, so their implementation will be most effective for adapting to the city. When planning adaptation measures, it is important to remember that the scale and intensity of the negative effects of climate change depend on the amount of greenhouse gases produced by human activities. Therefore, it is necessary to reduce greenhouse gas emissions at the level of each country and city in order to mitigate climate change and facilitate adaptation to the inevitable consequences.

## 4. Conclusions

From the above it is possible to conclude that climate change is a natural process of development of the planet Earth and does not depend on the existence of people and their activities. Global climate change on Earth is derived from astronomical processes and their cyclical nature, and which humanity cannot influence. This understanding of the causes of climate change should be the basis for developing a methodology for adapting agriculture to climate change.

Studies of global climate change show an increase in the number of natural disasters and the synchronization of their manifestations. In the period from 2011 to 2020 alone, the number of natural disasters in the world increased 7 times, in particular in Europe – 41 times. The most threatening for Europe were floods, tornadoes, tornadoes, earthquakes and volcanic eruptions. European countries such as Italy, Spain, Portugal and Greece are the most affected by climate change.

Climate modeling for Europe shows that the rise in air temperature in general will continue. Further changes in the amount of precipitation during the year will lead to shifts in climatic seasons, changes in the length of the growing season, reducing the duration of stable snow cover, changes in local water resources, and so on.

After all, the consequences of natural disasters are the destruction of local ecosystems and the local economy, the emergence of threats to food and water supply, the creation of social conflicts, internal and external migration. Damage from natural disasters is estimated at billions of dollars. The economies of countries in which natural disasters are being synchronized cannot recover on their own and need international assistance, especially the accommodation of climate refugees in other countries.

It is proved that the Concepts of Anthropogenic Impact on Climate Change, Sustainable Development and Possible Adaptation to Climate Change through Environmental and Energy and Resource Conservation Measures must be considered erroneous. Expenditures of various countries around the world in the framework of international programs to adapt to climate change are inefficient. The theoretical basis on which these concepts have been built so far needs to be revised, and the environmental policy of all countries is subject to radical transformation.

Models of climate change, which are used to develop forecast scenarios for world events, are based on the dependence of $CO_2$ emissions on anthropogenic human activities. Since the results of any mathematical model depend on the input data and the correlation of the relationships embedded in such a model, the percentage of reliability and probability of implementation of such a model is also estimated. Therefore, climate models developed at the initiative of the International Group of Experts on Climate Change cannot be used as a basis for substantiating recommendations for the transformation of agriculture in accordance with climate change.

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***Oksana Drebot,*** *Doctor of Economic Sciences, Professor, Academician of the National Academy of Agrarian Sciences of Ukraine, Institute of Agroecology and Nature Management of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-2681-1074*

***Natalia Zinovchuk,*** *Doctor of Economic Sciences, Professor, Institute of Agroecology and Nature Management of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-3221-8173*

✉***Mariya Vysochanska,*** *Doctor of Economic Sciences, Senior Researcher, Institute of Agroecology and Nature Management of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine, e-mail: mariya_vysochanska@ukr.net, ORCID: https://orcid.org/0000-0003-2116-9991*

***Lyudmyla Sakharnatska,*** *PhD, Associate Professor, Uzhhorod National University, Uzhhorod, Ukraine, ORCID: https://orcid.org/0000-0002-5863-4917*

✉*Corresponding author*