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DEVELOPMENT OF A DATABASE FOR THE PURPOSES OF GEOSPATIAL MODELING OF REGIONAL CLIMATE CHANGE

Viktor PUTRENKO [1], Nataliia PASHYNSKA [2]
[1] *American University Kyiv, EPAM School of Digital Technology*
Poshtova Square, 3, Kyiv, 04070, Ukraine
e-mail: viktor.putrenko@auk.edu.ua
[2] *Taras Shevchenko National University of Kyiv*
Bohdana Hawrylyshyna, 24, St. Kyiv, Ukraine
e-mail: nat.pashynska@gmail.com

Abstract

The study used data from global and regional climate change modelling in the Zakarpattia region for the period up to 2050 using various climate models and scenarios. The study also used data on the administrative-territorial division of the territory, land cover monitoring, analysis of the territory's relief, statistics on natural hazards and socio-economic monitoring of the region's development. All data were structured on the basis of a number of geospatial databases.

The result of the use of GIS is the development of mathematically sound proposals for the formation of a climate change adaptation strategy in the Zakarpattia region of Ukraine for the time horizon up to 2050, based on the use of a set of analytical tools and geospatial databases.

Keywords: Climate Change, Zakarpattia Region, Geoinformation Modelling, Strategy.

Introduction

One of the biggest challenges of our time is the process of global climate change, which directly affects all spheres of life. However, the effects of climate change have very different outcomes depending on the spatial and temporal scale. Therefore, to meet the adaptation needs of individual communities, it is necessary to develop information systems that can cover large, diverse data sets not only in the field of climatology, but also in the social, economic, environmental, governance and security domains. These tasks are solved through the creation of geographic information systems (GIS) with distributed databases, applied modelling algorithms and decision support modules.

The purpose of this study is to develop an integrated approach to building a GIS for generating recommendations and monitoring the process of community adaptation to climate change and global warming. The study formulated requirements for the formation of a geodatabase, modelling of the main components of the natural environment and its response to climate change, vulnerability assessment for the economy, population and ecosystems. The study was carried out for the Zakarpattia region of Ukraine, which is characterized by a variety of natural conditions and significant risks of natural disasters.

Materials and Methods

Methodology is based on methodology created by ESPON CLIMATE project. In the frame of CLIMADAM project, methodology will be adjusted according to conditions in Zakarpattya oblast in Ukraine and respecting expert opinions of project team members or subcontractors. Analysis of exposure, sensitivity, impact, adaptive capacity, and vulnerability is relevant for the preparation process of adaptation strategy. We are not solving problems of emissions, mitigation, climate variability etc., which are subjects of IPPC, energy efficiency strategies, sustainable transport plans or reduction of carbon emissions strategies (Fig. 1).

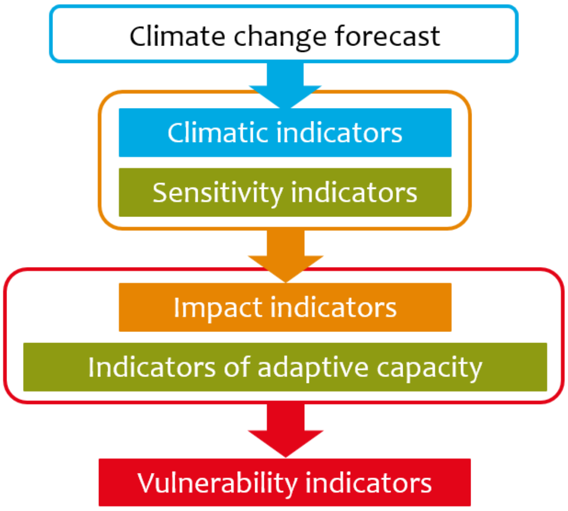

Figure 1. *A general model for assessing the impact of climate change*

At the first stage, the basic administrative units of data collection and unification were determined. Such units are the territorial communities that were formed in the Zakarpattya region in 2019 in the course of the decentralization reform.

Individual indicators are expressed in numerical value for each territory. One numerical value is assigned for each indicator to each territory (municipality). For better clarity, indicators are usually expressed in the form of a map (scheme) where each area of the municipality is assigned to one color depending on the value of the indicator [1].

The calculation of indicator scenarios was undertaken for both regional climate models (models of general atmospheric circulation KMNI and MPI) with a spatial resolution of 25x25 km and a medium emission scenario RPC4.5 [2]. Regional scenarios modification to geographical positions of selected meteorological stations was performed by statistical downscaling, based on comparison of model outputs with measured data in the reference period 1961-1990 (in order to maintain averages and data variability in model outputs). The time horizon scenarios were calculated as the change in the 30-year averages in periods with the midpoint in the years 2005, 2030 and 2050. Scenarios for time horizons are processed for selected meteo stations in the studied region and the surrounding area [3]. Due to the fact that the scenarios differ only slightly between individual stations, such scenarios can be calculated for all stations where the 1961-1990 normals are available. From these scenarios, it is then possible to process temperature maps in future time horizons. Precipitation indicators: In the next procedure, the vertical gradient was calculated, then the meridional and zonal trends were determined. Subsequently, based on the calculated spatial dependencies, scenarios were calculated for all stations where the 1961-1990 normals are available [4].

Based on scenario calculations and statistical downscaling, the projected values of indicators were accessible in the positions of selected meteorological stations. Raster maps of the indicators were developed where selected interpolation methods were used [5].

Several types of interpolation algorithms were tested, and finally values from individual point data were assigned (interpolated) to individual raster cells. Three-dimensional deterministic interpolation methods were used, which work with information about the latitude, longitude and value of the investigated variable, while another additional variable is the altitude that entered the interpolation in the form of a digital relief model (DEM50). The output was a raster map of the indicator.

Next step:

- convert the raster map to a cadastral ma;
- find a suitable way of data representation (center of cadastre, center of municipality, etc.);
- find suitable weights for indicators when compiling vulnerability maps.

There is also a possibility to consider calculating the aggregate exposure that would result from overlaps (combinations) of multiple exposure indicators. This way, a map of the aggregated exposure (or several thematic aggregated exposures, exposure to extreme phenomena related to drought and high temperature, exposure to extreme water-related phenomena, etc.) will be created, which will generally reflect the extent to which individual parts of the region will be exposed to climate change [6].

In turn, the impact of climate change is determined on the basis of indicators of the territory's sensitivity to climate change correlated with climate indicators, namely:

- change in the average annual air temperature;
- change in the average annual number of frosty days;
- change in the average annual number of summer days (with the maximum daily temperature above 25 degrees Celsius);
- change in the average annual number of tropical days (with a maximum daily temperature above 30 degrees Celsius);
- relative change in the average amount of precipitation in the winter months;
- relative change in the average amount of precipitation in the summer months;
- change in the average number of days with precipitation above 20 mm per day;
- change in the average number of days with snow cover per year;
- relative change in annual potential evaporation;
- change in the arid-climatic moisture indicator.

The cumulative impact of climate change consists of physical, environmental, social, economic, and cultural impacts, which are calculated by comparing the indicators of the territory's sensitivity to climate change with climate indicators.

The physical impact of climate change takes into account the following sensitivity indicators:

- sensitivity of built-up areas to flooding;
- sensitivity of roads and railways to flooding;
- sensitivity of built-up areas to freshets;
- sensitivity of roads and railways to freshets;
- sensitivity of built-up areas to landslides;
- sensitivity of roads and railways to landslides.

The environmental impact of climate change takes into account the following sensitivity indicators:

- sensitivity of forest to fires;
- share of protected areas;
- soil sensitivity to erosion;
- organic carbon content in the soil;

- soil sensitivity to drought;
- share of green areas;
- share of built-up areas.

The social impact of climate change takes into account the following sensitivity indicators:

- a population sensitive to summer heat;
- Flood-sensitive population.

The economic impact of climate change takes into account the following sensitivity indicators:

- sensitivity of forest to drought;
- sensitivity of summer tourism to summer temperatures;
- sensitivity of energy demand to heat;
- sensitivity of energy demand to frost.

The cultural impact of climate change takes into account the sensitivity of immovable cultural heritage sites and museums to flooding.

The combination of the five types of impacts provides an indicator of the cumulative impact of climate change on the territory.

The adaptability of the territory was determined based on the following indicators:

- specific weight of expenditures on development measures in local budgets;
- the percentage of financed expenditures on development measures in local budgets;
- capacity (surplus) of local budgets;
- share of the population with higher education;
- number of places in tourist facilities;
- a population sensitive to summer heat;
- connection to centralized water supply (share of connected households);
- connection to a sewerage network with treatment facilities (share of connected households);
- high-speed Internet access (the share of built-up areas with high-speed Internet connections);
- public participation (voter activity in local government elections);
- provision of services to the population (accessibility of social infrastructure facilities);
- age dependence (the ratio of the elderly population to the working-age population);
- transport accessibility (distance to the regional centre).

The result of comparing the indicators of the cumulative impact of climate change and the adaptive capacity of the territory is the degree of vulnerability of the territory to climate change [7].

Results and Discussion

Based on the collected data, a geospatial data base was formed, which has a rather complex structure. The database includes raster and vector data sets and describes the distribution of the main factors influencing climate change, administrative structure. The sequence of data processing includes primary data from international climate databases, secondary data from input processing, tertiary data that are summarized on the basis of the administrative system, and normalized data that are used in subsequent calculations [8].

Taking into account the expected impacts of climate change and the adaptive capacity of territorial communities, the degree of vulnerability to climate change of the territorial communities of Zakarpattia Oblast was determined. According to the results of the vulnerability calculation, spatial patterns can be noted across the region - the territorial communities of the highlands in the east of the region are characterized by the highest vulnerability, while the western part of the mountainous territorial communities is less vulnerable to climate change, and the territorial communities of the Zakarpattia lowlands are characterized by mostly average vulnerability indicators (Picture 2).

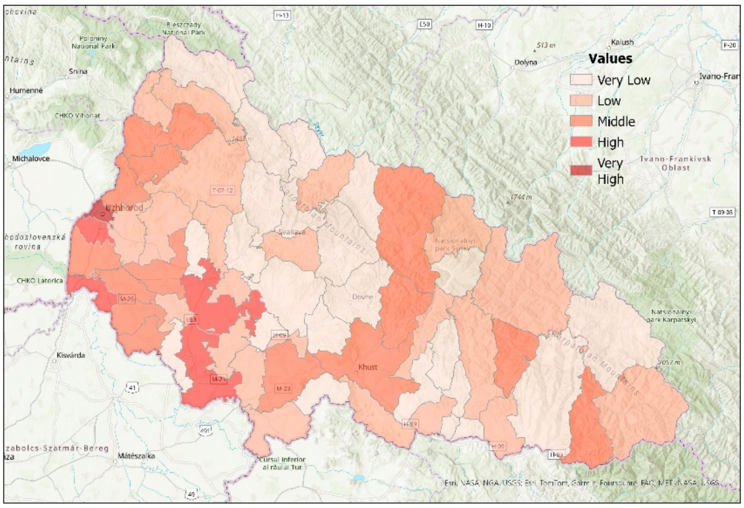

Figure 2. *The degree of vulnerability of communities to climate change*

The territorial communities with the highest level of vulnerability are mountainous, farthest from the regional center with difficult transport accessibility, characterized by higher absolute altitudes than the rest of the region, difficult engineering and geological conditions, the development of hazardous natural processes, and the predominance of forestry and tourism in the economic complex.

Territorial communities with a medium level of vulnerability are mainly concentrated in the Zakarpattia lowlands and are characterized by a high risk of flooding by flood and freshet waters, large areas of agricultural land, higher population density, and most communities have relatively high levels of adaptive capacity [9].

Territorial communities with a low level of vulnerability are located in the western half of the mountainous and foothill territory of Zakarpattia. Most of them are characterized by a low level of cumulative impact and, at the same time, relatively high levels of adaptive capacity.

Conclusion

The result of the study is the formation of an integrated geoinformation system, which, based on a common database and rules for its processing and analysis, provides recommendations on adaptation to climate change at the level of administrative units of Zakarpattia region. Due to the flexibility of the data model, the system periodically updates data analysis and adjusts program measures that are recommended for communities. This will contribute to achieving the goals of sustainable development by the communities of the region.

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РОЗРОБКА БАЗИ ДАНИХ ДЛЯ ЦІЛЕЙ ГЕОПРОСТОРОВОГО МОДЕЛЮВАННЯ РЕГІОНАЛЬНИХ ЗМІН КЛІМАТУ

Віктор ПУТРЕНКО
Амерікан Юніверсіті Київ
Поштова пл., 3, Київ, Україна
https://orcid.org/0000-0002-0239-9241

Наталія ПАШИНСЬКА
Київський національний університет імені Тараса Шевченка
вул. Богдана Гаврілішина, 24, Київ, Україна,
https://orcid.org/0000-0002-0133-688X

Анотація

У дослідженні використано дані глобального та регіонального моделювання змін клімату Закарпатської області за період до 2050 року з використанням різних кліматичних моделей та сценаріїв. У дослідженні також використовувалися дані про адміністративно-територіальний поділ території, моніторинг ґрунтового покриву, аналіз рельєфу території, статистичні дані про стихійні лиха та соціально-економічний моніторинг розвитку регіону. Усі дані були структуровані на основі низки геопросторових баз даних.

Результатом використання ГІС є розробка математично обґрунтованих пропозицій щодо формування стратегії адаптації до змін клімату в Закарпатській області України на часовий горизонт до 2050 року на основі використання комплексу аналітичних засобів та геопросторових баз даних.

Ключові слова: Зміна клімату, Закарпатська область, Геоінформаційне моделювання, Стратегія.