2025

160th anniversary of Odesa I. I. Mechnikov National University

CLIMATE SERVICES: SCIENCE AND EDUCATION

Proceedings of the Second International Research-to-Practice Conference

ClimEd

SUNRISE

GROMADA

Co-funded by the Erasmus+ Programme of the European Union

CLUVEX

CLIMATE UNIVERSITY FOR VIRTUAL EXCHANGES

16-18 April 2025 | ODESA

ODESA I.I. MECHNIKOV NATIONAL UNIVERSITY

www.cs2025.onu.edu.ua

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
ODESA I. I. MECHNIKOV NATIONAL UNIVERSITY
FACULTY OF HYDROMETEOROLOGY AND ENVIRONMENTAL SCIENCE

CLIMATE SERVICES: SCIENCE AND EDUCATION

Proceedings of the Second International
Research-to-Practice Conference

Odesa, 16-18 April 2025

ODESA
ONU
2025

UDC 378:551.58
C61

Editors:
Valeriya Ovcharuk, DSc (Geography) - Chair of the Editorial Board;
Inna Khomenko, PhD (Geography);
Alina Semerhei-Chumachenko, PhD (Geography).

Recommended for publication by the Academic Council of the Faculty of Hydrometeorology and Environmental Science of Odesa I. I. Mechnikov National University. Minutes No 12 dated 31 March 2025.

Supported by the Erasmus+ Programme of the European Union.
The publication reflects the authors' view, the EACEA and the European Commission are not responsible for any use that may be made of the information it contains.

C61 **Climate** Services: Science and Education [Electronic resource] : Proceedings of the Second International Research-to-Practice Conference (Odesa, 16-18 April 2025). – Electronic text data (1 file : 5,7 MB). – Odesa : Odesa I. I. Mechnikov National University, 2025. – 171 p.
ISBN 978-966-186-334-6

The Proceedings of the Second International Research-to-Practice Conference on 'Climate Services: Science and Education' are presented in the collected volume. The presented materials highlight the current challenges and achievements in the development and implementation of climate services in climate-sensitive sectors of the economy. Special attention is given to the growing role of education in building capacity for climate-informed decision-making through interdisciplinary learning and professional training. The reports also cover issues of climate risks and adaptation strategies implemented at regional and local levels. Published studies reflect the author's vision of the problems of climate change and climate service. Materials are submitted in the author's editorial office.

The publication is intended for applicants, pedagogical, scientific and scientific-pedagogical employees of educational and scientific institutions.

UDC 378:551.58

ISBN 978-966-186-334-6

© Authors of articles, 2025
© Odesa I. I. Mechnikov National University, 2025

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
ОДЕСЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ ІМЕНІ І. І. МЕЧНИКОВА
ФАКУЛЬТЕТ ГІДРОМЕТЕОРОЛОГІЇ І ЕКОЛОГІЇ

КЛІМАТИЧНЕ ОБСЛУГОВУВАННЯ: НАУКА І ОСВІТА

Матеріали Другої міжнародної
науково-практичної конференції

Одеса, 16-18 квітня 2025

ОДЕСА
ОНУ
2025

УДК 378:551.58
К492

Редактори:
Валерія Овчарук, доктор географічних наук - голова редколегії;
Інна Хоменко, кандидат географічних наук;
Аліна Семергей-Чумаченко, кандидат географічних наук.

Рекомендовано до друку вченою радою факультету гідрометеорології і екології Одеського національного університету імені І. І. Мечникова.
Протокол №12 від 31 березня 2025 року.

За підтримки програми Erasmus+ Європейського Союзу.
Публікація відображає точку зору авторів, Європейське виконавче агентство з освіти та культури (EACEA) та Європейська Комісія не несуть відповідальності за будь-яке використання інформації, що міститься в ній.

К492 **Кліматичне** обслуговування: наука і освіта [Електронний ресурс] : матеріали Другої міжнар. наук.-практ. конф. (Одеса, 16-18 квіт. 2025 р.) – Електрон. текст. дані (1 файл : 5,7 МБ). – Одеса : Одес. нац. ун-т ім. І. І. Мечникова, 2025. – 171 с.
ISBN 978-966-186-334-6

У виданні подано матеріали Другої міжнародної науково-практичної конференції «Кліматичні послуги: наука і освіта». У поданих матеріалах висвітлюються актуальні виклики та досягнення у розвитку й впровадженні кліматичних сервісів у кліматозалежних секторах економіки. Особлива увага приділяється зростаючій ролі освіти у формуванні спроможностей для ухвалення рішень, обґрунтованих кліматичними даними, через міждисциплінарне навчання та підготовку фахівців. Доповіді також охоплюють питання кліматичних ризиків та адаптаційних стратегій, що реалізуються на регіональному та місцевому рівнях. Опубліковані дослідження відображають авторське бачення проблем зміни клімату та кліматичного сервісу. Матеріали подаються в авторської редакції.

Видання розраховане на здобувачів, педагогічних, наукових і науково-педагогічних працівників закладів освіти та науки.

УДК 378:551.58

ISBN 978-966-186-334-6

© Автори статей, 2025
© Одеський національний університет імені І. І. Мечникова, 2025

TABLE OF CONTENTS

PLENARY SESSION

OVERVIEW OF CO-CREATION OF CLIMATE SERVICES AT THE CENTRE FOR CLIMATE CHANGE AND RESEARCH INSTITUTE ON SUSTAINABILITY, CLIMATE CHANGE, AND ENERGY TRANSITION OF UNIVERSITAT ROVIRA I VIRIGILI

Jon Xavier Olano Pozo[1,2], PhD
Enric Aguilar Anfrons[1,2], PhD
Anna Boqué Ciurana[1,2], PhD
Caterina Cimolai[1,2], MsC

[1] Research Institute of Sustainability, Climate Change and Energy Transition (IU-RESCAT), Universitat Rovira i Virgili, Spain
[2] Centre for Climate Change (C-3), Universitat Rovira i Virgili, Spain

Providing climate services has become crucial in addressing the challenges posed by climate change. The World Meteorological Organization (WMO) has developed a framework of competencies to ensure the effective development and delivery of these services (WMO, 2015). At the Centre for Climate Change and the Research Institute on Sustainability, Climate Change, and Energy Transition, we integrate these competencies into our research, education, and co-creation processes, facilitating the development of user-centred climate services (Font et al., 2021). This communication presents an overview of our experiences co-creating climate services across various domains, including agricultural resilience, infrastructure adaptation, and cultural heritage preservation.

One of our key initiatives has been the development of crop calendars designed to support farmers in optimising planting and harvesting calendars under changing climatic conditions in intertropical areas of the Gulf of Guinea countries (Aguilar et al., 2024). These tools are developed through collaborative stakeholder workshops that integrate scientific climate projections with local agricultural knowledge. Implementing these crop calendars is supported by an interactive Moodle platform, which serves as a hub for training and knowledge exchange. Additionally, we have developed both online and offline applications to facilitate the maximum execution of the program that generates these calendars.

Another significant project involves adapting railway infrastructure to climate variability (Olano Pozo et al., 2024 (a)). The ETS railway project explores how climate data can be integrated into risk management strategies to enhance the resilience of railway networks. This initiative leverages climate indices and projections to assess potential impacts on railway stability and efficiency, providing valuable insights for infrastructure planning and maintenance.

Our research also extends to the cultural domain, where we have examined the implications of climate variability on traditional events, such as the Castells

—the human tower festivals in Catalonia (Olano Pozo et al., 2024 (b)). Through meteorological data analysis, we have assessed the risks associated with extreme heat during these events and proposed climate-informed adaptation measures to ensure the safety of participants. Additionally, co-creation processes have been conducted to design and implement adaptation measures, ensuring that local communities actively participate in developing strategies to mitigate climate risks.

Furthermore, the "Project 5: Co-Creation of a Climate Service" course at the Universitat Rovira i Virgili (URV) exemplifies our commitment to education and capacity building (Olano Pozo et al., 2024 (c). This course immerses students in the development of real-world climate services, fostering interdisciplinary collaboration and engagement with stakeholders from diverse sectors. By integrating the WMO competencies, we equip students with the necessary skills to develop climate services that address sector-specific needs and requirements.

This presentation will highlight the methodologies and lessons learned from these initiatives, emphasising the importance of co-creation in developing effective climate services. By fostering collaboration between researchers, practitioners, and end-users, we aim to bridge the gap between climate science and societal needs, ensuring that climate services are actionable, relevant, and impactful.

REFERENCES

1. Aguilar, E., Boqué, A., Olano, J., Gascon, T., Gray, S., & Agniga, K. (2024). *Developing tools for generating weather-based crop calendars to support climate services. At EGU 2024, Vienna, Austria.*

2. Font Barnet, A., Boqué Ciurana, A., Olano Pozo, J. X., Russo, A., Coscarelli, R., Antronico, L., De Pascale, F., Saladié, Ò., Anton-Clavé, S., & Aguilar, E. (2021). Climate Services for Tourism: An Applied Methodology for User Engagement and Co-Creation in European Destinations. *Climate Services, 23,* 100249. https://doi.org/10.1016/j.cliser.2021.100249

3. Olano Pozo, J. X., Saladié, Ò., & Boqué-Ciurana, A. (2024 (a)). Rising Temperatures, Wavering Human Towers? Temperature Trends and Thermal Comfort during Castells Exhibitions in Catalonia (1951–2023). Case Studies in Valls (24 June), La Bisbal del Penedès (15 August), Tarragona (19 August), and Vilafranca del Penedès (30 August). *Climate*, *12*(8), 112. https://doi.org/10.3390/cli12080112

4. Olano Pozo, J. X., Boqué-Ciurana, A., Aguilar, E., Alberich, J., Sigró, J., Gutiérrez, A., & Cimolai, C. (2024 (b)). Utilizing WMO's competencies for the provision of climate services in a bachelor's degree program: The experience of the URV's Bachelor's Degree in Geography, Territorial Analysis, and Sustainability. *At EGU 2024, Vienna, Austria.*

5. Olano Pozo, J. X., Boqué-Ciurana, A., Skrynyk, O., Brichese, M., Panico, F., Calicchio, M., Pantaneschi, S., Balart, A., Dermitt, D., di Meglio, M., Foria, F., Miceli, G., & Aguilar, E. (2024 (c)). C2Risk: Co-creating Climate Management Tools for Mobility Infrastructures. *At EGU 2024, Vienna, Austria.*

GLOBAL AND NATIONAL FRAMEWORK FOR CLIMATE SERVICES

Wilfran Moufouma-Okia*[1]*, PhD

[1] Chief of Regional Climate Prediction Services, Climate Services Division, World Meteorological Organization, Geneva, Switzerland

Credible and actionable climate information, products, and services are essential for effective climate risk management and climate change adaptation—particularly for the most vulnerable nations. With growing awareness of the socio-economic benefits of science-based climate information, there is increasing demand for operational, high-quality, and user-targeted services, guided by robust standards and protocols. This has driven a global shift toward strengthening scientific capabilities not only to advance research but also to meet the evolving needs of policy and decision-makers.

In this context, the World Meteorological Organization (WMO) established the Global Framework for Climate Services (GFCS) to support the systematic development and delivery of climate services across five foundational pillars: Climate Services Information System (CSIS), Observations and Monitoring, Research, Modelling and Prediction, Capacity Development, and User Interface Platforms. At the national level, these are operationalized through National Frameworks for Climate Services (NFCS), which serve as inclusive platforms to coordinate the co-design, co-production, communication, and use of tailored climate services that inform actions in key sectors such as agriculture, water, health, disaster risk reduction, and energy.

This presentation will provide an overview of the global and national frameworks for climate services, highlighting the role, benefits, and implementation process of NFCS. It will also showcase recent experiences from Mauritius, Jamaica, and Kuwait, where NFCS implementation is enhancing coordination among stakeholders, bridging gaps between climate science and end-user needs, and supporting national adaptation and development priorities. Emphasis will be placed on the value of sustained engagement with research communities to improve the usability and impact of climate information across multiple timescales—from sub-seasonal to decadal. Discussion will include with reflections on enabling conditions, emerging challenges, and pathways to scale up climate services for resilience and sustainable development.

REFERENCES

1. Chris Hewitt and Wilfran Moufouma-Okia,, 2023: Climate Services Based on Climate Predictions and Projections, WMO Bulletin; 72 (2).

APPLYING ACTIVITY THEORY TO EDUCATION AND TRAINING FOR CLIMATE SERVICES

Patrick Parrish, PhD

WMO SERCOM, Standing Committee on Marine Meteorology and Oceanography, Expert Team on Competencies and Capacity Development

Like any of the functions of a national environmental service, a climate service is a highly complex activity with many stakeholders who have many varying responsibilities to cooperate. A climate service and all the individuals working within it needs to understand the full context of the activity system in which they function, as well as continually review how the system is changing.

Cultural-Historical Activity Theory[1], or just “Activity Theory,” is a learning theory that can help teachers and trainers assess systemic organizational learning needs and develop curriculum plans, exercises and simulations that help learners to better understand the context of their work.

Activity Theory[1] views learning from the perspective of a social system, not only a contributing individual, as do most psychological theories of learning. Activity theory also views socio-cultural systems (such as professional practices) as dynamic, not stable, and that the systems themselves and the individuals within them continually influence one another. In this theory, it is the system that learns, not only the individuals contributing to it.

The triangle below (Figure 1) depicts an activity system in a very general way. From this high level, the model can apply equally well to describe activity systems as diverse as a bank, a university, a national train system, or a football club.

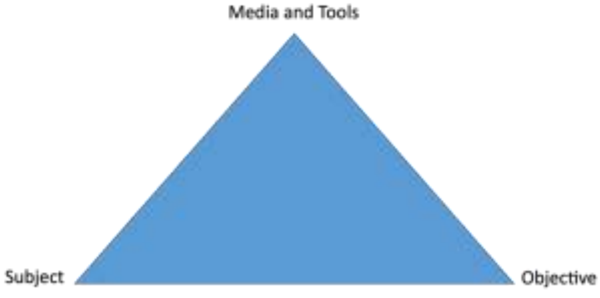


Fig. 1. A general depiction of an activity system.

We need to provide specific details for the theory to be of use. From the perspective of climate services, we might depict the relationship more specifically as in the diagram in Figure 2.

When the model includes the objective of issuing products and providing services, we are describing what drives traditional approaches to defining training needs. However, considering the larger social context we might instead define an alternative objective--the effective utilization of these services by end-users (see Figure 3), which requires changes in each of the other two vertices of the triangle. For example, a climate service now has responsibilities for helping the customers become intelligent users.

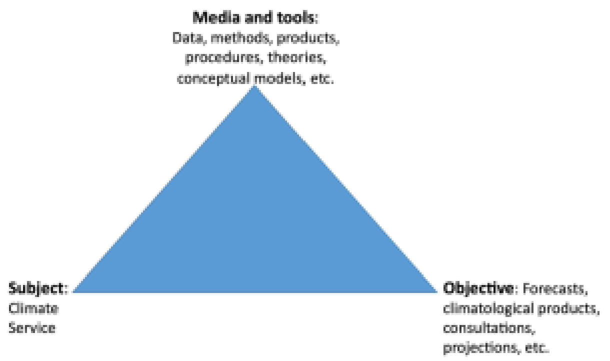


Fig. 2. An activity system for the subject: Climate Service

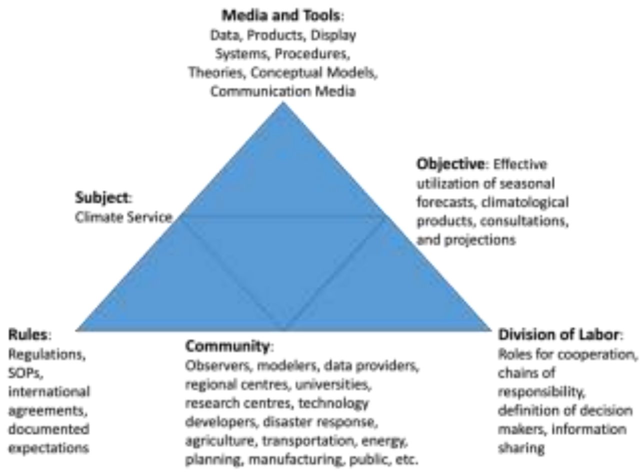


Fig. 3. A more complete instantiation of the Climate Service activity system.

This new depiction of the activity system, including Rules, Community, and Division of Labor, reveals a more complete social context of climate services. It reminds us to consider the entire system when defining learning needs.

This presentation and brief paper will examine this fully instantiated system and consider its implication for education and training for achieving the best climate services outcomes. A representative training solution for marine forecasting services is included.

REFERENCES

1. Engström, Y. 1999: Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen & R-L. Punamäki (Eds.), Perspectives on activity theory. Cambridge: Cambridge University Press.

INTEGRATED URBAN SERVICES: TOWARDS CLIMATE-SMART, RESILIENT, AND SUSTAINABLE CITIES AND SETTLEMENTS

Alexander Baklanov, Dr.Sci. in Physics & Mathematics, Professor in Meteorology

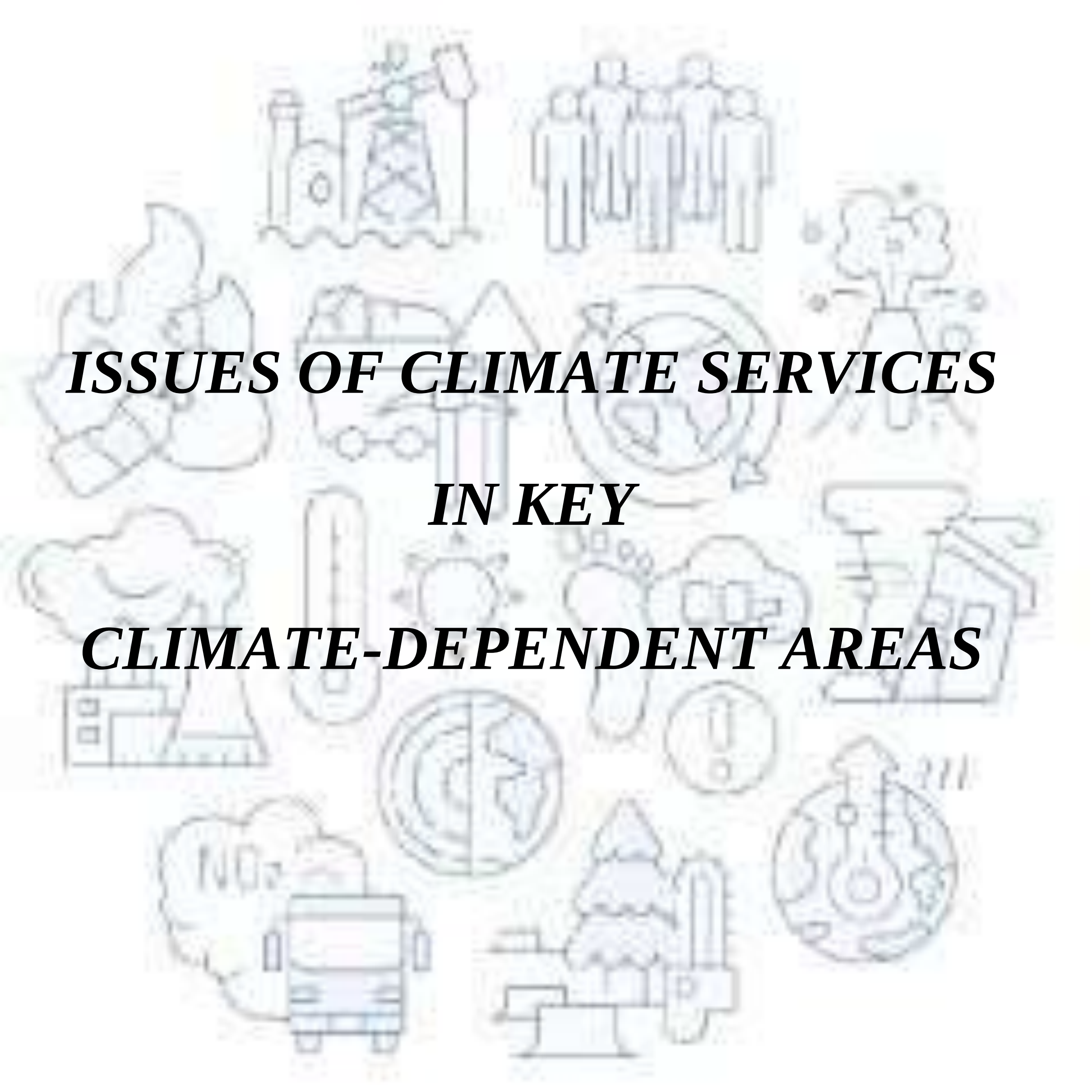
Niels Bohr Institute, Copenhagen University, Denmark

The third United Nations Conference on Housing and Sustainable Urban Development (HABITAT-III) in October 2016 adopted the New Urban Agenda (United Nations, 2017), which brings into focus urban resilience, climate and environment sustainability, and disaster risk management. Following the event at the United Nations Economic and Social Council, efforts are required from WMO to consolidate its input to the revision of the New Urban Agenda (NUA) and support urban related activities in a comprehensive manner. Urban development is now a cornerstone of the United Nations 2030 Sustainable Development Goals. It has its own sustainable development goal (SDG 11): Make cities inclusive, safe, resilient and sustainable.

To support implementation of urban activities the WMO inter-programme Urban Expert Team under the Commission for Atmospheric Sciences and Commission for Basic Systems (2018) supported by a dedicated team of urban focal points in the Secretariat developed the Guidance on Integrated Urban Hydro-Meteorological, Climate and Environmental Services (IUS). The needs for integrated urban services (IUS) include information for short-term preparedness (e.g. hazard response and early warning systems), longer-term planning (e.g. adaptation and mitigation to climate change) and support for day-to-day operations (e.g. water resources).

The aim is to build urban systems and services that meet the special needs of cities through a combination of dense observation networks, high-resolution forecasts, multi-hazard early warning systems, disaster management plans and climate services. This approach gives cities the tools they need to reduce emissions, build thriving and resilient communities and implement the UN Sustainable Development Goals.

The ways and approaches, as well as priorities for realization of such systems depend on specific climatic, geographical, economic and environmental conditions specific cities. In this presentation we will classify and consider different approaches, methodologies and tools for selected cities in different climate zones (e.g. northern, tropical), economic conditions (developed and developing worlds) and combinations of risk factors (e.g., multi-hazards, heat stress, floods, air quality). Specific focus will also be done on the mitigation and adaptation strategies and their combinations.



ISSUES OF CLIMATE SERVICES

IN KEY

CLIMATE-DEPENDENT AREAS

INTRINSIC MULTI-SCALE CHARACTERISTICS OF RAINFALL VARIABILITY IN NZÉRÉKORÉ, SOUTHEASTERN GUINEA, WEST AFRICA

Noukpo M. Agbazo, *Lonsenigbe Camara, Lancei Koivogui*

Département d'Hydrologie, Université de N'zérékoré, N'zérékoré, Guinée

Based on CEEMDAN algorithm, the multi-scale characteristics of rainfall change in Nzérékoré during 1991-2020 were investigated. The results indicated that five significant intrinsic mode functions (IMFs) and a nonlinear trend governed monthly rainfall variations in Nzérékoré. However, the 6-month quasi-period, inter-annual oscillations and nonlinear trend are main contributors to monthly rainfall variability.
Keywords: Rainfall, multi-scale fluctuations, Nzérékoré, Guinea

Table: Variance contribution rate, VCR (%) for each IMF and Trend

	IMF1	IMF2	IMF3	IMF4	IMF5	IMF6	Trend
Variance contribution rate, VCR (%)	19.10	5.90	3.80	4.50	15.40	13.90	37.40

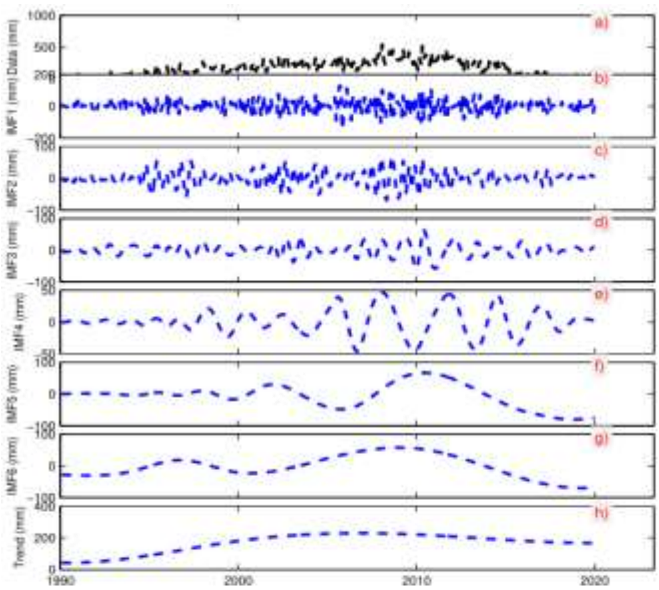


Fig. 1. The IMFs and trend component of monthly rainfall time series in N'zérékoré during 1970-2020.

REFERENCES

1. Agbazo, N. M., Tall, M., Sylla, M.B. (2023) Nonlinear Trend and Multiscale Variability of Dry Spells in Senegal (1951–2010). Atmosphere, 14, 1359. https://doi.org/10.3390/atmos14091359

2. Guan, X., Yao, J., Schneider, C. (2022). Variability of the precipitation over the Tianshan Mountains, Central Asia. Part I: Linear and nonlinear trends of the annual and seasonal precipitation. International Journal of Climatology, 42(1), 118–138. https://doi.org/10.1002/joc.7235

3. Guo, B., Chen, Z., Guo, J., Liu, F., Chen, C., Liu, K. (2016). Analysis of the Nonlinear Trends and Non-Stationary Oscillations of Regional Precipitation in Xinjiang, Northwestern China, Using Ensemble Empirical Mode Decomposition. Int. J. Environ. Res. Public Health 2016, 13, 345. [CrossRef]

FORMATION OF THE HYDROLOGICAL CYCLE IN URBAN AREAS AND VULNERABILITY OF WATER SUPPLY SYSTEMS UNDER THE INFLUENCE OF CLIMATE CHANGE

Dmytro Diadin, PhD, *Valeriy Yakovlev, D.Sc.,*
Drozd Olema, PhD, Vergeles Yuriy, Drs.

O.M. Beketov National University of Urban Economy in Kharkiv, Ukraine

The continuous process of urbanization is accompanied by an increasing impact on the water balance of urbanized areas. In the course of historical development of any city, the growth of the urban population, the expansion of urban built-up areas, and the development of industrial and social infrastructure, the hydrochemical and hydrodynamic characteristics of surface and groundwater change both in the urban and periurban areas.

The components of the hydrosphere – surface, ground and atmospheric water – within built-up areas differ from those in adjacent areas due to significant anthropogenic impact. The factors of this impact are primarily a high territorial concentration of water consumption and a significant anthropogenic load from industry, utilities and transportation.

Cities use water resources that are generated over an area much larger than the city itself. Therefore, the water balance of urban areas is deformed relative to the natural balance in proportion to the size of the city. On the one hand, local water resources are usually insufficient for supplying urban customers, and surface and groundwater resources formed in adjacent territories are used. On the other hand, a significant share of this water remains in the city for various reasons. First, this leads to a decrease in river flow and the development of depression sinkholes in underground aquifers. Second, reservoirs are created to supply water users and there is an increase in the mass of water in the first aquifer from the surface, which leads to water logging. In general, under the influence of a complex of direct and indirect anthropogenic impacts, most components of the water balance of a water-exchange geosystem change.

The hydrological cycle, which includes the processes of interaction between precipitation, surface water and groundwater, is significantly transformed in urbanized areas due to intensive water use and drainage. The main factors that shape the hydrological cycle and cause its changes in the city are microclimatic conditions, redistribution of surface runoff, changes in surface permeability, and transportation of significant volumes of water, including trans-basin transfer.

Water supply systems in Ukraine's major cities are largely based on surface water resources, the quantity and quality of which are heavily influenced by changing climatic conditions. Only 9 of the country's 25 regional cities have water supply systems based entirely on groundwater resources. This makes most urban water systems highly vulnerable to climate-related threats that could lead to water shortages or deterioration in water quality. Such threats include changes in the seasonal distribution of precipitation, droughts, heavy rainfall, increased frequency of extreme weather events, and sea level rise. They lead to changes in the surface and groundwater regime, and put additional strain on urban water supply systems, which are often not adapted to the effects of projected climate change.

In some cases, urban water supply systems use trans-basin water transfers, which complicate the formation of the hydrological cycle of an urbanized area and increase its vulnerability to climate change.

The city of Kharkiv is a typical example of an urban agglomeration with a complex water supply system and disturbed water balance. The natural component of the hydrological cycle in the city's area is represented by precipitation, which is the main source of infiltration to groundwater, causing evapotranspiration and surface runoff. Groundwater is discharged in the form of downstream sources in the valleys of the Kharkiv, Lopan, and Udy rivers with their small tributaries. The anthropogenic component is represented by water taken from other sub-basins – the Siverskiy Donets River (Pecheniz'ke Lake) and the Dnipro-Donbas Canal (Krasnopavlivs'ke Lake) and supplied to the city's centralized water supply system. The built-up urban area, due to the large proportion of impermeable surfaces, contributes to the intensification of water evaporation, especially in summer. Given the projected increase in air temperature, the role of these processes in the hydrological cycle changes will also increase.

At the same time, the extensive system of water supply lines, the total length of which reaches 2,485 km in the city, due to its high wear and tear, forms an additional anthropogenic component of the water balance due to tap water leaks. According to the estimates, in some cases, the amount of additional infiltration recharge may exceed the natural recharge by precipitation. The isotopic composition of groundwater from the maintained sources indicates a significant contribution of leaks from water supply systems to the recharge of the first aquifer from the surface in the city of Kharkiv.

Taking into account the projected climate change, in particular, the increase in air temperature, redistribution of precipitation and high climate risks of degradation of surface water bodies, it is recommended revising the concepts of water use in large cities in Ukraine. The rational and economical use of artesian groundwater, protected from climate threats and anthropogenic pollution, is an effective adaptation measure that will help to conserve water resources and ensure the sustainability of urban systems.

THE PAST KEY RESEARCH INTERNATIONAL PROGRAMS FOR THE STUDY OF ENVIRONMENT AND CLIMATE OVER WEST AFRICA

Francis Dide
International Consultant on Aviation Meteorology and African Climate, Benin

During the last three decades, two key international programs have been implemented in West and Central Africa: The African Monsoon Multidisciplinary Analysis (AMMA) and DACCIWA: Dynamics-Aerosol-Chemistry-Cloud interactions in West Africa.

AMMA is very big international research program concerning with the environment and climate involving hundreds of researchers working in many countries.This program has a duration from 2001 to 2010 and included an intensive observational campaign in 2006. AMMA contributed to the design strategies to determine the variability of atmospheric phenomena, as well as their duration and intensity, which helped nations to orient their objectives and social and productive policies to face the onslaught of the nature.

A radiosonde program is a special part of the African Monsoon Multidisciplinary Analysis international research project. The measurements were made by instruments called "radiosondes", balloons-borne sensors which are released from a network of ground stations and carried from the ground, through the troposphere and up into the stratosphere, reaching around 25 km altitude. The data were transmitted to a ground station and then are relayed in real time to international weather forecasting centers. The radiosonde data were collected routinely from stations all around the world, including West Africa. It was a fundamental principle of the AMMA project to invest effort in the existing operational radiosonde stations in West and Central Africa. Therefore, this has been a highly collaborative effort involving specialists in Africa, Europe, and the Americas.

DACCIWA concerns with the study of impact of anthropic emissions in West Africa on health, ecosystems, food security and regional climate. Over five years from 2013 to 2018, the DACCIWA project improved understanding of meteorology and air pollution of West Africa.

A key element of DACCIWA project was a major field campaign in densely populated southern West Africa in summer 2016, involving three research aircrafts and a wide range of surface-based instrumentation at three sites in Ghana, Benin and Nigeria.

DACCIWA produced the most comprehensive observational dataset of the atmosphere over West Africa to date and this dataset to foster our understanding of atmospheric processes, and to evaluate dynamical models and satellite data.
It is evident then the importance that these kind of international programs have on the well-being of the environment and the living beings that inhabit in close relationship with it.

TRENDS IN RASPBERRY BREEDING DUE TO CLIMATE CHANGE

Nataliya Dyman, PhD student

Bila Tserkva National Agrarian University, Ukraine

Research on the effects of climate change, rising temperatures, and increased CO_2 emissions has focused mainly on the yield and production of row crops such as rice, wheat, corn, and others. Fruit crops, on the other hand, have received much less attention. Despite the great economic importance of fruit worldwide, the physiological characteristics and quality of these crops under elevated temperatures have been little studied. To a large extent, this applies to such an important crop for Ukraine as raspberries. Experts predict that the berry business in our country can be highly profitable if properly organized. This is confirmed by the experience of Poland, which has similar climatic conditions to Ukraine, where the yield of berry crops is 7–20 % higher [4]. Raspberry production in Ukraine is expected to grow due to high prices in recent years and growing international demand.

The present study was aimed at revealing current trends and developments in raspberry breeding due to climate change. Throughout the history of scientific raspberry breeding, which began in the last century, breeding objectives and directions have changed. In the middle of the XX century, when the main raspberry plantations were concentrated in small farms of various forms of ownership, the selection of the best raspberry samples in the breeding process was carried out in the direction of increasing winter hardiness and productivity. The spread of industrial raspberry cultivation has necessitated breeding to increase fruit weight, improve taste and attractiveness of the berry's appearance. In the XXI century, the suitability of raspberry varieties for intensive cultivation became a breeding advantage. The selection of varieties and hybrids based on a set of traits that determined their suitability for mechanized harvesting (bush habit, plant height, berry density, etc.) has become one of the main tasks of raspberry breeding and variety study.

Along with rapidly changing weather and climatic conditions that have accelerated the evolution of plant diseases and pests, growing demands from producers and consumers, raspberry breeders face new challenges. Today, the goal of most raspberry breeding programs is to obtain a new cultivar that has good fruit quality and high productivity, is resistant to the most important pests and diseases and is well adapted to the conditions where it will be grown [2].

Often, to solve emerging problems, scientists look for new genetic sources among wild species or create varieties using existing forms. Scientists have confirmed the independent inheritance of the main economically useful traits among themselves and proved the possibility of combining their optimal level in one genotype. There are many varieties with these characteristics in different regions of the world.

The help of information technology, molecular genetic approaches to decision-making, such as genomic selection and the affordable use of molecular genetic marker technology, make breeding more accurate and enable rapid adaptation to constantly changing conditions.

Danish researchers have found that when raspberry plants are exposed to temperatures above their physiological optimum, the regulation of certain genes is disrupted, leading to changes in plant morphology, anatomy, physiology and biochemistry, including photosynthesis. Scientists have been studying three varieties of autumn and four varieties of summer raspberries for two years in a row in Denmark. Part of the research was conducted in a climate chamber and a greenhouse, where the temperature was raised from 20 °C to 27, 32, and 37 °C for seven days during flower formation. A total of 38 genes were identified that were down-regulated [1].

Examples of recent successful breeding solutions include the creation of new berry varieties by British specialists from Global Plant Genetics in collaboration with James Hutton Institute. These are the Skye raspberry variety, which is suitable for growing in different climatic conditions because it does not require a long period of low temperatures in winter, and the Glen Mor variety, which is characterized by no need for a long period of low temperatures in winter. Glen Mor is the first raspberry variety in the Global Plant Genetics breeding program to be resistant to root rot. It has excellent quality, keeping quality, high yield, taste and size [3].

Thus, breeders are working hard to purposefully provide new varieties and hybrids with improved resistance characteristics, taking into account projected climate change, to create conditions for the profitability and success of the farmer in the future. Drought resistance, increased stress tolerance, and a focus on disease tolerance are the main breeding objectives of today's crops.

REFERENCES

1. Janne Hansen Will rasberries suffer from warmer summers? 2014. URL: https://dca.au.dk/en/current-news/news/show/artikel/translate-to-english-naar-hindbaer-faar-det-varmt .
2. Luz F.R., Valdiviesso T., Oliveira P.B. Raspberry breeding and agronomy for mild winter climates. ISHS Acta Horticulturae 1381. DOI: 10.17660/ActaHortic.2023.1381.5
3. Scientists have identified the main directions of development of raspberry breeding for the fresh market. URL: https://www.growhow.in.ua/naukovtsi-vydilyly-osnovni-napriamy-rozvytku-selektsii-malyny-dlia-svizhoho-rynku/
4. Ukrainian berry market rises on the wave of growing global demand. Baker Tilly Ukraine. URL: https://bakertilly.ua/id38503/.

ASSESSMENT OF THE APPLICATION OF PLANT GROWTH REGULATORS IN MAIZE CULTIVATION FOR GRAIN UNDER DIFFERENT CLIMATIC SCENARIOS

Mykola Grabovskyi, *Doctor of agricultural sciences, professor*,
Pavlo Basyuk, *PhD student*,
Valeriy Zhelezniak, *PhD student*,
Oleksandr Mandrysh, *PhD student*,
Ihor Labunskyi, *PhD student*

Bila Tserkva National Agrarian University, Ukraine

Maize cultivation for grain is a strategically important direction in ensuring food and energy security in Ukraine. However, in the context of global climate change, there is an increasing frequency and intensity of stress factors such as drought, temperature fluctuations, and extreme weather events. These factors significantly affect the growth, development, and productivity of maize plants, leading to yield reduction and deterioration of grain quality.

One of the promising approaches to minimising the negative impact of environmental stress conditions is the application of plant growth regulators. It is known that growth regulators can activate physiological and biochemical processes, improve water balance, enhance the synthesis of antioxidant enzymes, and consequently reduce plant stress levels. However, the effectiveness of such preparations largely depends on their composition, method of application, and specific growing conditions.

The aim of the research was to determine the effectiveness of applying growth regulators in maize cultivation for grain under different climatic conditions. The research was conducted in 2023–2024 at the experimental field of Bila Tserkva National Agrarian University following the scheme: Factor A. Maize hybrids. 1. RAGT Dublikks (FAO 320) 2. RAGT Vinkks (FAO 360) 3. RAGT Elekks (FAO 370). Factor B. Plant growth regulators. 1. Control (no growth regulators) 2. Erise (1.0 l/ha) 3. Equilibrium (1.5 l/ha) 4. Kelpak (2.0 l/ha). The accounting area of the experimental plot was 115.8 m². The experiment was conducted in triplicate. The research followed standard agronomic methodologies. Grain yield was determined by harvesting and weighing grain from the accounting plot area with subsequent recalculation to 14% moisture content. Statistical data processing was performed using analysis of variance with the Statistica 12 software package. The significance of differences between mean values was assessed using Duncan's test ($p<0.05$).

Based on observations, it was found that the study years were characterised by different weather conditions: 2023 was more favourable for maize growth and development, whereas 2024 experienced a significant rainfall deficit (90.8 mm) and elevated temperatures, negatively affecting soil moisture availability and maize grain productivity.

In 2023, grain yield in the studied hybrids ranged from 8.45 to 9.03 t/ha. The highest grain yield that year was recorded for the RAGT Elekks hybrid at 8.95 t/ha. In 2024, under adverse weather conditions, yield was 12.5–26.4% lower, ranging from 6.94 to 7.70 t/ha. The highest productivity that year was observed in the RAGT Dublikks hybrid at 7.58 t/ha. On average over two years, the highest grain productivity was recorded for the RAGT Dublikks hybrid, ranging from 7.94 to 8.21 t/ha.

Among plant growth regulators, the best grain yield indicators over two years were obtained using Kelpak (2.0 l/ha) (8.21, 8.11, and 8.08 t/ha), indicating its higher effectiveness regardless of weather conditions. In the RAGT Dublikks, RAGT Vinkks, and RAGT Elekks hybrids, grain yields using Erise (1.0 l/ha) were 8.09, 8.02, and 8.01 t/ha, while for Equilibrium (1,5 l/ha), they were 8.14, 8.05, and 8,05 t/ha, respectively.

Analysis of climate data from 2023 and 2024 indicates a very strong relationship between maize grain yield and air temperature and precipitation during the growing season. Specifically, yield had a strong direct correlation with precipitation and a strong inverse correlation with air temperature. The calculated correlation coefficient between precipitation and yield (r=0.96) indicates an almost complete direct correlation: in a year with higher precipitation, the highest grain yield was obtained. There was also an inverse negative correlation (r=–0.94) between average growing season temperature and grain productivity, where an increase in temperature corresponded to a decrease in grain yield.

The calculated regression equation for yield–precipitation (y=0,02x+2,95) indicates that an additional 100 mm of precipitation during the maize growing season increases yield by 2,02 t/ha, while 1 mm of precipitation increases yield by 0,02 t/ha. The regression equation for yield–temperature (y=-2,11x+47,36) shows that an increase in average temperature by 1°C results in a decrease in maize grain yield by 2,11 t/ha.

For the studied temperature range (18,3–19,0°C), the model describes the effect of temperature on maize productivity, but outside this range, the linear dependence may not hold.

DESIGNING CITIZEN-SCIENCE PROJECT FOR ASSESSING WAR DAMAGE TO ENVIRONMENT IN UKRAINE

Yurii Hrinchenko, Assistant Prof., Sc.D.,

Odesa I. I. Mechnikov National University, Ukraine

In a highly specialized area of education, like the environmental sciences, it is widely recognized to rely on interinstitutional cooperation to support continuous development of the capacity to secure both quality education and research excellence. Under different frameworks representing European Union programs in the field of higher education Odesa I. I. Mechnikov University has inherited several international projects specifically focused on environmental issues varying from climate change to war impact on natural preserved areas. One of the projects is Erasmus+ project “European universities supporting legal and community capacities for Ukraine’s environmental recovery” (registration number 2023-1-SE01-KA220-HED-000151848). The project is focused in fostering cooperation between several Universities from EU and Odesa I. I. Mechnikov National University for capacity development in a field of public support and legal provisions for postwar recovery of the environment. The war along other atrocities caused enormous damage to Ukraine`s natural ecosystems. The project aims to bring policies of more broad civic engagement in assessing the impact of the war on environment, developing and implementing recovery policies on a local but also national level. The citizen science approach is a key method to achieve this level of engagement bridging civic activity and academic research for the same goal. This approach creates prospects for developing a proper legal framework for recovery efforts as well as potential trial on environmental crimes within evidence gathered by nonprofessional civil activists. This approach will definitely lead to empowering war-affected communities.

Under GROMADA project several student-driven citizen-science projects were launched to cover various aspects of civic engagement and testing citizen-science tools for collecting, analyzing, proofing and communicating environmental data reflecting the war impact on the environment. One of the projects under title of “Environment: War Impact on Regional Development in Terms of SDG”. The outline of the project is to use open data bases for collecting the data referring to parameters of the sustainable development of the regions of Ukraine and applying these data to assess the regional performance.

The project consists of several stages, which are designed to develop a comprehensive approach on data collecting, data analysis and outcomes assessment. The stages may be presented as following:

1. Formulating a review question and developing a search strategy based on explicit inclusion criteria for the identification of eligible studies, identifying the key concepts to use.

2. Searching for eligible studies using multiple databases and information sources, including grey literature sources, without any language restrictions, or applying language restrictions, and noting down the ‘limitations of the study’

3. Selecting studies, extracting data, and assessing risk of bias in a duplicate manner using two independent reviewers to avoid random or systematic errors in the process.

4. Analyzing data using quantitative or qualitative methods with a cross-team interaction and methodological support of project mentors representing partner universities of the GROMADA project.

5. Interpreting results, revealing the relevance of data, prioritizing different clusters of data for the purpose of assessing regional development, defining problem areas and data still required for better quality of conclusions.

Many indicators of sustainable development goals and potential are based on the government collected data, but in war time it is extremely challenging to provide the data of the same level of accuracy and relevance as in peacetime. Thus this data will be in extreme demand for designing efficient policies for postwar recovery of war-affected communities.

A sustainable development indicator is an indicator (most often quantitative) that reflects economic, social and environmental development in a certain region, and has such properties as ease of interpretation, wide scope, sensitivity to changes, quantitative determination and allows making forecasts and timely identifying trends. In the absence of effective indicators of sustainable development, it is impossible to carry out the cycle of the policy-making process - defining and formulating the goal, implementing and evaluating the result. Instead, management decisions in the field of sustainable development are subject to drift of characteristics, unclear expression of priorities, incoherence of political goals and the lack of possibility of assessing the characteristics of the development of society from objective criteria.

REFERENCES

1. Fraisl, D., Hager, G., Bedessem, B. Gold, M. Hsing, P-Y, Danielsen, F., Hitchcock, C.B., Hulbert, J.M., Piera, J., Spiers, H., Thiel, M. & Haklay M. Citizen science in environmental and ecological sciences. Nat Rev Methods Primers 2022, 2, 64. https://doi.org/10.1038/s43586-022-00144-4
2. Somerwill, L., Wehn, U. How to measure the impact of citizen science on environmental attitudes, behaviour and knowledge? A review of state-of-the-art approaches. Environ Sci Eur, 2022, 34, 18. https://doi.org/10.1186/s12302-022-00596-1

ORGANIC PRODUCTION AS A STRATEGY FOR CLIMATE CHANGE ADAPTATION

Lesia Karpuk, Doctor of Agricultural Sciences, *Liudmyla Ezerkovska, Andrii Pavlichenko, Vitalina Karaulna, Larysa Filipova, Oksana Titarenko, Artur Ezerkovskyi, Nataliia Zaika, PhD, assoc. prof.*

Bila Tserkva National Agrarian University, Ukraine

Ukraine has strong traditions in organic production. Despite the ongoing war, the country has demonstrated accelerated development of the organic sector, which has allowed it to take a leading position in organic product exports. However, the implementation of organic production faces challenges related to improving these technologies in the context of climate change [1]. Organic production has the potential to reduce agriculture's impact on climate and to adapt to climate change. It is essential to support and develop organic farming to ensure a sustainable future for our planet.

Through the implementation of organic production, we have the opportunity to address climate change adaptation challenges. Specifically, organic production helps reduce greenhouse gas emissions: the use of organic fertilizers, such as compost and manure, instead of synthetic ones, reduces nitrous oxide emissions, while crop rotation and cover crops help sequester carbon in the soil. Resource-saving soil tillage also contributes to carbon conservation. Moreover, it helps to reduce fossil fuel use by incorporating renewable energy sources on farms and promoting local product sales to minimize transportation-related emissions. Adaptation to climate change can be achieved by cultivating diverse crops that are resistant to drought, heat, and other extreme weather conditions, using traditional varieties adapted to local conditions, and retaining soil moisture through organic matter and cover crops. Organic farming also supports biodiversity by creating and preserving windbreaks and other natural habitats within organic farming systems [1–4].

The aim of our research was to improve the cultivation technology of agricultural crops for organic production based on the conservation and restoration of soil fertility in the conditions of the Right-Bank Forest-Steppe of Ukraine. The experimental work was conducted in 2021–2024 at the experimental field of the Educational and Production Center (EPC) of Bila Tserkva National Agrarian University (BNAU). The experiment compared the following technologies: the control variant with minimal production costs for crop cultivation technology, the studied technology, which involved using all possible organic farming techniques (investigating, utilizing, and implementing auxiliary substances permitted in organic production), and the recommended intensive technology, which involved the broad application of all necessary resources to optimally supply crops in the crop rotation with essential life-supporting factors.

The crop rotation scheme included the following crops: leguminous crops (chickpeas, lentils, peas), winter or spring cereals, row crops (sunflower), oil-bearing brassicas (white mustard), leguminous crops (soybean), spring row crops (grain corn), melon crops (hard-shell pumpkin), and spring crops (millet, buckwheat). An analysis of agricultural crop yields from our studies in 2021–2024 showed a clear dependence on the technologies applied. The lowest yields were recorded in the control variants, where standard agronomic practices were used. Intensive farming, with the use of modern agrochemicals and technologies, provided the highest yield increase—exceeding control levels by 25–50%. Under organic production, a positive yield impact of 5.3–30% was observed compared to basic methods. This growth was attributed to the use of biopreparations, which improve soil health, stimulate plant development, and enhance resistance to stress.

REFERENCES

1. Cardelli R., Levi-Minzi R., Saviozzi A., Riffaldi R. *Organically and Conventionally Managed Soils: Biochemical Characteristics.* Journal of Sustainable Agriculture. 2004. vol. 25 (2). p. 63–74.
2. Ezerkovskyi A.V. *Efficiency of basic cultivation and fertilization for winter rye organic growing on peat-gley soils in the Left Bank of Forest Steppe.* Ukrainian Journal of Ecology, 2018, 8 (2). p. 128–133.
3. Malynka L.V., Shyshkina K.I., Didur I.M., Ezerkovska L.V., Karaulna V.M., Karpuk L.M., Pavlichenko A.A., Kozak L.A. *State and production of organic products in Ukraine. Buckwheat cultivation using biopreparations.* Agrobiology, 2020, No. 2.
4. Primak I.D., Khakhula V.S., Filipova L.M., Obrazhii S.V., Marchuk I.U., Martyniuk I.V., Panchenko O.B., Ezerkovska L.V., Karaulna V.M., Karpuk L.M., Pavlichenko A.A., Titarenko O.S., Voitovyk M.V., Kulyk R.M. *Fertilizers in Organic Farming: History, Theory, Practice.* Edited by Professor I.D. Primak. Vinnytsia, 2023, “Tvory”, 263 p.

SIMULATION OF RAIN FLOODS OF THE STRYI RIVER USING ARTIFICIAL NEURAL NETWORK

Borys Khrystiuk, Sc.D., *Liudmyla Gorbachova, Prof., Sc.D.*

Ukrainian Hydrometeorological Institute, Ukraine

The Stryi River is the largest mountain tributary of the Dniester River. After heavy rainfall in the Stryi watershed in the warm season of the year, heavy rain floods occur. In the past, mathematical models and models based on the regularities of movement of water masses in the river network were used to simulate the water flow of Stryi River [1-2]. Mathematical models have not found their practical application, as they require a significant amount of hydrometeorological data, which are not always available at the time of forecast modeling. Models based on the regularities of movement of water masses in the river network require a much smaller amount of hydrometeorological data, but they do not take into account the forecast of the amount of precipitation for the nearest period, which reduces the lead time of the water flow forecast according to these models. Also, the "Rainfall-Runoff" module of the Mike 11 software complex and the forecast of weather parameters according to the WRF model were used to simulate rain floods of the Stryi River [3]. The accuracy of forecasting of the "Rainfall-Runoff" module depends on the accuracy of forecasting weather parameters.

We used an artificial neural network (ANN) to simulate the water flow of the Stryi River. In our study we used the data of the observation network of the Ukrainian Hydrometeorological Center: water discharge of the Stryi River at water gauge Verkhne Sinyovydne and the amount of precipitation at the meteorological stations Turka, Stryi and Slavske for May-September 2005-2012 with a time step of 6 hours. Functional relationship between the various input data and the water discharge of Stryi River at time moment t (Q_t) we found by correlation analysis

$$Q_t = f(Q_{t-6}, P_{t-6}, P_{t-12}, P_{t-18}, P_{t-24}) \tag{1}$$

where Q_{t-6} – the water discharge of Stryi River at time moment $t-6$ hours;

P_{t-6}, P_{t-12}, P_{t-18}, P_{t-24} – the average amount of precipitation at the meteorological stations Turka, Stryi and Slavske at time moment $t-6, \ldots, t-24$ hours.

Input layer of ANN model have five nodes (fig. 1). The number of hidden layer nodes was determined by optimization. Calculations were performed in RStudio (version 2024.12.0 Build 467) using the nnet package [4].

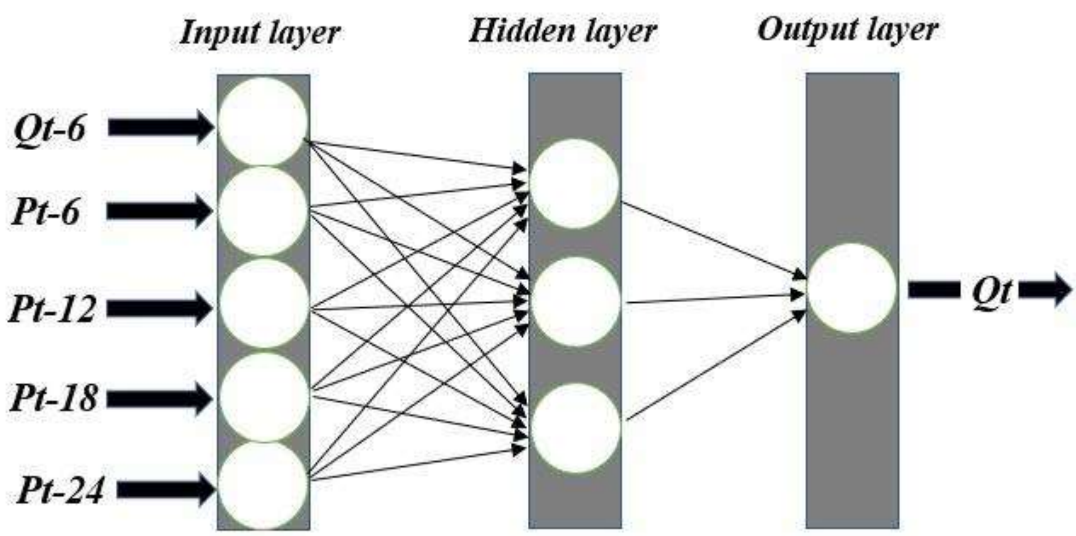


Fig. 1. Architecture of ANN model used in the study.

The database was split into two, for training and testing. The results of modeling the training and test samples were evaluated according to three statistical indicators: RMSE (root mean square error), Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2).

The ANN model has better results compared to the classic linear multiple regression (CLMR) because the ANN model can take into account nonlinearity of the system due to parallelism of its architecture (tabl.1).

Table 1. Statistical indices of ANN and CMLR models

Model	Training set			Testing set		
	RMSE, (м³/с)	NSE, (%)	R^2	RMSE, (м³/с)	NSE, (%)	R^2
ANN	20,1	91,6	0,92	21,1	92,5	0,93
CMLR	29,8	81,5	0,82	25,2	89,4	0,89

REFERENCES

1. Sosedko M.N., 1980: Peculiarities of applying the mathematical model of rain runoff formation for the calculation of floods in mountainous areas, Proceedings of UHMI, Vol. 181, pp. 59-73 (in Russian)

2. Sosedko M.N., 1976: Forecasting the course of rainwater runoff in the Dniester basin based on taking into account the processes occurring in the channel network, abstract of the pHD dissertation, 26 p. (in Russian)

3. B Khrystiuk, L Gorbachova, V Shpyg, 2022: Verification of the automated flood forecasting system on the Stryi River, Acta Hydrologica Slovaca, 23 (2), pp. 234-240

4. Ripley B. D., 1996: Pattern Recognition and Neural Networks. Cambridge University Press, ISBN 0-521-46086-7.

ASSESSMENT OF THE BIOCLIMATIC POTENTIAL OF THE DNIPROPETROVSK REGION IN THE CONDITIONS OF CLIMATE CHANGE

Nataliia Kyrnasivska, PhD, Associate Professor

Odesa I. I. Mechnikov National University, Ukraine

A new mandatory aspect of the development of adaptive intensification in agriculture is the consideration of the rapid changes in the Earth's climate. The main condition for the successful cultivation of a particular crop is the availability of agro-climatic resources that ensure its growth, development, and product formation under natural conditions [1]. In this regard, the assessment of the bioclimatic potential (BCP) of territories under climate change conditions represents both a theoretical and practical interest. The bioclimatic potential of the climate is one of the few types of practically inexhaustible natural resources that are constantly renewed, available for human use, and do not worsen the ecological situation during exploitation.

In this study, based on the results of the World Climate Research Programme, a set of climate change scenarios was used, namely the Representative Concentration Pathways (RCP 4.5 and 8.5). This allowed for the assessment of the biological productivity of the region's arable land under climate change conditions and a comparison with long-term agro-climatic data published in the Agro-climatic Handbook of the Dnipropetrovsk Region (1986–2015) – the baseline period [2].

The evaluation scores of the bioclimatic potential of the region's territory were determined using the algorithm for calculating the biological productivity of land based on the D.I. Shashko model (1985) for open, flat areas under natural and optimal moisture conditions.

The obtained values of the bioclimatic potential in the "baseline period" characterize the average and moderately high conditions of biological productivity of the region's climate. Under optimal moisture conditions, the bioclimatic potential increases, indicating higher biological productivity of the climate. To improve climate conditions for agricultural production, periodic irrigation is recommended as a reclamation measure.

To assess changes in the bioclimatic potential, the baseline period and calculated periods for the RCP4.5 and RCP8.5 scenarios were analyzed. It was established that under the implementation of the RCP scenario family, a decrease in bioclimatic potential in the Dnipropetrovsk region will be observed in both cases. A clear trend towards a decrease in precipitation compared to the "baseline" period is evident at all stations, especially in the warm season (30-40% below normal), which will lead to a reduction in moisture indicators (GTC, Md, Kε) and an intensification of arid conditions in the area. The dates for the beginning and end of the warm period will also change, resulting in a shorter duration. Accordingly, the temperature sum for the warm period will decrease by 4-5% under the RCP 4.5 scenario and by 1-1.5% under the RCP 8.5 scenario compared to the baseline period of 1986-2015.

As a result, by 2050, under the implementation of the RCP4.5 scenario, BCP will decrease by 9-18% compared to the baseline period, which corresponds to reduced biological productivity of the climate. Under optimal moisture conditions, the decrease will be 8 points. Under these conditions, periodic irrigation is recommended to improve agricultural production (Table 1).

Under the RCP8.5 scenario, the BCP will decrease by 17-34%, to 93-122 points, which characterizes conditions of reduced or very low biological productivity of the climate. Under optimal moisture conditions, the bioclimatic potential also decreases by 1-2 points, totaling 165-172 points, which characterizes conditions of increased biological productivity of the climate and is close to the conditions of the "baseline" period. To improve agricultural production, periodic irrigation is recommended (Table 1).

Table 1. Comparative assessment of bioclimatic potential indicators under the implementation of the RCP scenario family

Station	Bioclimatic Potential			Bioclimatic Potential		
	"Baseline" period	under RCP 4.5	deviation in %	"Baseline" period	under RCP 8.5	deviation in %
Hubynykha	143	122	-21	143	122	-21
Dnipro	145	119	-26	145	119	-26
Loshkarivka	131	110	-21	131	114	-17
Synelnykove	127	115	-12	127	93	-34

REFERENCES

1. Stepanenko S.M., Polyovyi A.M. Climate Risks of the Functioning of Economic Sectors in Ukraine Under Climate Change: Monograph. Odesa: "TES", 2018. 548 p.

2. Agro-climatic Handbook for the Dnipropetrovsk Region: (1986-2005) / edited by O.T. Prokhorenko, T.I. Adamenko; Ministry of Emergency Situations, Dnipropetrovsk Regional Hydrometeorological Center. Dnipropetrovsk: "Polygraph-Media", 2011. 231 p.

LOW-CARBON SOLUTIONS FOR KEY SECTORS OF THE UKRAINIAN ECONOMY: CLIMATE CHANGE MITIGATION STRATEGIES

Yurii Kovalenko, PhD, *Olena Drozd, PhD, Olga Khandogina, PhD*

O.M. Beketov National University of Urban Economy in Kharkiv, Ukraine

For Ukraine, as a country with ambitious plans to integrate into the European Union and EU's climate initiatives, the introduction of low-carbon technologies is becoming not only an environmental but also an economic imperative.

Global anthropogenic greenhouse gas emissions reached about 59 Gt of CO_2 equivalent in 2019. Their sectoral distribution shows that power generation is the largest source of emissions (approximately 75.7%). Other major sectors include: agriculture – 11.7%; industries – 6.5%; waste management – 3.4%; land use and forestry – 2.7%. According to the National Inventory of Anthropogenic Emissions, the structure of emissions in Ukraine shows certain differences from global trends, but also demonstrates the dominance of the power engineering sector: fuel combustion – 63.9%; industries – 18.0%; agriculture – 14.4%; waste management – 3.7%.

In 2021, Ukraine's total emissions amounted to 313.5 million tons of CO_2-eq. including sequestration by forests (or 327.7 million tons of CO_2-eq. excluding sequestration). According to the State Statistics Service of Ukraine, CO_2 accounts for 91% and CH_4 – for 9% of the contribution to global warming from stationary sources.

Transitioning to a low-carbon economy is a necessity path to reduce greenhouse gas emissions, improve energy efficiency, and adapt key industries to new environmental challenges.

Ukraine has significant potential for decarbonizing its power engineering sector by expanding the use of renewable energy sources. The average cost of solar electricity as of 2023 is ~$0.044/kWh, and solar power plants have become one of the cheapest sources of alternative electricity. In Ukraine, it is advisable to develop both industrial solar power plants and rooftop systems for households. Wind energy has a high potential in Ukraine, largely in the coastal areas. Modern installations demonstrate high efficiency with a utilization rate of 25-40% on land and 40-50% offshore. Bioenergy is a promising source for Ukraine with its developed agricultural sector. The use of agricultural waste such as straw and husks to produce heat and electricity can significantly reduce the carbon footprint of the energy sector. The implementation of modern energy storage technologies, development of distributed generation and modernization of power grids will reduce dependence on fossil fuels and CO_2 emissions, as well.

Another effective solution would be to increase the efficiency of traditional power plants by introducing supercritical and ultra-supercritical boilers (at coal-fired power plants), which would increase their efficiency to 42-47% compared to the traditional 30-35%. Also promising is the development of high-efficiency combined-cycle plants with an efficiency of 55-62%, which ensures a significant reduction in both fuel consumption and emissions. In addition to equipment modernization, an effective way to decarbonize the power generation sector is to convert coal-fired power plants to biomass co-combustion. This approach reduces the carbon footprint without the need to completely dismantle existing power supply facilities.

Hydrogen technologies open up new opportunities for decarbonization. The production of green hydrogen through electrolysis and its use in heavy industry and transportation creates carbon-free fuel cycles. Hydrogen can also balance the power system, compensating for the instability of renewable energy sources.

The industry in Ukraine requires modernization in order to reduce emissions. In metallurgy, the use of hydrogen for iron reduction, powering electric arc furnaces with green electricity, and introducing carbon capture technologies are promising pathways. The cement industry can reduce emissions by replacing some clinker with low-carbon materials and using alternative fuels. In the chemicals industry, important solutions include green hydrogen-based ammonia production, catalytic N_2O reduction, and CO_2 capture for producing plastics and synthetic fuels.

The agricultural sector also plays an important role in reducing greenhouse gas emissions. In crop production, one of the main areas of focus is precision farming, which optimizes the use of fertilizers and reduces nitrogen losses. The use of cover crops, which absorb carbon and prevent the formation of N_2O, helps to reduce emissions. An important step is the development of agroforestry, which can increase carbon sequestration by introducing trees into croplands. In livestock farming, it is necessary to optimize livestock diets to reduce methane emissions and introduce biogas plants for manure utilization with energy production.

To effectively reduce greenhouse gas emissions in Ukraine, a comprehensive approach is needed, including decarbonization of industrial processes, modernization of the energy system, and transformation of agriculture. The introduction of innovative technologies, economic mechanisms, and sustainable development strategies will allow the country to achieve its climate goals, increase energy independence, and reduce its overall environmental footprint.

PVC PROFILES RECYCLING TECHNOLOGIES AS PART OF THE EUROPEAN SUSTAINABILITY CONCEPT

Sergii Kozhevnikov, post-graduate student, *Yuliia Bereznytska, k.t.s*

Kyiv National University of Construction and Architecture, Ukraine

Sustainable development in Europe is a core principle that aims to balance economic growth, environmental protection, and social well-being. It is guided by the notion that economic activities should not come at the expense of future generations, but instead promote environmental stewardship and social equity. This concept has been widely integrated into European policy frameworks, including the European Green Deal, which seeks to transform the EU into a climate-neutral economy by 2050. In this context, sustainability is not just about reducing carbon footprints, but also about fostering circular economy practices, ensuring that resources are used efficiently and waste is minimized.

One key aspect of sustainable development is the circular economy, which aims to close the loop of product life cycles through recycling, reuse, and refurbishment. The building and construction sector, a significant contributor to waste and resource consumption, has increasingly focused on sustainable practices, particularly in materials like PVC (polyvinyl chloride). PVC is commonly used in the production of window profiles due to its durability, low maintenance, and energy efficiency. However, its environmental impact is a concern, especially when it comes to waste management at the end of a product's life cycle.

PVC window profile recycling plays a crucial role in minimizing the environmental impact of PVC in construction. When PVC windows reach the end of their life cycle, they can be recycled into new products, reducing the need for virgin material extraction and decreasing the volume of waste that ends up in landfills. This recycling process typically involves the collection of old window profiles, which are then cleaned, shredded, and processed to remove any non-PVC elements. The resulting material can be reused in the manufacturing of new PVC products, contributing to a more sustainable building sector. Through such recycling initiatives, the environmental footprint of PVC is significantly reduced.

In Europe, several regulations and initiatives encourage the recycling of PVC, aligning with broader sustainability goals. For example, the EU Waste Framework Directive promotes recycling targets and sets standards for product design, ensuring that materials are easier to recycle. Additionally, various industry collaborations and recycling schemes, such as the VinylPlus program, have been established to improve the recycling rate of PVC materials, including window profiles. These initiatives help address the challenges of PVC waste, encourage innovation in recycling technologies, and create a market for recycled materials, further advancing the European commitment to sustainable development.

By embracing the recycling of PVC window profiles, Europe demonstrates a practical approach to sustainable development. It shows how industries can integrate circular economy principles into their operations, reduce their environmental impact, and contribute to a more sustainable future. The continued improvement of recycling technologies and policies will further enhance the efficiency of these processes, promoting sustainability not only in the construction sector but across the economy as a whole.

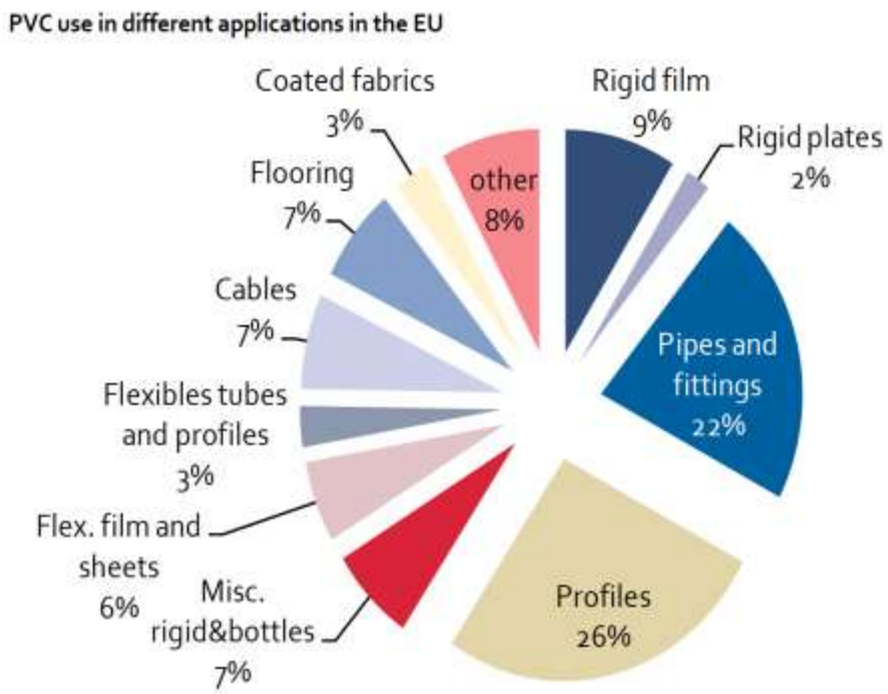


Fig. 1. PVC use in different applications in the EU.

Globally, the recycling of PVC window profiles is still in the early stages compared to other materials like aluminum or glass, but it is steadily gaining momentum, particularly in Europe. According to VinylPlus, a voluntary sustainability program for the PVC industry, over 813,266 tonnes of PVC were recycled in 2022 across Europe, with a significant portion of this being from building and construction materials, including window profiles.

However, recycling rates for PVC window profiles vary widely by region, with Europe leading the charge due to stricter regulations and more established recycling systems. In other parts of the world, like North America and Asia, the recycling of PVC windows is less prevalent, largely due to insufficient infrastructure, lower public awareness, and limited regulations that encourage the reuse of materials.

Table 1. Global statistics of polyvinyl chloride

Global statistics of PVC recycling [2, 6]*.		
	2022, tons	2023, tons
PVC waste	813 266	737 645
PVC window profiles	408 151	391 093

Despite the challenges, global efforts to improve PVC window profile recycling are growing, driven by the push for a circular economy and sustainability goals. Initiatives such as the VinylPlus program aim to increase the global PVC recycling rate, targeting the recycling of at least 1 million tonnes of PVC by 2025. Additionally, technological advancements in the recycling of mixed plastics, including PVC, are opening up new possibilities for scaling up recycling efforts globally, reducing landfill waste, and conserving natural resources.

REFERENCES

1. Anna Fråne (IVL Swedish Environmental Research Institute) PVC waste treatment in the Nordic countries, ISBN 978-92-893-5969-6 , pp.28-32
2. Vinyl Plus "Progress report 2024", pp. 13-24, www.vinylplus.eu
3. PlastEurope Analitic Report "Volume of recovered waste in Europe heavily declines in 2023", www.plasteurope.com
4. Krzysztof Lewandowski and Katarzyna Skórczewska , "A Brief Review of Poly Vinyl Chloride (PVC) Recycling", pp. 2-6
5. PVC—A Circular Material for the Future. Available online: https://pvc.org (accessed on 1 July 2022).
6. Sustainable development and energy saving. Analytical data of EPPA (The European Trade Association of PVC window systems supplier. Electronic resource. Access mode: https://www.eppa-profiles.eu/

CLIMATE ASPECTS OF ESG STANDARDS IN THE CONSTRUCTION SECTOR OF UKRAINE

Tetiana Kryvomaz, prof.*, Artem Tsyba, Roman Hamotskyi, PhD students*

Kyiv National University of Construction and Architecture, Ukraine

The Ministry of Finance of Ukraine has published a draft of amendments to the Law of Ukraine “On Accounting and Financial Reporting in Ukraine”, which is related to the introduction of the European Sustainability Reporting Standards (ESRS). If these amendments are approved, then from 2026 large enterprises with an average number of employees of more than 500 people will have to report on environmental, social and governance (ESG) aspects of their business activities, and in subsequent years, medium and small companies should join the reporting.

In the construction sector, ESG factors are crucial for determining the overall value and potential of a real estate object, which helps investors receive more information for decision-making and risk assessment. The use of (ESG) indicators ensures transparency, objectivity and measurability of company performance.

The first disclosure requirement in ESRS is about climate change affects in terms of material positive and negative actual and potential impacts. It is help to understand the financial effects on the undertaking over the short-, medium- and long-term time horizons of risks and opportunities arising from the undertaking’s impacts and dependencies on climate change.

ESRS E1 "Climate change" shows the nature, type and extent of the undertaking’s material risks and opportunities arising from the undertaking’s impacts and dependencies on climate change, and how the undertaking manages them. The information shall include an explanation of the decarbonisation levers identified, and key actions planned, including changes in the undertaking’s product and service portfolio and its adoption of new technologies. The undertaking shall describe the process to identify and assess climate-related impacts, risks and opportunities. When disclosing the information required, the undertaking shall explain how it has used climate-related scenario analysis to inform the identification and assessment of physical and transition risks and opportunities over the short-, medium- and long-term time horizons. The undertaking shall indicate whether and how its policies address the following areas: climate change mitigation, climate change adaptation, energy efficiency, renewable energy deployment, and other.

In the ESG report, the company analyzes climate-related transition risks are risks that arise from the transition to a low-carbon and climate-resilient economy. They typically include policy risks, legal risks, technology risks, market risks and reputational risks, that can arise from related transition events. Climate-related opportunities refer to the potential positive effects related to climate change on the undertaking. Efforts to mitigate and adapt to climate change can produce opportunities for undertakings, such as through resource efficiency and cost savings, the adoption and utilisation of low-emissions energy sources, the development of new products and services, and building resilience along the supply chain. Climate-related opportunities will vary depending on the region, market, and industry where the undertaking operates.

The most difficulties with ESRS standards arise when calculating emissions for Scope 1 (direct GHG emissions from sources owned or controlled by the undertaking), Scope 2 (indirect GHG emissions from the generation of purchased or acquired electricity, steam, heat, or cooling consumed by the undertaking) and Scope 3 (indirect GHG emissions that occur in the value chain of the reporting company, including both upstream and downstream emissions). Scope 3 GHG emissions are considered as estimated emissions in comparison with Scope 1 and 2 as their calculation is based on a combination of methods and primary and secondary data ranging from precise figures (supplier-specific or sites-specific methods) to extrapolated figures (average-data or spend-based methods).

Emission reductions may result from energy efficiency, electrification, suppliers' decarbonisation, electricity mix decarbonisation, sustainable products development or changes in reporting boundaries or activities (e.g., outsourcing, reduced capacities.), provided they are achieved within the undertaking's own operation and value chain. Among climate-related transition events next directions are distinguished: policy and legal, technology, market, reputation. Political and legislative changes may cause increasing pricing of GHG emissions, enhanced emissions-reporting obligations, mandates on and regulation of existing products, production processes and services. Technological development contributes to investment in new technologies with substitution of existing products and services with lower emissions options. Market development provides changing customer behaviour in conditions uncertainty in market signals and increased cost of raw materials. The company's reputation affect by shifts in consumer preferences, stigmatization of sector, increased stakeholder concern and their negative feedback.

Meanwhile, the European Commission plans to postpone the main set of requirements of the Sustainable Reporting Directives until 2030, as there is currently no consensus among member states. Against this background, Ukraine can become a flagship of sustainable reporting, because the war convinced us of the importance of tracking supply chains. ESG reporting for Ukraine during the war is a matter of survival. The new legislative initiative brings Ukraine's European integration closer and promotes the development of companies. Businesses that demonstrate specific commitments to sustainable development will become undisputed leaders in their industries in the next 30 years and will gain access to investment capital. On the other hand, companies that do not take care of compliance with international standards in a timely manner risk losing their business in the medium term.

A WEB-BASED SYSTEM FOR ENHANCING AGROMETEOROLOGICAL DECISION-MAKING IN THE FACE OF CLIMATE CHANGE

Oleksandr Kryvoshein, PhD, *Kryvobok Oleksii, PhD*

Ukrainian Hydrometeorological Institute, Ukraine

In the face of climate change, agricultural systems must adapt to rapidly changing environmental conditions to ensure food security. Agrometeorologists play a crucial role in monitoring and managing agricultural productivity, but the increasing complexity of climate patterns demands more advanced tools. To support their work, we developed a web-based system (Fig.1) designed to assist agrometeorologists in monitoring weather conditions at various scales, from regional to district and grid levels. This tool offers a comprehensive solution to enhance decision-making processes that are essential for agricultural management in a changing climate. The main principles of this web-based system are described in article [1]

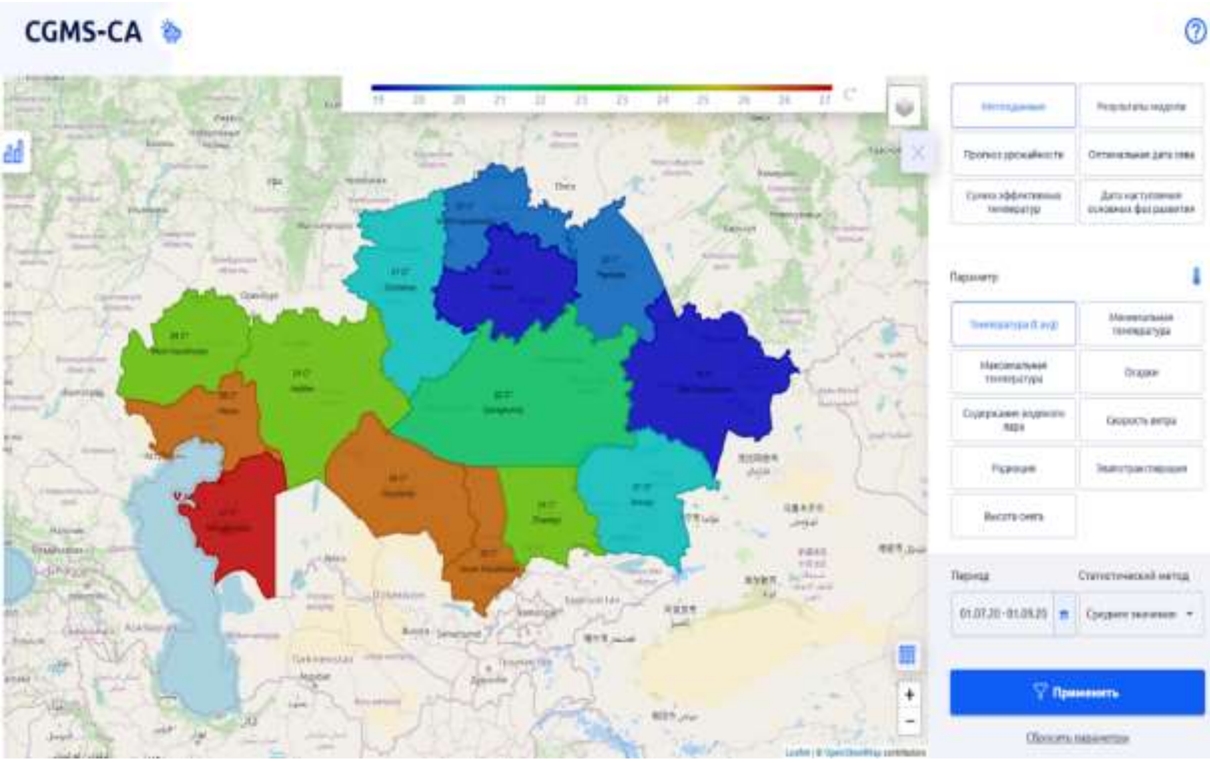


Fig. 1. A visual of the system's user interface, showing weather data integration results.

One of the key features of the system is its integration of the WOFOST (World Food Studies) crop growth model, which simulates the total above-ground biomass of major crops, such as winter wheat and maize. By using weather data and this model, the system can generate high-accuracy predictions regarding crop development, providing users with valuable insights for optimizing sowing times, estimating yield potential, and determining critical growth stages.

The system's ability to simulate crop growth at multiple scales allows agrometeorologists to analyze local variations in climate and soil conditions, improving the precision of their predictions. For example, it can identify the optimal sowing date for different regions based on weather data, which helps minimize risks associated with late or early planting. Additionally, the model can detect the key phenological stages of crop development, such as flowering or maturity, and monitor the growth process in near real-time. These insights are critical for making data-driven decisions that enhance crop yields and contribute to food security.

Furthermore, the system incorporates advanced forecasting tools that provide high-accuracy predictions at the administrative level, offering detailed insights that can be applied to larger-scale agricultural policy and management. This enables local authorities to make informed decisions about irrigation schedules, pest management, and crop rotation strategies, thereby optimizing resource use and ensuring that food production is resilient to climate variability.

The integration of this system into climate services represents a significant step forward in the application of science and technology in agriculture. By providing accurate, localized data, this tool enhances the ability of agrometeorologists to respond to climate challenges, improving the resilience of agricultural systems to extreme weather events. The system's ability to simulate and predict crop growth based on dynamic climate and weather data directly contributes to the broader goal of ensuring food security in the face of climate change. Furthermore, its web-based architecture makes it an accessible and scalable tool for use by a wide range of stakeholders, from small-scale farmers to governmental bodies responsible for food policy and disaster response.

Ultimately, this system is a vital resource for improving agricultural productivity in the face of climate variability. By providing actionable, science-based insights, it not only supports agrometeorologists in their day-to-day work but also contributes to long-term agricultural sustainability and food security.

REFERENCES

1. Kryvobok O., Kryvoshein O., Adamenko T. 2018: Peculiarities of technological adaptation of the CGMS system for agricultural crops monitoring in Ukraine, Ukrainian hydrometeorological journal, No. 22, pp. 64-79.

CLIMATE CHANGE IN TRANSCARPATHIA: IMPACT, CHALLENGES, AND ADAPTATION

Oksana Kuklyshyn*[1,2]*, 1st year PhD student

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Transcarpathian Regional Center for Hydrometeorology

Climate change significantly affects the Transcarpathian region, impacting forestry, tourism, agriculture, water resources, and energy security. Rising temperatures, shifting precipitation patterns, and extreme weather events create new challenges for the region's economy and environment. This study analyses key climate trends, such as increased average annual temperature, reduced snow cover, and changing vegetation cycles. It also explores the main issues in climate services, including insufficient meteorological monitoring and outdated forecasting technologies. To mitigate these challenges, the paper proposes solutions such as expanding the meteorological network, implementing automated monitoring systems, and integrating AI-based climate forecasting. Enhancing climate literacy and incorporating climate adaptation strategies into regional development plans are crucial for sustainable economic growth and environmental resilience in Transcarpathia.

Introduction. Transcarpathia is a region of Ukraine with unique natural conditions, making its economy highly dependent on climatic factors. Especially agriculture, which is the most vulnerable to climate change. This in turn affects the food security of the region, which is the most land-poor in Ukraine. The mountainous terrain influences climatic processes, leading to vertical climatic zoning. Effective climate service plays a crucial role in ensuring the sustainable development of climate-dependent sectors of the economy.

Impact of Climate Change

Forestry – increased vulnerability of forests to pests, higher risk of wildfires.

Tourism – seasonal shifts, reduction of snow cover, increased frequency of extreme weather events.

Energy Sector – decreased river water levels affecting small hydroelectric power plants.

Water Resources – changes in water balance, water shortages, and more frequent droughts.

Agriculture – change in wintering conditions, the duration of interphase periods is reduced, changes in crop vegetation, the need for irrigation in the lowland areas of the region.

Key Climate Trends

• Increase in the average annual temperature by 0.7-1.0°C. Due to the rise in average summer air temperature, the number of hot days has increased compared to previous climate norms. A significant increase in the number of hot days began in the 1990s (Fig. 1).

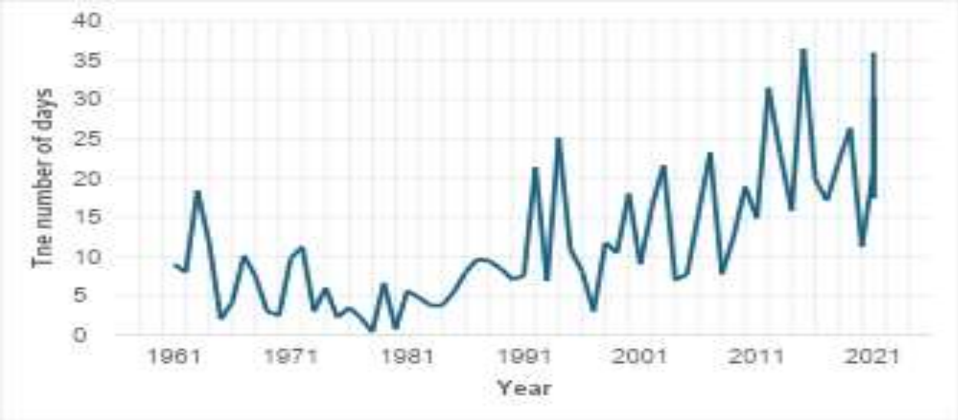


Fig. 1. The number of days with maximum air temperatures of 30°C and above

• As temperatures rise, the probability of spring frosts increases.
• Reduction in the number of days with snow cover.
• More frequent droughts and extreme weather conditions. The decrease in annual precipitation occurred mainly due to the summer months.

Problems of Climate Services

• Insufficient number of meteorological stations.
• Outdated observation equipment.
• Low awareness among farmers about adaptation measures.
• Limited use of modern forecasting technologies.

Ways to Improve

1. Expanding the meteorological station network and implementing automated observations.
2. Utilizing big data and artificial intelligence for climate forecasting.
3. Educational programs for entrepreneurs and farmers on adaptation strategies.
4. Integrating climate forecasts into regional development programs.

Conclusions. According to climatologists, the coming decades will bring a steady increase in the intensity and frequency of extreme weather events. Therefore, timely assessment of extreme climate phenomena and climate change trends is crucial. Planning economic activities and making management decisions should focus not only on average indicators but primarily on extreme values to mitigate consequences and minimize losses as early as possible. As a region highly dependent on natural conditions, Transcarpathia requires a well-developed climate service system. The implementation of modern monitoring technologies, increasing climate literacy, and integrating climate forecasts into development strategies will help minimize the negative effects of climate change and contribute to the sustainable development of the region’s economy.

CHANGES IN CLIMATE AND RIVER WATER CONTENT IN THE UPPER DNIESTER BASIN AT THE BEGINNING OF THE 21ST CENTURY

Nataliia Loboda, Prof., Dr. Geogr. Sci., *Mykyta Rozvod, PhD Student*

Odesa I. I. Mechnikov National University, Ukraine

The Dniester River is a transboundary river whose water resources, according to Goal 6 of the UN General Assembly Resolution of 25 March 2015 on the Global Sustainable Development Goals by 2030, should provide the population of Moldova and southwestern Ukraine with safe and affordable drinking water of adequate quality.

Climate services for the Dniester water users (hydropower, agriculture, industrial and municipal enterprises, fish farming, water transport, etc.) are intended to effectively implement integrated water management of the Dniester River in the context of climate change and anthropogenic pressure. The Dniester River basin is characterised by uneven distribution of the river's water resources, which makes the economies of the middle and lower Dniester dependent on the Upper Dniester's water supply. The water regime of the Dniester is characterised by the fact that the runoff formation zone is concentrated in the upper part of the Dniester basin, namely in the Carpathian Mountains.

The paper uses data on average monthly values of air temperature, precipitation and water discharge in the Dniester basin provided by the Boris Sreznevsky Central Geophysical Observatory (CGO).

The analysis of the impact of the Dniester Reservoir on the nature of the Dniester runoff fluctuations showed that the cyclic nature of the annual runoff fluctuations in the upstream and downstream sections of the reservoir has not been disturbed, and the position on the time axis of the main characteristic points (dates of transition from one water availability phase to another) of the mass residual curves (1964, 1981, 1995, 2010) also remained almost the same. In the lower reaches (Dniester - Bendery), the patterns of intra-annual runoff distribution inherent in the upper reaches have been preserved. The effects of flow regulation are manifested in April and July for dry years, and in March-April for wet years [1].

The results of the study revealed that the nature of fluctuations in the main Dniester river is determined mainly by fluctuations in the flow of the Carpathian tributaries (Carpathian region), for which the number of water availability cycles and the boundaries of water availability phases coincide with the corresponding indicators of the main river [2]. It was found that for the tributaries of this group there is a close correlation between the ordinates of the mass residual curves of fluctuations in annual and rainfall runoff, which indicates a significant contribution of rainfall to river water content. In the External Carpathian region, snowfall plays a significant role in the formation of fluctuations in annual runoff. It was found that since the late 1990s, the contribution of spring floods to the formation of annual runoff has been gradually decreasing and the role of rainfall floods has been increasing.

It is shown that air temperature fluctuations occur synchronously at all meteorological stations located in the catchment area of the entire Dniester and adjacent territories (Ukraine). The existence of statistically significant positive trends (trends) in fluctuations of average annual air temperatures, average monthly air temperatures of warm and cold periods through 1989-2021 was established [3]. It should be noted that in terms of the effects of climate change, 1989 is considered a turning point for the territory of Ukraine (Hrebin V.V., 2010). No general trends have been identified in the fluctuations of precipitation characteristics since 1989. It is established that for most of the meteorological stations of the Upper Dniester, the patterns of fluctuations in annual precipitation amounts correspond to the patterns of fluctuations in annual runoff to a greater or lesser extent. It has been shown that since the mid-1990s, negative trends have been formed in the fluctuations of rainfall amounts in the rainy period (VI-XI), which are statistically significant for most of the basin's meteorological stations [4].

Thus, the transition to a dry phase, which has been observed in the fluctuations of the Dniester's annual runoff since 2010, is mainly due to the intensive increase in air temperature since 1989 and the emergence of negative trends in rainfall fluctuations (VI-XI) starting from 1990s.

REFERENCES

1. Loboda N. S., Rozvod M. R., 2024: Characteristics of runoff fluctuations and climatic factors of its formation in the Dniester river basin in the early XXI century, proceedings of the International Scientific and Practical Conference “Natural and Geographical Studies of Relief, Climate and Surface Water: Current state and development prospects”, Kyiv, pp. 35-36.

2. Loboda N. S., Rozvod M. R., 2023: Patterns of runoff fluctuations of the Dniester river (Ukraine) under conditions of climate change at the beginning of the XXI century, Ukrainian hydrometeorological journal, Vol. 32, pp. 50-62

3. Loboda N.S., Rozvod M. R., 2024: Changes in the air temperature regime in the Dniester river basin at the beginning of the XXI century, Ukrainian hydrometeorological journal, Vol. 33, pp. 38-48

4. Loboda N.S., Rozvod M. R., 2024: Changes in temperature regime and wetting regime in the upper Dniester basin at the beginning of the XXI century, proceedings of the 79th Reporting Scientific Conference of the Faculty of Hydrometeorology and Ecology of the I. I. Mechnikov Odesa National University, pp. 71-74.

RISKS OF WATER RESOURCES DEPLETION IN SOUTHERN UKRAINE AND THEIR CONSEQUENCES ACCORDING TO CLIMATE SCENARIOS

Nataliia Loboda, Prof., Dr. Geogr. Sci.,
Nataliia Otchenash, PhD in Geography, Mykyta Rozvod, PhD Student

Odesa I. I. Mechnikov National University, Ukraine

The assessment of changes in water resources in southern Ukraine in the context of warming is based on the climate-runoff model, which uses meteorological data of climate scenarios and quantitative indicators of water management transformations in catchments as input [1]. Natural water resources under given climatic conditions are determined by the components of the water-heat balance of a catchment. The assessment of heat and moisture resources is based on long-term data on air temperatures and precipitation. The result of the calculations is the average long-term value of annual runoff, calculated from the data of meteorological stations or in the data grid nodes of the selected climate scenario [2].

Expected climate conditions in the near future (2021-2050) were determined based on the results of the Euro-CORDEX project for two climate change scenarios RCP4.5 and RCP8.5. From an ensemble of 14 simulations using different regional climate models, one regional model (CLMcom-CCLM4-8-17 with the global model MPI-ESM-LR) was selected as the best match for the ensemble average [3].

The risk of a natural hazard can be calculated based on a probabilistic approach

$$R_{q.r.}=p(N.H.)\cdot P \qquad (1)$$

where $R_{q.r}$ - is a quantitative risk indicator;

p - probability of a hazardous event *(N.H.)*

P - percentage of damage caused by a hazardous climate event

In this paper, the depletion of water resources as a result of climate change is considered a dangerous phenomenon. According to the UN recommendations, a decrease in water resources by more than 10% means statistically significant changes, a decrease in water resources by more than 50% indicates the destruction of water resources, and more than 70% - irreversible destruction.

The following approach to assessing the climate risk of water resources depletion is proposed in [4]:

- percentage of damage P due to climate change was estimated through the degree of water resources reduction (10%, 50%, 70%);

- the probability of occurrence of a hazardous event (p) was set by the ratio of the number of weather stations n (grid nodes) where this event was established to the total number of weather stations N (grid nodes)

$$p=n/N. \tag{2}$$

It is established that for the next thirty-year period (2021-2050), the empirical probability p of a satisfactory state (decrease to 10%) of water resources will be 34% for the RCP4.5 scenario and only 2% for the RCP8.5 scenario. The empirical probability p of the occurrence of a stressed state of water resources (their decrease from 10% to 50%) will be 56% for the RCP4.5 scenario and 76% for the RCP8.5 scenario.

The highest risk factors R' of water resources depletion will be possible in the intervals of changes from -20 to -30% (R'=5.25) and from -30 to -40% (R'=4.55) for the RCP4.5 scenario. For the RCP8.5 scenario, the highest values of the risk coefficients were found in the intervals from -30 to -40% (R'=9.80); from -40 to -50%% (R'=13.0); from -50 to -60% (R'=8.25).

The high risks of water resource depletion identified by observations and predicted by climate scenarios indicate real prospects for the destruction of local water resources in southern Ukraine and, in particular, in the Northwest Black Sea region, which has been preserved as the main center of irrigated agriculture in the face of Russian aggression. Increasing deficits in the annual freshwater balance of the ‘closed’ estuaries of the northwestern Black Sea region may pose a threat of salinisation and subsequent disappearance [4].

REFERENCES

1. Loboda N. S., Prediction of change in water resources of Ukraine under the RCP4.5 and RCP8.5 climate scenarios and assessment of risks for water management, 2018: Climate risks of functioning of Ukrainian economic sectors in the context of climate change: a collective monograph, edited by S.M. Stepanenko, A.M. Polevyi Odesa, pp. 498-521.

2. Loboda N. S., Kozlov M. O., 2020: Assessment of water resources of the Ukrainian rivers according to the average statistical models of climate change trajectories RCP4.5 and RCP8.5 over the period of 2021 to 2050, Ukrainian hydrometeorological journal, Odesa, vol. 25, pp. 93-104.

3. Khokhlov V., Tuchkovenko Y., Loboda N., 2024: Selection of representative near-future climate simulations by minimizing bias in average monthly temperature and precipitation, Theor. Appl. Climatol. 155 (4), pp. 2857-2859.

4. Loboda N. S., Otchenash N. D., Kozlov M. O., 2024: Methodological approaches to assessing the risks of water resources depletion in the context of climate change (using plain territories of Ukraine as an example), Ukrainian hydrometeorological journal, Odesa, vol. 33, pp. 5-17.

ELABORATING THE ATLAS 'CLIMATE AND WATER RESOURCES OF UKRAINE'

Andrii Oreshchenko, PhD.

Ukrainian hydrometeorological institute, Ukraine

The web-based atlas “Climate and Water Resources of Ukraine” was developed at the UkrGMI as object of the research topic in 2021—2023 and published at https://maps.uhmi.org.ua. The atlas contains 5940 maps grouped into 74 themes (subsections). In particular, the subsection “Average maximum air temperature per month from 1946 to 2020” contains 900 maps. The main sections are solar radiation, air temperature, precipitation, heat waves and sudden temperature changes, wind power, hydrological and meteorological observation network, snow cover and avalanches, runoff modules (1 map), and hydrochemistry of surface water. The atlas also includes maps related to the Kakhovka disaster — the drainage of the reservoir and flooding of the Kherson region.

A web-based atlas consists of a web shell and a map library. The web shell, in turn, contains a multi-section page (first) for a presentation for the atlas and a main menu page (second). The first page contains the description of the atlas — this page contains the purpose of the atlas, its structure and source data, and also information about the developer. The main menu page consists of two frames: the menu itself with a list of maps and a frame that loads web pages with map thumbnails. A special image viewer have written in JavaScript and embedded in the web page. It displays raster maps. With its help, you can customize the magnification and extent of the map available for viewing.

The main problem for creating such cartographic work is in large amount of labour. A number of methods and approaches have been used to reduce it.

The most productive method was ***serial mapping using an automatic mapping system***. It was used to create series of maps, i.e. sets of analytical maps, each of which reflects the same mapping indicator, with a difference in time.

Related to the previous method, ***the method of map unification*** consists in the use of the same ways and means of cartographic representation, mapping methods, cartographic bases, and software for different maps.

Reducing the number of production processes in the creation of thematic maps implies retaining the preparation of geodata (1), their processing in GIS: interpolation, drawing isolines, transforming the form of geodata representation (2), creating thematic layers and labels in GIS (3). But the transferring layers to a map base in vector graphics software (4), editing small errors and pre-press production of the map (5) can be eliminated.

In order to avoid processes (4) and (5) we created a special map base with correct thicknesses of lines and curvature of labels. So the map export to raster correctly preserved their thicknesses and locations of letters.

Large-scale unit assembly used to elaborate the web shell of the atlas and modules in Java-Script. It is necessary to develop a high quality web shell in a short period of time (2-3 months), at the level of products created by specialists from foreign institutions. This task is solved by combining of open source HTML fragments and Java scripts. The author founded an open source template for a one-page landing html with clearly defined sections, the content of which is easy to edit. The sections contained code snippets such as “carousels” (images that change each other), Google maps, html forms, etc. The missing components were integrated from the library sites. Large-node assembly was used to create the map viewer, which consisted of two parts. The first one is designed to create a mosaic of images from the list of links, and the second one is designed to display the selected image on the screen.

High-performance equipment: a computer with three monitors is designed to work in several programs simultaneously. A programmable keyboard and mouse allowed for complex commands to be executed at the touch of a button. A “replaceable” hard drive was installed in various laptops, PCs and tablets, and there was no need for data verification.

Automation of production processes includes a number of life hacks. An atlas consists of many almost identical structural components, unlike, say, a car, where there are few identical parts. The atlas contains 4,000 similar maps, their thumbnails, and more than two dozen web pages that differ only in the title and links to the maps. All of them can be processed in batches, for example, raster graphics editors can create map thumbnails in batches.

The pyramidal project development algorithm involves creating a small amount of labour, but a working result that provides for possible further retrofitting and expansion of functionality.

The development of such methods becomes possible with the ***use of a third-generation cognitive platform***. A cognitive platform is a set of rules that describe the methods of acquiring, memorizing, generalizing in the form of experience, and using knowledge, skills, and abilities. One of the purposes of a cognitive platform is to provide the ability to combine several heterogeneous professions belonging to several areas. In this case, graphic and web design, cartography, programming in Java-script, Python, and ArcPy. As well as use of production optimization and project management.

ASSESSMENT OF THE CHEMICAL POLLUTION RISKS OF RIVERS IN THE NORTHWESTERN BLACK SEA REGION

Nataliia Loboda, Prof., D.Sc. (Geography),
Antonina Kuza, Senior Lecturer, Ph.D. (Geography)

Odesa I. I. Mechnikov National University, Ukraine

The relevance of this study is determined by the need to assess the risks of pollution of surface and groundwater in the Northwestern Black Sea region under the conditions of climate change and military aggression against Ukraine by Russia.

The main factors contributing to the pollution of surface and groundwater include discharges from stationary and diffuse sources. The former consists of point-source discharges of municipal wastewater, while the latter includes the distributed inflow of pollutants from the catchment surface. Prior to the outbreak of hostilities, diffuse pollution was primarily associated with the runoff of nitrogen compounds from agricultural lands. The EU Nitrates Directive specifically aims to protect water from pollution by ammonia, nitrites, and nitrates. However, with the onset of military actions in the Northwestern Black Sea region, new industrial pollutants have emerged due to the destruction of energy, railway, and port infrastructure, damage to bridges and overpasses, and the release of hazardous substances from military debris (missiles, drones, etc.). The impact of chemical pollutants of various origins is further aggravated by the reduction in river inflows as a result of climate changes. It has been established that modern warming trends lead to the depletion of local water resources, a decrease in the inflow of freshwater to the estuaries of the Northwestern Black Sea, and their gradual shallowing and salinization. The Odesa region plays a key role in supplying the country with agricultural products under the conditions of military operations, as the agricultural lands of the Mykolaiv and Kherson regions have suffered significant damage due to the hostilities. The importance of irrigation is increasing, along with the need for the restoration and modernization of irrigation systems.

Quantitative assessments of pollution at different levels (permissible, significant, high, critical) and the corresponding potential damage are provided using special indicators known as risks. The simplest ecological risk assessments are based on data on anthropogenic load levels and the concentration of substances serving as indirect indicators of water pollution (oxygen, biological oxygen demand, nitrates, nitrites, etc.). Probabilistic models of risk assessment have become widely adopted, wherein exceeding the concentration of a pollutant beyond the regulatory threshold is considered a hazardous event for aquatic ecosystems, and the risk indicator itself is determined as the probability-weighted average value. The foundation of these calculations is the correlation of quantitative risk indicators with water quality parameters at a semantic level and the creation of a risk scale [4].

One type of probabilistic risk assessment model is the mathematical model based on the probit function, which is associated with the normal law of probability distribution (Rybalova, O., Artemiev, S., 2017). Once this function is determined, the deterioration of water bodies is characterized using a specially developed ranked ecological risk scale. The classification of water bodies based on ecological risk levels determines their suitability for use by different types of users.

An analysis of chemical pollution of small and medium-sized rivers in the North-Western Black Sea region up to 2022 showed that the main pollutants are nitrogen compounds (ammonium, nitrites, nitrates). Heavy metal contamination was not detected. The impact of nitrogen compound pollution in rivers was assessed by comparing the total nitrogen compound concentration (sensitivity index) to its threshold value (50 mg/dm3 or 11.3 mgN/dm3). Based on data on the total nitrogen concentration in small and medium-sized rivers of the Southwestern Black Sea region, it was found that exceedance of the sensitivity index over the threshold value was observed only in certain rivers. The risk zones included small catchments with a high proportion of arable land. The most probable risk levels were classified as moderate and permissible. An analysis of biogenic pollution risks along the lengths of the Kogilnik and Sarata rivers, based on the probit-function model [1,2], established that the pollution risk decreases in the lower reaches. The developed methodology for assessing the risks of water pollution with heavy metals [3] is recommended for use in watersheds with the consequences of military operations.

REFERENCES

1. Loboda N.S., Kuza A.M. Analysis of the ecological state of the Sarata River in Odesa region. Ukrainian Hydrometeorological Journal. 2024. No. 33. P. 18-37.
2. Loboda, N. S., Kuza, A. M. Assessment of ecological risks of biogenic pollution in the Kogilnik River based on probit functions. Ukrainian Hydrometeorological Journal. 2023. No. 32. P. 34-49.
3. Loboda N. S., Otchenash N. D., Fedina N. O. Development of a methodological approach for determining ecological risks of water pollution in industrially developed territories (on the example of rivers in Kharkiv city). Ukrainian Hydrometeorological Journal. 2023. No. 31. P. 88-102.
4. Loboda N., Daus M. Development of a method for assessing ecological risk of surface water pollution by nitrogen compounds. Eastern-European Journal of Enterprise Technologies. 2021. Vol.5 No.10 (113): Ecology, P.15-25.

ANALYSIS OF TOTAL SOLAR RADIATION FLOWS ON THE TERRITORY OF UKRAINE

Larysa Nedostrelova, Associate Professor, PhD

Odesa I. I. Mechnikov National University, Ukraine

The main problems that humanity has entered the 21st century with are energy and ecology. The rapid industrial development of a group of countries in the Northern Hemisphere has been driven by intensive growth in the production of electrical and thermal energy. Over the past 150 years, since the mid-19th century, the Earth's population has increased fivefold, while energy production has increased 21 times. According to expert assessments by the International Energy Agency, global primary energy production will continue to grow at an average annual rate of 1.7% until 2030, reaching 15,300 million tons. At the same time, it is estimated that more than 90% of this energy production growth will be ensured by fossil fuels. The ever-increasing consumption of fossil fuels leads to rising CO_2 emissions and other greenhouse gases in the atmosphere, raising serious concerns about their potential impact on the planet's climate.

The use of solar energy not only helps preserve the Earth's climate but also reduces countries' dependence on imported hydrocarbons. The amount of solar energy that reaches the Earth's surface in one week exceeds the total energy reserves of oil, gas, coal, and uranium combined. Humanity currently utilizes only one ten-thousandth of this energy. Scientists are confident that if humans used at least 1% of solar energy, the energy crisis would be a thing of the past.

Solar energy is steadily securing a strong position in global energy production. The attractiveness of solar energy is due to several factors. Solar energy is available at every point on our planet, with the radiation flux density varying by no more than a factor of two. Therefore, it is appealing to all countries, aligning with their interests in energy independence. Solar energy is an environmentally friendly energy source that can be used on an ever-growing scale without negative impacts on the environment. Solar energy is an almost inexhaustible energy source that will remain available for millions of years.

Currently, thanks to the development of solar installation designs, the operation of which is economically feasible in certain physical-geographical regions, the prospects for using the radiant energy of the Sun have become more specific. However, this, in turn, requires researchers to conduct a detailed investigation of the energy resources of specific regions of the globe to determine their energy potential.

The use of solar energy primarily depends on the geographical location of a territory, while the efficiency of solar installations depends on the level of solar radiation. Therefore, it is necessary to analyze the feasibility of utilizing solar radiation in different regions of Ukraine, depending on their geographical location, cloud cover, and the time of year.

Alternative energy is primarily aimed at addressing two important issues – environmental safety and energy efficiency. The issue of energy efficiency of alternative fuels is even more relevant for Ukraine than for the rest of the world. The efficiency of solar installations is primarily influenced by the level of solar energy, which, in turn, depends on the geographical location of the territory. The operation mode of solar energy installations (SEI) is determined by a set of heliophysical parameters for utilizing the energy potential, considering the necessary specialized characteristics that take into account the chronological continuous course of solar radiation and its random variability over time, associated with various atmospheric phenomena.

To determine the potential solar energy resources of a particular area, justify the technical and design indicators of different solar systems, assess their economic efficiency of their operation during different seasons of the year and times of the day in a certain location, a set of indicators is required, namely: the possible total amount of direct, diffuse, and global solar radiation; the number of sunshine hours (duration of sunshine); average cloud cover levels; the number of clear and overcast days.

The purpose of the work. Identification of the features of the distribution of total solar radiation fluxes in the regions of Ukraine over different climatic periods. To achieve the goal, meteorological stations in different regions of the country were selected: Kovel – northwestern Ukraine, Odesa – southwestern Ukraine, Poltava – central Ukraine, Pokoshychi – northern Ukraine.

In general, the annual indicators for three periods, do not differ significantly, except for the data from the Kovel station. Here, the annual sum of total solar radiation under clear-sky conditions was the highest in 1951–1963 and gradually decreased from period to period. In Poltava, on the contrary, the annual sums increased from the first to the third period. At the Pokoshychi and Odesa stations, a certain oscillatory pattern is observed, with a minimum in the second period. Under average cloudiness conditions, a similar distribution of total radiation is observed at the stations, except for Poltava. Here, the annual sums increased from the first to the third period. Analysis of total radiation fluxes in Ukraine over different climatic periods under different sky conditions shows that maximum amounts are typical for Odesa, while minimum values are observed in Kovel.

Annual distributions have a clearly defined character with a peak in June or July. An exception is the Kovel station, where, during the period 1991–2020, a certain wave pattern was detected in the summer season, with a minimum in July and maximum in June and August. The sums of total radiation vary under different sky conditions in different regions: in summer, these variations range from 10% to 30%, while in winter, these indicators can change by 1.5 to 2.5 times (especially during the period 1991–2020). Overall, annual amounts of total radiation are lower during the climatic norm period of 1961–1990.

WEB SERVICE "CLIMATE & WATER": HOW TO DEVELOP CLIMATE SERVICE FOR WATER MANAGERS

Valeriy Osypov, PhD, *Nataliia Nikitenko, Yevhenii Matviienko, Yurii Ahafonov, Herman Mossur, Andrii Bonchkovskyi, PhD, Victor Nikoriak, Nataliia Osadcha, Prof., Sc.D.*

Ukrainian Hydrometeorological Institute of the SES of Ukraine and NAS of Ukraine, Ukraine

Building a web-based climate service requires collaboration between scientists, engineers, and designers to ensure that complex data is both accurate and easy to use [1]. The main difficulty is balancing scientific precision, usability, and system scalability so that decision-makers can rely on the platform [2, 3].

Future climate projections must be integrated into river basin management strategies to address climate change impacts; however, Ukraine lacks detailed assessments of future water resources across all basins.

This study aims to develop a web service for water managers, incorporating best practices in user experience design along with high-resolution climate projections.

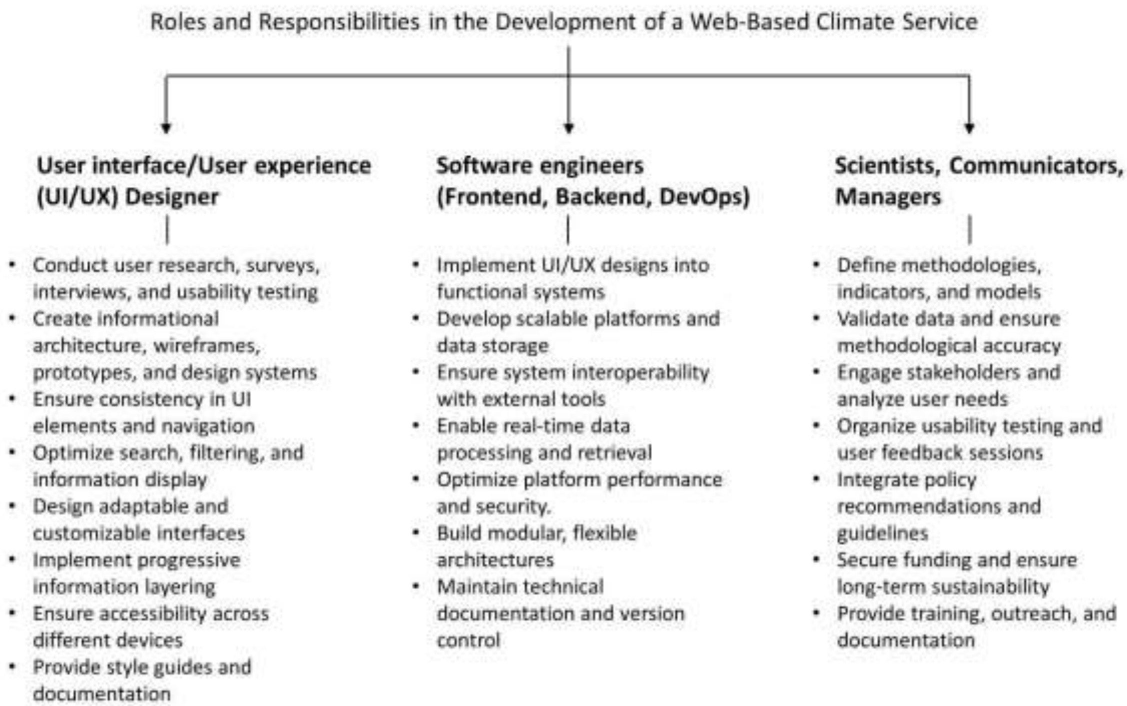


Fig. 1. Responsibilities of UI/UX designer, software engineers, and scientists in the Development of a Web-Based Climate Service.

To understand user needs and determine the best way to present the range of future climate scenarios, we conducted 52 surveys during the preliminary stage and 13 personal interviews with water managers from regional departments during testing. Figure 1 outlines the responsibilities of each team member in the service development.

We developed the "Climate & Water" web service (https://climatewater.uhmi.org.ua/), integrating a user-centered design process with high-resolution hydrological modeling of Ukraine's future water resources. Detailed information on data sources and modeling methodology is available under the "Data Sources" tab.

For user convenience, the results are aggregated by official river basins and water management areas. Users can explore annual, seasonal, or monthly values through interactive charts and maps. All data is freely available and can be downloaded.

"Climate & Water" is built using a client-server architecture. The technologies used are the same as in the "Land & Water" web platform (https://landwater.uhmi.org.ua/) and are summarized in [4].

This approach ensures that the web service effectively supports water managers by providing actionable climate insights. Future work will focus on enhancing user interaction and expanding available datasets.

REFERENCES

1. Whitney K.M., Vivoni E.R., White D.D., 2023: Enhancing the accessibility and interactions of regional hydrologic projections for water managers. Environ. Model. Softw. 167, 105763. https://doi.org/10.1016/j.envsoft.2023.105763

2. Kalsnes B., Oen A., Frauenfelder R., Heggelund I., Vasbotten M., Vollstedt B., Koerth J., Vafeidis N., van Well L., Jan Ellen G., Koers G., Raaphorst K., 2023: Stakeholder evaluation of the co-production process of climate services. Experiences from two case studies in Larvik (Norway) and Flensburg (Germany). Clim. Serv. 32, 100409. https://doi.org/10.1016/j.cliser.2023.100409

3. Terrado M., Calvo L., Christel I., 2022: Towards more effective visualisations in climate services: good practices and recommendations. Clim. Change 172, 18. https://doi.org/10.1007/s10584-022-03365-4

4. Osypov V., Matviienko Y., Bonchkovskyi A., Osadcha N., Mossur H., Ahafonov Y., 2023: Land & Water: an Interactive Web Cartography Platform for Hydrological Research in Ukraine, in: 17th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment. European Association of Geoscientists & Engineers, pp. 1-5. https://doi.org/10.3997/2214-4609.2023520162

ANALYSIS OF WATER DISCHARGE IN THE MOUTHS OF LARGE UKRAINIAN RIVERS FLOWING INTO THE BLACK SEA UNDER CLIMATE CHANGE

Valeriya Ovcharuk, Prof., Sc.D.

Odesa I. I. Mechnikov National University, Ukraine

The northwestern part of the Black Sea (NWBS) within Ukraine includes the mouths of its largest rivers—the Dnipro, Southern Buh, Dniester, and Danube. The inflow of fresh surface water from these rivers significantly affects the hydrological and chemical regimes of transitional and marine waters in the study area. In recent years, climate change and increasing anthropogenic pressure have led to substantial changes in river runoff in southern Ukraine. The objective of this study is to analyze the water discharge trends of recent decades to identify current changes in the volume of water flow from major rivers entering the Black Sea within the NWBS, which significantly influence the spatial-temporal variability of temperature, salinity, and the thermohaline structure of the waters.

To achieve this objective, archival data stored in the Research and Educational Laboratory of Hydrological Information and Calculations at the Department of Land Hydrology, Faculty of Hydrometeorology and Ecology, Odesa National University, were used. The study was conducted within the framework of the project funded by the Ministry of Education and Science of Ukraine—"Advanced Automated Modeling Complex for Diagnosis and Forecast of Oceanographic Characteristics in the Ukrainian Part of the Azov-Black Sea Basin Water Area and Results of Its Application in Test Mode", under the supervision of Prof. Y.S. Tuchkovenko.

The study analyzes the water discharge dynamics of the largest Ukrainian rivers discharging into the Black Sea over the past four decades (1981–2021), along with the latest available data up to December 2024.

The analysis of Southern Buh’s water discharge indicates a sharp decline since 2010, reaching a historical minimum in 2020. According to real-time data from the ARM-Hydro resource, this decreasing trend continues to the present (Fig. 1a).

Between 1981 and 2021, the Dnipro River’s discharge exhibited relatively stable periods of high and low water levels compared to the norm. However, the last decade has shown a prolonged low-water phase, with two record-low discharge values observed in 2015 and 2020 (Fig. 1b).

The fluctuations in the Dniester River’s discharge over the past 40 years exhibit a cyclic pattern, alternating between high-water and low-water periods. However, over the past decade, the river has predominantly experienced low-flow conditions, similar to those observed in the Dnipro and Southern Buh Rivers (Fig. 1c).

An analysis of the discharge dynamics in the Danube Delta within Ukrainian territory shows a low-water phase between 1983 and 1994, followed by a high-water period from 1995 to 2002. From 2003 to 2015, high- and low-water years alternated with a 2–3-year periodicity. However, since 2016, a persistent low-water phase has been observed (Fig. 1d).

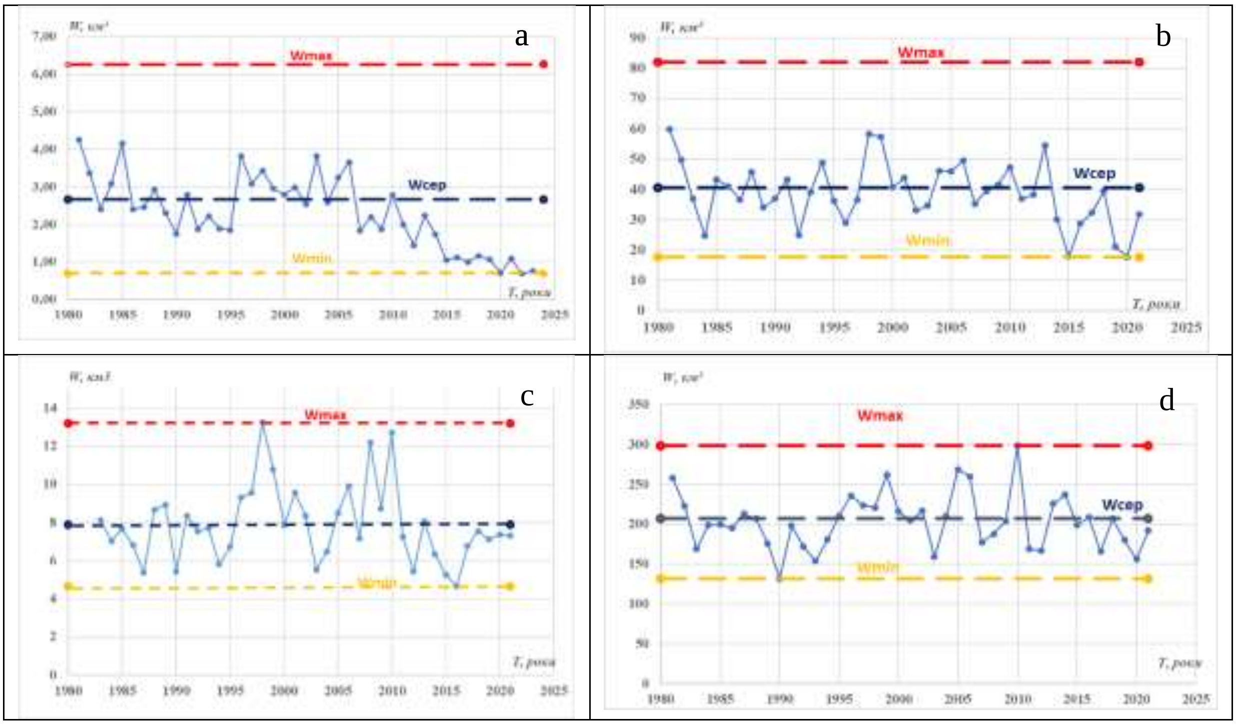


Fig. 1. Chronological graph of annual water discharge volumes (1981–2021)**:**
a – Southern Buh River (Oleksandrivka settlement);
b – Dnipro River (Kakhovka HPP);
c – Dniester River (Mohyliv-Podilskyi city);
d – Danube River (Reni city, hydrological station, 54th mile).

The study indicates that all major Ukrainian rivers are currently experiencing a prolonged low-water phase, with varying onset times and durations. However, the past decade has been characterized by consistently low water levels across all analyzed rivers. The situation is particularly critical for the Southern Buh, where discharge has reached historical minimum values in the entire period of instrumental observations.

Given these results and the projected climate change scenarios outlined by the Intergovernmental Panel on Climate Change (IPCC), it is recommended to use a typical low-water year distribution when modeling the current hydrological conditions of the Dnipro, Southern Buh, Dniester, and Danube Rivers.

DECADAL TRENDS IN MUNICIPAL WASTE GENERATION IN UKRAINE

Alona Perebynos, PhD

Kyiv National University of Construction and Architecture, Ukraine

The issue of establishing a sustainable municipal waste (MW) management system in Ukraine remains relevant and is actively debated among representatives of the executive branch, local governments, and the public. After the adoption of the Framework Law of Ukraine "On Waste Management" dated 20.06.2022, a number of important legislative acts are expected to be adopted that will contribute to the implementation of best practices for preventing and reducing waste generation, as well as a separate collection of MW at the source. The National Waste Management Plan until 2033 dated 27.12.2024 defines the general strategy for effective waste management and obliges regional councils to develop and adopt regional waste management plans within a year, according to which local plans will be developed.

Ensuring effective planning and management of the MW system is achieved with the availability of reliable and up-to-date data. The State Statistics Service of Ukraine collects and presents quantitative data on the generation and treatment of waste of hazard classes I-IV by material categories, among which the category "municipal and similar waste" is represented. Data is available for 2011-2023, but this study will consider data for 2013-2023 (Table 1).

Table 1. Quantitative and qualitative data on MW generation in Ukraine according to the State Statistics Service of Ukraine, 2013-2023

Indicators	**Years**										
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
MW generation, *thousand tons*	10804	7126	6789	6946	6183	6211	6618	6726	6482	5242	4858
Population, *million*	45.43	42.93	42.76	42.58	42.39	42.15	41.9	41.59	41.17	34.51*	34.03*
MW generation, *kg/person*	237.8	166.0	158.8	163.1	145.9	147.3	157.9	161.7	157.5	151.9	142.8

Note: * - International Monetary Fund estimates

The initial analysis of MW generation showed an increasing trend during 2011-2013, while 2014, the year of the beginning of the russian-Ukrainian war, is characterized by a sharp decrease to 7,126 thousand tons. Military operations on the territory of a state usually lead to economic instability and changes in the number of the population and their residence, which directly affects the MW generation. This hypothesis also supported the reduction in waste generation to

5,242 thousand tons in 2022 (Fig. 1), when a full-scale invasion of the territory of Ukraine took place, compared to an average of 6,565 thousand tons during 2015-2021. According to the Ministry of Foreign Affairs of Ukraine, approximately 20% of the current population was abroad at the beginning of 2023, which affected the reduction of MW in 2022 by 19%.

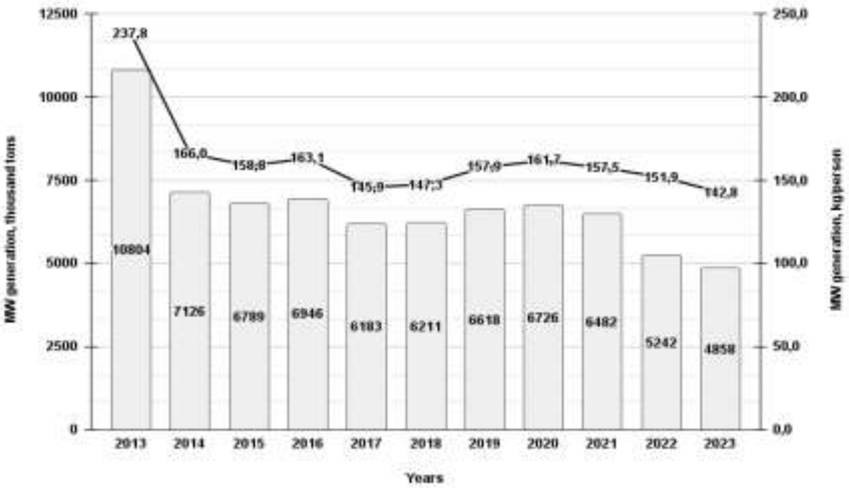


Fig. 1. MW generation trends in Ukraine for 2013-2023, thousand tons and kg/person

The indicator of MW generation per person showed no significant changes (Fig. 1). The average waste generation for 2014-2021 was 157.3 kg/person. Comparing this value with the indicators for 2022 and 2023 151.9 kg/person and 142.8 kg/person, respectively, allows us to conclude a trend towards a decrease in MW generation per person. However, it should be noted that the population of Ukraine for 2022 and 2023 is estimated, so the calculations are not valid. Overall, the average MW generation for 2014-2023 is 155.3 kg/person and does not differ much from the value calculated based on accurate population data.

The generation and treatment of municipal waste remain a significant unsolved problem in the management of many Ukrainian cities, directly affecting the quality of life of residents and environmental safety. Analyzing statistical data on municipal waste generation over the past 10 years, the study emphasizes the importance of relying on quantitative and qualitative data when planning waste management to take into account cause-and-effect relationships.

REFERENCES

1. Generation and management of waste of hazard classes I-IV by material categories. State Statistics Service of Ukraine. Retrieved March 14, 2025, from https://www.ukrstat.gov.ua/

2. International Monetary Fund (n.d.). World Economic Outlook Database. Retrieved March 14, 2025, from https://www.imf.org/

GREENHOUSE GAS EMISSIONS FROM THE WINTER WHEAT AGROECOSYTEM IN CLIMATE CHANGE CONDITIONS

***Anatoly Polevoy*[1], *Prof., D. Geogr. Sc*,**
Olena Barsukova[1,2], *As. Prof., Can.Geogr. Sc.*

[1]Odesa I. I. Mechnykov National University
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine (NAASU),

The problem of global climate change is one of the most important issues in modern environmental science. Against the backdrop of discussions about the causes of climate change, a concept is being formed that modern climate change (e.g., temperature increase) is mainly caused by anthropogenic emissions of greenhouse gases, including carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) (IPCC, 2001). In this regard, an extremely important task is the assessment of greenhouse gas emissions from soil ecosystems .

As a theoretical basis for the quantitative assessment of CO_2 and N_2O emissions from the soils of the winter wheat agroecosystem during its spring-summer vegetation period, we used a comprehensive model of greenhouse gas emissions from agroecosystem soils (Polyovyi A.M., Bozhko L.Yu., 2021). Let us consider the results of modeling CO_2 emissions from agroecosystem soils during the spring-summer vegetation period of winter wheat in the main agroclimatic zones of Ukraine under climate change conditions. (Fig. 1).

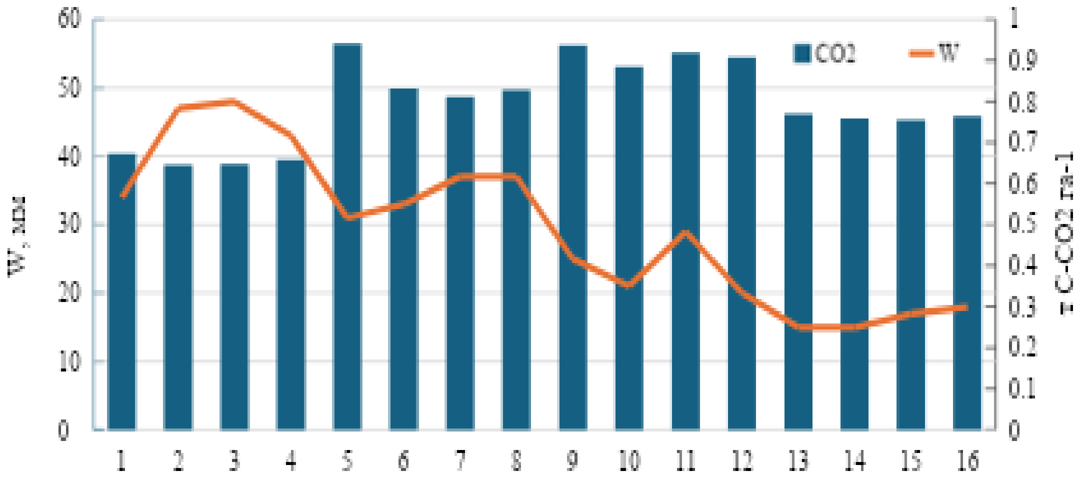


Fig. 1. Dynamics of CO_2 emissions from the winter wheat agroecosystem and productive moisture reserves in the arable soil layer (W).

The highest CO_2 emissions (0.886–0.940 t C-CO_2 ha^{-1}) are expected when the average productive moisture reserves in the arable soil layer during the spring-summer growing season of winter wheat range from 20 to 40 mm, with air temperatures of 12–15°C. Exceeding the average moisture reserves of 40 mm and air temperatures of 11–12°C leads to a decrease in CO_2 emissions (0.645–0.658 t C-CO_2 ha^{-1}). Under drought conditions, when the average moisture reserves in the arable soil layer drop below 20 mm and the average air temperatures during the spring-summer growing season of winter wheat rise to 14.5–15.2°C.

The process of N_2O emissions is primarily driven by denitrification and nitrification of nitrogen compounds, whose intensity is determined by the soil moisture-temperature regime and the content of mineral nitrogen in the soil. The results of modeling these processes are presented in Fig. 2 for the main agro-climatic zones of Ukraine.

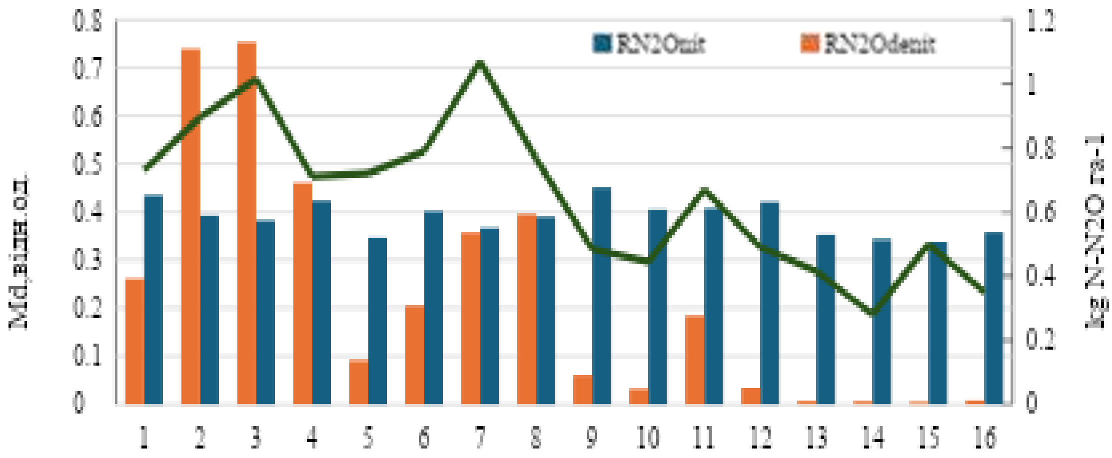


Fig. 2. Dynamics of N_2O emission owing to nitrification (RN2Onit) and denitrification (RN2Odenit) from the winter wheat agroecosystem and Shashko moistening indicator Md.

A small N_2O emission (1,089–1,703 kg N-N_2O ha^{-1}) during the spring-summer growing season of winter wheat is expected under high moisture levels (Md = 0,474–0,713 relative units) and air temperatures of 11,3–13,0°C. Moderate N_2O emissions (0,706–0,890 kg N-N2O ha^{-1}) occur under moisture levels of Md = 0,298–0,447 relative units and air temperatures of 13,4–14,7°C. In these conditions, denitrification processes slow down, while the contribution of nitrification to total N_2O emissions increases. The lowest N_2O emissions (0,508–0,537 kg N-N_2O ha^{-1}) are expected under severe and extreme drought conditions (based on Md criteria), with elevated average air temperatures of 14,5–15,2°C during the spring-summer growing season of winter wheat.

YIELD OF CEREAL CROPS IN UKRAINE AND PROBLEMS OF MARKET DEVELOPMENT

Svitlana Reshetchenko[1], PhD in Geographical Sciences,
Tetiana Tkachenko[2], PhD in Geographical Sciences,
Daria Orekhova[3], student of the Department
Physical Geography and Cartography

[1] V.N. Karazin Kharkiv National University, Ukraine
[2] Kharkiv Environmental Protection Professional College
of Odesa I. I. Mechnikov National University, Ukraine
[3] V.N. Karazin Kharkiv National University, Ukraine

Agriculture is a key sector of Ukraine's economy, providing the country with food, forming a significant share of exports, and serving as a source of raw materials for many industrial enterprises. One of the leading areas of Ukraine's agricultural activity is the cultivation of cereal crops, with wheat, barley, corn, and rye playing a dominant role. These crops account for about 60% of crop production and occupy the largest share of the country's sown areas, highlighting their strategic importance for the national economy. Grain production is the foundation of agricultural policy, aimed at ensuring food security, supporting exports, and fostering the growth of the agricultural sector.

However, modern challenges such as climate change, increasing competition in the global market, the need to stabilize the economy, and ensuring food independence make the issue of cereal crop yield highly relevant. Over the past decades, the yield of these crops has remained dependent on numerous factors, including natural and climatic conditions, the level of modern technology application, and the efficiency of agricultural management. At the same time, the economic and political situation in the country, particularly recent events such as the COVID-19 pandemic and the full-scale war of 2022–2024, have had a significant impact on the stability and productivity of the agricultural sector. The study of cereal crop yields is of great importance for ensuring strategic planning in agricultural policy, optimizing resource use, and increasing the efficiency of agricultural production. Analyzing the factors affecting yield allows for identifying the most promising directions for investment, improving technologies, and adapting to external challenges such as climate change. The aim of this study is to analyze the yield of cereal crops in the country over the period from 1991 to 2024. Cereal crops form the foundation of Ukraine's agriculture and occupy the largest share of agricultural land.

During the period from 1991 to 2024, the sown areas of cereal crops underwent significant changes due to economic, political, climatic, and social factors. In 1991, the sown area of cereal crops amounted to 14,671 thousand hectares, one of the highest figures for the studied period. However, throughout the 1990s, a gradual decline in sown areas was observed, with a decrease to

13,154 thousand hectares in 1999, representing a 10.4% reduction. The main reasons for this decline were the economic crisis, lack of funding in the agricultural sector, and the decreasing financial solvency of agricultural enterprises. Starting in the 2000s, a gradual recovery of sown areas began. In 2001, the area reached 15,586 thousand hectares, the highest recorded figure for the entire study period. This growth was driven by reforms in the agricultural sector, particularly the land privatization process and the introduction of new soil cultivation technologies.

However, after 2005, the sown areas began to decline again and stabilized at the level of 14,500–15,500 thousand hectares. Between 2011 and 2020, the sown areas of cereal crops demonstrated relative stability. However, since 2014, due to the annexation of Crimea and military actions in eastern Ukraine, a significant portion of agricultural land was lost. This led to a decrease in the sown area to 14,801 thousand hectares in 2014. The loss of territories and instability in the agricultural market contributed to a further decline in sown areas in the following years. A significant reduction occurred in 2022 due to full-scale military actions, bringing the area down to 12,171 thousand hectares, and in 2023 – to 10,985 thousand hectares, representing a 25% decrease compared to 1991.

The dynamics of cereal crop sown areas in Ukraine from 1991 to 2024 indicate a significant impact of both external and internal factors on the development of agriculture. To stabilize and restore these indicators, comprehensive measures are required, including the return of territories, the implementation of modern technologies, and state support for farmers. Ukraine has traditionally been one of the largest grain-producing countries in Europe, and cereal crops hold a crucial place in the structure of agricultural production. Over the past three decades, the sown areas of cereal and leguminous crops in the country have shown varying trends. In particular, following the economic crisis and during the early years of independence, the areas under cereal crops declined due to the low efficiency of agricultural production and deteriorating economic conditions for farmers.

REFERENCES

1. FAO. Global perspectives on cereal crops production. Rome: FAO, 2022. URL: https://www.fao.org.
2. IPCC. Climate Change 2021: The Physical Science Basis. URL: https://www.ipcc.ch/report/ar6/wg1/.
3. OECD-FAO Agricultural Outlook 2023–2032. URL: https://www.oecd.org/agriculture-outlook.

CHALLENGES IN ACCURATE AIR QUALITY RESEARCH, MANAGEMENT, AND ASSESSMENT IN UKRAINE AMID WAR AND CLIMATE CHANGE

Mykhailo Savenets, PhD, *Lyudmila Nadtochii, PhD, Tetiana Kozlenko, Kateryna Komisar, Antonina Umanets, Natalia Zhemera*

Ukrainian Hydrometeorological Institute, Ukraine

Air pollution is recognized by the international community as a significant global problem requiring urgent attention, particularly in the context of current climate change. Discussions and solutions for addressing air quality challenges range from a global perspective (such as regulating emissions and monitoring transboundary pollution) to local efforts (like improving air quality in specific cities or districts within megacities). Historically, air quality in Ukraine has been adversely affected by industrial facilities and, more recently, by emissions from mobile sources. Since the onset of the Russia – Ukraine conflict in 2014, which began in the eastern regions and escalated into a full-scale war in 2022, military activities have become a major source of hazardous emissions, including those from biomass burning near the frontline. Even before the full-scale war, Ukraine's air quality monitoring network faced challenges, including inadequate financial support, outdated instrumentation, inaccurate reporting by industries, and consequent issues with the development of national emission inventories. All these challenges collectively converted into a number of significant issues for air quality monitoring, assessment, and management in Ukraine.

Taking the mentioned problems into account, this study aims to highlight the major challenges in accurately assessing air quality amid the ongoing war and current climate change in Ukraine.

We analyze the consistency between pollutant emissions and near-surface concentrations data over 20 years from different databases, including national emission inventories, Copernicus Atmosphere Monitoring Service (CAMS), and observations from air pollution network operated by hydrometeorological organizations. In urban areas, where numerous emission sources are typically present, significant discrepancies have been identified between ground-level pollutant concentration data and the emissions responsible for them. These discrepancies negatively impact (1) the ability to assess interannual changes; (2) the quality of modeling; (3) data interoperability; (4) verification of results in evaluating the effectiveness of air quality management measures, and various other outcomes. We determine only a limited number of cities that have the capacity to conduct such research and analysis.

Official reports require significant improvements in both calculation algorithms (better representation of mobile sources and secondary pollution) and the accuracy of industrial emission data. Models available through CAMS need to substantially enhance the specified emission inventories for the period covered the full-scale war in Ukraine. Despite all existing challenges and the lack of high-quality equipment, the monitoring network of hydrometeorological organizations provides some of the most reliable results on changes in urban air quality. This further underscores the necessity of expanding and upgrading its equipment base.

It has been found that the CAMS reanalysis data fail to capture the majority of the consequences of military actions on the territory of Ukraine during 2022–2023 and, therefore, cannot be used to assess the impacts of the war or serve as input data for initial and boundary conditions in numerical chemical transport models.

In addition to the general, physically justified patterns of atmospheric phenomena influencing pollutant concentrations, up to 25% of monitoring stations (depending on the pollutant) exhibit atypical dependencies, highlighting the localized nature of pollution field formation near monitoring sites. An analysis of wind characteristics revealed that the formation of high and low pollutant concentrations varies across monitoring stations within the same city, further underscoring the critical role of local conditions at each station's location. This must be considered in future studies of air pollution changes to distinguish between causes related to shifts in emission source distribution and those driven by meteorological conditions.

The challenges of restoring quantitative indicators of gaseous and aerosol parameters for assessing emission impacts or establishing an evidence base for future reparations for environmental damages have been demonstrated. For example, in 2022, we confirmed only 60 cases of changes in ground-level pollutant concentrations as a result of missile strikes. Three types of effects on ground-level concentrations can be identified: (1) confirmed short-term changes in concentrations following missile strikes; (2) unconfirmed short-term atypical changes in pollutant concentrations, which cannot be correlated with missile strike data due to military secrecy and the lack of open information; (3) prolonged changes in pollutant concentrations that had not been observed previously.

Assessing the impact of the Russia – Ukraine war on air pollution is challenging due to the lack of comprehensive ground-based measurement data. However, remote sensing of NO_2 and CO content provides insights into general patterns of air quality changes. The effects of individual missile strikes are often difficult to detect due to cloud cover or significant time gaps between pollutant release and sensing time. Unlike remote sensing of qualitative parameters with distinctive visual traces, reliable detection of changes in quantitative parameters remains highly limited in applicability.

IMPACT OF SEASONAL FLUCTUATIONS IN VITAMIN D LEVELS ON THE HEALTH OF THE POPULATION OF SOUTHERN REGIONS OF UKRAINE AS A FACTOR OF CLIMATE RISKS

Anton Shanyhin, PhD in Medicine
Volodymyr Babienko, Professor, Doctor of science
Kostyantyn Talalayev, Professor, Doctor of science

Odesa National Medical University, Ukraine

Relevance. Vitamin D deficiency and insufficiency is a global problem affecting public health regardless of the level of insolation. Vitamin D plays a key role in metabolic processes, immune system function, and the prevention of cardiovascular diseases, obesity, diabetes, and other pathologies. The World Health Organization (WHO) recognizes vitamin D deficiency as a pandemic phenomenon, particularly in low- and middle-income countries, where the lack of this vitamin affects between 50% and 99% of the population, depending on the age group.

In Ukraine, the situation is also critical. According to an epidemiological study conducted in 2014, 81.8% of the population had vitamin D deficiency, 13.6% had insufficiency, and only 4.6% had adequate levels of 25(OH)D. Later studies conducted in 2019 showed some positive dynamics, but the overall level of vitamin D sufficiency remains unsatisfactory.

Research on vitamin D levels among residents of southern Ukraine, particularly in the Odesa region, is limited, and the scope of preventive measures aimed at preventing vitamin D deficiency remains uncertain. Given the importance of this vitamin for human health, further research is needed to assess its levels and develop effective recommendations for the prevention and correction of vitamin D insufficiency in a regional context.

Objective. To assess vitamin D levels among residents of the southern regions of Ukraine, particularly the Odesa region, considering seasonal fluctuations, gender, and age. The study aims to identify the characteristics of vitamin D sufficiency in the regional population, analyze potential risk factors for its deficiency and insufficiency, and justify the need for preventive measures to correct possible imbalances.

Materials and Methods. The study involved 928 residents of southern Ukraine (Kherson, Mykolaiv, and Odesa regions), including 507 women and 421 men aged 19–82 years. The study was conducted from January to December 2020, allowing for an assessment of seasonal fluctuations in 25(OH)D levels in blood serum.

Before participating in the study, individuals completed a questionnaire to exclude those with comorbidities and factors affecting vitamin D levels.

Results and discussion. The average level of 25(OH)D in the studied subjects was 26.66±12.62 ng/ml, varying from 4.31 to 89.19 ng/ml. Deficiency, insufficiency and sufficient levels of vitamin D were observed in 33.6%, 33% and 33.4% of participants, respectively, which indicates a significant prevalence of hypovitaminosis D among the population of the southern regions of Ukraine. Analysis of seasonal fluctuations in the level of 25(OH)D revealed that its minimum values were observed in winter (41.68% of cases of deficiency), while the highest level was in the summer (48.52% of sufficient values). The lowest concentrations of 25(OH)D were recorded in men in December (20.62±11.45 ng/ml) and in women in May (20.20±9.92 ng/ml). The highest values were observed in July: in men – 36.45±10.86 ng/ml, in women – 32.47±15.62 ng/ml.

The distribution of 25(OH)D levels by age group revealed that the highest values were observed in participants aged 19–29, while the greatest deficiency was observed in people over 60 years of age. Correlation analysis showed a statistically significant inverse relationship between age and vitamin D levels ($r = -0.47$, $p < 0.01$), indicating an increase in the risk of deficiency with age.

The obtained results emphasize the importance of monitoring the level of 25(OH)D in different age groups and seasons, as well as the need to correct vitamin status, especially in the winter period and in the elderly.

Conclusions. The obtained results of the study showed a significant prevalence of vitamin D deficiency and insufficiency among residents of the southern regions of Ukraine, despite the high level of solar insolation. The average level of 25(OH)D in the studied subjects was insufficient, which indicates a general tendency to hypovitaminosis.

Analysis of seasonal fluctuations showed that the minimum levels of vitamin D are observed in winter, when the number of people with deficiency is the largest, and the maximum - in summer, although even during this period a significant part of the population has an insufficient level of the vitamin. The revealed inverse relationship between age and the concentration of 25(OH)D confirms the increased risk of deficiency in the elderly. The obtained results emphasize the need to monitor the level of vitamin D in different age groups and seasons, as well as to develop effective preventive measures.

An important area of prevention is raising public awareness of the importance of vitamin D for health, rational exposure to the sun, dietary correction and, if necessary, the use of vitamin supplements, especially in the winter and among older people.

Thus, the results of the study indicate the need to implement comprehensive measures aimed at preventing vitamin D deficiency, which can have a significant positive impact on the health of the population of the southern regions of Ukraine.

FINANCIAL AND ECONOMIC MEASURES TO IMPROVE CLIMATE SERVICES IN FLOOD MANAGEMENT IN UKRAINE

Snizhko Sergiy, Prof., Sc.D.,
Shevchenko Olga, Prof., Sc.D., Pavlovskyi Volodymyr

Taras Shevchenko National University of Kyiv, Ukraine

As an associate member of the European Union, Ukraine is implementing Directive 2007/60/EC on Flood Assessment and Management, the main principles of which are the implementation of an integrated basin model of water resources management and flood management. Flood management is primarily about monitoring, forecasting and risk assessment.

In recent years, due to the full-scale invasion of Ukraine by Russian troops and the destruction of the economy, spending on environmental protection, research, and education has been reduced to a minimum. This has become the main reason for the formation of financial and economic barriers to the introduction of flood management technologies.

In order to improve climate services in flood management in Ukraine, it is necessary to overcome financial barriers to implement the following urgent organizational and structural changes in the National Meteorological and Hydrological Service (NMHS): introduction of technologies, modern technological equipment for obtaining, processing and storing ground and satellite monitoring data; to purchase modern software (meteorological and hydrological models, data processing programs, digital terrain models, other software products); training of specialists who will be able to use modern technologies for monitoring and processing information.

In fact, we are talking about creating a modern monitoring system. In the current situation, the likelihood of attracting domestic financial resources to overcome the existing barriers is unlikely, so there is an urgent need to seek external investment in modernization NMHS. Financial resources should be involved not only in the form of a loan, but also investments, contributions of beneficiaries and holders and other stakeholders. Here, private interests with the interests of local authorities should be united. To attract an additional cost for implementation of the technology may help access of NMHS of Ukraine to the WMO service delivery strategy and strengthen collaboration with European Flood Awareness System (EFAS) to access to innovative technologies. The implementation of the WMO service delivery strategy (2014) can be a very real mechanism for overcoming financial and economic barriers. The goal of the Strategy is to help NMHSs to raise the standards of service delivery in the provision of products and services to users and customers. On the basis of improved quality of services, there should be the implementation of commercial activities that will generate income, additional to the state provided funding.

The implementation of technology requires the following types of costs: enabling costs, capital costs, maintenance costs. Enabling costs associated with setting up technology infrastructure and administration costs where these are currently not available. There is capital cost associated with hydrometric installation, development of forecasting models, software and hardware costs and dissemination systems. There is maintenance cost associated with operational running costs and national, regional and local training and exercises. Costs remain low with comparison to measures to reduce the extent of flooding.

EBRD experts have established that the modernization of hydrometeorological monitoring system in Ukraine requires attracting investments of USD 82 million, which will pay off in 2 years, and after 7 years, their efficiency will exceed to 300%. The cost effectiveness of investments required for the technical modernization and development for the National Hydrometeorological Service of Ukraine ranges from 1:4.1 to 1:10.8: each dollar that will be invested in monitoring system upgrades can benefit from USD 4 to USD 11 at the expense of the warning losses from natural meteorological phenomena. Upgrading the monitoring system and use of modern drought and flood's risk assessment and mapping technologies will also produce significant economic effects in various weather-dependent sectors of the economy. For example, the application of drought's risk assessment and mapping technology on the basis of modernized monitoring would reduce crop losses in droughts annually by USD 950 million to USD 1400 million. This means that every year Ukraine will additionally benefit from the implementation of this technology in the agricultural sector at 2.1–3.1% of GDP.

The following areas of hydrometeorological monitoring activities should be provided for setting up any new organizational structures for the implementation and exploitation of flood assessment and mapping technology; installing, operating and maintaining hydrometric equipment; developing, configuring and running forecasting models; buying computer software and hardware to support the above operations. The cost of the technology can be 60–70% of the cost of creating and developing a flood management system.

The difference in the cost of technology implementation can be very different. For example, in developing and least developed countries, investments for FEWS implementation range from USD 5,000 in Namibia to USD 5 million in Myanmar, including USD 100,000 in Nepal for an intermediate system, USD 1 million in Cambodia, and USD 2.5 million in Bangladesh for advanced systems. For the implementation of the National Flood Forecasting System in the UK, it was used from 2002 to 2007 GBP 15 million.

If we assume that flood losses in Ukraine during 1995–2010 amounted to USD 7.5 billion, then a reduction in flood losses of at least 1%, which can be achieved through the implementation of modern flood management, can help save USD 75 million per year in which a flood occurs.

REGIONAL FEATURES OF STRUCTURAL AND FUNCTIONAL CHANGES OF AQUATIC ECOSYSTEMS

Pavlo Starzhynskyi, graduate student of the second year of study,
Ihor Prokopenko, graduate student of the second year of study

Kyiv National University of Construction and Architecture, Ukraine

Today, urban areas are among those that are dynamically developing. Urban ecosystems are characterized by a wide variety of architectural objects and a high degree of transformation of the natural environment. Urban water bodies located on the territory of cities have a special specificity.

Most often, small rivers, ponds, lakes and canals are found on the territory of urban agglomerations, which, similarly to large water bodies, in the floodplains of which cities are located, have an impact on the environment with formative, socio-cultural and recreational functions.

Most applied research ends with the development of recommendations for practitioners, which usually contain methods for evaluating the territory, object or process. To assess the effectiveness of the process of recreational development of water bodies in urban areas and the consequences of the influence of anthropogenic factors, it is important to determine the following indicators - intensity, duration of influence, origin of pollutants, source of influence.

Formally, it can be considered that any assessment is a type of classification. To carry out the assessment, signs of certain properties of objects are selected, criteria for ranking and subordination are put forward. As for simple, such a procedure takes place when the division is carried out on the same basis.

To assess the ecological state of water bodies in urban areas, special attention should be paid to the selection of evaluation factors and the determination of their significance. Among the evaluation factors, the genesis of the water body (objects of natural origin, reclaimed objects, artificially created watercourses and reservoirs), the degree of urbanization of the water basin should be taken into account (up to 25%, 25-50%, 50-75%, more than 75%), the level of man-made transformation (type of channel, presence of reservoirs, etc.), hydrochemical and hydrobiological indicators of the state of the water mass (water quality classes according to PWI, hydrochemical indices), biodiversity, recreational importance and amenities (a water body equipped for mass recreation, unequipped), socio-cultural value of objects.

Especially important are the factors that make it possible to assess the degree of ecological transformation. In the course of research, we developed a principle scheme for assessing the level of transformation of water bodies (Fig. 1)

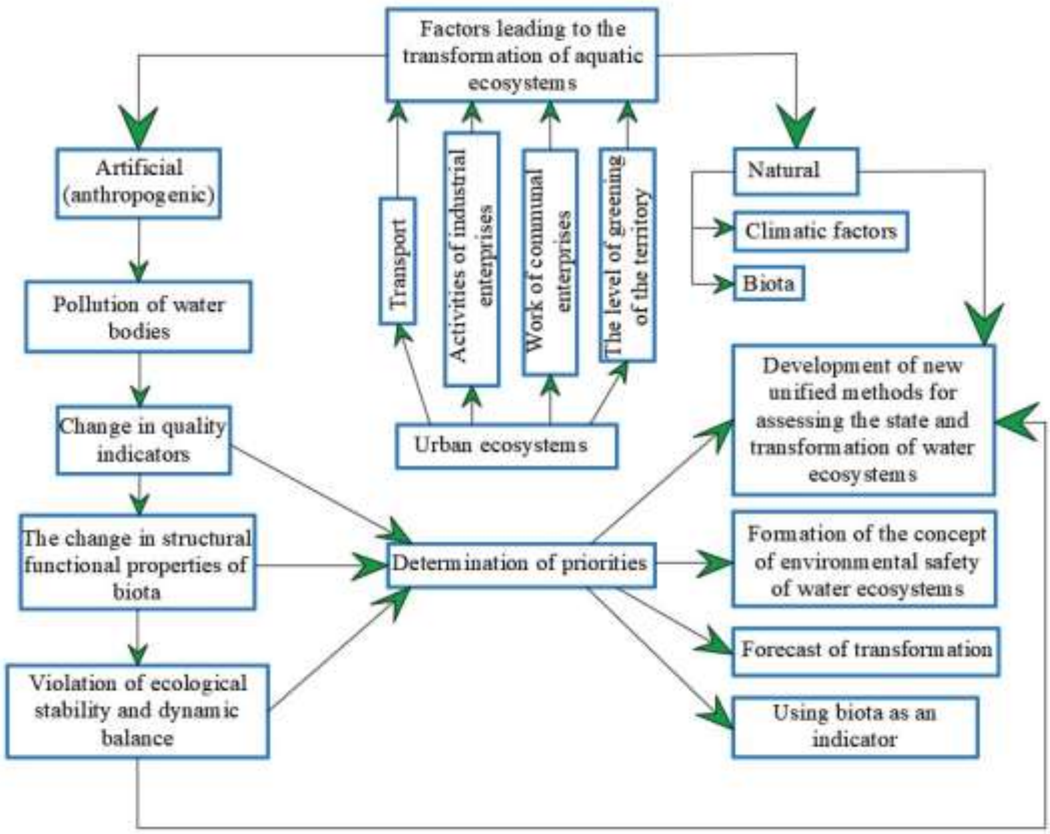


Fig. 1. Schematic diagram of the assessment of the level of transformation of water bodies

The schematic diagram in Fig. 1 allows to assess the level of transformation in the "urban environment-water ecosystems" system, to determine the main main sources of negative impact, to characterize the level of damage, change in self-healing capacity and intensity of intra-water body processes.

The stability of the development of aquatic ecosystems directly depends on natural and anthropogenic factors, allowing to achieve a high level of biotic self-regulation.

REFERENCES

1. Ecological approach in evaluating the efficiency of intra-reservoir processes of water systems of the rivers Kalmius and Ingulets / V.M. Udod, I.L. Wildman, O.H. Zhukova // Bulletin of Mykhailo Ostrogradsky Kremenchug National University. – Kremenchuk: KrNU, 2014. No. 2 (85). S. 161–165.

2. Implementing the Ecosystem Approach for Freshwater Ecosystems – A case study on the Water Framework Directive of the European Union / V. Hartje, A. Klaphake. Bonn, Germany: BfN, 2006. 65 p.

3. Snizhko S.I. Evaluation and forecasting of the quality of natural waters. - K. : Nika Center, 2001. 262 c.

OVERVIEW OF THE URBAN SOLUTIONS TO CLIMATE CHANGE

Sergiy Stepanenko*[1,2]*, Prof., Sc.D.

[1] Institute of Market and Economic&Ecological Researches of the National Academy of Sciences of Ukraine
[2] Ukrainian Joint Meteorological and Hydrological Society, Ukraine

According to the IPCC report [1], global warming, caused by human activities, has led to a temperature increase of 1.1°C globally, triggering alterations in the earth's climate that have not been seen in the recent human history. The rise in global temperatures also increases the risk of reaching perilous tipping points in the climate system. Once these points are crossed, they can trigger self-reinforcing feedback loops that further escalate global warming, such as the thawing of permafrost or extensive forest dieback. The activation of these feedback loops can also lead to other significant, sudden, and irreversible changes to the climate system [2]. The negative effects of climate change are already more widespread and severe than expected.

In urban areas, intensifying heatwaves associated with global warming can increase power demand since more power is needed to cool down. This is met with a higher power supply, leading to an increase in greenhouse gas emissions if the power is derived from non-renewable energy sources and there is not enough time for a successful transition to renewable energy [3]. In fact, urban areas are responsible for 70% of global CO_2 emissions, with transport and buildings being among the largest contributors, and these contributors are invariably associated with power generation for electricity and heating. This contributes to the vicious cycle of climate change.

Therefore, urban solutions have caught attention in the quest to mitigate and adapt to climate change. Urban solutions are fundamentally approaches taken by cities to become climate-friendly. These approaches can be mitigations focusing on reducing greenhouse gas emissions or adaptations aiming to increase the resilience of cities and their dwellers in coping with the changing climate. These approaches, either as mitigations or as adaptations, usually take the form of nature-based solutions, technological solutions, social solutions, and a combination or integration of these solutions [4]. These solutions are discussed in the subsequent sections, with reference to recent cases or examples in different regions. Urban solutions have been mentioned or emphasized in multiple climate events, thus accentuating their prospect of spurring cities toward being climate-friendly. For instance, the COP27 Presidency and the United Nations Human Settlements Programme co-developed the Sustainable Urban Resilience for the Next Generation (SURGe) Initiative, aiming to establish sustainable and resilient urban systems. This is achieved by enhancing the execution of the climate agenda in collaboration with cities, thus facilitating access to urban climate finance, building capacity, and promoting fairness. In the Ecocity World Summit (2023), the vital role of cities in climate action was emphasized. The summit highlighted the need for a new climate governance architecture that includes civil society, the private sector, and sub-national governments such as cities and regions. Earlier, the COP26 Glasgow Climate Pact encouraged participants to incorporate adaptation measures more thoroughly into their local planning strategies. Despite these calls, few reviews have been dedicated to presenting the latest progress in urban solutions to climate change.

This review aims to provide an overview of the latest progress in urban solutions to climate change, encompassing nature-based, technological, social, and integrated solutions. Nature-based solutions use natural ecosystems and processes, such as urban greening, green space, ecosystem restoration, and sustainable drainage systems, to address climate change problems. They could be vulnerable to the very climate challenges they address. Technological solutions encompass sustainable heating and cooling, innovative and green building materials, retro-reflective materials, cleaner modes of transportation, and big data and IoT devices for city planning. These solutions could be costly and resource-intensive. Social solutions involve promoting changes in behaviors and habits, which may require government and community intervention and engagement. They rely on political representation and social integration, which are sometimes lacking. Urban solutions are often integrated, combining two or more categories of solutions. Nature-based and technological solutions have been supported through urban greening and transportation plans aiming to encourage behaviors such as community-led greening and using public transport. Techno-ecological approaches are evident in urban greening that embeds technology. Social elements are incorporated to garner inclusiveness and engagement. However, integration is inherently complex as it involves multiple stakeholders. Potential suggestions for better integration of urban solutions are community engagement, policymaking, government support, and awareness-raising.

REFERENCES

1. IPCC. Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC; 2023.
2. Lenton T.M., et al., 2019: Climate tipping points - too risky to bet against. Nature. No 575, pp. 592–595
3. Santamouris M., et al., 2015: On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings - a review. Energy Build. No 98, pp. 119–124.
4. Ramakreshnan L, Aghamohammadi N., 2024: The application of nature-based solutions for urban heat Island mitigation in Asia: progress, challenges, and recommendations. Curr. Environ Health Rep., No 11(1), pp. 4–17.

BRIDGING THE COMMUNICATION GAP IN AGROMETEOROLOGICAL SERVICES: ENHANCING THE UPTAKE AND EFFECTIVENESS FOR USERS IN DEVELOPING COUNTRIES

***Vieri Tarchiani*[1]*,** *Sebastian Grey*[2],

[1]Istituto per la BioEconomia – Consiglio Nazionale delle Ricerche, Italy
[2]World Meteorological Organization, Switzerland

Relevant scientific literature, along with sectoral policies and strategies, recognizes climate services as essential tools for sustainable development in strategic and climate-sensitive sectors. In developing countries, particularly in Africa, numerous documented applications exist, primarily in the agricultural sector, which is highly sensitive to climate variability and change and continues to employ a significant portion of the rural workforce. Over recent decades, advancements in agrometeorological monitoring and forecasting have been driven by improvements in technology, infrastructure, and capacity building. The literature underscores that agrometeorological services enhance agricultural decision-making, increasing farmers' resilience and income on a global scale.

Although the concept and application of climate services have been under discussion for more than a decade, only recently the attention shifted toward the co-development process. A climate service is increasingly understood as a cyclical and iterative process in which various actors—including information producers, intermediaries, users, decision-makers, and other stakeholders—interact, exchange knowledge, and establish relationships based on mutual trust. However, despite their potential, climate services in agriculture still face challenges in communication and dissemination, limiting their effectiveness, particularly for smallholder farmers in remote areas. These challenges extend beyond the choice of media type and format to encompass issues of accessibility, comprehensibility, and user trust. While technological advancements have enabled greater customization and significantly reduced the time required for information dissemination, there remains a risk of new services being technology-centered rather than user-focused.

The broader principles of co-production and user engagement can support the transition from an information- or product-centered approach to one that is user-driven and responsive to specific needs. This shift requires adjustments in communication strategies, acknowledging that different users require tailored channels and formats to effectively receive and apply information.

This paper, based on a non-systematic review, recognizes the diversity of users, decision-making contexts, dissemination channels, and information types. It identifies key components for designing effective communication strategies, including:

Stakeholder Engagement: Various participatory approaches and iterative monitoring, evaluation, and learning (MEL) processes can facilitate inclusive and effective communication.

Language, Knowledge, and Culture: The use of local languages, incorporation of indigenous knowledge, and engagement of local leaders foster community involvement and establish a foundation of trust and relevance.

Communication Channels and Formats: While the increasing use of ICT offers opportunities for rapid and widespread dissemination, challenges related to access and comprehension persist. Factors such as gender, literacy, and language barriers can marginalize certain groups, making simple communication technologies, such as rural radio, crucial for last-mile dissemination.

Capacity Building: Empowering approaches are essential to ensure that farmers can interpret and apply information to their specific contexts. Effective capacity-building activities must recognize different learning styles and social value systems. Extension agents, journalists, and other intermediaries need the skills and confidence to convey technical concepts in accessible and actionable ways.

Timing: The timing of agrometeorological information dissemination is critical for its relevance and impact. A practical approach to aligning farmers' practices with useful information throughout the season is the development of decision calendars that complement traditional crop calendars.

Monitoring, Evaluation, and Learning (MEL): MEL facilitates an interactive and iterative social learning process, enabling the capitalization of experiences and continuous refinement of ongoing processes.

As highlighted in this review, no universal solution exists for effectively communicating agrometeorological information. Future directions should focus on enhancing the legitimacy and salience of climate services by integrating local knowledge, expanding the scope to include herders and off-farm stakeholders, strengthening capacity among intermediaries and users, incorporating user feedback, and fostering public–private partnerships to support scaling-up and sustainability.

USING TRITICALE IN ANIMAL FEEDING AS A MEANS OF ADAPTING LIVESTOCK FARMING TO GLOBAL CLIMATE CHANGES

Olena Tytariova, PhD in Agricultural Sciences

Bila Tserkva National Agrarian University, Ukraine

The climate in Ukraine is undergoing significant changes, manifested through rising average annual temperatures, prolonged periods of drought, and uneven precipitation distribution. These phenomena are most pronounced in the southern and eastern regions of the country, where limited water resources pose serious challenges to traditional agricultural production.

Over the past decade, Ukrainian soils have undergone substantial changes caused by global climate processes. One of the key issues is the reduction in soil moisture due to intensified droughts, uneven rainfall distribution, and rising temperatures. This impacts the productivity of agricultural crops, particularly grains, creating risks for sustainable agricultural production.

The increasing frequency of extreme weather events, such as heavy rains, hail, and strong winds, has led to soil erosion in many regions of Ukraine. Simultaneously, soil exhaustion due to the continued use of intensive agricultural technologies, without adequate restorative measures, has resulted in declining fertility. In the southern and eastern regions, the problem of soil salinization is becoming pressing, driven by the rising levels of groundwater and active irrigation.

Climate change also influences the biological activity of soils. As temperatures rise, the rate of organic matter mineralization increases, leading to the loss of humus. This negatively affects soil structure and its ability to retain water and nutrients.

The reduction in soil moisture significantly decreases the yields of staple traditional forage crops, endangering food security stability. Key grain crops like wheat, corn, and barley are especially affected.

Climate change is driving the active implementation of modern agricultural technologies and the development of innovative strategies for agricultural production. Notably, the study of adapted grain crop varieties capable of withstanding harsh climatic conditions has become a vital direction. Drought-resistant crops, such as triticale, deserve particular attention. This unique crop, a hybrid of wheat and rye, combines high yields with resilience to adverse climatic conditions. Thanks to its biological traits, such as a well-developed root system, triticale efficiently utilizes moisture and nutrients even under challenging growing conditions.

Triticale also stands out due to its high drought tolerance and ability to successfully adapt to different soil types, including less fertile ones. This makes it a promising crop for cultivation in areas with limited precipitation. Moreover, triticale has significant potential for livestock feeding, particularly in grain feed production. In countries with intensive livestock industries, this crop has long established itself as an effective and nutritious feed for various animal species.

Research confirms that triticale can replace traditional grain crops in compound feed formulations for many types of animals. For instance, it is recommended to include up to 50% triticale in the diet of heifers (Zobell et al., 1990), while for pigs, this crop can fully replace wheat or barley. For poultry, the permissible proportion of triticale grain in compound feed is up to 20% (Gaviley et al., 2024). The use of enzyme preparations and extrusion technologies, such as triticale-soy and triticale-sunflower extrudates, significantly increases this proportion while minimizing the impact of antinutritional substances.

Considering climatic challenges, the role of triticale in Ukraine's agriculture continues to grow. This crop not only ensures high yields even under adverse conditions but also opens new opportunities for stabilizing and optimizing the feed base of livestock farming. Its active use in strategies for adapting agriculture to climate change will contribute to ensuring the country’s food security and the sustainable development of the industry.

REFERENCES

1. Gaviley, O.V.; Katerynych, O.O.; Ionov, I.A.; Dekhtiarova, O.O.; Griffin, D.K.; Romanov, M.N. Triticale: A General Overview of Its Use in Poultry Production. *Encyclopedia* 2024, 4, 395-414. https://doi.org/10.3390/encyclopedia4010027

2. Zobell, D.R., Goonewar-Dene, L.A., Engstrom ,D.F. 1990. Potential of triticale as a feed for finishing heifers. *Canadian Journal of Animal Science*. 70(1), 325-328. https://doi.org/10.4141/cjas90-040

3. Glamoclija, N., Glisic, M., Boskovic, M., Djordjevic, J., Markovic, R., Sefer, D., Baltic, M. 2018. The impact of triticale diet on production charchteristics and meat quality in pigs. *Scientific Journal «Meat Technology»*, 58(2), 73-79.

INFLUENCE OF AIR TEMPERATURE ON PHYSIOLOGICAL INDICATORS OF GOATS

Vakula Bohdan, PhD student, *Dyman Tetiana, professor, Stavetska Ruslana, professor*

Bila Tserkva National Agrarian University, Ukraine

Warming and climate change are a global challenge. Among farm animals, goats are less sensitive to heat stress, so their use is promising [1]. The main indicators of heat stress in goats are increased body temperature, respiratory rate and pulse rate [2].

In goats, the normal body temperature is about 39 °C, the respiratory rate is 10–20 breaths/min, and the pulse rate in goats at rest is 60–80 beats/min [3, 4]. Under heat stress, an increase in respiratory rate and rectal temperature is an adaptive response that helps to remove excess heat from the centre to the periphery [3, 5], and an increase in pulse rate promotes more intense blood flow, which transfers heat to the body surface, ensuring effective thermoregulation [3]. In view of the above, the **aim** of this study was to investigate the physiological parameters of goats depending on the ambient temperature.

The work has been carried out in a herd of Saanen dairy goats on the farm "Babyny Kozy", Kyiv region (Ukraine). The animals have been kept year-round in free-range housing with free access to feed and water (supplied by automatic drinkers). Information on air temperature in June 2024 was obtained from the State Hydrometeorological Service of Ukraine.

The research has been conducted over a period of 10 days (June 21–30, 2024). The experimental group has included 15 second lactation goats. The respiratory rate, pulse rate, and rectal temperature of goats have been assessed daily at 6:00, 12:00, and 18:00 according to generally accepted methods [4]. The results have been statistically processed using the "Statistica" software.

It has been found that the average daily air temperature during the study period was 21,2 ± 0,71 °C, with fluctuations from 18,6 to 24,4 °C. The lowest temperature was observed at 6:00 a.m., averaging 14,1 ± 0,61 °C, and by 12:00 it increased by 12,9 °C to 27,0 °C on average. By 18:00, the air temperature was expected to decrease (Fig. 1).

It has been found that at 6:00, when the average ambient temperature was 14,1±0,61 °C, the physiological parameters of goats were at the following level: rectal body temperature – 39,0±0,08 °C, respiratory rate – 17,9±0,31 breaths/min, pulse rate – 71,8±0,35 beats/min. At 12:00, when the average temperature was 27,0 °C, the physiological parameters of the goats have increased significantly; in particular, the rectal body temperature has increased by 0,6 °C; respiratory rate by 4,1 breaths/min; pulse rate by 10.9 beats/min ($P < 0,001$ in all cases). By 18:00, the studied physiological parameters of goats have decreased, but have remained higher compared to those at 6:00, respectively, by 0,3 °C ($P < 0.05$), 1.6 breaths/min ($P < 0,01$), and 2,7 beats/min ($P < 0,001$). It has been calculated that the effect of ambient temperature on the physiological parameters of goats has been reliable and of medium strength (η^2x = 48,8–64,6 %; $P < 0,01$ i $P < 0,001$).

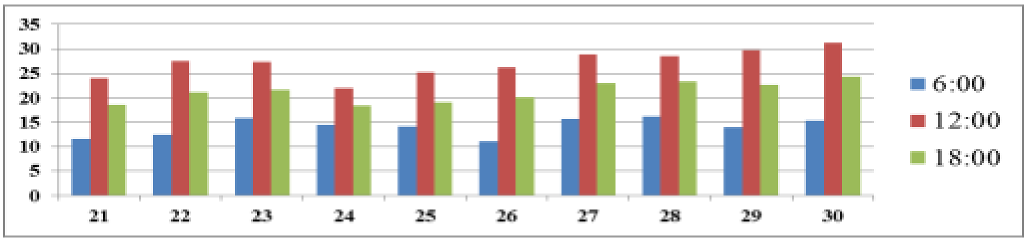


Fig. 1. Changes in air temperature during the day in 21-30 June, 2024.

Physiological parameters of goats varied depending on the time of day and ambient temperature. The highest rectal temperature, respiratory rate and pulse rate were observed at 12:00, i.e. at the highest ambient temperature (Table 1).

Table 1. Physiological parameters in goats depending on the time of day, $x \pm S.E$

Indicator	Time of day:		
	6:00	12:00	18:00
Rectal temperature, °C	39,0 ± 0,08	39,6±0,12³	39,3±0,12¹
Respiratory rate per minute	17,9± 0,31	22,0± 0,40³	19,5± 0,34²
Pulse rate per minute	71,8± 0,35	82,7± 0,48³	74,5± 0,40³

Note: difference compared to the values obtained at 6:00, ¹ – $P < 0.05$; ² – $P < 0.01$; ³ – $P < 0.001$.

Conclusion. In Saanen dairy goats, the values of physiological parameters (respiratory rate, pulse rate and rectal temperature) have increased with increasing air temperature. In the hottest period of the day (12:00), these parameters have exceeded the accepted physiological norms.

REFERENCES

1. Danso F., Iddrisu L., Lungu S.E., Zhou G., Ju X. Effects of Heat Stress on Goat Production and Mitigating Strategies: A Review. *Animals*. 2024. Vol. 14. P. 1793. https://doi.org/10.3390/ani14121793

2. Alam M., Hashem M., Rahman M., Hossain M., Haque M., Sobhan Z., Islam M. Effect of Heat Stress on Behavior, Physiological and Blood Parameters of Goat. *Progressive Agriculture*. 2013. Vol. 22. P. 37–45. DOI:10.3329/pa.v22i1-2.16465

3. Sejian V.; Silpa M.V.; Reshma Nair M.R.; Devaraj C.; Krishnan G.; Bagath M.; Chauhan S.S.; Suganthi R.U.; Fonseca V.F.C.; König S. Et al. Heat Stress and Goat Welfare: Adaptation and Production Considerations. *Animals*. 2021. Vol. 11. P. 1021. https://doi.org/10.3390/ani11041021

4. Клінічна діагностика хвороб тварин / В.І. Левченко, В.В. Влізло, І.П. Кондрахін та ін.; за ред. В.І. Левченка і В.М. Безуха. Біла Церква, 2017. 544 с.

5. Sarangi S. Adaptability of goats to heat stress: A review. *The Pharma Innovation Journal*. 2018. Vol. 7 (4). P. 1114–1126. https://www.thepharmajournal.com/archives/2018/vol7issue4/PartR/7-4-94-414.pdf

HAVE WINTERS WARMED UP IN EASTERN UKRAINE?

Yuriy Vergeles, Drs., *Inna Rybalka, PhD*

O.M. Beketov National University of Urban Economy in Kharkiv, Ukraine

The changes that have been observed in the Earth's climate since the mid-20th century are attributed to an increase in greenhouse gases contents in the Earth's atmosphere due to the increased burning rates of fossil fuels. The combination of the warming trend caused by anthropogenic activities with natural climate variability (e.g., the El Niño Southern Oscillation, the Pacific Decadal Oscillation, etc.) makes the temperature record look more like an upward staircase than a steady climb. The global average temperature is expected to reach or exceed 1.5 °C over the next few decades.

The average annual temperature in Ukraine has increased by 1.2 °C over the past 30 years. Between 1961 and 2013, the rate of change in average, maximum, and minimum temperatures was 0.3 °C per decade. A number of authors note that all seasons are getting warmer in Ukraine. In our study, we decided to test this hypothesis. A significant obstacle to climate change research in Ukraine is lack of technical equipment. Few settlements have weather stations, mostly big cities. However, a "heat island" traditionally forms over a large city, which further affects the research results and conclusions drawn. Therefore, in our work, we focused on small cities to minimize the urban heat island effect.

The model area in the study is the city of Izyum with a population of about 50 thousand people (as of 2020), a district center in the Kharkiv region, located 127 km southeast of the city of Kharkiv on both sides of the Siverskiy Donets River. The initial climate data for the study were archival results of observations at the meteorological station in Izyum, Ukraine (WMO code: 34415), obtained from the website *rp5.ua*. The data sample covers the period from February 01, 2005 to September 22, 2023 and includes 51,847 unique climate data records. The data for 2005, 2022 and 2023 are incomplete (data for one, six and three months, respectively, are missing). As the first step, we divided the raw data into several groups: cold period (covering data for December – February), off-season (March, November), and warm period (April – October).

For the cold and warm periods, we calculated the average temperature for several months. We were most interested in the data collected for the cold season (°C): -3,111; -6,019; -1,201; -3,507; -2,672; -3,833; -4,960; -6,023; -1,103; -3,436; -1,259; -2,776; -1,606; -2,885; -0,875; -0,607; -2,090; 0,722; -2,284. Here, there was a clear upward trend in the average monthly temperature. Instead, the other graphs, which illustrated the temperature indicators for the off-season and the warm season, showed random fluctuations around a straight line parallel to the abscissa (time) axis.

The above data represent non-random stochastic fluctuations: the value of the autocorrelation coefficient at the second lag is 0.422 (critical value is equal to 0.316, n = 17, P < 0.05). When testing the series for stationarity, we limited ourselves to a period of 17 years, from 2007 to 2023. To do this, we divided the series into three equal parts. For the first segment (2007-2012), the average is -3.699 °C, for the second - -2.036 °C, and for the third - -1.337 °C. The results of the series evaluation for stationarity: the value of the Student's criterion when comparing the first and third segments of the series is 2.16, which exceeds the critical standard value of 1.81 (P < 0.10). A similar result was obtained when comparing the first and third segments. However, the difference between the second and third intervals is not significant.

Thus, the series is non-stationary with respect to its central tendency, and the temperature is indeed rising. The assessment of the normality of the series yielded a positive result (C = 4.03, within the confidence limits with high reliability). The equation that reflects the dynamics of warming is y = 0.1617x - 4.1545, R^2 = 0.2374 (Pearson correlation coefficient R = 0.4872, which exceeds the critical value of 0.48, n = 17, k = 15, P < 0.05). The model shows that the temperature has increased by 0.2 °C over the past 17 years (Fig. 1).

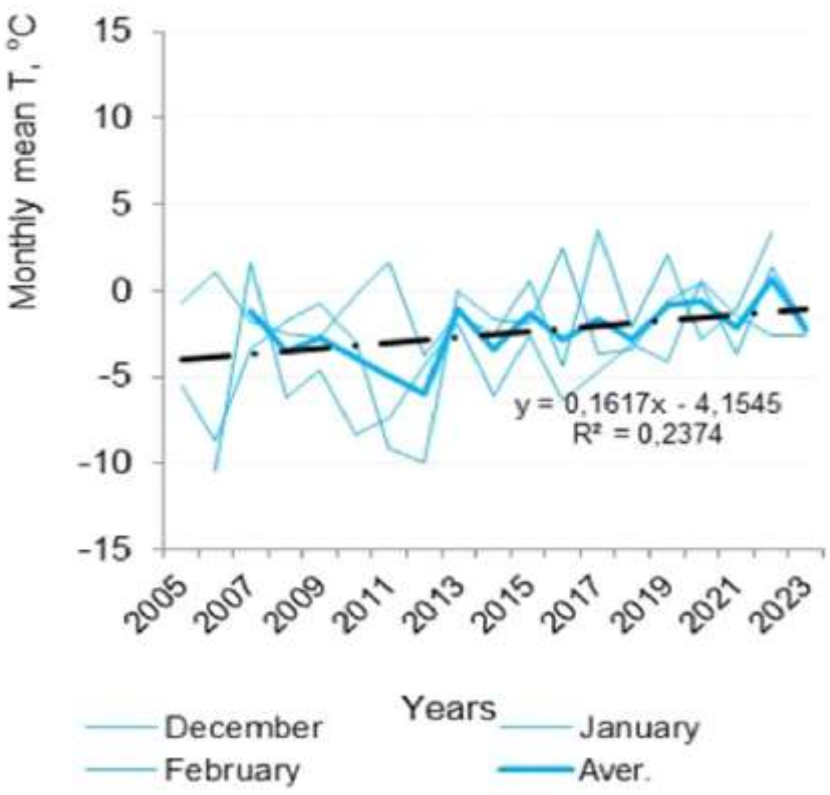


Fig. 1. Trends in average monthly temperatures in winter months in the city of Izyum (Kharkiv region, Ukraine)

Thus, over the past almost two decades, there has been a tendency for air temperature to increase in the winter season.

THE IMPACT OF CLIMATE FACTORS ON THE ENERGY SECTOR

Nataliya Vronska, PhD, assoc. prof., *Oksana Liuta, PhD, assoc. prof., Olena Popovych, PhD, assoc. prof. and Vira Sliusar, PhD*

Lviv Polytechnic National University, Ukraine

Global climate change is one of the most important environmental issues of our time, attracting worldwide attention. It causes dangerous natural phenomena, such as abrupt weather changes, severe storms, floods, droughts, heavy rains and hail. All this causes serious environmental and economic damage. It covers all regions of the world and affects every segment of the population, intensifying existing social and economic problems.

Different economic sectors and geographical regions have different levels of vulnerability to the effects of climate change. The energy, agriculture, forestry, and water sectors will be most affected by climate change, as they are directly dependent on natural conditions.

Each sector has its own characteristics and responds differently to environmental changes. Agriculture suffers the most from droughts, abnormal temperatures, uneven distribution of precipitation and shifting seasons, which threatens food security. Forest ecosystems are at risk of degradation due to decreased precipitation, an increase in the number of forest fires and changes in species composition. Water resources are under threat due to rising temperatures, increased evaporation, uneven precipitation and melting glaciers, which affects the population's drinking water supply and reduces the potential for hydropower generation.

The energy sector is the main source of greenhouse gases and has a significant impact on climate change. At the same time, the energy sector is one of the most vulnerable sectors to climate change due to its dependence on natural conditions and the need for adaptation.

Climate change is reducing the efficiency of thermal and nuclear power plants due to rising temperatures and drying up of cooling ponds. As one of the ways to adapt, the IAEA (International Atomic Energy Agency) suggests using expensive closed water circulation systems or dry cooling.

On the other hand, hurricanes, floods and droughts pose an even greater threat to the energy sector, and measures to protect against them require significant funding.

The search for possible ways to mitigate the negative effects of climate change in the energy sector involves reducing greenhouse gas emissions through decarbonization and transition to renewable energy sources. However, the development of wind and solar energy is also accompanied by challenges due to climate change, which requires constant modernization of equipment and adaptation to environmental conditions.

Rising temperatures reduce air density and, consequently, the efficiency of wind power plants. A solution may include improved wind resource assessment, the installation of backup capacities, and the adaptation of blade designs to prevent icing (e.g., heating systems).

Solar energy is also affected by climate change, particularly cloud cover and insolation. Promising solutions include concentrator solar power plants, new materials for photovoltaic panels that more efficiently absorb diffuse light, tracking systems for optimal panel positioning, and improved energy storage systems.

Temperature and precipitation fluctuations, increased frequency of droughts and extreme weather conditions have a significant impact on river flows, making hydropower vulnerable to climate change. Depending on environmental conditions, the operation of hydroelectric power plants changes. Low-snow winters become a problem for ensuring their capacity, reducing the level of water reserves in reservoirs and electricity production.

Power grids are another weak link in the power system under extreme natural conditions. Rising average annual temperatures increase electrical resistance, which increases losses on power lines. The heat also causes wires to sag and trees to grow rapidly near power lines, which threatens the stability of supply.

The adaptation of power grids involves the installation of additional poles and on-time clearing of the territory, as well as the use of new insulation materials, heating systems and structural reinforcement to reduce the impact of icing.

Thus, adaptation of the energy sector to climate change is a necessary condition for its stable functioning. The impact of higher temperatures and extreme weather events creates additional risks for infrastructure, increases energy costs and affects labor productivity. At the same time, these challenges stimulate the development of green technologies and energy-efficient solutions, which opens up new opportunities for sustainable development of the industry. Changes in legislation and international agreements can contribute to the development of adaptive strategies in business and increase the environmental responsibility of enterprises. At the same time, it is necessary to take into account the possible economic and social consequences for employees, as well as regional peculiarities of the impact of climate factors.

REFERENCES

1. Eremenko I., Vyniarska M., Melnyk Y., 2019: Climate policy of Ukraine: energy component: K: G. Böll Foundation Office in Ukraine, 43 p.

2. Ivanyuta S.P., Kolomiyets O.O., Malynovska O.A., Yakushenko L.M., 2020: Climate change: impacts and adaptation measures: analytical report. Kyiv: NISS, 110 p.

ASSESSMENT OF THE CURRENT STATE OF SOME TRIBUTORS OF THE SOUTHERN BUG RIVER BY HYDROCHEMICAL INDICATORS

Yaroslav Yarov, master, senior lecturer,
Tetiana Graschenkova, master, senior lecturer,
Viktor Pylip'yuk, PhD (Geogr.), senior lecturer

Odesa I. I. Mechnikov National University, Ukraine

In the modern period, due to the high level of anthropogenic load, there is a deterioration in the qualitative state of the rivers that are part of the hydrographic network of the Southern Bug basin.

Purpose of the work: assessment of the qualitative state of the Kodyma River and the Velyka Vys River according to hydrochemical indicators based on actual monitoring data of the State Agency of Water Resources of Ukraine. An ecological assessment of water quality, an assessment of water quality for fishery use and an assessment of the risks of not achieving good ecological status according to hydrochemical indicators were performed.

The Kodyma River [1] (area 2470 km^2) is a right tributary of the Southern Bug River, there is 1 industrial water intake in the basin, there are no recorded wastewater discharges. The basin is used for agricultural needs (there are 33 settlements, 1 oil pipeline and 11 gas pipelines cross the river; water is taken for industrial water supply and irrigation, there are 31 ponds). The river has been polluted for a long time by discharges of insufficiently treated wastewater from the cities of Kodyma and Balta, and runoff from farms and farmland.

The Velyka Vys River [2] (area of 2860 km^2) is a left tributary of the Synyukha River. The basin has 6 industrial water intakes and 7 wastewater discharges (4 discharges of the «polluted, untreated» category, 2 discharges of «standardly treated» type, and 1 discharge of «polluted, insufficiently treated» type). The river basin has a significant degree of urbanization and agricultural activity (106 ponds, 20 pressure sewer collectors pass through the river).

The work used data from monitoring of the Kodyma River (Balta city, 2008–2018) and the Velyka Vys River (Likareve village, 2012–2018).

Ecological assessment of water quality: according to average indicators, the waters of the Kodyma River belong to class III (category №5) («medium, moderately polluted»), the Velyka Vys River - to class III (category №4) («satisfactory, slightly polluted»); according to the worst values, the waters of the Kodyma River belong to class V (category № 7) («very bad, very dirty»), and the waters of the Velyka Vys River have class III (category № 5) («medium, moderately polluted»). In both rivers, the water has a high content of biogenic compounds and indicators of organic pollution.

Assessment of water quality compliance with fishery standards using the PKIZ method showed: the waters of the Kodyma River belong to the IV-a water quality class («very dirty»); the waters of the Velyka Vys River belong to the III-a quality class («dirty»); the waters of both rivers are unsuitable for safe fish farming; the high level of nitrite nitrogen pollution indicates constant fresh fecal pollution by wastewater and indicates a low level of anthropogenic load, which is at the limit of the self-purification capabilities of the rivers.

The analysis of hydrochemical indicators of the studied rivers showed that the risk of failure to achieve environmental goals for the Kodima River arises due to the high content of ammonium nitrogen, phosphates, and biochemical oxygen consumption (5) in the water; for the Velyka Vys River - due to ammonium nitrogen and phosphates. Water pollution by these substances indicates the presence of point sources of untreated municipal wastewater, which may be caused by the absence and improper operation of treatment facilities in the studied surface water body.

Thus, the current state of the Kodima River and Velyka Vys River can be described as unsatisfactory, which is manifested in poor water quality, a high risk of failure to achieve ecological well-being and requires solving a whole complex of problems that have accumulated in the catchments of the studied rivers in recent times. The first priority should be to improve the treatment of wastewater from settlements that are discharged into the rivers. Also, for the Velyka Vys R., it is important to resolve issues with the closure and reclamation of the uranium mine on the Kilten River in the village of Smolino, from which not only household wastewater is discharged into the river, but also drainage water pumped from a non-operating mine without appropriate treatment.

REFERENCES

1. *Yarov Ya.S.* Otsinka stanu richky Kodyma za pokaznykamy antropohennykh navantazhen ta ekolohichnykh ryzykiv. Suchasni problemy nauky, osvity ta suspilstva. [Assessment of the state of the Kodyma River based on indicators of anthropogenic loads and environmental risks. Modern problems of science, education and society. Proceedings of the XII-th International scientific and practical conference. SPC «Sci-conf.com.ua».]. Materialy XII Mizhnarodnoi naukovo-praktychnoi konferentsii 5-7 liutogo 2024. Ukrayina, Kyiv. Pp. 361-367.
http://eprints.library.odeku.edu.ua/id/eprint/12804/

2. Yarov Ya.S. Otsinka stanu richky Velyka Vys za pokaznykamy antropohennykh navantazhen ta ekolohichnykh ryzykiv. Suchasni tekhnolohii ta protsesy vprovadzhennia novykh metodiv. [Assessment of the state of the Velyka Vys River based on indicators of anthropogenic loads and environmental risks. Modern technologies and processes of implementation of new methods. Proceedings of the V International Scientific and Practical Conference International Science Group]. Pratsi V Mizhnarodnoi naukovoi ta praktychnoi konferentsii 6-9 liutogo 2024. Ispaniia, Madryd. Pp. 83-91. doi 10.46299/ISG.2024.15.
http://eprints.library.odeku.edu.ua/id/eprint/12805/

ASSESSMENT OF CLIMATE RISK OF SUNFLOWER SEED YIELD LOSS IN UKRAINE FOR 2021–2050

***Olena Zhygailo*[1], *Ass. Prof.*,**
Taras Zhygailo[2]*, Doct. St.,*
Demian Zhyhailo[2]*, PhD*

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of climate-smart agriculture. National Academy of Agricultural Sciences of Ukraine. Ukraine

The climate has already become more arid throughout the entire territory of Ukraine. The rapid increase in thermal resources. combined with an almost unchanged amount of precipitation – both annual and during the spring-summer period – leads to a higher frequency of droughts and their expansion into the western and northern regions. In recent years. droughts have been observed in areas where they had not occurred before. The calculated climate aridity indices over the past decade indicate a significant expansion of areas with insufficient natural moisture. Therefore. the issue of assessing the vulnerability of territories and the climate risk of crop yield losses in Ukraine is now more relevant than ever (Adamenko, 2019; Stepanenko et al., 2018).

According to the results of sunflower productivity modeling under future climate change conditions. carried out using the RCP4.5 and RCP8.5 climate change scenarios. during the period from 2021 to 2050. certain years are expected when weather conditions will favor achieving sunflower seed yields of up to 4-5 t/ha. Conversely. very unfavorable conditions are also possible. which will lead to a significant reduction in sunflower crop productivity. resulting in yields dropping to as low as 0.5-1.0 t/ha.

According to calculations based on the RCP4.5 climate change scenario. low risks (2-4%) are expected in the Western and Eastern Forest-Steppe regions (Table 1). In the central part of the Forest-Steppe. the Northern Steppe. and the western part of the Donetsk region. moderate risks of yield shortfall are projected. specifically: Kyiv region – 6.1%. Cherkasy and Kirovohrad regions – 8.5%. Kharkiv and Donetsk regions – 10.6%. and Dnipropetrovsk region – 12.8%. High risks of up to 17.2% are expected in the southwestern part of the Steppe and the eastern part of the Donetsk region. In the central part of the Southern Steppe. significantly high risks of yield loss are anticipated (26%).

In the case of the RCP8.5 scenario. extremely high risks of yield loss are not expected. However. throughout the Southern Steppe zone. high risks of yield loss (15.5-18.0%) are projected.

In the central and eastern parts of both the Steppe and Forest-Steppe zones. moderate risks of yield loss are expected. including 7.5% in Cherkasy region. 10.3% in Poltava and Kirovohrad regions. 13.2% in Kharkiv region. and 12.6% in Dnipropetrovsk region.

Table 1. Projected risks of sunflower seed yield loss in 2025–2050 under RCP4.5 and RCP8.5 climate change scenarios

№	Districts	Scenario					
		RCP4.5			RCP8.5		
		Risks of yield reduction		Average annual HTC, relative units	Risks of yield reduction		Average annual HTC, relative units
		%	assessment		%	assessment	
1	Sumy	4.0	low	1.0	1.8	low	1.1
2	Kyiv	6.1	medium	0.9	4.2	low	1.0
3	Cherkasy	8.5	medium	0.8	7.5	medium	0.9
4	Poltava	2.2	low	1.1	10.3	medium	0.8
5	Vinnytsia	2.2	low	1.1	0.2	low	1.2
6	Kirovohrad	8.5	medium	0.8	10.3	medium	0.8
7	Zaporizhzhia	26.0	very high	0.5	18.0	high	0.5
8	Odesa	17.2	high	0.6	15.5	high	0.6
9	Mykolaiv	26.0	very high	0.5	15.5	high	0.6
10	Kherson	26.0	very high	0.5	18.0	high	0.5
11	AR of Crimea	26.0	very high	0.5	18.0	high	0.5
12	Kharkiv	10.6	medium	0.7	13.2	medium	0.7
13	Dnipropetrivsk	12.8	medium	0.7	12.6	medium	0.7
14	Luhansk	17.2	high	0.6	18.0	high	0.5
15	Donetsk	10.6	medium	0.7	18.0	high	0.5

Note: (0-5% – low. 6-15% – medium. 16-25% – high. >25% – very high)

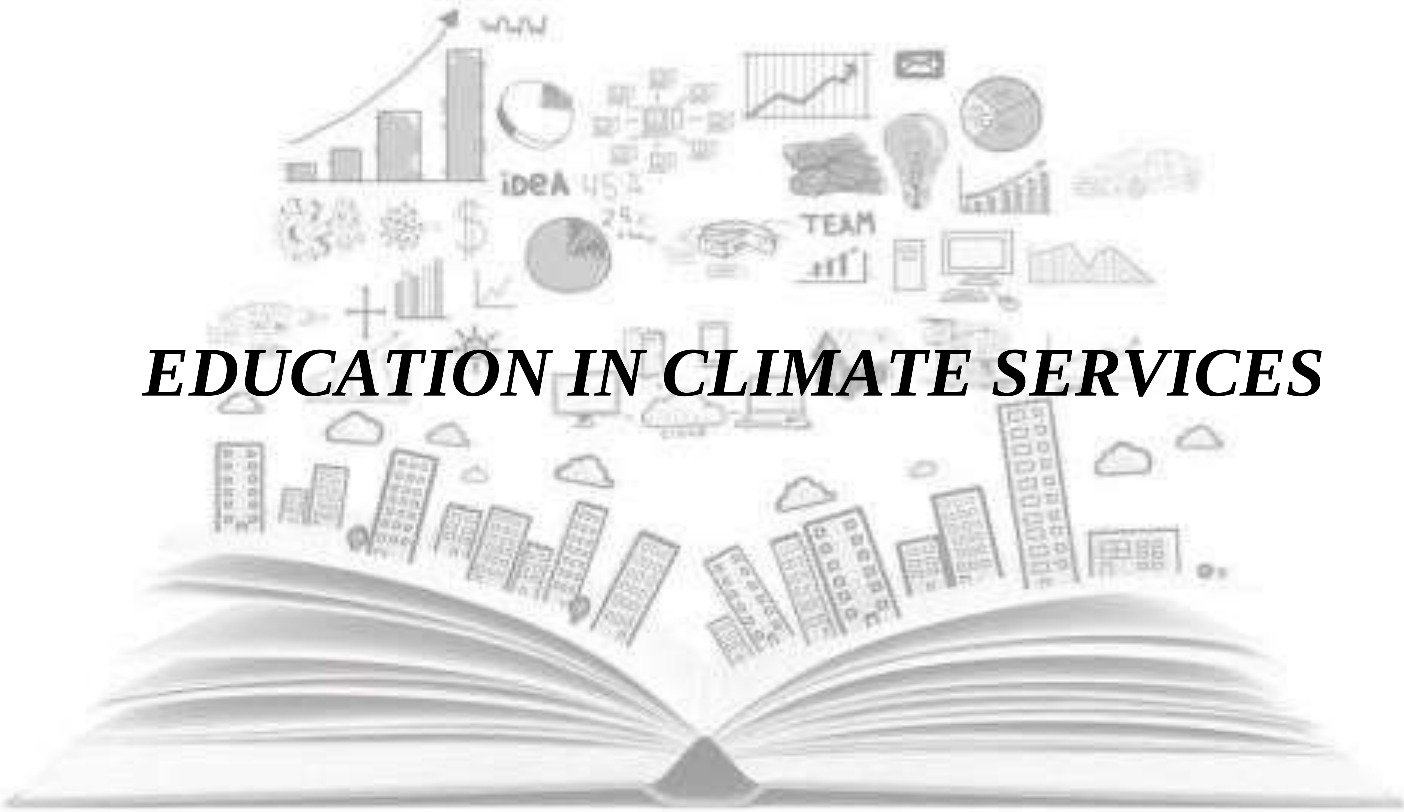
It should be noted that under the RCP4.5 climate change scenario. the risk of yield shortfall in Poltava region is expected to be 7% lower. Low risks of yield shortfall can be expected in the Western Forest-Steppe (0.2%) and in the northern part of the Eastern Forest-Steppe (1.8%).

In Kyiv region compared to the risks projected under the RCP4.5 climate change scenario (6.1%). the expected risks under this scenario will be lower – 4.2%.

REFERENCES

1. Adamenko, T., 2019: Climate change and agriculture in Ukraine: what should farmers know? German-Ukrainian Agricultural policy dialogue. 36 p. URL: https://mepr.gov.ua/wp-content/uploads/2023/07/5_Zminaklimatu-ta-silske-gospodarstvo-v-Ukrayini.pdf

2. Stepanenko, S.M., Polovyi, A.M. (Eds.), 2018: Climate Risks of Economic Sectors in Ukraine under Climate Change: Monograph. p. 259-497.



EDUCATION IN CLIMATE SERVICES

CLIMATE SERVICES AND MODELLING: SIMULATIONS OF THE EARTH ATMOSPHERIC CIRCULATION AND ENTROPY AND ANGLE MOMENTUM BALANCE

Alexander Glushkov, Prof., DSc., *Olga Khetselius, Prof., DSc., Mykhailo Lobachev, Prof., DSc., Oleh Shablii, Andrey Svinarenko, Prof., DSc.*

Odesa Polytechnic National University, Ukraine

Understanding and quantitatively describing global mechanisms in atmospheric low-frequency processes, teleconnection effects, and related phenomena is of fundamental interest in modern climate physics and the study of heat and mass transfer within complex atmospheric systems. Currently, there are various consistent approaches to modeling global atmospheric macroprocesses, as well as methods for modeling the temporal and spatial dispersion of pollutants in the atmosphere and other geospheres. However, achieving an accurate quantitative description of global atmospheric processes, heat and mass transfer mechanisms in the atmosphere, and macro-modeling the dispersion of pollutants remains a highly relevant and, as yet, unresolved challenge.

We present an effective non-stationary balance approach for modeling global climate mechanisms and macro-turbulent atmospheric low-frequency processes, including heat and mass transfer at spatial and temporal macro scales, teleconnection effects, and tropospheric radio waveguide physics, among others [1-3]. The primary forming factor is a triplet of interacting solitons: the "planetary soliton of Hadley cells – the entire complex of atmospheric fronts – the Rossby soliton wave packet." This approach is based on balance relationships for entropy, energy, and angular momentum, as well as the spectral theory of atmospheric macroturbulence and atmospheric moisture flow, further connected to the continuity of atmospheric circulation forms (teleconnection and the genesis of fronts). A specific application involves studying the spatiotemporal distribution of long-term atmospheric pollutants, including radionuclide dispersion following nuclear power plant accidents, such as Fukushima, while accounting for macro-turbulent, low-frequency circulation processes. An advanced non-stationary angular momentum balance equation in planetary dynamic movements of air masses is expressed in the following standard integral form [24]:

$$\frac{\partial}{\partial t}\int \rho M dV = \int_{\varphi_1}^{\varphi_2}\int_0^H\int_0^{2\pi} \rho v M d\varphi dz d\lambda + \int_0^H\int_{\varphi_1}^{\varphi_2}\int_0^{2\pi}\left(p_E^i - p_W^i\right) a\cos\varphi dz d\varphi d\lambda + \int_{\varphi_1}^{\varphi_2}\int_0^{2\pi}\int_0^H \tau_0 a\cos\varphi d\varphi d\lambda 2\pi, \quad (1)$$

where M = $\Omega a^2 \mathbf{cos}\varphi + ua\mathbf{cos}\varphi$ - angular momentum; Ω - the angular velocity of rotation of the Earth; a - radius of the Earth; φ - Latitude (φ_1 - φ_2 - separated latitudinal belt between the Arctic and polar fronts); λ - longitude; u, v - zonal and meridional components of the wind velocity; ρ - air density; V - the entire volume of the atmosphere in this latitude belt from sea level to the average height of the elevated troposphere waveguide - H (in notations [1] H = ∞); $p_E^i - p_W^i$ - the pressure difference between the eastern and western slopes of the *i*-th mountains; z - height above sea level. The cycle of balance of angular momentum in the contact zones with the hydrosphere and lithosphere becomes a singularity. This singularity can be detected through the occurrence of zones of fronts and soliton-type front. Then the kernel of equation (1) can be defined in the density functional ensemble of complex velocity potential the corresponding complex velocity:

$$v = U + iV = \frac{df}{dz} = \overline{v_\infty} + \frac{1}{2\pi}\sum_{k=1}^{n}\frac{q_k}{z-a_k} - \frac{1}{2\pi}\sum_{k=1}^{p}\frac{M_k e^{\alpha_k i}}{(z-c_k)^2} - \frac{i}{2\pi}\sum_{k=1}^{m}\Gamma_k/(z-b_k)$$

$$f = \overline{v_\infty} z + \frac{1}{2\pi}\sum_{k=1}^{n} q_k \ln(z-a_k) + \frac{1}{2\pi}\sum_{k=1}^{p}\frac{M_k e^{\alpha_k i}}{z-c_k} - \frac{i}{2\pi}\sum_{k=1}^{m}\Gamma_k \ln(z-b_k) \qquad (2)$$

where v_∞ - complex velocity; b_k – coordinates of vortex sources in the area of singularity; c_k - coordinates of the dipoles in the area of singularity; a_k – coordinates of the vortex points in areas of singularity; M_k – values of momenta of these dipoles;α_k– orientation of the axes of the dipoles; Γ_k, q_k – values of circulation in the vortex sources and vortex points, respectively. The primary outcomes of our approach highlight the connection between the tropospheric radio waveguide and atmospheric moisture circulation, which, in turn, is linked to the structure of atmospheric circulation through the positioning of frontal sections - atmospheric fronts serving as the main accumulators of moisture. Additionally, atmospheric moisture turnover is associated with the low-frequency process of maintaining the angular momentum balance. The dynamics and characteristics of atmospheric radio waveguides are influenced by teleconnection and, consequently, by circulation patterns, specifically the continuity of these forms.

The presented theories, outlined for the first time, clearly demonstrate that the dynamics of tropospheric radio waveguides, atmospheric moisture circulation, the balance of atmospheric angular momentum, and changes in circulation forms (including their continuity, frontogenesis, and teleconnection) are closely interconnected physical characteristics of the atmosphere, exhibiting both direct and inverse relationships. Further details can be found in Refs. [1-3].

REFERENCES

1. Glushkov A.V., Svinarenko A.A., Khetselius O.Y., 2019: Modeling an ecological state of environment with accounting for radioactive contamination m radionuclides transfer. Odessa: OSENU, TES, 184p.

2. Glushkov A., Khetselius O., Stepanenko S., Ternovsky E., 2021: Chaos, bifurcations and strange attractors in environmental radioactivity dynamics of some geosystems. Springer Proc. in Math. & Statistics, vol 363. pp.79-88.

3. Glushkov A., Khetselius O., Svinarenko A., Serbov N., 2008: The sea and ocean 3D acoustic waveguide: rays dynamics and chaos phenomena. J. Acoust. Soc. Amer. Vol.123(5), p.3625.

CLIMATE SERVICES IN CITY MANAGEMENT: GREEN CITY TECHNOLOGY, AIR POLLUTION & VENTILATION DATA ANALYSIS, ARTIFICIAL INTELLECT, MANAGEMENT SOLUTIONS

Alexander Glushkov, Prof., DSc., *Olga Khetselius, Prof., DSc., Mykhailo Lobachev, Prof., DSc., Oleh Shablii, Kateryna Husieva, PhD*

Odesa Polytechnic National University, Ukraine

One of the most pressing and important problems of the modern cities is the problem of air quality. The development of modern cities (megapolises) is not possible without a scientifically sound strategy for monitoring, analyzing and forecasting data on the pollution of the atmosphere of industrial cities. It should be added that the rapid economic development over the past decades driven mainly by combustion of a lot of fossil fuels results in dramatic growth of both gaseous and particulate pollutants in the atmosphere of industrial cities [1-4]. The strategic aim of our work is to present scientific fundamentals of the so called "Green-Smart City" Technology, which includes carrying out a set of the combined building blocks (optimal IT, management and atmospheric–environmental ones, including air pollution, atmosphere ventilation data analysis, artificial intellect and management solutions and framework for smart city effective planning. The first step includes development of the quantitative theory of air pollution and city's atmosphere ventilation. The second step is its applied application for concrete industrial cities. The third step is its combination with the optimal IT, management and other similar blocks [3-6].

An effective and innovative mathematical approach to analyzing and modeling natural air ventilation in the atmosphere of industrial cities is based on a new theory of atmospheric ventilation. This combines the Arakawa model, modified to calculate the current involvement of cloud ensembles, with a hydrodynamical forecast model [2,3]. Calculations for balance relations in the inner-urban zone turbulence have been conducted using the turbulent regime kinetic energy equation. To calculate the inflowing streams reaching the city territory, the Arakawa system of equations for humidity and thermal flow is solved [3-5]. A scheme of urban zone ventilation by airflows in the presence of cloud convection is presented below (Fig. 1). If A represents the work of the convective cloud and $m_B(\lambda)$ denotes the air mass drawn into the cloud with a drawing velocity of λ, it consists of the standard convection work and the work of downward-falling streams:

$$\frac{dA}{dt} = 0 = \frac{dA}{dt}_{conv} + \frac{dA}{dt}_{downstr.}, \quad \frac{dA}{dt}_{downstr.} = \int_0^{\lambda_{\max}} m_B(\lambda')K(\lambda,\lambda')d\lambda', \tag{1}$$

The solution of the Arakawa type Eq. with accounting for air streams superposition of synoptic process is as follows [1,2]:

$$m_B(\lambda) = F(\lambda) + \beta \int_0^{\lambda_{\max}} F(s)\Gamma(\lambda, s{:}\beta)ds, \quad \Gamma(\lambda, s{:}\beta) = \sum_{m=1}^{\infty} \beta^{m-1} K_m(\lambda, s) \qquad (2)$$

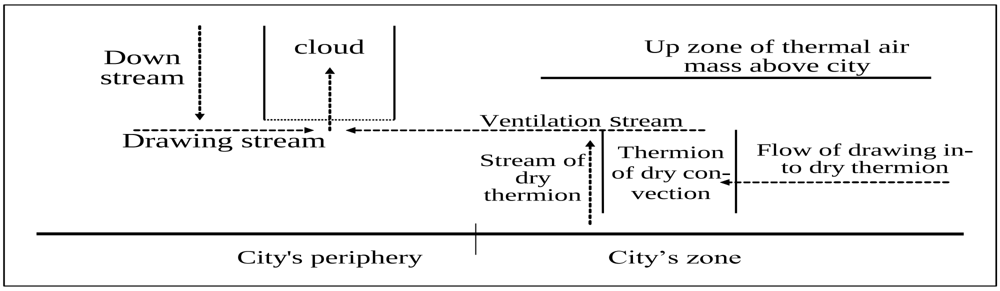


Fig. 1. Scheme of an air driving between the city and its periphery.

where $\Gamma(x, s{:}\beta)$ is a resolventa; it is determined as the Loran series in a complex plane ζ; its centre coincides with the centre of the urban heating island (spot) and internal cycle with its periphery. The equations of atmosphere circulation above city's zone can be taken in a "shallow water" approximation. Its solution can be bound by methods of the plane complex field theory:

$$v_x - iv_y = \frac{df}{d\xi} = \frac{\Gamma}{2\pi i}\left[\frac{1}{\zeta-\zeta_0} + \sum_{k=1}^{\infty}\left(\frac{1}{\zeta-\zeta_0-kl} + \frac{1}{\zeta-\zeta_0+kl}\right)\right] + \frac{d}{d\zeta}\left[\sum_{k=1}^{n}\Gamma_k \ln(\zeta-b_k)\right] \quad (3)$$

Here Γ_k –circulation on the vortex elements, created by clouds; b_k – co-ordinates of this forming; r – circulation's on standard vortexes for the Carman chain; l – distance between standard vortexes for the Carman chain; ζ - centre co-ordinate for line of convective perturbations or front divider; ζ (+-)kl – co-ordinate of beginning and the end for line of convective perturbation; Method for calculation of the turbulence spectra is based on the tensor Eq. of the turbulent tensions:

$$\frac{\partial \overline{u_i'u_j'}}{\partial t} + \frac{\partial}{\partial x_k}\left(\overline{u_k}\cdot\overline{u_i'u_j'} + \overline{u_k'u_i'u_j'}\right) + \frac{\partial \overline{p'u_i'}}{\partial x_j} + \frac{\partial \overline{p'u_j'}}{\partial x_i} = -\overline{u_i'u_k'}\frac{\partial \overline{u_j}}{\partial x} - \overline{u_j'u_k'}\frac{\partial \overline{u_i}}{\partial x} + \overline{p'\left(\frac{\partial u_i'}{\partial x} + \frac{\partial u_j'}{\partial x}\right)}; \quad (4)$$

Other details can be found in Refs. [2,3]. There are listed some results of application of our method combined with the standard monitoring, diagnosing and IT and management blocks for indicated cities, which can be firstly considered as realization of the "Green-Smart City" construction technology.

REFERENCES

1. Glushkov A.V., 1999: Calculation of turbulent ventilation of industrial city in a zone of dry subtropics. Meteor., Climat. and Hydrology, Vol.38, pp. 77-83.
2. Glushkov A.V., Khetselius O.Y., Buyadzhi V.V., 2019: Analysis, modeling and forecasting air pollution for industrial cities. Odessa: OSENU, TES, 144p.
3. Glushkov A.V., Svinarenko A.A., Khetselius O.Y., 2019: Modeling an ecological state of environment with accounting for radioactive contamination m radionuclides transfer. Odessa: OSENU, TES, 184p.
4. Rusov V.D., Glushkov A.V., Vaschenko V.N., et al., 2010: Galactic cosmic rays – clouds effect and bifurcation model of the earth global climate. Part 1. Theory. J. of Atm. and Solar-Terrestrial Phys. (Elsevier), Vol.72, pp.498-508.

CLIMATE PRODUCTS (CLIMATIC AND SOCIO-ECONOMIC INDICATORS FOR CLIMATE SERVICES)

Inna Khomenko, Associate Professor, PhD
Larysa Nedostrelova, Associate Professor, PhD
Halyna Katerusha, Associate Professor, PhD
Halyna Borovska, Associate Professor, PhD

Odesa I. I. Mechnikov National University, Ukraine

The course "Climate Products (Climatic and Socio-Economic Indicators for Climate Services)" is one of the core components of the professional cycle of disciplines in the master's program "Climate Services".

The main goal is to train specialists who, using all modern tools and techniques to provide high-quality information tailored to user needs, including explanations of its possible applications, can create and interpret various climate products for different geographical regions and time periods.

Human economic activities lead to a sharp global change in the substance cycles in the biosphere, which has been forming over thousands of years. With climate change, natural resources are altered, and these are not only purely climatic resources but also those that are somewhat dependent on the climate's condition. The consideration of climate-dependent natural resources has always been of great importance in sectors of the economy closely linked to weather and climate conditions. This, first and foremost, includes the agro-industrial complex, where the costs of agricultural production are determined by a corresponding set of climate-dependent natural resources.

Next, it is necessary to mention the fuel complex – here, the thermal resources of the territory are of primary importance, as they determine the heating regime, the operation of ventilation systems, and refrigeration units. Climate-dependent natural resources play a significant role in the energy sector, determining such components as hydroenergy resources, wind energy, and anthropogenic solar resources. An important role is also attributed to the ecological component of climate-dependent natural resources, which reflects the part that affects health and, conversely, the risks of disease among the population. It is also important to note water resources, the consideration of natural resources in construction, in the planning and operation of transport networks, tourism, and recreational use of territories, and so on.

Scientific and technological progress, and primarily the rapid growth of the energy capacity of civilization, generates numerous problems that require assessment, analysis, and in-depth study. Understanding this situation highlights the necessity of addressing the issue of observation, research, analysis, and forecasting the changes in climate-dependent natural resources in connection with climate change.

The main audience is master's students of higher education institutions in Ukraine who are studying in the field of climate services. Partially, the course can also be used as a qualification enhancement course for specialists in meteorology and climatology, as well as for specialists in other fields where decision-making based on climate information is required.

Competencies.

C3. Create and interpret various climate products for different geographic regions and time periods, using all available state-of-the-art tools and techniques to provide quality information tailored to the user's needs, including an explanation of their possible uses and associated.

C5. Ensure constant and effective communication to end users/stakeholders to identify and select the best solutions for the economy and society as a whole.

Performance Criteria.

PC1. Compute sector-specific climate indices and other sector-oriented climate products.

PC2. Apply statistical and geostatistical analysis to monitor the spatial distribution and temporal evolution of climate

PC3. Design climate products for specific sectors such as agriculture and food security, disaster risk reduction, energy, health and water.

Learning Outcomes.

LO1. Tailor climate data and information to meet the specific needs of diverse end users, such as policymakers, researchers, and industry professionals, ensuring the relevance and usability of the information provided.

LO2. Make use of climate data, climate indices, other climate-related information and sectorial data to derive climate product.

LO3. Define the impact of climate on strategic sectors, especially GFCS key sectors: agriculture and food security, disaster risk reduction, energy, health and water.

LO4. Create synthesis reports, including textual, graphical, and cartographic information, to convert climate products into climate services and communicate them to users.

The following **teaching strategies** will be used during the course:

Discussion strategy – will help develop practical experience in participants for joint participation in discussions and solving theoretical and practical problems.

Situational analysis strategy – is an essential element in the training of future manager-climatologists.

Simulation strategy – interactive models of climate products, which are oriented towards specific sectors of the country's economy, and are maximally close to the corresponding real climate conditions based on their internal characteristics.

CITIZEN-SCIENCE STUDENT PROJECT UNDER GROMADA ERASMUS+: MONITORING AIR QUALITY IN URBAN AREAS

Khomenko Inna, Assoc. Prof., *Oleh Prokofiev, Assoc. Prof., Volodymyr Andrusenko, Anastasiia Mokan, Tetiana Chorna, Zlata Bratova*

Odesa I. I. Mechnikov National University, Ukraine

The war in Ukraine has led to severe environmental consequences, particularly air pollution caused by infrastructure destruction, military operations, fires, and chemical releases. These hazards pose significant risks to public health and hinder post-war recovery efforts. Toxic substances released into the atmosphere can have long-term effects on respiratory health, exacerbate chronic diseases, and impair the resilience of ecosystems already stressed by climate change. Despite the seriousness of the issue, access to localized, high-quality air quality data remains limited, particularly in smaller communities, rural areas, and frontline regions. This data gap restricts the development of evidence-based recovery policies and public health strategies.

The project “Clean Air for Recovery” aims to establish a citizen-driven air monitoring network in war-affected regions of Ukraine using open-source technologies. By empowering local communities, the project promotes both environmental stewardship and public engagement in post-conflict reconstruction. The initiative seeks to democratize access to environmental data and create new mechanisms for transparency, accountability, and adaptive governance. It is rooted in principles of inclusiveness, sustainability, and scientific integrity.

Through the use of Arduino and ESP32 microcontrollers, citizens will install affordable monitoring stations equipped with sensors measuring PM2.5, PM10, CO2, NO2, SO2, temperature, humidity, atmospheric pressure, wind speed, and precipitation. Data will be collected every 5–10 minutes, averaged, stored, and transmitted via Wi-Fi, LoRaWAN, or GSM to cloud platforms such as ThingSpeak or OpenAQ, where it will be visualized and analyzed in near real-time. These stations will be powered either by the electrical grid or autonomous solar panels with battery backup to ensure resilience in energy-deficient areas.

The research methodology combines technological data collection with citizen participation. Sensor data will be validated, statistically analyzed, and compared with satellite datasets (e.g., Sentinel-5P, MODIS). Data fusion techniques will enhance the spatial resolution of atmospheric information, while long-term monitoring will allow for trend analysis and risk mapping. Citizen engagement ensures both widespread collection of localized data and the development of environmental awareness. Educational programs, online courses, and hands-on workshops will empower volunteers to operate stations, interpret data, and communicate results to stakeholders at local, regional, and national levels.

The project's sustainability is supported by its open design, low-cost and accessible hardware, and strong partnerships with universities, non-governmental organizations (NGOs), environmental initiatives, and governmental agencies. The modular architecture of the stations allows for scalability and adaptation to local needs and capacities. Developed guides, technical documentation, and multilingual educational materials will facilitate replication by other communities in Ukraine and beyond. All data collected will be publicly accessible and integrated into national and international open-data platforms, enhancing their influence on public health and environmental policymaking.

This initiative holds strong potential for scalability and transferability to other regions affected by conflict, environmental degradation, or disasters. Its methodology can serve as a global model for citizen-based air quality monitoring—providing low-cost, high-engagement, and scientifically robust data. Ultimately, the project fosters a new ecosystem of collaboration among citizens, researchers, policymakers, and institutions, aiming to protect the environment, rebuild trust in science and governance, and contribute meaningfully to Ukraine's green and just recovery.

The "Clean Air for Recovery" project envisions the development and implementation of a national-scale citizen science network for atmospheric monitoring in Ukraine. Leveraging low-cost microcontroller platforms such as Arduino Uno, ESP32, and their compatible sensor modules, the initiative will enable residents in war-affected communities to independently monitor and report on ambient air quality. These stations will be custom-built to include environmental sensors measuring key parameters relevant to war-related pollution and climate risks.

The stations will be housed in weather-resistant enclosures and installed on rooftops or poles to ensure standardized sampling conditions. Each unit will be capable of detecting fine and coarse particulate matter (PM2.5 and PM10), trace gases ($CO2$, $NO2$, $SO2$), and meteorological variables (temperature, humidity, wind speed, atmospheric pressure, rainfall). The devices will be programmed to operate autonomously, with data logging intervals adjustable between 1 and 15 minutes depending on the level of pollution variability and user requirements.

Data acquisition and transmission will be managed via wireless connectivity: Wi-Fi in urban areas with stable infrastructure, LoRaWAN in rural zones, and GSM in remote or disrupted locations. Data will be sent to platforms such as ThingSpeak, OpenAQ, and optionally ThingsBoard for visualization, storage, and remote diagnostics. Project developers will provide firmware sketches for Arduino boards and setup instructions for users. These will include automatic reconnection protocols, real-time clock synchronization, data buffering, and security features such as device authentication.

AWARENESS OF GREEN BUILDING AS A COMPONENT OF CLIMATE CHANGE ADAPTATION

Maryna Kravchenko, Sc.D., *Tetiana Tkachenko, Sc.D.,*
Olena Voloshkina, Sc.D. and Lesya Vasylenko, PhD

Kyiv National University of Construction and Architecture, Ukraine

Climate change is one of the most pressing challenges of our time, resulting from both natural and human factors. Annual global CO_2 emissions exceed 36 billion tonnes, with a significant portion attributed to the construction sector, a major consumer of natural resources and a source of greenhouse gases. In Ukraine, construction activities are on the rise, particularly in infrastructure renewal, which increased by 37.1% in the first half of 2024. Additionally, 50% of buildings in Ukraine have low energy efficiency, contributing to 6% of carbon emissions.

Green buildings represent an effective solution for reducing the carbon footprint of the construction industry. In scientific literature, the terms «sustainable construction», «green building», and «high-performance buildings» are often used interchangeably to encompass environmental, social, and economic aspects. However, the growth of this sector is hindered by low awareness, legislative barriers, and resource limitations. Enhancing competence in sustainable construction is essential for fostering environmentally responsible behavior. The main aspects of environmental literacy are summarized in Table 1.

Table 1. Key elements of green building awareness

Category	**Description**
	Knowledge and skills:
Factual knowledge	Comprehension of the key components of green buildings, including renewable energy sources, sustainable materials, and green structures such as green roofs, vertical gardens, and rain gardens
Conceptual knowledge	Understand the relationship between building elements and their environment. Assess the impact of architectural solutions on energy efficiency, air quality, water conservation, and CO_2 emissions. Analyze the effects of urban development on microclimate and biodiversity within urban ecosystems
Practical competences and skills	Application of ecological design, development of energy-efficient solutions for buildings, optimisation of operational processes, life cycle assessment of building materials to minimise environmental impact
	Environmental awareness:
Background	Formation of personal environmental values, responsibility for environmental protection, motivation to implement sustainable practices in professional activities and everyday life
Skills developed	Fostering ecological thinking through engagement with green architecture, hands-on experience with ecological technologies, and the incorporation of sustainable development principles into professional practices
	Behavioural aspects:
Popularisation	Actively spreading knowledge about green technologies through educational initiatives, lectures, training sessions, and public events. Initiating environmental projects in communities and workplaces, and collaborating with scientists, as well as governmental and non-governmental organizations, to implement environmental standards in construction
Practical implementation	Implementing environmental practices in daily life, such as waste sorting, energy-saving behaviors, and using eco-friendly materials at home and work

Building awareness of green construction involves not only acquiring knowledge but also understanding its impact on environmental and social systems. Figure 1 illustrates the relationship between factual and conceptual knowledge and environmental and social literacy. It demonstrates how various elements of the construction process – ranging from material selection to resource management – are interconnected with broader outcomes, such as air quality, biodiversity loss, and social justice. This figure emphasizes the importance of educational approaches that integrate factual knowledge with a systematic understanding of environmental interconnections in order to promote sustainable construction practices.

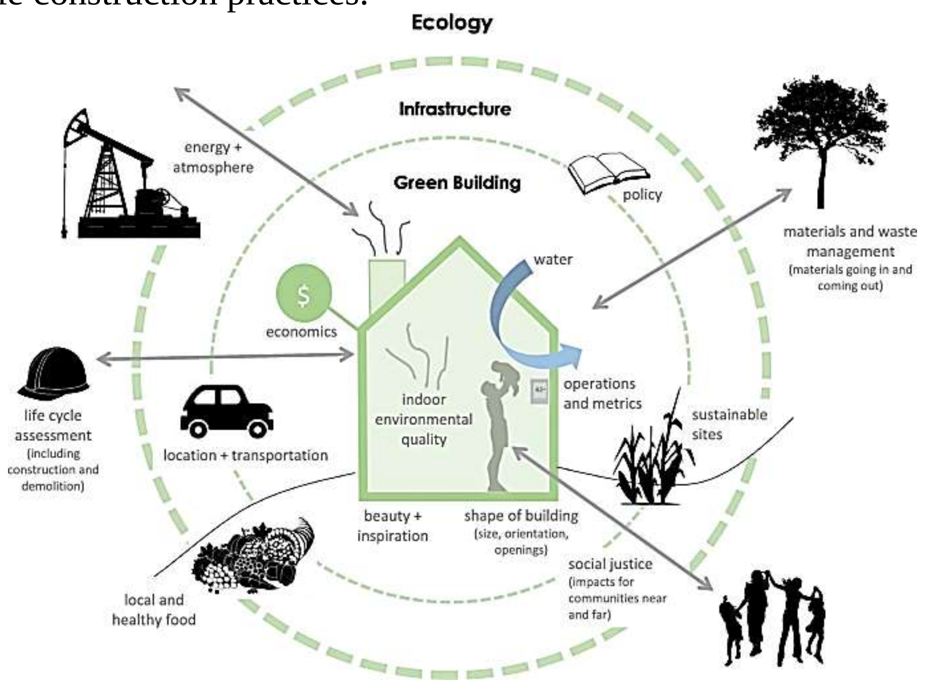


Fig. 1. Factual and conceptual knowledge in the field of green building: interconnections with social and ecological systems

Building awareness of green building is an important element of climate change adaptation, as it promotes the adoption of environmentally responsible practices. Education in this area should include factual, conceptual and procedural knowledge, the development of environmental awareness and appropriate behaviour. Increasing the competence of the public and professionals allows not only more efficient use of resources but also contributes to the transformation of the construction sector towards sustainable development.

REFERENCES

1. Agboola O.P., Alotaibi B.S., Dodo Y.A., Abuhussain M.A., Abuhussain M., 2024: Built Environment Transformation in Nigeria: The Effects of a Regenerative Framework, J. Asian Archit. Build. Eng., Vol. 23, pp.789–812.

2. Cole L.B., 2019: Green Building Literacy: A Framework for Advancing Green Building Education, Int. J. STEM Educ., Vol. 6, No. 18, pp. 1 – 13.

CLIMATE-ORIENTED TRAININGS ON CLIMATE SERVICES, CLIMATE CHANGE ADAPTATION AND MITIGATION

Alexander Mahura[1], *Valeriya Ovcharuk*[2], *Inna Khomenko*[2],
Hanna Lappalainen[1], *Svaytoslav Tyuryakov*[1,3]
& the ClimEd Teams hosted the trainings

[1] University of Helsinki, Institute for Atmospheric and Earth System Research, Finland
[2] Odesa I. I. Mechnikov National University, Ukraine
[3] Finnish Meteorological Institute, Finland

The Erasmus+ ClimEd ("*Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation*"; 2021-2026; climed.network) project aim is to develop a competency-based curricula for continuous comprehensive training of specialists in the field of climate services and additional education in climate change for decision-makers, experts in climate-dependent economic sectors, and public. It should be noted that some of the ClimEd goals and objectives are closely related to the Pan-Eurasian EXperiment (PEEX; www.atm.helsinki.fi/peex) programme, and especially with multi-disciplinary, -scale and -component study climate change at resolving major uncertainties in the Earth system science and global sustainability issues. The ClimEd project organized and carried out 7 trainings (climed.network/events/climed-trainings) focused on training the faculty/ teaching/ research staff and postgraduates at the ClimEd partner institutions and collaborating organizations in advanced educational and information-and-communication technologies for building a flexible multi-level integrated practice-based education system in the field of Climate Services, Climate Change Adaptation and Mitigation.

Although all trainings were planned to be carried out as face-to-face/onsite events, but because COVID pandemic situation, first several trainings (planned in Estonia, Ukraine, and Finland) were converted into virtual/online training. Program of such online trainings was divided into 3 consecutive blocks: (i) online lecturing, (ii) home-work-assignments (HWAs) as group work (as Small-Scale Research Projects, SSRPs) with established internal communication between the member of the groups and with an option of zoom-consulting during remote work, and (iii) final oral presentations (projects' defences) of HWAs with evaluation and feedbacks, discussions, and awarding certificates (corresponding to ECTS credits) with achieved learning outcomes and obtained skills.

The majority of HWAs is based on the ClimEd main themes linking climate change vs. agriculture, energy, technical design and construction, urban economy, water management, health care; although other themes of interest were allowed to select by groups. Trainings also included questionnaires distributed among participants: evaluation of the training, and self-evaluation of own learning outcomes. Technically, the Moodle system, Zoom-hosting, e-evaluations, etc. were actively utilized in such trainings. All materials of the trainings are publicly accessible online at the ClimEd project website as well as long-term stored at the Moodle system for each training. Since spring 2024, the trainings, taking a similar approach, were arranged as hybrid events (with both onsite/online participation) in Spain (4th & 7th) and Estonia (5th & 6th).

The outcomes/ summaries – including the lecture topics and learning outcomes, information resources, themes of groups' projects, feedbacks, and training results, established network-community of the training participants (trainees, lecturers and teachers of HWAs) – are freely/ publicly available at (https://climed.network/events/climed-trainings). These are available for online trainings: 1st – "*Competence-Based Approach to Curriculum Development for Climate Education*" (19 Apr – 12 May 2021), 2nd – "*Adaptation of the Competency Framework for Climate Services to conditions of Ukraine*" (29 Jun – 26 Aug 2021), and 3rd – "*Digital tools and datasets for climate change education*" (26 Oct – 12 Nov 2021); as well as for hybrid (onsite/online) trainings: 4th – "*Developing learning courses in climate services considering needs of different users*" (6–10 May 2024); 5th – "*Blended/ Online Learning for Climate Change: Bridging Theory, Technology, and Practical Application*" (30 Sep – 4 Oct 2024); 6th – "*Mastering technologies of massive open on-line courses development for general public*" (10-14 Feb 2025); and 7th – "*Developing skills to use climatic information and services for various climate-dependent branches of economy*" (7-11 Apr 2025).

REFERENCES

1. Mahura et al. (**2021**): "*Online Approaches for Climate-Oriented Education*". Proc. International Conference "Climate Services: Science and Education" (22-24 Sep 2021, Ukraine), pp. 79-80, ISBN 978-966-186-162-5, 144 p.
2. Ovcharuk et al. (**2022**): "*Climate-Oriented Trainings in the Field of Climate Services, Climate Change Adaptation and Mitigation*". EGU General Assembly 2022, 23–27 May 2022, Austria. EGU22-4895.
3. Mahura et al. (**2024**): "*ClimEd: Climate-oriented Trainings*". Proc. ACCC-FASN Science Conference (11-12 Nov 2024, Finland), pp. 213-214, ISBN 978-952-7507-37-7, 274 p.
4. D5.1: ClimEd Training N1: "*Competence-based approach …*", 13 p, **2021**
5. D5.2: ClimEd Training N2: "*Adaptation of Competency …*", 18 p, **2021**
6. D5.3: ClimEd Training N3: "*Digital tools and datasets …*", 16 p, **2021**
7. D5.4: ClimEd Training N4: "*Developing learning courses …*", 16 p, **2024**
8. D5.5: ClimEd Training N5: "*Applying Different Technologies …*", 15 p, **2024**
9. D5.6: ClimEd Training N6: "*Mastering Technologies …*", 16 p, **2025**
10. D5.7: ClimEd Training N7: "*Developing skills …*", 16 p, **2025**

CITIZEN-SCIENCE STUDENT PROJECT UNDER GROMADA ERASMUS+: ASSESSING THE HYDROLOGICAL AND SATELLITE DATA ON BLACK SEA COASTAL WATERS AFTER KAKHOVKA DAM DESTRUCTION

Valeriya Ovcharuk*[1]*, Prof., Sc.D., *Maksym Martyniuk* [2]*, PhD, Yurii Pisariev*[1]*, Andriy Stetsyuk*[1]*, Alina Tashku,*[1] *and Anastasiia Sryberko*[1]*, students*

[1] Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Marine Biology of the National Academy of Sciences of Ukraine, Ukraine

This project aims to assess the environmental consequences of the destruction of the Kakhovka Hydroelectric Power Station (HPP) due to military actions in Ukraine, focusing on its impact on the hydroecological conditions of the Black Sea's coastal waters. By integrating hydrological, hydrobiological, hydrochemical, and radiometric measurements with satellite data, the study will evaluate changes in water quality, suspended matter distribution, and biological indicators, particularly chlorophyll-a concentrations. The research is conducted within the framework of cooperation between UkrSCES, IMB, and ONU as part of the UK-Ukraine Collaboration within the CORNELIA and TOPCOAT Projects under the Twinning Program, dedicated to remote monitoring of water bodies and water quality. The findings will provide critical insights into the long-term consequences of war-related environmental disasters and their effects on marine ecosystems.

The use of Earth-observation satellites to assess and monitor water quality in lakes, reservoirs and large rivers and sea coastal waters has matured over recent years to such an extent that we now have operational systems producing water quality data for thousands of waterbodies in near real-time (e.g., Copernicus Global Land Service (CGLS); while reprocessings of archive data using state-of-the-art methods are also delivering long-term, internally consistent time- series data for use in climate studies (e.g., the European Space Agency's Climate Change Initiative).

Observations are to be conducted on the dates of Sentinel-2A/2B satellite overpasses under cloud-free conditions to calibrate satellite data based on laboratory and instrumental (express method) measurements of chlorophyll-a and suspended matter concentrations. The known satellite overpass dates range from March to May 2025.

Measurements starting 7.03.2025 in the area of Langeron Beach (coordinates: 46.475048, 30.766554), Fig.1. During the observations, water samples were collected to determine salinity (50 ml), suspended matter concentration (2 L), and chlorophyll-a concentration (2 L).

Simultaneously with water sampling, measurements of water temperature and transparency (using a Secchi disk) were also conducted.

Fig. 1. Field observations on March 7, 2025, on Langeron Beach, Odesa within the framework of the GROMADA Erasmus+ citizen-science project.

Chlorophyll-a concentration (Chl mg·m^{-3}) and phycocyanin (CPC mg·m^{-3}) were measured in the field using two express methods – a portable hyperspectral radiometer WISP-3 and the Chelsea Technologies Tri-Lux sensor.

Additionally, using WISP-3, values for total suspended inorganic matter (TSM g·m^{-3}) and the spectral light attenuation coefficient (Kd m^{-1}) were obtained.

The project's methodology can be sustained through continued collaboration between research institutions and integration with existing remote sensing initiatives. This approach is scalable and can be expanded to cover additional coastal regions and inland water bodies, thereby enhancing global efforts in water quality monitoring.

Moreover, these studies can contribute to the development of ***climate services*** by providing critical data for assessing the long-term impacts of hydrological changes on aquatic ecosystems. The developed database and validated satellite calibration methods can be transferred to other geographical areas, supporting international research on aquatic ecosystems under varying environmental conditions.

INTERNATIONAL AGREEMENTS AND NATIONAL LEGISLATION IN THE FIELD OF CLIMATE CHANGE

Oleh Prokofiev*[1,2]*, PhD, Associate Professor,
Larysa Nedostrelova[1]*, PhD, Associate Professor,*
Oksana Volvach[1,2]*, PhD, Associate Professor*

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine

The course “International Agreements and National Legislation in the Field of Climate Change” is one of the core components of the professional cycle of disciplines within the master's program "Climate Change Mitigation and Adaptation." The course aims to develop analytical skills in the field of environmental/climate law, foster an understanding of legal obligations of states and mechanisms for their implementation, and support the development of practical approaches to integrating international standards into national legislation.

The main goal is to equip students with a solid knowledge of international agreements and national legislation on climate change, their role in global and national climate policy regulation; to examine key international treaties (the Paris Agreement, the Kyoto Protocol, the UN Framework Convention on Climate Change), mechanisms of their implementation, as well as Ukraine’s legislative initiatives and policies on climate change. The primary audience includes master’s students at Ukrainian higher education institutions pursuing studies in the field of climate services. The course may also serve as a professional development program for specialists in meteorology and climatology, as well as for professionals in other fields requiring climate-informed decision-making. This includes experts and civil servants working in environmental policy, law, or international cooperation, as well as civil society activists and experts interested in the implementation of climate policy.

Competencies. **C4**. Apply the knowledge obtained to navigate legal, communicative, and ethical challenges, contributing to effective global climate governance.

Performance Criteria: **PC1.** Evaluate the implications of specific legal instruments (e.g., treaties, regulations) on climate action and policy development. **PC2.** Evaluate the roles and responsibilities of various stakeholders (e.g., governments, NGOs, private sector) in achieving climate goals outlined in international agreements.

Learning Outcomes: **LO4.** Analyse the key legal frameworks and principles governing climate change at the international, national, and local levels, including treaties, regulations, and case law, to understand their implications for climate action and policy.

LO5. Evaluate the effectiveness of major international agreements, such as the Paris Agreement and the Kyoto Protocol, in addressing climate change, assessing their mechanisms for compliance, enforcement, and the role of various stakeholders in achieving climate goals.

For master's students, a blended learning format is recommended whenever possible. Based on practical considerations, it can be concluded that such a format would allow this audience to more easily regulate their study time. Given their educational needs, it can be assumed that master's students are generally well-prepared for online learning, as they typically possess developed self-study skills, time management abilities, and high levels of motivation.

However, since the expected learning outcomes are quite complex and demanding, it is advisable that the learning process be complemented by practical reinforcement of acquired knowledge – something best achieved through offline engagement. Therefore, it is recommended that students meet with the instructor in person 1-2 times per week to discuss the material covered in video lectures and other resources, as well as to refine and consolidate skills and competencies.

The online portion of the course, which will largely take place in asynchronous mode, will be supervised by the instructor through the use of discussion forums, allowing for closer interaction and the opportunity to address questions that may arise during the learning process.

At the end of the course, a final assessment of the learning outcomes will be conducted.

Considering the current difficult conditions in Ukraine, asynchronous online learning with the possibility of synchronous sessions may be offered to master's student groups.

In the case of online learning, it is often possible to better accommodate the educational needs of students compared to offline formats, as it allows for the involvement of a wider range of experts in relevant fields who might otherwise be unavailable due to scheduling constraints. This can have a positive impact on the overall effectiveness of the training.

In such a format, it is particularly important to ensure frequent and targeted communication between the instructor and students, as deep understanding of the multifaceted nature of climate-related issues – including environmental, economic, and legal aspects – can only be achieved through close interaction.

The following teaching strategies will be employed during the course:

- Discussion-based strategy – aimed at developing students' practical experience in collaborative discussion and in addressing both theoretical and applied problems.
- Case-study strategy – an essential component in the preparation of future climate managers, helping to develop analytical and decision-making skills in real-world contexts.

TRAINING COURSE FOR MASTERS ‘DATA AND INFORMATION FOR CLIMATE SERVICES’

***Alina Semerhei-Chumachenko*[1], PhD, Associate Professor,**
Yelyzaveta Halych[1], PhD, Associate Professor,
Oleh Prokofiev[1,2], PhD, Associate Professor

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine

Climate change is a profound and complex challenge impacting both society and the economy, with its consequences potentially exceeding previous expectations. While uncertainties remain regarding specific interactions, extreme weather events are increasingly linked to human activities. This has heightened the urgency of preparing for and adapting to climate change. Understanding its effects requires identifying regional vulnerabilities and opportunities for adaptation and resilience.

The course “Data and Information for Climate Services” (DICS) is one of the core components of the professional cycle of disciplines within the master's program "Climate Change Mitigation and Adaptation."

The aim of this course is to train professional meteorologists, senior and mid-level meteorological managers and masters of natural sciences in working with climate databases for the provision of climate services.

The target audience for this course is second-level students in natural sciences (103 Earth Sciences, 101 Ecology, 193 Geodesy and Land Management), as well as meteorological service employees, managers, and leaders who face the risks of climate change and want to learn about methods to mitigate the impact of global warming.

Expected that course participants will have basic training in these areas:

• Physical foundations of atmospheric processes.
• Analysis of climate data.
• Modelling of climate processes.
• Information and analytical activities: the ability to apply information and analytical technologies to collect, process and present climate information.

In addition, knowledge in the fields of ecology, economics and risk management will be useful, as climate change has a wide range of impacts on different aspects of society and the economy. These competencies will help students work effectively with climate data and develop strategies for adapting to climate change.

Competencies. C2. Obtain climate information to meet end-user needs, using all available services and climate databases (IRI/LDEO Climate Data Library, Copernicus Climate Data Store, IS-ENES Climate4Impact, etc.).

Learning Outcomes (LO) and Performance Criteria (PC):

LO1. Collect information about additional climate data sources and metadata and use it to prepare and conduct data recovery campaigns.

PC1. Implement procedures for preserving and recovering climate data.

LO2. Discuss the strengths and weaknesses of the observation network and the availability of data for climate research.

PC2. Quality control processes for climate data and derived time series

LO3. Apply quality control and homogenization techniques, assess the quality and homogeneity of a climate data network after collecting documentary, statistical and graphical evidence.

PC3. Assess the homogeneity of climate data and correct for heterogeneous time series.

LO4. Design a climate data and metadata database using a climate data management system, including raw, quality-checked and homogenized data.

LO5. Create and document climate datasets for specific purposes, including metadata, and explain their potential uses and associated uncertainties.

PC.4. Create, archive, and document climate datasets.

Whenever possible, a blended learning format is advisable for master's students. This approach allows them to better organize their study schedule. Considering their academic requirements, it can be inferred that master's students are generally well-prepared for online learning, as they usually possess strong independent learning abilities, effective time management skills, and a high level of motivation.

It is important to adapt the learning process to the needs and interests of each student, to provide the opportunity to independently choose the topics of practical tasks, because individualization of learning contributes to deeper involvement and motivation of students.

The learning activities will consist of lectures and practical exercises (classroom or online). Case studies will be performed using time series of meteorological and climate data to enable students to obtain spatiotemporal distribution of climate indicators for the analysis of climate change.

Practice exercises will be suggest to retrieve climate data from different sources and generate time series. Main tasks in exercises will be devoted to computation of the basic climate products, such as normal, anomalies and Climate Indices, such as those defined by the WMO.

An online Input Control test is planned for the first lesson, which will be used to determine the level of participants.

Tests are conducted on each topic of the DICS. At the end of the course, a final assessment of learning outcomes will be conducted involving both theoretical and practical questions (40 questions in total).

Given the current difficult conditions in Ukraine, master's groups can be offered asynchronous online learning with the possibility of synchronous sessions.

TRAINING COURSE FOR PHD STUDENTS ‘MANAGEMENT OF CLIMATE DATABASES’

Alina Semerhei-Chumachenko*[1]*, PhD, Associate Professor,
Yelyzaveta Halych[1]*, PhD, Associate Professor,*
Oleh Prokofiev[1,2]*, PhD, Associate Professor*

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine

In the context of climate change, effective management of climate data is a crucial task for scientific research, forecasting, and decision-making in ecology, meteorology, and environmental management. PhD students conducting research in climatology, ecology, and related fields require a deep understanding of methods for collecting, processing, analyzing, and storing large volumes of climate data. This course is relevant because it:

- provides knowledge of modern approaches to creating, administering, and optimizing climate databases;
- introduces international standards for climate data storage and working with global climate repositories;
- teaches methods for data analysis, anomaly detection, and reconstruction of missing records;
- develops practical skills in using software tools for managing large climate datasets.

Thus, the course **"Management of Climate Databases"** prepares PhD students for scientific and practical work in the face of modern challenges related to climate change and the digital transformation of science.

The course aims to provide PhD students with the theoretical knowledge and practical skills necessary for the effective collection, storage, processing and analysis of climate data. The course is aimed at mastering modern methods of managing large volumes of climate information, using specialized software, adhering to international standards for data storage and ensuring their reliability.

The target audience for this course is PhD students in natural sciences (103 Earth Sciences, 101 Ecology, 193 Geodesy and Land Management, etc).

The postgraduate course “Climate Database Management” (DM) will have a common basis with the master’s course “Data and Information for Climate Services” (DICS), but will differ in depth, emphasis and learning objectives.

The DICS course is focused on practical skills in working with climate databases, familiarization with the basic principles of their organization, processing and analysis, with an emphasis on the use of ready-made software solutions. The DM course is characterized by an in-depth study of the theoretical and methodological foundations of climate database management, consideration of complex algorithms for data analysis and recovery, and research into new approaches to managing large data sets.

Competencies. C1. Assessment of the impact of climate change and variability and climate extremes on different spheres (society, environment, economy, etc.) at different scales, taking into account the full range of interconnections between the links of the climate system and transdisciplinary interactions with society

Learning Outcomes (LO) and Performance Criteria (PC):

LO1. Explain the process of creating and managing climate datasets, including the consistent application of data recovery, quality control, homogenization, and integration into a climate dataset management system.

PC1. Apply quality control processes to climate data and derived time series.

LO2. Describe geographic features and historical events that affect the climate observing network, including political events and changes in observing methods and techniques

PC2. Evaluate the location and characteristics of observation sites in accordance with the requirements of a climate observing reference network

LO3. Demonstrate skills in using a variety of software tools required for climate data management, including office suites, statistical software, GIS, and specialized packages for quality control and homogenization of data.

PC3. Perform procedures for preserving and restoring climate data.

LO4. Design a climate data base and metadata using a climate data management system, including raw, quality-checked, and homogenized data.

PC.4. Collect and store climate data and metadata in appropriate databases

LO5. Create, document, and analyze climate data for specific purposes, including metadata, and explain their applications and associated uncertainties.

PC.5. Create, archive, and document climate data sets.

Online courses are more appropriate for working with graduate students, because graduate students often combine studies with scientific research, teaching or work on projects. The online format allows you to independently adjust the study schedule and combine it with other responsibilities.

Using the online format makes it possible to work with international climate databases, digital libraries, open scientific platforms and modern software regardless of your location.

The use of virtual laboratories, simulations, automated data analysis algorithms and machine learning tools allows PhD students to practice their skills in a real environment.

Thus, the online course "Climate Database Management" not only meets the needs of postgraduate students, but also opens up more opportunities for them for effective learning, research and international cooperation.

PROSPECTS FOR THE DEVELOPMENT OF HIGHER EDUCATION IN GEODESY AND LAND MANAGEMENT IN UKRAINE IN THE INTERESTS OF CLIMATE SERVICE AND POST-WAR RESTORATION OF UKRAINE

Mykola Serbov, Doctor of Economic Sciences, Professor,
Dean of the Faculty of Hydrometeorology and Ecology
Nataliia Danilova, Candidate of Geographical Sciences, Senior Lecturer

Odesa I. I. Mechnikov National University, Ukraine

The integration of the Ukrainian education system into the European educational space not only opens up prospects for international cooperation, but also sets new goals for improving all components of the educational process, especially in the higher education system. Ukraine is an active participant in integration processes in the field of higher education of European countries. One of the most important directions of state policy in the field of higher education in modern conditions is ensuring high quality professional training of specialists based on preserving its fundamental nature, compliance with the current and prospective needs of the individual, society and the state, maintaining competitiveness and international integration.

At the same time, modern changes in the country's economic development require fundamentally new approaches to the formation of human resources in the system of managing the country's natural resources, among which land and water resources of Ukraine occupy a special place.

The main tasks of land management education [3,4] are: satisfying the interests of the individual in the continuous improvement of professional, general educational and general cultural levels, creating conditions for constant updating and deepening of professional knowledge, skills and abilities; psychological restructuring of stereotypes of the activities of land management engineers. Modern professional education of land managers should solve three main functions [3]:

1. To form adequate relationships in the chain "Man - Nature - Society" and in nature itself. This allows the individual to know what and how between man and nature, between nature and society and how to act from the point of view of socio-economic and ecological expediency.
2. To form environmentally appropriate behavior of the individual, for this purpose an appropriate attitude towards nature is also necessary.
3. Forms a system of skills, abilities and strategies of interaction with the environment for the purpose of sustainable use of natural resources. Special attention should be paid to forecasting the rational use of land resources, and professional activity should be devoted to the problems of land management, land assessment and be based on the application of modern information technologies and GIS.

In addition to the above socio-economic and environmental, the training of land managers should also perform the following functions:

I. To develop a person's communicative abilities through the clarification of concepts that are a necessary component of the modern communicative minimum of every person, regardless of their educational and social status.

II. To perform an informative function, since professional education in geodesy and land management provides comprehensive information about the natural environment, natural resources that constitute the material basis of human existence, and clarifies the place of man in nature.

III. To form the personality of a specialist and citizen, developing mainly the psycho-emotional and intellectual spheres, the ability to think logically, and the ability to predict the consequences of one's behavior in nature and society.

In the conditions of modern Ukraine, the training of specialists in the field of geodesy and land management is of critical importance. Armed aggression, which has been going on for the fourth year, is causing unprecedented damage to the country's environment in general and to its individual components. Not only the population, objects of the economic complex and infrastructure, but also all components of the natural environment of Ukraine are suffering from hostilities. In fact, since February 24, 2022, the country has turned into a military training ground for testing numerous types of weapons and practicing modern methods of warfare. The damage caused to the environment of Ukraine because of the military invasion as of the beginning of 2024 is about $ 59.7 billion, of which 49.0% is damage to atmospheric air, 50.2% is damage to land and water resources [1,5].

The post-war reconstruction of entire regions of the country will require, first, large-scale work, which should later form the basis of updated land management and land use schemes for territories, where, along with classical engineering topographic and geodetic research and development, modern assessments of socio-ecological orientation should be presented.

The new model of training specialists in geodesy and land management should provide for increased pluridisciplinarity, i.e., a combination of disciplines between which certain meaningful connections are assumed, and interdisciplinarity - the interaction of several disciplines for the purpose of mutual integration. The characteristic features of higher education should be the rejection of stereotyped thinking, orientation on the development of creative potential and an individual approach to each higher education applicant.

REFERENCES

1. Grabchuk I., Bugaychuk V., Tkachuk V., Tymchak V. (2024). Strategic management of land resources in conditions of war and post-war restoration of the agricultural sector of Ukraine. Current issues of economic sciences. # 5. 22 p. https://doi.org/10.5281/zenodo.14231913

2. Rusina N.G. (2019). Peculiarities of training future specialists in geodesy and land management in higher education institutions of Ukraine. Scientific journal of the NPU M.P. Dragomanov. Is. 67. Ser. 5. P. 242-246.

3. Spoditel A., Golubtsov O., Chumachenko S., Sorokina L. Land pollution because of the RF aggression against Ukraine. https://ecoaction.org.ua/wp-content/uploads/2023/03/zabrudnennia-zemel-vid-rosii-full3.pdf

PLANNING (CLIMATE) SENSITIVE CITIES – CONNECTING SPATIAL PLANNING WITH ENVIRONMENTAL SCIENCES IN HIGHER EDUCATION

Ana Sopina, Sen. Assist., PhD, *Tamara Zaninović, Assist. Prof., PhD*

University of Zagreb, Faculty of Architecture, Croatia

Planning is a diverse and multidisciplinary research field connecting and overlapping various spatial scales and perspectives [1]: Spatial / Landscape / Regional / Urban / Environmental Planning. Climate change is one of many environmental challenges in planning cities along with topics of: habitat fragmentation and biodiversity loss, preservation of natural and cultural heritage, development of infrastructure and public transport, governance and public participation, local community engagement, quality of life and public health, safety and security, urban equity and affordability of living in the cities.

Contemporary challenges in the adaptation of cities to climate change are visible in the exploitation of natural resources and the transformation of water flows due to urban development pressures. Climate change is evident in the increasing number of floods, storms, and droughts which are connected to oscillating water cycles. Planning sensitive cities raises a need for holistic urban and spatial planning that equally involves biological systems of landscape, food, waste, and water, complemented with social systems of humanity and urban systems of economy, energy, mobility, structure, and technology [2]. Holistic planning can be achieved through an interdisciplinary educational framework [3].

Globally recognized concepts and solutions in addressing climate change, that involve both achieving climate neutrality (mitigation) and increasing climate resilience (adaptation) [1, 4], are examined in a comparison of European case studies in planning sensitive cities. The overview of six representative strategies and plans for European regions and cities (Table 1) brings various concepts, strategies, and tools in different planning scales: spatial planning – interregional and regional level; urban planning – urban region and city level; urban design – city district and public space level.

The explored planning elements and educative concepts in addressing climate (Table 1) confirm the approach towards climate sensitive city complemented with concepts of water sensitive city and socially sensitive city. The climate sensitive city - resilient and adaptive – is identified in multilayer flood protection, urban intervention for stormwater management, resilient green and blue infrastructure, and adaptive building. The water sensitive city - promotes biodiversity and natural-based solution (NBS) – by involving planning water city, open waterways, and stormwater solutions, resilience by nature, connecting urban nature with natural and ecological context of the city, and green and blue infrastructure. The socially sensitive cities – that protects inherited cultural and heritage values – relates to opening waterways to the community, stormwater solutions as public spaces, rain gardens, urban interventions for stormwater solutions, and adaptive building.

Table 1. European case studies of planning sensitive cities

Project	Region / City	Author, year	Scale	Planning concepts, strategies, and tools
South Essex Strategic Green and Blue Infrastructure Study	South Essex	Alexandra Steed URBAN, 2020	Spatial planning – Interregional and regional level	resilience by nature + resilient green and blue infrastructure
Rotterdam Adaptation Strategy	Rotterdam	DE URBANISTEN, 2013	Urban planning / Urban design	multilayer flood protection + adaptive building
Greater London – National Park City	London	Declared 2019	Urban planning – Urban region and city level	urban nature + connect natural and ecological context
Copenhagen Strategic Flood Masterplan	Copenhagen	Hennig Larsen, 2013	Urban planning – Urban region and city level	urban interventions for stormwater management
Antwerpen Waterplan	Antwerpen	DE URBANISTEN, 2018/2019	Urban planning / Urban design	planning water city + open waterways to the community
Rainproof Ringsted	Ringsted	DE URBANISTEN, 2016	Urban design – City district and public space level	stormwater solutions as public space + rain garden

Overview of examples tools in addressing climate change provides a framework for developing (climate) sensitive cities: 1) integrated and interdisciplinary (transdisciplinary) approach to planning of sustainability and resilience is achieved by overlapping ecological, social, economic, and cultural benefits; 2) collective (social) and personal (individual) awareness and responsibility in achieving sensitive cities is a public good; 3) education of all stakeholders (quintuple helix of government, industry, academia, public, and environment) in the planning processes as well as integral and interdisciplinary higher education of future professionals and planners.

REFERENCES

1. Omićević, N., Bojanić Obad Šćitaroci, B., 2023: The Urban Rehabilitation of Post-Disaster Scapes, Springer

2. McGregor, A., 2022: Biourbanism, Biourbanism Publishing Pty Ltd

3. Zaninović, T., Sertić Perić, M., Sopina, A., in publishing: Urban ecology within multidisciplinary educative framework, STOO4 conference, 26.-27.09.2024., Zagreb, Croatia

4. Swart, R., Timmermans, W., Boon, E., Van Ginkel, M., Goosen, H., Van Veldhoven, F., Cilliers, J., & Ndaguba, E., 2023: Can Managing Climate Risks Be a Catalyst for Broader Transformative Change? *Social Sciences*, *12*(3), 158.

THE RELEVANCE OF TEACHING THE DISCIPLINE ‘CLIMATE-FORMING ABILITY OF PLANTS IN URBAN LANDSCAPES’ FOR APPLICANTS FOR SPECIALITY 206 ‘GARDEN AND PARK MANAGEMENT’

Yulia Vashchuk, PhD, *Olena Oleshko, Candidate of Agricultural Sciences*

Bila Tserkva National Agrarian University, Ukraine

The relevance of teaching the discipline ‘Climate-forming ability of plants in urban landscapes’ for training specialists in the specialty 206 ‘Garden and park management’ of the second master's level of higher education is revealed, the content of competencies, the acquisition of which is ensured by its study, is analysed. The description and structure of the discipline, which covers 10 topics, are presented. The introduction of the discipline ‘Climate-forming ability of plants in urban landscapes’ into the educational programme of training at Bila Tserkva National Agrarian University is an example of the integration of modern demands of the greening industry and scientific developments in sustainable urban development and climate change mitigation in the urban environment. It broadens the professional outlook of students and increases their competitiveness in the labour market.

Key words: higher education, landscape gardening, professional competences, climate change, green spaces, urban environment.

An important area in the integration of national higher education into the European education system requires attention to the content of educational programmes and the provision of future specialists with skills relevant to the labour market to solve modern problems in the field of professional activity.

Compliance with current trends in the field of landscape gardening includes the formation of students' understanding of ways to effectively manage landscape gardening facilities for the sustainable development of urban ecosystems in the context of climate change [1–3]. The future professional activities of landscape gardening specialists should be aimed at solving practical problems related to the impact of climate change on the functioning of green spaces in urban ecosystems; developing integrated approaches to the formation of green spaces to mitigate the effects of climate change and ensure the environmental safety of urban areas; developing mechanisms for adaptation and stimulating the processes of self-renewal of plant complexes in urban ecosystems.

These problems and trends are the basis for the development of the course ‘Climate-forming ability of plants in urban landscapes’ for master's degree students at Bila Tserkva National Agrarian University.

The elective discipline ‘Climate-forming ability of plants in urban landscapes’ is aimed at developing an understanding of how vegetation affects the climate of the planet, and how plants regulate microclimatic areas of urban landscapes. It also considers mechanisms for increasing the adaptive potential of ornamental plants in the face of global climate change for practical use in greening urban areas, improving the well-being of urban populations, and protecting biodiversity.

The discipline has close direct and indirect interdisciplinary links with the normative courses and the cycle of professional and practical training ‘Ecotechnology in gardening and park management’, ‘Environmental protection in an urban environment’.

The discipline ‘Climate-forming ability of plants in urban landscapes’ consists of a lecture part (20 hours), seminars and practical classes (10 hours) and involves independent work of students (60 hours). The course ends with a test. The effective acquisition of competences occurs in the process of mastering the course material, which consists of 2 content modules and 10 topics (Table 1).

The study of the discipline ensures the formation of a system of general, professional competencies in students in accordance with the Standard of the second master's level of speciality 206 ‘Garden and Park Management’ and the educational programme. General competences: ability to apply knowledge in practical situations; ability to adapt and act in a new situation. Specialist competences: ability to carry out phyto-optimisation of anthropogenically altered landscapes, to select plants for landscaping urban environments of various functional purposes, taking into account the peculiarities of plant interaction and specifics of root nutrition in urban landscapes, as well as their climate-forming ability.

The first module, ‘Climate-forming ability of plants in urban landscapes,’ addresses the role of vegetation in shaping the planet's climate and microclimate in urban environments. In the second module, Mechanisms of Plant Adaptation and Resilience of Plant Communities to Changing Climate Conditions, students consider the impact of climate change on urban ecosystems and learn technologies for plant adaptation to climate change.

Table 1. Characteristics of the lecture course
'Climate-forming ability of plants in urban landscapes'

№ з/п	Title of the lecture topic	The number of classroom hours
Content module 1. Climate-forming ability of plants in urban landscapes		
1	Topic 1.1. Climate, climate system, classification of climates. Planetary role of vegetation.	2
2	Topic 1.2. Features of climatic conditions of urban ecosystems.	2
3	Topic 1.3. The concept of urban landscape. General characteristics of the green infrastructure of populated cities in Ukraine and the European Union.	2
4	Topic 1.4. Climate-forming ability of plants in urban landscapes.	2
Content module 2. Mechanisms of plant adaptation and resilience of plant communities to changes in climatic conditions		
5	Topic 2.1. Changes in climatic conditions and their impact on plant growth and development in urban landscapes.	2
6	Topic 2.2. Adaptation of plants to changes in temperature. Drought and heat resistance.	2
7	Topic 2.3. Mechanisms of plant water metabolism regulation in urban landscapes.	2
8	Topic 2.4. Mechanisms for regulating the phytosanitary condition of urban plantations in the context of climate change.	2
9	Topic 2.5. Effective use of plants in landscaping in different regions of Ukraine and creation of plant communities resistant to climate change.	4

Thus, the course 'Climate-forming ability of plants in urban landscapes' is relevant, broadens the professional outlook of applicants, and highlights the need to take into account climate change for the effective management of gardening facilities and mitigation of social and environmental impacts in Ukrainian cities.

REFERENCES

1. Yakovshina T.F. (2023): EU adaptation to climate change and sustainable urban ecosystems: Textbook, Dnipro: PDABA, pp. 109.

2. Pandey B and Ghosh A (2023): Urban ecosystem services and climate change: a dynamic interplay, Front. Sustain, Cities 5:1281430. doi: 10.3389/frsc.2023.1281430.

3. Vahid Amini Parsa, Esmail Salehi, Ahmad Reza Yavari & Peter M. van Bodegom (2019): Evaluating the potential contribution of urban ecosystem service to climate change mitigation, Urban Ecosystems, Vol. 22, pp. 989–1006.

MECHANISMS FOR CLIMATE SERVICES INTEGRATION INTO THE STRUCTURE OF A 'GREEN UNIVERSITY'

Kateryna Vasiutynska, Assoc. Prof., PhD,
Eleonora Zabarna, Prof., DSc,
Oleh Shablii, Kateryna Husieva, PhD

Odesa Polytechnic National University, Ukraine

The climate service system is an information-and-analytical platform that ensures the collection, analysis, modelling, and interpretation of climate data for decision-making in various activities. Its structure includes four levels: data collection, processing and modelling, interpretation and visualization, and application in management.

Data Layer involves obtaining climate data from satellite systems – Copernicus, NASA, NOAA and WMO, meteorological stations, and sensor networks. Processing and Modelling Layer provides data analysis using artificial intelligence and machine learning methods to create climate models and forecasts. Interpretation and Visualization Layer ensures the graphical presentation of results in the form of maps, 3D models, interactive dashboards, and analytical reports. User and Decision-Making Layer facilitates the use of the obtained data in urban planning, environmental management, education, and research. It is at this level that the possibilities for integration of climate services into educational processes and research activities are formed. This fosters ecological thinking among students and expands interdisciplinary competencies. Building on the newly formulated Sustainable Development Concept, Odesa Polytechnic National University integrates climate services into syllabi, contributing to the training of a new generation of professionals aware of the environmental consequences of their professional activities.

The developed model of a 'Green University' with an integrated climate service (Fig. 1) establishes the foundation for an environmentally responsible academic area. The climate service integrates strategic management, educational processes, scientific research, infrastructure management, student initiatives, and cooperation with the community and businesses into a unified ecosystem. Strategic university management is aimed at implementing climate-oriented education, developing energy-efficient infrastructure, and establishing partnerships with businesses and NGOs. The educational component forms ecological culture through the integration of climate knowledge into academic disciplines and research projects. The research focuses on assessing climate risks, forecasting climate change, and developing innovative environmental solutions. The climate service provides access to high-precision data for modelling climate change scenarios and their impact on urban ecosystems. The research results are integrated into national environmental policy and used in cooperation with enterprises for the implementation of green technologies. Infrastructure activities of the university depend on the analysis of climate data for optimizing energy consumption, monitoring CO_2 emissions, and increasing the resilience of university buildings to climate change. The introduction of green technologies contributes to reduction in the university's environmental footprint.

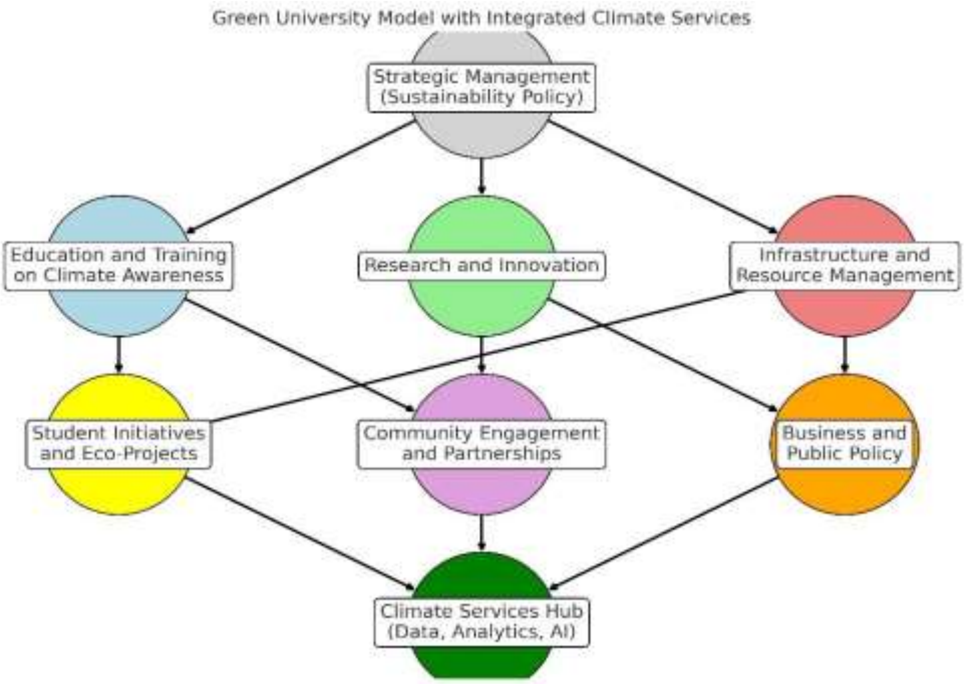
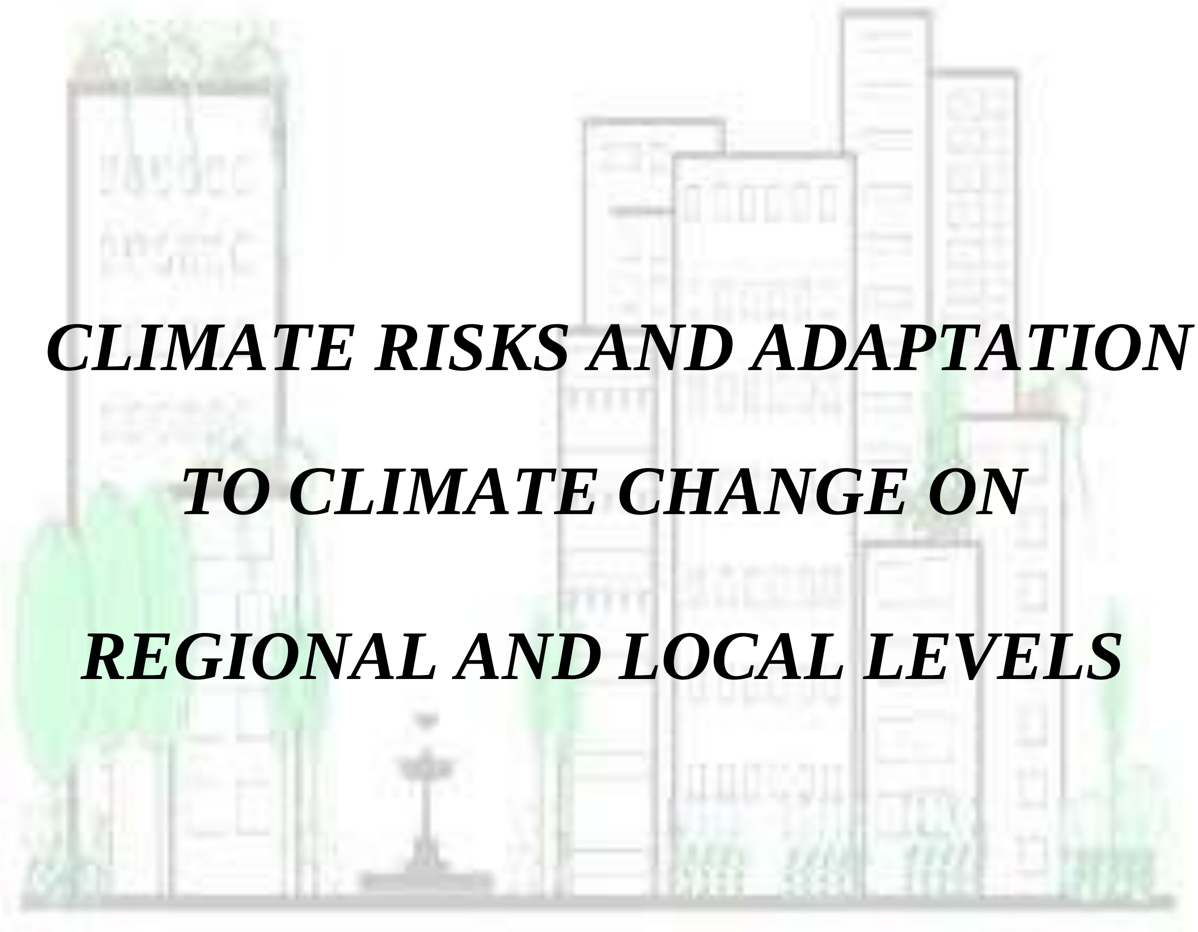


Fig. 1. The Green University Model with Integrated Climate Services

Student initiatives play a crucial role. Climate services enable monitoring the campus's environmental condition, developing adaptation strategies for climate change, and participating in research programmes. Community cooperation ensures the use of climate data for adapting urban infrastructure, developing environmental projects with local organizations, and promoting environmental education. The university serves as a centre for environmental literacy, offering training, open lectures, and consultations on climate change adaptation. Business partnerships further integrate climate services, promoting eco-technology development and optimizing production processes using climate models. The climate service provides data to minimize environmental impact and support corporate environmental responsibility strategies.

A key element of the model is the Climate Services Hub – an analytical centre connecting all university activities. It ensures effective climate change monitoring, enhances academic syllabi, optimizes resource management, and fosters sustainable partnerships.

Thus, the developed model of a ‘Green University’ with integrated climate service contributes to sustainable university development and the creation of innovative environmental solutions for regional and national use.



CLIMATE RISKS AND ADAPTATION TO CLIMATE CHANGE ON REGIONAL AND LOCAL LEVELS

CLIMATE CHANGES AS A CALL FOR WATER SUPPLY OF SOUTHERN UKRAINE

Vira Babienko*[1]*, Prof., Sc.D.,
Andrii Mokienko[2]*, Ass. Prof., Sc.D.,*
Anton Shanigin[1]*, PhD*

[1]Odesa National Medical University, Ukraine
[2]National University «Ostroh Academy», Ukraine

Ukraine is one of the least water-supplied countries in Europe. The Strategy for Environmental Security and Adaptation to Climate Change for the period up to 2030 [1] states: in the South and Southeast, the quality of surface water will deteriorate, which will require both additional water purification measures and possible water transportation to these regions. In case of insufficient surface water, it is necessary to attract water from deep underground aquifers. In case of insufficient recharge of adjacent water bodies from the Dnipro River, measures to limit water supply may be introduced.

The Ukrainian Black Sea coast is the most vulnerable to the risk of water scarcity, as it uses surface water and is the most visited by tourists. The outdated infrastructure of water supply and wastewater systems in this region also contributes to increasing threats.

The tasks aimed at achieving the goals of the Strategy [1] are the construction of new, reconstruction and modernization of treatment facilities and the development of action plans for adaptation to climate change in the areas of water resources management (within the framework of the river basin management plan).

It is expected that as a result of the implementation of the Strategy by 2030, the level of non-communicable diseases will decrease, which will contribute to a decrease in the mortality rate due to diseases caused by the negative impact of environmental factors. At the same time, the authors of the Strategy diligently bypass the more significant and even more difficult-to-solve problem of water-borne infections.

But the feasibility of such plans is questionable, which is convincingly proven in the Report on the Implementation of the Sustainable Development Goal of the SDGs (“Clean Water and Sanitation”) [2]. It is noted that despite significant progress in achieving the indicators of SDG 6 in 2020-2021, a full-scale war not only makes it impossible to achieve them by 2030, but also sets the country back [2].

The only national document that underpins the objectives and indicators of Goal 6 is the Water Strategy of Ukraine for the period up to 2050, approved in December 2022 [3]. It is planned to ensure 100 percent access of the rural and urban population to safe, affordable drinking water by 2030. This will allow for results such as reducing the risks of population diseases associated with the consumption of drinking water of inadequate quality [3].

An analysis of projected climate changes in the Dniester basin showed that the following will be most vulnerable [4].

Water supply. Reducing groundwater, drying of wells and sources - major water suppliers in rural areas. There is a shortage of water resources available at the bottom of the pool and deterioration of water quality.

Population. The risk to life associated with extreme weather and hydrological phenomena. General vulnerability due to low income, social stratification, deterioration of the demographic situation, and reducing the quality of education.

Calculations on the global scenario A1B for the Dniester basin show a probable decrease in the average and minimum runoff in the Middle and lower reaches of the Dniester. This will be accompanied by a deterioration in the quality of drinking water, in particular for the population of Odesa. Even before the war, the improper quality of drinking water caused about 20% of the incidence in Moldova, including acute intestinal and chronic diseases of the digestive and immune systems, urolithiasis and fluorosis) [4].

Conclusion.

Climate change in the near future is a serious threat to the water management of the southern regions (Odesa, Mykolaiv, Kherson, Zaporizhia), which requires urgent development and implementation of appropriate adaptation measures, the main of which should be considered the rational use of existing water resources and their protection from pollution, overcoming unauthorized withdrawal of water resources from surface and underground sources, and encouraging low-water technologies in the region.

REFERENCES

1. The environmental safety strategy and adaptation to climate change for the period up to 2030. Approved by the order of the Cabinet of Ministers of Ukraine from October 20, 2021 N 1363-r. Access mode: https://ips.ligazakon.net/docment/kr211363

2. Report on the implementation of the CSR's Sustainable Development Objective ("Clean Water and Sanitation"). Ukraine, 2023. 14 p.

3. The water strategy of Ukraine for the period up to 2050. Approved by the order of the Cabinet of Ministers of Ukraine of December 9, 2022 No. 1134 p.

4. Strategic directions of adaptation to climate change in the Dniester basin. Envsec. UNEEK. OSCE. 2015. 72 p. ISBN: 978-92-9234-240-1.

CLIMATE BULLETIN OF UKRAINE

Vira Balabukh, Cand. of Geogr. Sciences,
Hanna Dovhal, Yahodynets Stepan.

Ukrainian Hydrometeorological Institute, Ukraine

Due to rapid climate change, there is a growing need for climate services that are based on scientific knowledge and facilitate adaptation to climate change. These services include climate products that track global and regional climate conditions and are part of climate services. Such information is provided by climate bulletins used in different countries and prepared by international organizations, such as WMO, Copernicus, NOAA, and others [1-5].

Climate bulletins allow accumulating knowledge about the past and present state of the climate system, its regional and local features, and contribute to providing an evidence base of climate change and variability for developing climate change adaptation strategies and plans for individual regions, communities, and economic sectors. The obtained operational data on the state and trends of the climate system can be used to support decision-making by government agencies, to substantiate Ukraine's climate policy in the negotiation process, to conduct educational and outreach activities, and to increase the scientific value of climate information.

To assess global and regional climate trends, bulletins mainly use climate indices that reflect long-term changes in key parameters, such as average monthly and average annual surface air temperature and precipitation. However, this information is not enough to assess the impact of climate change on the economy, the environment, and human life. Reliable and regular operational information on climate variability and change and other factors, their trends and spatial and temporal features is needed.

The electronic climate bulletin developed by the UkrGMI of the SES of Ukraine and the National Academy of Sciences of Ukraine allows for online monitoring of current changes not only in the average annual, seasonal, and monthly air temperature and precipitation, but also other indicators of temperature, humidity, and wind conditions.

The Climate Bulletin is implemented as a Web application. It provides two levels of users: Developer and Consumer. The Developer creates the Bulletin by selecting the required region, indicator, period in relation to which anomalies are calculated (1961-1990, 1981-2010, 1991-2020), builds the relevant maps, graphs, tables, analyzes and describes them by filling in the appropriate forms. The Consumer can only view the product created by the Developer and use the information received.

There are three types of bulletins in the Climate Bulletin: Basic, Specialized and User. The Basic Bulletin provides information on the values and anomalies of the main climatic indicators: average, average maximum and average minimum air temperature and precipitation for a selected period (month, season, year) for a selected region/oblast/observation point. The Specialized Climate Bulletin provides information on specialized climate indicators for the priority areas of climate services: energy, agriculture, water resources, health, transport and construction. In particular, the Specialized Climate Bulletin presents such characteristics of the temperature regime as the duration of warm and cold periods, the number of days with vegetation and active vegetation, the number of summer days and tropical nights, the number of hot days with a maximum daily air temperature of 25 °C and above and 30 °C and above, the number of days with a minimum daily temperature below -10°C and -20°C, with an average daily air temperature of 8°C and below, which characterizes the duration of the heating season. To characterize the humidification regime, the Specialized Bulletin provides information on the number of days without significant precipitation (less than 1 mm per day), the number of days with precipitation of more than 1 mm and more than 5 mm per day. To assess the change in the wind regime, we use the number of days with calm, with an average daily wind speed of 3 m/s and above and 6 m/s and above, with a maximum daily wind speed of 10, 15 and 25 m/s and above.

The User bulletin allows you to generate a bulletin from indicators of the user's choice for a specified or self-created region. Such a region can be a river basin, a territorial community, etc. that are not included in the list of pre-created regions.

The Climate Bulletin allows for the creation of other products used for climate services, including analytical reviews of climate change trends and peculiarities of weather and climate conditions for each year in Ukraine as a whole and in individual regions and oblasts. Such reviews are part of the National Environmental Reports prepared by the Ministry of Ecology and other national and international documents.

REFERENCES

1. 2024 State of Climate Services. [Electronic resource]: https://wmo.int/publication-series/2024-state-of-climate-services

2. Annual Global Climate Report/ National Centers for Environmental Information NOAA [Electronic resource]: https://www.ncei.noaa.gov/access/monitoring/monthly-report/global/202213

3. Climate Bulletins/Copernicus [Electronic resource]: https://climate.copernicus.eu/climate-bulletins

4. Monthly climate diagnostic bulletin – African Regional Climate Centre (ACMAD) [Electronic resource]: https://acmad.net/rcc/index.php

5. State of the Climate. Bulletin of the American Meteorological Society. [Electronic resource]: https://www.ametsoc.org/index.cfm/ams/publications/bulletin-of-the-american-meteorological-society-bams/state-of-the-climate/

CONTEMPORARY TRENDS IN SOIL TEMPERATURE CHANGES, THEIR CONSEQUENCES AND ADAPTATION OF THE TERRITORY

Svitlana Budnik, Sc.D.

Boris Sreznevsky Central Geophysical Observatory, Kyiv, Ukraine

Climate change, one way or another, affects all aspects of the functioning of natural and anthropogenic systems. Soil cover is no exception to this rule. A direct consequence of climate change is a change in the temperature regime of soils, which affects the processes of soil formation, the formation of conditions for the occurrence of soil droughts, the accumulation of heat in the soil layer contributes to the occurrence of forest fires, overheating of surfaces in populated areas adversely affects the well-being of the population, etc..

High soil temperature disrupts energy metabolism in plants and prevents protein synthesis, cells lose their osmotic properties and are destroyed [4]. For many plants, a temperature of 40 °C is critical, at which many normal physiological functions of plants are inhibited, which leads to their death. Succulents and cacti can tolerate fairly high temperatures. Some blue-green algae are the most heat-resistant, they tolerate temperatures up to 70 °C [4]. The optimal soil temperature for sunflower seed germination is 25 °C, on average, the maximum temperature for seed germination usually does not exceed 40–45 °C, however, some hybrids continue to germinate at temperatures up to 48.9 °C [3]. In the soil temperature range of 10–24 °C, the metabolic rate of soil macroorganisms increases, which requires them to either eat more or burn their own fat reserves. [2]. At extremely high temperatures of 58 °C, soil macroorganisms die due to unfavorable soil temperatures. Soil temperatures of 40 °C and above slow down the growth of microorganisms in the soil. If the soil temperature reaches 60 °C and above, microorganisms die [5], etc. Temperature affects the content of carbon dioxide in the soil air. High temperature stimulates the activity of microorganisms, which leads to an increase in the production of carbon dioxide in the soil [1].

Analysis of long-term series of observations of soil temperature at the Kyiv, Pokoshichi and Lugansk meteorological stations shows that over the past 30-40 years there has been a tendency to increase both the average soil surface temperature and the absolute maximum and minimum soil temperature (Fig.). A good correlation with the sum of air temperatures for the year is shown by the average annual soil temperature, the correlation with the sum of temperatures for the vegetation period is weaker, which most likely indicates the influence of cooling of the soil layer in the winter. The correlation with the sums of air temperatures for different periods of extreme characteristics of the soil surface temperature is weak. Since here the influence of precipitation, wind, cloudiness, etc. is felt to a greater extent. The change in the sums of soil temperatures for the year and for the vegetation period in the long-term context tends to converge, since temperatures increase in the winter.

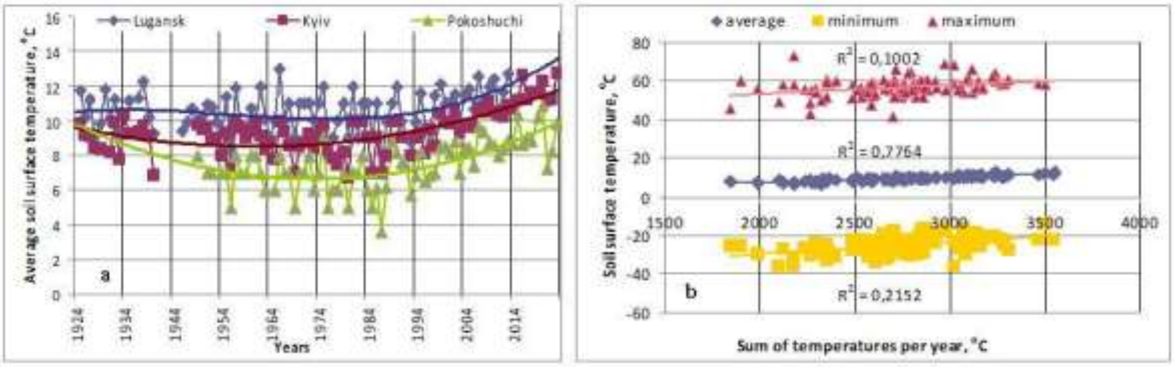


Fig. 1. a) Change in time of average annual soil surface temperature at the Kyiv, Pokoshichi and Lugansk meteorological stations; b) Dependence of average annual soil surface temperature and absolute maximums and minimums of soil surface temperature for the year at the Kyiv meteorological station on the sum of air temperatures for the year.

Conclusions. At present, the accumulation of cold in the thickness of subsoil during the winter period acts as a restraining buffer against the growth of extreme soil temperatures. In order to adapt natural and anthropogenic systems to the ongoing climate changes, it is necessary to fill them with vegetation cover as much as possible, which is capable of reducing the heating of the soil and other surfaces, and to create a favorable microclimate. Namely: plant trees and shrubs, do not mow lawns without urgent need. These measures have a multifaceted purpose - protection from the sun, wind, water, cleaning the air from pollutants, filling it with phytoncides that have a beneficial effect on the epidemiological situation, etc. In agriculture, apply crop rotations with maximum filling of fields with cultivated vegetation throughout the year, apply strip placement of crops, etc.

REFERENCES

1. Allison S.O., 2005: Cheaters, diffusion and nutrient content decomposition by microbial enzymes in spatially structured environments. Ecology letters, 2005;8(6):626–635.

2. Conant RT, Drijber RA, Haddix MC., 2008: Sensitivity of organic matter decomposition to warming varies with its quality. Global change biology, pp. 14(4):868–877.

3. Khalifa F.M., Schneiter A.A., Eltayeb E.I., 2000: Temperature-germination responses of sunflower (Helian- thus annuus L) genotypes //Helia, V. 23, No 33, pp. 97–104.

4. Лебедев С.И. 1988: Физиология растений. М.:Агропромиздат, 544 с.

5. Maitland Katherine, 2014: Soil temperature impact of stubble critical for soil and plant health. SANTFA The Cutting Edge AUTUMN. p. 50-51.

POSSIBILITIES OF USING BIOCLIMATIC INDEXES TO ASSESS WEATHER COMFORT

Vitalina Fedoniuk*[1]*, PhD (Geography), Assistant Professor,
Marharyta Pavliuk [2]*,*
Mykola Fedoniuk[1]*, PhD (Geography), Assistant Professor*

[1]*Lutsk national technical university, Ukraine*
[2]*Volyn JAS Regional Department, Ukraine*

The favorableness, or comfort, of weather and climatic conditions has a great influence on the quality of human life. It is characterized by the help of bioclimatic indices, one of which is the bioclimatic index of pathogenicity of weather conditions by V.G. Boksha [1]. The number of meteosensitive people is increasing in the world, the issue of assessing the favorableness of weather conditions is very relevant, this determined the choice of the topic of the work.

The purpose of the study was to analyze the favorableness of weather and climatic conditions in the regions of Ukraine using the bioclimatic pathogenicity index of V.G. Bokshi, the calculation method of which was evaluated by Pavliuk M.M., Stashchuk A.P., Fedoniuk V.V. in the article [1]. The theoretical foundations of the study of the comfort of weather and climatic conditions were analyzed in the works of Fedoniuk V.V., Zhadko O.A., Ivantsiv V.V., Fedoniuk M.A. [2, 3, 4], which the authors relied on. In the process of the study, the authors systematized and statistically processed meteorological information in 26 cities of Ukraine (regional centers and the city of Sevastopol) for the period 2018 - 2023; calculated daily, average monthly, average annual and average values of the total pathogenicity index for the studied period. A set of tables and graphs was constructed in Excel, and a set of cartograms and cartograms in Surfer. The final cartogram of the spatial distribution of the pathogenicity index within the territory of Ukraine in 2018–2023 is presented in Fig. 1.

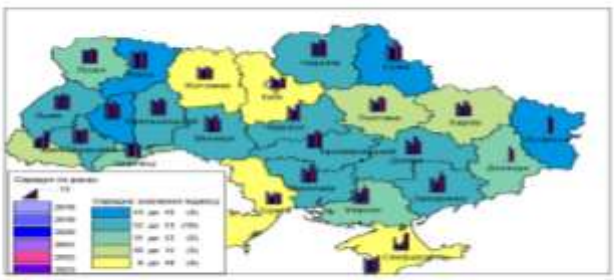


Fig. 1. Distribution of average annual values of the bioclimatic pathogenicity index of Ukraine.
Note: bar charts – average annual valuesof the index in cities, cartogram – average index value for the period 2018-23 (developed by the authors)

Using ICT methods, two online bioclimatic index calculators have also been developed (the first one allows manual input of weather data, the second one is automated, for the city of Lutsk). The automatic index calculator for the city of Lutsk uses weather data from an automatic weather station operating at the Lutsk National Technical University. You can learn more about the operation of the index calculators in the Menu of the educational website of Volyn JAS Regional Department: https://pogoda3kota.blogspot.com/

The program that was developed for the operation of the automatic calculator can be used in the future for similar automated weather stations anywhere in the world, and the value of the bioclimatic index calculated by the program can be added to weather forecasts to inform people about the comfort of meteorological conditions today, tomorrow, or on any day for which the weather forecast is given.

Research results: the features of fluctuations, temporal and spatial dynamics of the bioclimatic index Isumar and its intermediate components (dynamics of temperature, relative humidity, wind speed, atmospheric pressure, interdaily changes in temperature and pressure) within Ukraine were determined. A set of maps was constructed that represent the spatial and temporal dynamics of the index and the favorableness of weather and climatic conditions in modern conditions of climate change.

REFERENCES

1. Pavliuk M.M.., Stashchuk A.P., Fedoniuk V.V. Analiz bioklimatychnykh indeksiv ta komfortnosti klimatu u m. Lutsku. *Stalyi rozvytok: zakhyst navkolyshnoho seredovyshcha. Enerhooshchadnist. Zbalansovane pryrodokorystuvannia*. IX Mizhnarodnyi molodizhnyi konhres, 28-29 bereznia 2024, Lviv : Lviv : zb. mater. El. dan. K. : Yarochénko Ya. V., 2024. S. 20 – 21. DOI: https://doi.org/10.51500/7826-43-8 [in Ukrainian]

2. Fedoniuk V.V., Zhadko O.A., Ivantsiv V.V., Fedoniuk M.A. Porivnialnyi analiz komfortnosti pohody protiahom kurortnoho sezonu v natsionalnykh pryrodnykh parkakh Volyni. *Ekolohichni nauky:* naukovo-praktychnyi zhurnal. K.: Vydavnychyi dim «Helvetyka», 2023. № 4 (49). S. 232 – 237. URL: http://ecoj.dea.kiev.ua/archives/2023/4/31.pdf [in Ukrainian]

3. Fedoniuk M.A., Fedoniuk V.V., Ivantsiv V.V. Possibilities for improvement of environmental monitoring of precipitation in the city (a case of Lutsk). *Visnyk of V.N. Karazin Kharkiv National University, series «Geology. Geography. Ecology»*. Kharkiv : 2019. V. 50. P. 210-219. DOI: https://doi.org/10.26565/2410-7360-2019-50-16

4. Fedoniuk V.V., Fedoniuk M.A. Doslidzhennia sezonnoi dynamiky atmosfernoho tysku v m. Lutsku. *Fizychna heohrafiia ta heomorfolohiia*. 2016. Vyp. 4 (84). S. 82-89. [in Ukrainian]

COAL CREDITS AS AN INSTRUMENT OF SUSTAINABLE DEVELOPMENT

Anhelina Dokus, PhD (Geography), researcher of the department
Integration of Science, Education and Business

Institute Of Market And Economic&Ecological Researches
of the National Academy of Sciences of Ukraine, Ukraine

In 2015, an agreement on climate change control was signed in Paris. Its main goal is to protect the environment and limit the annual increase in average temperature to 1.5–2°C compared to pre-industrial levels. The countries that signed this agreement committed to reducing emission levels without decreasing overall food production.

Ukraine also ratified the Paris Climate Agreement and was expected to reduce emissions by 35% compared to 1990. However, it is important to understand that since the 1990s, many large industrial enterprises have ceased operations. As a result, calculations show that greenhouse gas emissions in Ukraine decreased by 62.5% from 1990 to 2021, meaning the target was exceeded by almost twice.

Therefore, the reference point was set to the last year before the pandemic, and the Ukrainian government committed to reducing greenhouse gas emissions by 7% by 2030 compared to the pre-COVID year of 2019.

Carbon credits are a universal tool that grants the right to emit or confirms emission reductions, facilitating the creation of carbon markets at both national and international levels. Carbon credits is a general term referring to a specific electronic asset that grants permission for emissions or verifies the reduction of a certain volume of greenhouse gas emissions (typically, one carbon credit corresponds to one ton of CO_2 equivalent emissions) [1].

The presence of supply and demand for carbon credits has led to the creation of carbon markets, where the corresponding carbon units are bought and sold. Such transactions can take place either through direct agreements between companies or via specialized electronic platforms. To offset carbon emissions from their activities, companies purchase so-called "carbon credits" on the international carbon market, thereby supporting the restoration of natural areas that can absorb and retain this carbon. Currently, the carbon credit mechanism is primarily designed for the restoration of forests and wetlands.

The world's largest platform for trading such quotas is the European Emissions Trading System (EU ETS). It was launched to help achieve the EU's climate goal of reducing greenhouse gas emissions by at least 40% from 1990 levels by 2030. However, credits earned through agriculture are not yet traded there, so startups are currently focusing on the commercial market.

According to various estimates, the agricultural industry is responsible for 25-35% of global CO_2 emissions, which is more than the entire transportation sector. This number can be reduced by increasing the humus content in the soil. If the organic matter content in one hectare of land increases by one percent, the soil can capture 12 tons of CO_2 and retain up to 225 liters of water. By increasing humus levels, farmers can make their land more resilient to climate change and earn carbon units-credits for the amount of CO_2 removed from the atmosphere.

Carbon credits are generated according to specific rules and procedures and are recorded and tracked in specialized electronic registries.

There are many types of carbon units and, accordingly, various mechanisms for their creation, including: carbon units generated within national, regional, or municipal emissions trading systems (e.g., the European Emissions Trading System (EU ETS)); carbon units created by governments under international agreements (e.g., emission reduction units from Joint Implementation projects under the Kyoto Protocol or carbon units to be generated under the new mechanisms of the Paris Agreement); carbon units produced through regulated national or regional emission reduction project mechanisms (e.g., carbon units from Australia's Carbon Farming Initiative); carbon units issued under existing voluntary carbon market standards (e.g., Gold Standard for Global Goals or Verra Verified Carbon Standard); other types of carbon units, such as regional voluntary initiatives for wetland restoration, like MoorFutures.

On May 16, 2022, the United Nations Development Programme (UNDP) office in Ukraine, as part of the "Support to Green Recovery in Ukraine" project, published a detailed report on international voluntary and compliance carbon markets. The report, authored by international consultant Fortunato Costantino, focuses on mechanisms applicable to low-carbon agriculture and potential opportunities for Ukrainian developers [2].

There are two types of carbon markets: the "voluntary market" and the "compliance market" (also referred to as the "regulated market").

The compliance carbon market is used by companies and governments that are legally required to offset their emissions. Participants in these markets include countries that have adopted and approved emission limits set by the United Nations Framework Convention on Climate Change (UNFCCC).

On the other hand, the voluntary carbon market operates outside compliance markets but alongside them, allowing private companies and individuals to purchase carbon offsets voluntarily. The primary purpose of purchasing Verified Emission Reductions (VERs) is to neutralize carbon footprints, mainly driven by corporate social responsibility (CSR), public perception, certification considerations, reputation management, and achieving environmental and social benefits.

The key difference is that Verified Emission Reductions (VERs) from the voluntary market cannot be used to fulfill Kyoto Protocol obligations, unlike Certified Emission Reductions (CERs) from the compliance market. However, CERs can be accepted by entities wishing to voluntarily offset their emissions.

Ukraine already has some experience in utilizing carbon credits. Notably, the Carbon Credit Ukraine (CCU) project, supported by HeavyFinance, EIF, and Ukrainian partners, aims to develop local carbon offset projects in the agricultural sector. Rewilding Ukraine is implementing a project to assess carbon sequestration in steppe ecosystems to integrate them into the carbon credit system. Additionally, the American startup Indigo Agriculture, in collaboration with IFC, is exploring the possibility of launching a carbon credit trading marketplace in Ukraine.

Carbon credits offer significant opportunities for the sustainable development of Ukraine's agricultural sector, contributing to greenhouse gas emission reductions, increasing farmland resilience, and creating new income sources for farmers. The successful implementation and growth of this mechanism require: a favorable regulatory framework, investment attraction, development of transparent and verified accounting and monitoring systems, active participation of Ukrainian farmers in national and international carbon markets.

Further research and the practical implementation of pilot projects will be key to unlocking the full potential of carbon farming in Ukraine.

REFERENCE

1. WWF-Ukraine. URL: https://nbs.wwf.ua/
2. Report on international voluntary and mandatory carbon markets with a special focus on mechanisms applied in the case of low-carbon agriculture and potential opportunities for Ukrainian developers URL: https://www.undp.org/

SPATIOTEMPORAL VARIABILITY OF MONTHLY RUNOFF AT RIVERS OF THE TISZA SUB-BASIN UNDER CLIMATE CHANGE

Maryna Goptsiy [2]***, PhD***, *Valeriya Ovcharuk* [1]*, Prof., Sc.D., Yurii Pozdnyakov*[1]

[1] Odesa I. I. Mechnikov National University, Ukraine
[2] Taras Shevchenko National University of Kyiv, Ukraine

The water regime of the rivers is uneven both throughout the year and from year to year, as it depends on feeding, the ratio of snowmelt and rainwater, and temperature conditions. The Carpathian region is the most flood-prone region of Ukraine, and such uneven runoff distribution in the Tisza sub-basin often leads to hydrological hazards such as floods and inundations. In certain periods of prolonged low-water years, there are risks of drought.

According to studies by many domestic and foreign scientists, changes in precipitation distribution throughout the year are expected, which may lead to increased periods of drought and decreased runoff in summer, as well as increased runoff in winter due to more frequent thaws. Climate change also leads to an increase in the frequency and intensity of extreme precipitation, which can cause sudden and significant floods. This is especially dangerous for mountain rivers, where runoff velocity is high, and the risk of landslides and mudflows is significantly increased.

Therefore, the study of the spatial and temporal distribution of runoff and its intra-annual distribution, as well as the determination of the characteristics of seasonal runoff distribution, allows for the identification of trends and dynamics of changes caused by climatic factors, the assessment of their impact on water resources, and the forecasting of future changes in the water regime and the development of adaptation strategies.

Let's consider the runoff distribution by months (Fig. 1) and seasons, using the example of control catchments with an average annual runoff of 27.3-31.5 l/(s·km^2) for the rivers of the eastern part, 24.5-26.5 l/(s·km^2) for the central part, and 16.5-21.1 l/(s·km^2) for the western part.

It should be noted that the monthly runoff in the rivers of the Tisza sub-basin varies significantly throughout the year. For example, in the rivers of the eastern part of the sub-basin, 4.3-4.9% is formed per month in January and February, while in the rivers of the central and western parts, 5.9-10.1% is formed.

It should also be noted that in March and April, the rivers of the central and western parts of the sub-basin experience a spring flood with a total runoff share of 27.7-32.2% (monthly runoff share – 13.8-17.3%). In the rivers of the eastern part of the sub-basin, the runoff share for March is 7.1-7.8%, and the spring flood is formed in April and May with a monthly runoff share of 14.1-17.3%.

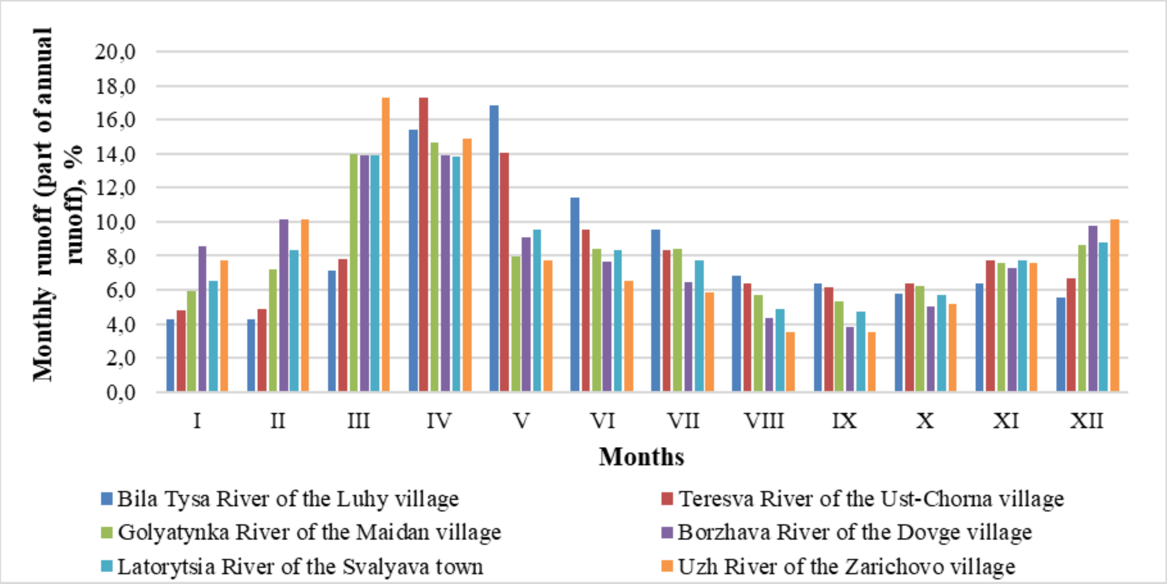


Fig.1. Spatial and temporal variability of runoff distribution by months (percentage of annual runoff) in the rivers of the Tisza sub-basin

In the central and western parts, during the summer-autumn low water period (from May to November), 3.5% to 9.5% of the annual runoff is formed. In total, 39.8-49.5% of the annual runoff is formed during this period. The smallest monthly runoff is formed in August (3.5-4.9%) and September (3.5-5.3%). In the winter low water period (from December to February), 5.9-10.1% of the annual runoff is formed monthly. Accordingly, 21.8-28.0% of the annual runoff is formed during the winter season.

A slightly different runoff distribution is observed in the eastern part of the sub-basin. Here, the least water-abundant months are January (4.3-4.8%) and February (4.3-4.9%). Accordingly, the least water-abundant winter season (total seasonal runoff 14.1-16.3%) is when the rivers are ice-covered, and snow accumulation is observed in the catchments. The beginning of melting starts in March, with a certain increase in runoff in the rivers, and the flood peak occurs in April-May. In total, 39.1-39.4% is formed during the spring flood period. Runoff in June (9.6-11.5%) and July (8.4-9.6%) is still higher than the pre-flood runoff due to intense precipitation. And in the period from August to November (summer-autumn low water season), 24.6-26.6% is formed (monthly runoff share – 6.1-7.7%).

Conclusion. The study of mountain river runoff distribution is important for ensuring ecological sustainability, water resource management, and adaptation to climate change. The monthly runoff in the rivers of the Tisza sub-basin has significant variability throughout the year, but a similar amount of runoff is formed in all rivers during the period from March to May – 38-39% of the annual runoff. It should also be noted that for the rivers of the eastern part of the sub-basin, more runoff is formed during the summer-autumn period than in the rivers of the central and western parts, and vice versa in the winter season.

CLIMATE SERVICES FOR SUSTAINABLE WATER QUALITY MANAGEMENT IN THE BLACK SEA BASIN

Natalia Kichuk, PhD in Geography, Assoc. Prof.,
Liliia Kushchenko, Senior Lecturer

Odesa I. I. Mechnikov National University, Ukraine

The hydrological and hydrochemical characteristics of rivers in the Black Sea basin are undergoing significant transformations due to climate change and anthropogenic factors. Climate services play a crucial role in managing these water resources by integrating monitoring, modeling, and forecasting systems to assess water quality and hydrological changes. The application of climate services ensures sustainable resource use, minimizes pollution risks, and enhances the resilience of aquatic ecosystems.

Long-term hydrological observations of the Sarata, Khadzhyder, Kaplan, Alkaliya, and Kogylnyk rivers indicate a declining trend in water flow and deteriorating water quality. Increasing extreme weather events, combined with agricultural runoff, have led to elevated pollutant concentrations and reduced freshwater availability. The accumulation of organic and mineral substances negatively affects aquatic ecosystems, exacerbating degradation processes that threaten biodiversity and limit the usability of water for drinking and irrigation. Changes in river runoff alter the dilution capacity of pollutants, worsening water quality under low-flow conditions.

This study assesses the ecological state of these rivers based on water quality indices such as the modified Water Pollution Index (WPI) and the Pollution Coefficient (PC), which offer a comprehensive evaluation from different perspectives. Results indicate that Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD5) significantly contribute to water pollution, exceeding maximum permissible concentrations (MPC) by 1.1 and 14.7 times, respectively, in 2013 (Fig.1). Additionally, ammonium nitrogen concentrations have remained consistently high across all study years, further signaling poor water quality.

Currently, the studied rivers exhibit a negative ecological state based on both methodologies (Fig.2). Without urgent intervention, excessive exploitation of water resources, river regulation, extensive water withdrawal for irrigation and domestic use, and the transformation of rivers into wastewater collectors could lead to irreversible degradation or even their disappearance.

Integrating climate services into water resource management allows for the development of targeted adaptation measures, including optimizing wa ter allocation, improving wastewater treatment, and implementing nature-based solutions.

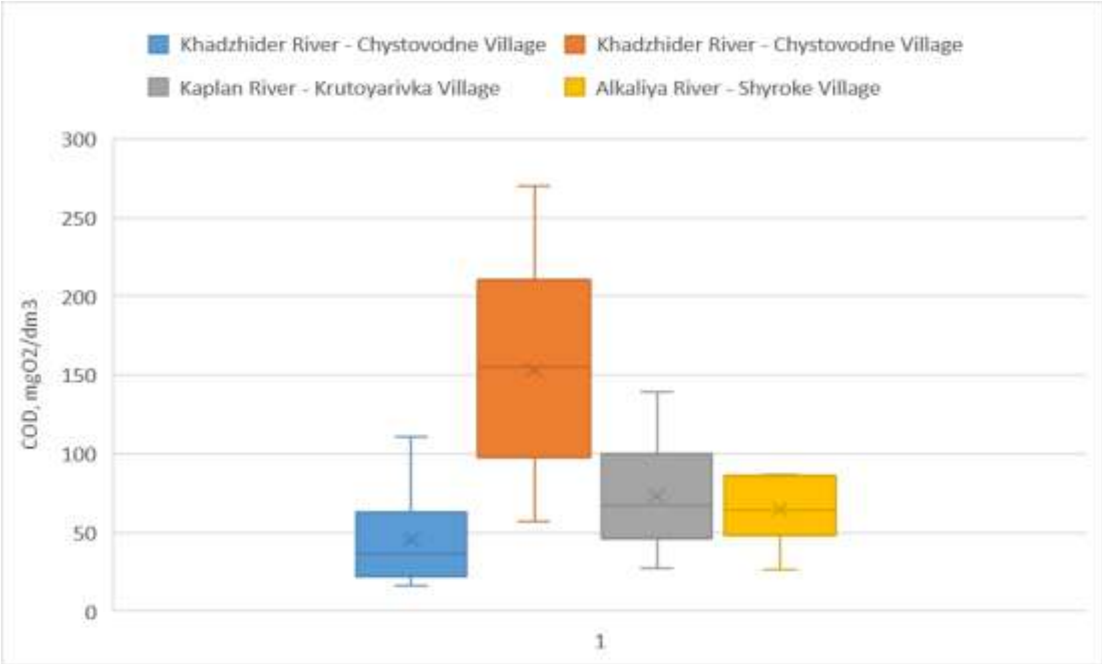


Fig. 1. Range of average annual COD values for the studied rivers of the Black Sea region for the period 2013 -2021.

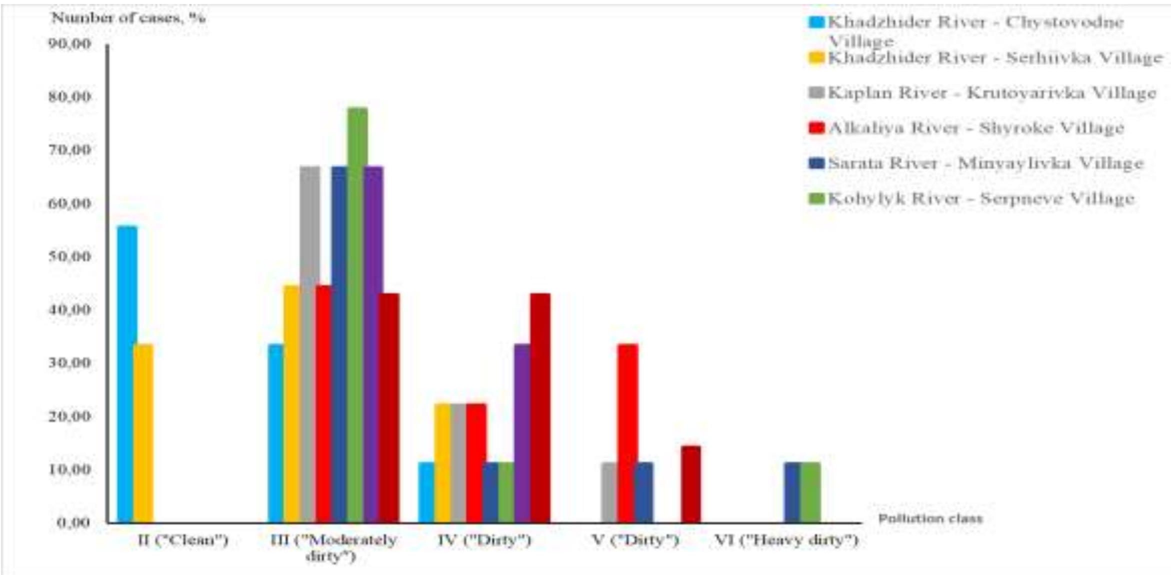


Fig. 2. Repeatability of pollution classes according to the modified ISR method in the studied rivers of the Black Sea region (2013-2021)

Forecasting models enable early identification of risks such as eutrophication, salinization, and contamination from industrial and agricultural sources. Given projected climate trends, future water resource planning should prioritize real-time data analysis, risk assessment, and mitigation strategies. Expanding the role of climate services in water management policies will enhance adaptive capacity, safeguard freshwater resources, and promote ecological stability in the Black Sea basin under changing environmental conditions.

REGIONAL PECULIARITIES OF THE DNIESTER RIVER RUNOFF CHANGES UNDER CLIMATE CHANGE CONDITIONS

Vasyl Grebin*[1], *Prof., Sc.D., *Vira Balabukh*[2], *PhD,*
Maryna Goptsiy[1], *PhD; Gherman Bejenaru*[3], *PhD*

[1] Taras Shevchenko National University of Kyiv, Ukraine
[2] Ukrainian Hydrometeorological Institute of the State Emergency Service of Ukraine and the National Academy of Sciences of Ukraine, Ukraine
[3] National Administration "Apele Moldovei", Moldova

The Dniester River Basin represents an important water resource for Ukraine and Moldova, providing drinking water, irrigation and hydropower to millions of residents in the region.

This study is based on hydrometeorological observation data, analysis of temperature regimes, precipitation, evapotranspiration, and river runoff. Climate change scenarios SSP2-4.5 and SSP5-8.5 from the Sixth Assessment Report of the IPCC are used, which allow for forecasting the future state of water resources. Projections are based on an ensemble of CMIP6 climate models, corrected using the quantile delta mapping method.

The hydrological regime of the Dniester basin is formed under the influence of climatic conditions, which have undergone significant changes in recent decades. Changes in the temperature regime and redistribution of precipitation have a direct impact on the river's water content, as well as on the processes of evapotranspiration, infiltration, and surface runoff. An assessment of long-term water balance trends, taking into account projected climatic conditions, has been conducted.

Analysis of the thermal and moisture regimes of the Dniester basin for the period 1991-2020 shows clear warming trends (relative to the period 1961-1990), especially in summer and winter. The average annual temperature has increased by 0.7-1.2°C, with summer months showing an increase of 1.5-2.0°C. Summer precipitation has decreased by 15-30%, exacerbating regional aridity and lowering groundwater levels. Winter precipitation has increased by 10-15%, leading to increased winter runoff and frequent floods.

Over the past 30 years (1991-2020), the Dniester basin has experienced significant changes in its hydrological regime due to climatic factors and anthropogenic influences. The total volume of water resources has decreased by 10-25% compared to the climatic period of 1961-1990. The average annual runoff in the lower reaches of the river has decreased by 15-30%, especially in dry years. Spring floods have become less pronounced, and the summer low-water period has lengthened. In summer, the river's water content decreases by an average of 20-40%. In winter, runoff increases by 10-15% due to increased rainfall, leading to flood risks.

Projected temperature changes in the Dniester basin for the period 2041-2060 show a persistent upward trend. The average annual air temperature is expected to increase by 1.8-2.7°C under the moderate climate change scenario (SSP2-4.5) and by 3.5-4.5°C under the intensive warming scenario (SSP5-8.5).

Annual precipitation may decrease by 10-20%, with a decrease in summer and an increase in winter. In dry years, the decrease in summer precipitation could reach 35%.

Consequently, the total river runoff will decrease by 15-30%, and in summer by 40-50%, exacerbating the water deficit in the lower reaches of the river.

Analysis of changes in the Dniester's water content indicates the need for urgent measures for adaptation and sustainable water resource management.

Within the Upper Dniester region, a decrease in average annual runoff values of 10-12% is expected. As in the current period, more than half of the annual runoff volume (56-57%) will occur during the summer-autumn low-water period. About a quarter of the annual runoff volume will occur during the spring flood, and only 17-18% during the winter low-water period (December-February). The distribution of runoff across individual hydrological seasons remains, with a corresponding decrease in absolute values.

For the Middle Dniester region, a decrease in average annual runoff values of 19-21% is expected. The distribution of runoff across individual hydrological seasons remains, with a corresponding decrease in absolute values of 16-21%. As in the current period, more than half of the annual runoff volume (54-55%) will occur during the summer-autumn low-water period. About a quarter (23-24%) of the annual runoff volume will occur during the winter low-water period, and only 17-18% during the spring flood (March-April), the significance of which in the intra-annual runoff distribution will decrease.

Within the Lower Dniester region, a decrease in average annual runoff values of 25% is expected. Unlike the upper and middle parts of the basin, the intra-annual runoff distribution of the Lower Dniester rivers will change. The proportion of spring flood runoff from the annual runoff volume will increase from 9.9% to 16.5% for the left tributaries of the Lower Dniester and decrease from 12.7% to 10.4% for its right tributaries. Accordingly, the proportion of summer-autumn low-water runoff will decrease from 65.9% to 58.1% for the left tributaries of the Lower Dniester and increase from 63% to 65% for its right tributaries. The proportion of winter low-water runoff will remain unchanged for both left and right tributaries compared to the current period.

REFERENCES

1. CMIP6: the next generation of climate models explained. CarbonBrief. https://www.carbonbrief.org/cmip6-the-next-generation-of-climate-models-explained/

2. ClimUAm: Ukrainian gridded monthly air temperature (min, max, mean) and atmospheric precipitation data (1946-2020). https://doi.org/10.15407/uhmi.report.02

GENERATING AND CONTROLLING HEAT WAVES IN UKRAINE

Inna Khomenko, Assoc. Prof., *Nadiia Prykhodko, PhD stud.*

Odesa I. I. Mechnikov National University, Ukraine

Introduction. Heatwaves, characterized by persistently extreme high temperatures, have become increasingly frequent and intense in recent decades. These phenomena, driven by global climate change, have catastrophic consequences for public health, the economy, and ecosystems. Given the forecasts for an increased likelihood of heatwaves in the future, it is crucial to comprehensively study the physical mechanisms that cause their formation and maintenance.

The aim of this study is to identify large-scale conditions and circulation anomalies that contributed to the establishment and persistence of abnormally hot weather during eleven of the most intense heatwave episodes that occurred in Ukraine between 1961 and 2020.

To detect blocking processes, fields of geopotential height on the 500 hPa isobaric surface from NCEP/NCAR for 00 and 12-hour periods [1] and fields of averaged temperature at 2 meters, sea level atmospheric pressure, geopotential height at 500 hPa, zonal wind speed, and relative humidity [2] during the heatwave period were used at nodes of a regular latitude-longitude grid with a resolution of 2.5ºx2.5º for the region bounded by 30° to 85° N and 0° to 60° E.

Backward trajectories for air particles were constructed using the NOAA HYSPLIT Trajectory Model [3].

Results. The study identified 11 cases of mega-heatwaves observed in Ukraine. The most powerful heatwaves were considered those with an average HWMId index value (proposed in [4]) greater than the threshold of 15 and a maximum value over 20. A compilation of mega-heatwaves from 1961–2020 was made and kindly provided by colleagues from the Meteorology and Climatology Department at Taras Shevchenko National University of Kyiv, Professor O. Shevchenko and Professor S.I. Snizhko.

In this work, each episode of mega-heatwaves was classified according to the heatwave classification proposed in [5], which was based on the analysis of sea-level pressure fields, temperature advection at 850 hPa, and the position of the jet stream at 300 hPa.

According to this classification, all five cases were classified into two types: radiation-advection, where the radiation factor plays the most significant role, and advection-radiation, where the advection factor plays the most significant role.

The most intense heatwave occurred in July-August 2010, when a 55-day-long anticyclone over European Russia caused abnormally hot and dry weather in the northern hemisphere, with daily temperature anomalies reaching 10°C in the boundary layer. This was classified as a radiation-advection type (subtype A1).

The 2015 heatwave, which lasted longer and covered Ukraine, formed in a branch of the Azores anticyclone with temperature anomalies up to 6–7°C. It also followed the radiation-advection type and had anticyclonic circulation in the upper troposphere.

The 1994 heatwave lasted 16 days and affected less than 20% of Ukraine, with anomalies of up to 6°C. Blocking was visible in the Tibaldi-Molteni index, and a Rossby wave and anticyclone appeared in the upper troposphere.

In 1964, a prolonged heatwave with temperature anomalies of up to 5°C formed in the Azores anticyclone, with a Rossby wave in the upper troposphere. Blocking was significant at the start and end of the period.

In 2012, two heatwaves occurred. The first, less intense, had anomalies up to 6°C, with weak anticyclonic circulation. The second, more intense, lasted 14 days and was classified as advection-radiation type (B2), with warm air from North Africa and reinforced by heat from the Caucasus and Iranian Plateau.

The 2007 heatwave, associated with a high-pressure belt extending from the Azores anticyclone, had significant temperature anomalies and anticyclonic circulation in the upper troposphere, classified as radiation-advection type (A2).

In 2002, a heatwave in the Azores high-pressure ridge had temperature anomalies of up to 5–6°C, with a Rossby wave and cutoff anticyclone in the upper troposphere.

The 1996 heatwave lasted 17 days, affecting a fifth of Ukraine, and formed in a branch of the Azores anticyclone, with the jet stream splitting in the upper troposphere.

In 2016, the heatwave in the Azores ridge had significant anticyclonic circulation and concentrated temperature anomalies near the surface, classified as subtype A1.

The 2019 heatwave, covering almost all of Europe, was associated with a high-pressure band from the Atlantic and a Rossby wave, classified as subtype A2.

REFERENCES

1. https://www.esrl.noaa.gov/psd/
2. https://psl.noaa.gov/data/composites/day/
3. https://psl.noaa.gov/data/atmoswrit/trajtool/
4. Russo S., J. Sillmann and E.M. Fischer, 2015, Top ten European heatwaves since 1950 and their occurrence in the coming decades. Environ. Res. Lett.10, 124003
5. Sfîcă, Lucian, Adina-Eliza Croitoru, Iulian Iordache, and Antoniu-Flavius Ciupertea. 2017. "Synoptic Conditions Generating Heat Waves and Warm Spells in Romania" Atmosphere 8, no. 3: 50. https://doi.org/10.3390/atmos8030050.

TEMPERATURE REGIME OF THE SOUTH OF UKRAINE IN THE CONDITIONS OF CLIMATE CHANGE

Viktoriia Kuryshyna, PhD in Geography, Assoc. Prof., Senior Lecturer

Odesa I. I. Mechnikov National University, Ukraine

The study of the temperature regime in the conditions of global warming in the world is of great scientific and practical interest for many sectors of the national economy and, in particular, for human life.

Having meteorological observation data of the territory of the South of Ukraine for 120 years (from 1900 to 2020), we can trace the dynamics of changes in air temperature both in space and in time. Conventionally, the time series of air temperature were divided into four thirty-year intervals, the averaged values of which are the climatic norm. Based on the constructed graphs of the time course of the average annual and seasonal air temperature using regression equations, the trends in temperature change for each climatic period separately were obtained. Analysis of the graphs showed that from 1900 to 1990 in all administrative centers of the South of Ukraine (stations Odesa, Mykolaiv, Kherson and Simferopol), the average annual air temperature changed little and averaged 10°C. The change in the average annual temperature from one climatic norm to another did not exceed 0,3°C. However, starting from the 90s, the trends increased and amounted to 2,59°C for Odesa and Mykolaiv, 2,64°C for Kherson, and 3°C for Simferopol. If we consider the entire period, the temperature increase was smaller: for Odesa it was 2,21°C, for Mykolaiv 1,86°C, for Kherson 1,81°C and Simferopol 1,18°C. On the contrary, the annual amplitude of air temperature decreased with almost every subsequent climatic period, with the exception of the first period. The general trend for the entire study period for all stations is negative, with the exception of Simferopol (+1,03°C), where positive values were noted until the 60s. It is noteworthy that in the 3rd climatic period, from 1961 to 1990, the lowest values of air temperature amplitude were observed at all stations.

The seasonal contribution to the increase of the overall annual temperature was also estimated. Analysis of trends for the entire period from 1900 to 2020 for Odesa, Mykolaiv and Kherson showed an increase in temperature due to the winter months by more than 3 degrees (3.19, 3.21 and 3.01°C, respectively). The smallest contribution was made by the summer and autumn months (for Odesa, the trend was 1,85°C, for Mykolaiv 1,55°C, for Kherson – 1,33° C. In Simferopol, the temperature remained virtually unchanged over 120 years, the increase was only +0.18 °C.

If we analyze trends for different climatic periods separately, the air temperature in the last thirty years (from 1991 to 2020) increased due to the warm half of the year. Thus, the greatest contribution to the growth of annual air temperature for Odesa and Mykolaiv was made by the spring months, the increase was 3,10 and 2,39°C, respectively. In Kherson, the air temperature increased due to the spring and autumn months, by 3,10 and 3,05°C, respectively. In Simferopol, on the contrary, the air temperature during the study period (from 1900 to 2020) mainly increased due to the summer months, the total increase over the summer was 3,16°C, the minimum trend falls on the spring months (1,48°C). If we consider the trends for the last climatic period, the maximum trend for the summer period remains and becomes equal to 3,03°C, the minimum - falls on the winter months (1,83°C).

Using data from climate reference books and cadastres, distribution fields of annual air temperature norms for different climatic periods were constructed and the differences between them were calculated (Fig. 1a). ввdThe differences between periods 1,2 and 3 are indicated by a blue dotted line ($\Delta T_{3\text{-}2,1} = T_{(1961\text{-}1990)} - T_{(1900\text{-}1961)}$), the solid black line - between periods 3 and 4 ($\Delta T_{4\text{-}3} = T_{(1991\text{-}2020)} - T_{(1961\text{-}1990)}$). The figure shows that the greatest differences are noted between periods 3 and 4, and they increase from the southeast to the northwest.

Continentality indices according to Gorchinsky and Khromov were also calculated. Fig. 1b shows the continentality index field according to Gorchinsky, where solid black lines highlight the curves of indices for period 4 (from 1991 to 2020), blue dotted lines highlight the curves for period 3 (from 1961 to 1990), and red dotted lines indicate the curves for periods 1 and 2 (from 1900 to 1960).

a b

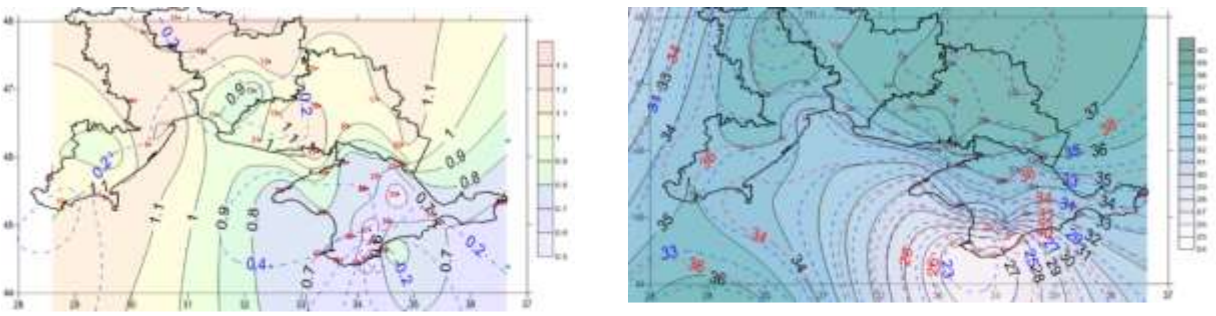


Fig. 1. Spatial distribution of the difference between the climatic norms of average annual air temperature (a) and the continentality index (b) for different climatic periods.

The figure shows that the greatest differences are observed between periods 3 and 4, and these differences, as well as the continentality index, increase in the direction from southeast to northwest. In the area of the southern coast of Crimea, the continentality indices are the lowest. Thus, we can say that in the territory of the South of Ukraine, the maritime climate becomes milder, with a mild winter, hot summer and a long warm autumn.

REFERENCES

1. Клімат України /За ред. В.М.Ліпінського, В.А.Дячука, В.М.Бабіченко. – Київ: Вид. Раєвського, 2003. 343 с.

HUMIDITY REGIME OF THE SOUTH OF UKRAINE UNDER CONDITIONS OF CLIMATE CHANGE

Viktoriia Kuryshyna, PhD in Geography, Assoc. Prof., Senior Lecturer

Odesa I. I. Mechnikov National University, Ukraine

One of the most important characteristics of climate is, which characterizes the moisture regime of the territory. This indicator is the basis of many climate classifications. Precipitation is one of the most variable meteorological quantities, it differs in quantity, annual course, amplitude of fluctuations and distribution pattern, so it is quite difficult to describe it.

Having data on average monthly precipitation amounts in the territory of the South of Ukraine for 120 years (1900-2020), we will trace the dynamics of changes in the amount of precipitation in this territory. Conventionally, we divide the time series of the values into four 30-year segments, the averaged data of each segment is the climatic norm for a given period.

Based on the constructed graphs with using regression equations, changes in the amount of precipitation were obtained both for the entire period and for each climatic period separately. It turned out that for Odesa, Mykolaiv and Kherson, the graphs of the time course of precipitation are close in pattern of changes, that is, until the 90s, the amplitude of fluctuations was unexpressed, but in the last period it increased sharply and significant jumps appeared in 2001, 2010, 2016. The increase in precipitation over the last climatic period was 80 mm in Odesa, 118 mm in Mykolaiv, but in Kherson a negative trend was observed - -33 mm.

If we consider the amount of precipitation for the entire period, then its amount has increased compared to the beginning of the last century by 129 in Odesa and by 126 mm in Kherson, in Mykolaiv - only by 39 mm.

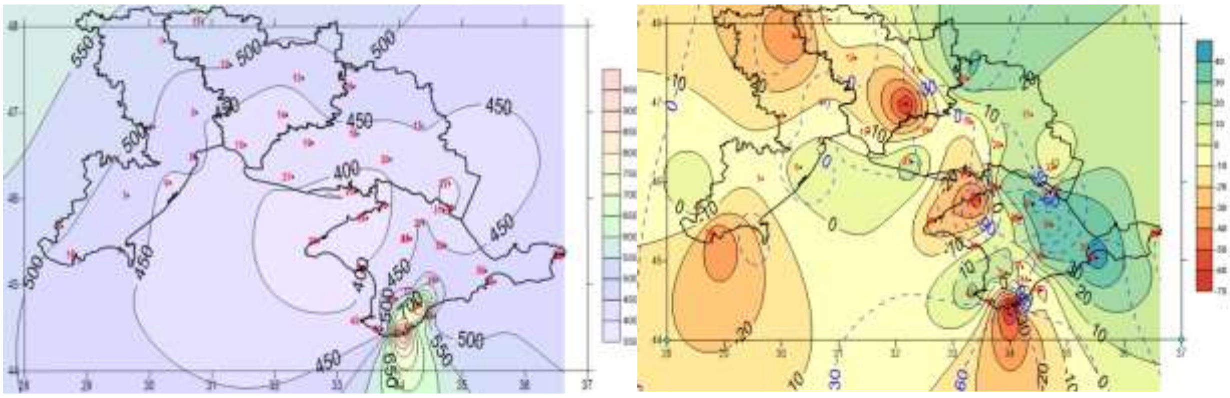
The graph of annual precipitation amounts in Simferopol differs from other cities in the pattern of fluctuations. The amplitude of precipitation fluctuations over 120 years is quite large, including the last period. However, over the entire period, the amount of precipitation decreased by 61 mm, in the last period the decrease was 69 mm.

In order to understand due to which half of the year the changes occur, the time series were divided into warm and cold periods. Analysis of the trend of changes for the entire period of research showed that humidification in Odesa and Mykolaiv occurs mainly in the cold half of the year, associated with the passage of fronts, in Kherson - due to the warm half of the year, associated with massive rainfall.

In Simferopol, on the contrary, the amount of precipitation decreases throughout the year, mainly due to the warm half of the year, which indicates an increase in the dryness of the region in the summer. If we consider the change in the amount of precipitation during the year, then in Odesa, Mykolaiv and

Kherson the maximum in June, which was observed at the beginning of the last century, gradually shifted to August and another maximum appeared in November, in Kherson the maximums occur a month earlier: in June and October, in Simferopol there is one maximum in June, which has not changed for 120 years.

Fig. 1a shows the distribution of precipitation across the territory of the South of Ukraine. Thus, in the Kherson region and in the western part of Crimea there are areas of low precipitation amounts, and in the north of the Odesa region and in the area of Ai-Petri, Yalta - an area of high annual precipitation amounts. The increase in precipitation in the south of Crimea is associated with the peculiarities of the local orography: the presence of the Crimean Mountains.



a b

Fig.1. Spatial distribution of average annual precipitation amounts for the period 1990-2020 (a) and annual precipitation amounts difference between different climatic periods: $R_{3\text{-}2,1} = R_{(1961\text{-}1990)} - R_{(1900\text{-}1961)}$ (dotted blue line) and $\Delta R_{4\text{-}3} = R_{(1991\text{-}2020)} - R_{(1961\text{-}1990)}$ (black solid line) (b).

Fig. 1b shows the distribution of annual precipitation amounts difference between different climatic periods, where a band with separate cells is visible, dividing the positive and negative differences in the precipitation amount between the last and penultimate periods. The zero isoline is directed from the southeast to the northwest, divides the Crimean Peninsula into its western and eastern parts, crosses the entire Kherson region and passes through the eastern part of the Mykolaiv region. To the right of the zero isoline there is an area of positive values, indicating the territory of increasing humidity, and in the western part of Crimea, in the southwest of the Mykolaiv region, as well as in the south and north of the Odesa region, there is an area of negative values, which indicates a tendency for increasing aridity in these areas.

The field of precipitation amounts differences between periods 1, 2 and 3 is blurred, but the main centers remain.

REFERENCES

1. Клімат України /За ред. В.М.Ліпінського, В.А.Дячука, В.М.Бабіченко. Київ: Вид. Раєвського, 2003. 343 с.

CLIMATE CHALLENGES UNDER MARTIAL LAW IN UKRAINE

Olena Nazhmudinova, PhD in Geography, Assoc. Prof.

Odesa I. I. Mechnikov National University, Ukraine

Hostilities in Ukraine caused by russia's armed aggression have an extremely negative impact on climate change, threatening global efforts to achieve the goals of the Paris Climate Agreement.

Hostilities cause a significant increase in greenhouse gas emissions. Monitoring according to the Ministry of Environment and research by scientists indicate that in the first two years of the full-scale war alone, climate costs were greater than the annual greenhouse gas emissions caused by 175 countries separately, which exacerbated the global climate emergency.

As a result of fires in natural ecosystems and ignition of crops, forests and forest belts, soot and gas-aerosol compounds are emitted. Greenhouse gases are also formed due to the combustion of fuel as a result of aircraft, heavy military equipment, and missile launches. Harmful compounds enter the atmosphere and useful components are destroyed. There is an expansion of the military industry, which is very energy-intensive and additionally emits greenhouse gases into the atmosphere. Such emissions will have significant climatic effects, because in terms of volume they can affect entire regions in terms of several months to several years. The destruction of energy infrastructure and equipment can lead to the flooding of abandoned coal mines, which can contaminate groundwater with toxic waste, including heavy metals.

Russia's military aggression significantly complicates monitoring and risk management, primarily in the regions of Ukraine that are in the zone of active hostilities or temporarily occupied.

The war also has indirect impacts on the environment, for example, the suspension of the activities of protected areas.

Public relations on responding to climate change and climate risks are also significantly complicated or disrupted. Martial law in Ukraine restricts access to public data for citizens and organizations. Communication and exchange of information in many regions is also difficult. This also adds the cost side (a significant reduction in funding), which is primarily aimed at overcoming the urgent challenges of the war, rather than expanding or modernizing climate change projects, holding forums, climate conferences, etc. Although even in such difficult conditions, work continues on adaptation and counteraction to climate change in scientific centers and public organizations.

However, despite the fact that it is military actions that worsen climate security, it is environmental issues, not climate risks, that come first in society.

Environmental safety in wartime is paramount, with a focus on disaster response. Environmental damage consists in the destruction of forests, water bodies, natural areas, pollution of territories and destruction of infrastructure, which creates additional threats to the population and the environment. The consequences of an environmental disaster are felt almost instantaneously, while climate risks, such as the impact of greenhouse gases, global warming, etc., are delayed in time. Such uncertainty, lack of awareness is a frequent problem in climate communications and in peacetime. But in critical situations of military aggression, personal involvement in climate change response, lifestyle change, political influence, and participation in climate science and political dialogue are leveled. First of all, there is the issue of access to resources – water, heat, shelter, etc., and not concern about the increase in plastic or emissions into the ocean, for example.

In the context of military aggression, the issue of climate justice is also acute. This includes migration of the population (internal displacement) – difficulties in obtaining education, access to medical care, employment, lack of housing, decreased income, impact on physical and mental health. At the same time, children, women and the elderly are at risk.

Climate inequality during the war is especially acute in the social and political isolation of people with disabilities, which increases their risk in the context of climate change.

The ecocide committed by russia on the territory of Ukraine throws the country back in the fight against climate challenges. Today, the topic of combating climate change appears not as an independent goal, but as a consequence of the implementation of other goals: in the context of energy security, environmental damage from the war, and the post-war recovery of Ukraine.

REFERENCES

1. Химович О., 2024: Зміни у співпраці громадського кліматичного руху та органів влади щодо протидії зміні клімату у 2023 році. СОЦІОІНФОРМ. Київ: представництво Фонду ім. Г. Бьолля в Україні, 60 с. https://ua.boell.org/sites/default/files/2024-04/climatereport_2024_2024-4-9_final.pdf
2. Kopytsia I., 2024: The Russian War Against Ukraine: a Case Study in Climate, Conflict, and Green Recovery. Problems of Legality, (165), P. 226–248. https://doi.org/10.21564/2414-990X.166.315465
3. Lennard de Klerk et al., 2024: Climate damage caused by russia’s war in Ukraine by Initiative on GHG accounting of war. Technical Report, 120 p. https://www.researchgate.net/publication/381530822_CLIMATE_DAMAGE_CAUSED_BY_RUSSIA'S_WAR_IN_UKRAINE_by_Initiative_on_GHG_accounting_of_war

FLOOD RISKS IN THE UKRAINIAN CARPATHIANS: THE ROLE OF INSURANCE AND CLIMATE SERVICES

Valeriya Ovcharuk, Prof., Sc.D.,
Mykhailo Kovalenko, PhD student

Odesa I. I. Mechnikov National University, Ukraine

Floods are one of Ukraine's most serious natural threats, particularly in the Carpathian region. They cause significant economic and social damage, destroying infrastructure, harming agriculture, and threatening the well-being of local communities. The mountainous terrain, high precipitation levels, and human activities such as deforestation contribute to the frequency and intensity of floods, which have become more severe due to climate change. In recent decades, an increase in flood frequency and intensity has been observed, necessitating a comprehensive approach to risk management (Fig.1).

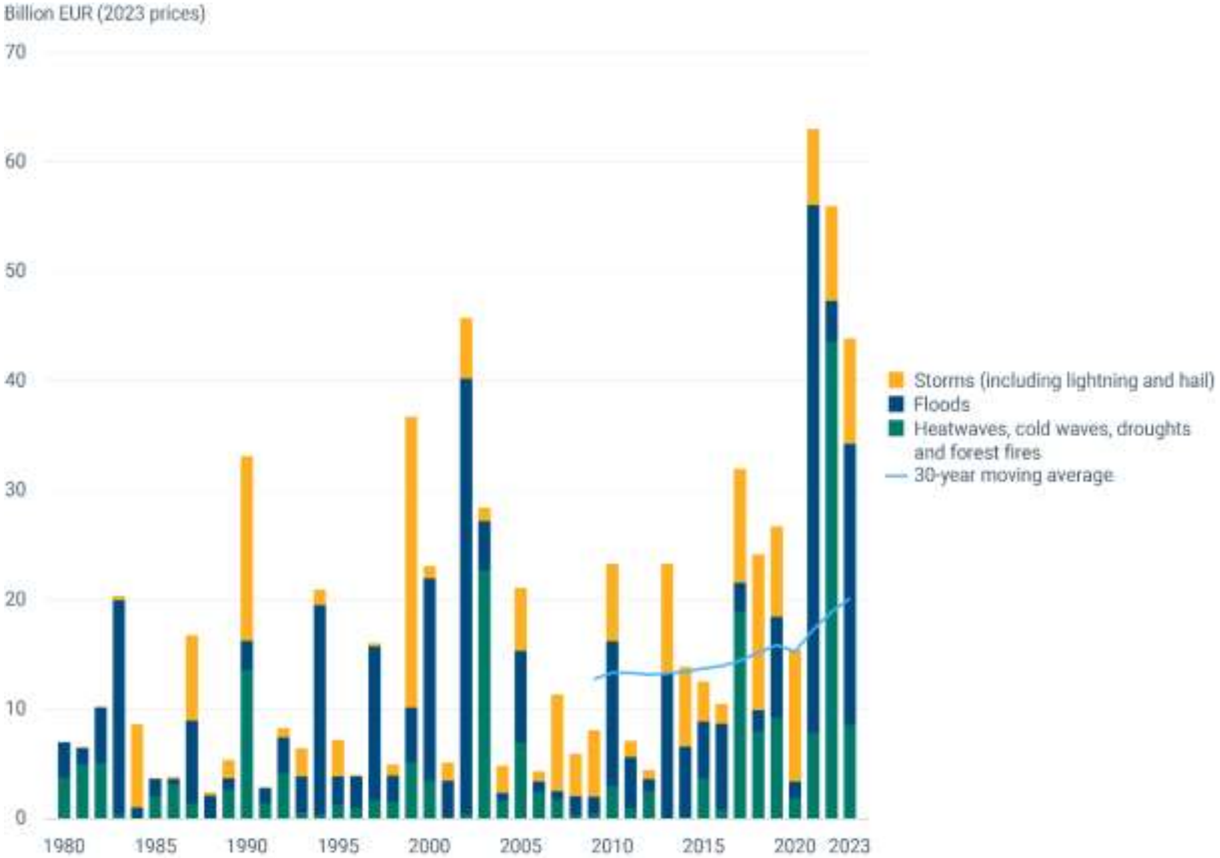


Fig. 1. Annual economic losses caused by weather-and climate-related extreme events in the EU Member States [1]

One of the key tools in this regard is climate services, which provide scientifically based data on climate change, extreme weather events, and their impacts on natural systems. These services rely on hydrometeorological observations, numerical modeling, and historical data analysis to predict flood probability, assess long-term risks, and adapt infrastructure to changing climate conditions.

Despite increasing flood risks, property insurance against such natural disasters remains underdeveloped in Ukraine. In 2023, property insurance accounted for only 13% of the total insurance market, mostly linked to bank loans rather than real protection against natural disasters. Most insured properties are located in major cities, while high-risk regions have minimal coverage. At the same time, there is effective international experience in integrating insurance programs with climate services. For example, the United States operates the National Flood Insurance Program (NFIP), which uses climate forecasts and risk assessments to determine insurance rates [2]. In Japan, mandatory disaster insurance ensures rapid compensation for affected populations and businesses [3].

Integrating climate services into the insurance sector in Ukraine would improve risk assessment, enable the development of regionally adapted insurance policies, and encourage preventive measures among the population. Additionally, implementing government-backed insurance programs, subsidizing premiums for high-risk regions, and incentivizing private insurers to expand coverage could significantly enhance the situation. To mitigate the negative impacts of floods, it is also crucial to develop alternative compensation mechanisms, such as government support for infrastructure restoration, construction of protective structures, and environmental measures promoting natural water flow regulation.

The development of flood insurance combined with climate services will minimize economic losses and improve regional preparedness for extreme weather events. The use of modern risk assessment and management approaches will contribute to sustainable regional development, reduce socio-economic losses, and enhance public protection.

REFERENCES

1. European Environment Agency. (2024, October 14). *Economic losses from weather- and climate-related extremes in Europe*. Retrieved from https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related.
2. Federal Emergency Management Agency. (n.d.). *Flood insurance*. Retrieved from https://www.fema.gov/flood-insurance.
3. OECD. (2016). *Financial Management of Flood Risk*. OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264257689-en.

THE PREVAILING WIND DIRECTION AT THE ODESA-OBSERVATORY STATION AND ITS DYNAMICS IN THE CONTEXT OF MODERN CLIMATE CHANGE

Oleh Prokofiev*[1,2]*, PhD, Associate Professor,
Liudmyla Goncharova[1]*, PhD, Associate Professor,*
Vadim Chernyshov[1]*, graduate student*

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine

Problem statement. The wind regime is one of the key factors determining the safety and efficiency of maritime transportation. For Odesa, where port infrastructure plays a crucial role in the local economy, changes in wind intensity or direction can have significant consequences. A comprehensive study of Odesa's wind regime holds great strategic importance. It not only helps reduce environmental, economic, and social risks but also enables the region to adapt to climate change, preserve its natural potential, optimize resource use, and ensure sustainable development in the future.

The **initial data** used in this study include the average frequency of wind direction occurrence as a percentage of the total number of observations for each month and year, excluding calm conditions. These values were calculated for the two most recent climatic norm periods (1961-1990 and 1991-2020). All source data were obtained from the climate cadastres of Ukraine.

Based on the data on the average frequency of wind direction, a wind roses have been constructed for each month of the year as well as for annual average values. Let us analyze the obtained results.

In January, during the first climatic norm period, the prevailing wind direction was north (19%). During the second climatic norm period, the north direction remained dominant (20%). Similarly, to the previous period, the southeast direction had the lowest frequency (5%). Thus, no significant changes in the prevailing wind direction were observed in January.

In February, during the first climatic norm period, a change in the prevailing wind direction is observed: the northeast direction becomes dominant with a probability of 20%, while the north direction remains highly frequent (19%), The southeast direction has the lowest frequency, like January (6%).

During the second climatic norm period, another shift occurs, with the north direction becoming the prevailing one again (19%). Thus, in February, a transition in the dominant wind direction is recorded-from northeast (first climatic norm) to north (second climatic norm). In March, during the first period, the north direction remains dominant (19%), with the northeast wind also showing a high frequency (18%). The southeast direction remains the least frequent (8%). In the second climatic norm period, the north wind continues to prevail (19%), but the frequency of the northeast direction significantly decreases to 13%. Thus, in March, as in January, no changes in the prevailing wind direction are observed.

In April, a significant restructuring of the near-surface wind field occurs. During the first climatic norm period, the south wind direction dominates (23%). The frequency of all other directions is significantly lower, ranging from 10% (southeast) to 16% (north). In the second climatic norm period, the south direction remains dominant (22%). Thus, in April, as in March, no change in the prevailing wind direction is observed at the Odesa-Observatory station.

The April wind direction distribution remains unchanged in May as well. The prevailing wind direction does not shift between the two periods at Odesa-Observatory, with the south wind continuing to be dominant throughout the entire observation period. In June, a shift in the prevailing wind direction is recorded: from south (22% in the first period) to northwest (21% in the second period). In July, no changes in the prevailing wind direction.

However, in August, the prevailing wind direction shifts from north (23% in the first period) to northwest (22% in the second period). Similarly, in September, the prevailing wind at Odesa-Observatory changes from north and west (which had equal frequency in the first period) to northwest (in the second period). In October, similar to September, a shift in the prevailing wind direction is recorded at Odesa-Observatory, changing from north (1961-1990) to northwest (1991-2020). In November, no change in the prevailing wind direction is observed; throughout the entire observation period, the west wind remains dominant. In the last month of the year (December), the wind direction distribution remains unchanged, with the west wind continuing to be the dominant direction throughout the observation period.

Now, let's analyze the annual distribution of wind direction frequencies across compass points for the two climatic norm periods and its dynamics. During the first climatic norm period (1961-1990), the north wind direction prevailed throughout the year with a probability of 18%. The west (15%) and northwest (14%) wind directions also showed relatively high frequencies. During the 1991-2020 the prevailing wind direction shifted to northwest, with a frequency of 17%. In this period, north (16%) and west (15%) wind components also maintained high frequencies throughout the year.

The analysis of the prevailing wind direction dynamics at Odesa-Observatory has revealed a disruption in the stability of the wind regime and a change in the prevailing wind direction during 1991-2020. The conducted study has revealed the impact of climate change on local atmospheric circulation, which may have significant consequences for coastal infrastructure, maritime activities, and regional climate adaptation strategies. Understanding these changes is crucial for developing effective measures to mitigate potential risks and ensure the sustainable development of the region.

STATISTICAL CHARACTERISTICS OF SURFACE WIND SPEED AT ODESA OBSERVATORY STATION AND THEIR DYNAMICS IN THE CONTEXT OF MODERN CLIMATE CHANGE

Oleh Prokofiev*[1,2]*, PhD, Associate Professor,
Liudmyla Goncharova[1]*, PhD, Associate Professor,*
Vadim Chernyshov[1]*, graduate student*

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]Institute of Climate-Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Ukraine

Problem statement and Initial Data. Let us examine the statistical characteristics of wind speed at Odesa-Observatory station, as they are essential for describing the wind regime of the studied area (Table 1).

The input data include average monthly and annual wind speeds, their standard deviations, and the coefficient of variation, which were calculated based on observation series for the two most recent climate periods (1961-1990 and 1991-2020).

Table 1 – Wind Speed at Odesa-Observatory Station

Wind speed	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
1961-1990													
Average	4,6	4,6	4,3	3,8	3,4	3,2	3,2	3,3	3,4	3,9	4,3	4,3	3,9
Standard deviation	1,1	1,1	0,7	0,7	0,6	0,6	0,7	0,6	0,6	0,9	0,9	0,9	0,6
Coefficient of variation	0,23	0,24	0,17	0,20	0,17	0,19	0,21	0,18	0,19	0,24	0,22	0,21	0,15
1991-2020													
Average	3.3	3.3	3.2	2.8	2.5	2.4	2.3	2.3	2.6	3.1	3.5	3.4	2.9
Standard deviation	0,6	0,5	0,4	0,4	0,3	0,2	0,3	0,3	0,4	0,6	0,7	0,7	0,2
Coefficient of variation	0,18	0,15	0,13	0,14	0,12	0,08	0,13	0,13	0,15	0,19	0,20	0,21	0,07

Results Obtained. Let us compare the average monthly and annual wind speed values recorded for different climate periods (Table 1). The analysis of the obtained results reveals a decline in these characteristics at the Odesa-Observatory station over the past 60 years. This decrease is observed throughout the year, reaching its maximum during the cold season: January and February (-1,3 m/s). In other months, the decline in wind speed varies between -0,8 m/s (June, September, October, and November) and -1,0 m/s (April and July).

The annual course of the average monthly wind speed demonstrates a distinct pattern, and the curves for different climate periods align well with each other and with the general atmospheric circulation patterns. The highest average monthly wind speeds at Odesa-Observatory station occur during winter, when advection processes dominate, reaching 4,3-4,6 m/s in the first climate normal period and 3,3-3,5 m/s in the second period. The lowest wind speeds are observed in summer, when solar radiation plays a crucial role, with values of 3,2-3,3 m/s in the first period and 2,3-2,4 m/s in the second period. The annual average wind speed at the station has decreased by 1 m/s from the first to the second climate normal period (from 3,9 m/s to 2,9 m/s).

It is also important to note that, in addition to the overall decrease in wind speed, there has been a shift in its intra-annual distribution at Odesa-Observatory station over the study period: During the first climate normal period, the highest wind speeds were recorded in January-February, while the lowest were observed in June-July. During the second climate normal period, the maximum wind speeds occur in November-December, whereas the minimum values are recorded in July-August.

The standard deviation of wind speed, similar to the average monthly values, exhibits a distinct annual pattern, reflecting the general atmospheric circulation characteristics: The highest standard deviations occur in winter: 1,1 m/s in the first period and 0,7 m/s in the second. The lowest deviations are observed in summer: 0,6 m/s in the first period and 0,2 m/s in the second.

Regarding the dynamics of standard deviations over the past 60 years, it should be noted that there has been a total decrease throughout all months of the year. The largest decrease occurs during the winter period – January-February – 0,5-0,6 m/s. A slightly smaller reduction in standard deviations at the Odesa Observatory Station is observed in summer – June-July – 0,4 m/s. The smallest decrease is recorded in the transitional seasons – 0,3-0,2 m/s – April, October.

Similarly, to wind speed itself, the annual distribution of standard deviation has changed. During the first climate normal period (1961-1990), the highest standard deviation values were observed in January-February and amounted to 1,1 m/s, while the lowest were recorded in May, June, August, and September, at 0,6 m/s. In the second climate normal period (1991-2020), the highest values are observed in November-December, reaching 0,7 m/s, while the lowest are recorded in June – 0,2 m/s.

The coefficient of variation for the analyzed periods has a clearly defined annual course, with a minimum in summer and a maximum in winter months. Over the last two climate normal periods, the coefficient of variation has undergone significant changes, decreasing in most months of the year by a magnitude ranging from 0,02 in November to 0,11 in June.

Conclusion. The conducted study of surface wind speed at the Odesa Observatory station for the period from 1961 to 2020 allows us to assert the restructuring of the wind field, namely, a decrease in wind speed over the studied period throughout all months of the year by a magnitude ranging from 1,0 to 1,5 m/s.

MUNICIPAL SOLID WASTE MANAGEMENT IN THE CONTEXT OF SUSTAINABLE CLIMATE POLICY

Veronika Prykhodko, Ass. Prof., PhD

Odesa I. I. Mechnikov National University, Ukraine

The problem of municipal solid waste (MSW) is one of the actual environmental issues of the world and Ukraine. The amount of waste generation is growing every year, the majority of which being disposed on landfills and dumps. As of 2020, 68% of the world's waste was disposed, 38% of which was uncontrolled dumping. All this exacerbates the problem of climate change due to greenhouse gases (GHG) emissions from the Waste sector. According to the latest data, the waste sector emits up to 3.3% of GHG and 20% of methane. The main processes in the waste sector for which GHG emissions are inventoried [1] are waste disposal, biological treatment of waste, incineration and open burning of waste, wastewater treatment and discharge (table 1).

According to the National Inventory Report [1], the Waste sector in Ukraine accounted for 6% of total GHG emissions in 2022. Between 1990 and 2022, the sector's emissions fell by 13.8%, while the overall reduction was 75.6%. Solid waste disposal is the main method of municipal solid waste management in the long term. As of 2023, 89.65% of municipal waste was disposed of at 5.6k of landfills and dumps with a total area of over 12k hectares.

Solid waste disposal accounts for 61% of total GHG emissions in the Waste sector. Despite the general downward trend in GHG emissions in the sector in 1990-2022, GHG emissions from waste disposal increased by 16.5%. This is due to the crisis in waste management, in particular, when existing landfills are overloaded and do not meet the national and european requirements for landfills. The overall reduction in emissions is achieved through the introduction of biogas collection and recovery systems. As of 2022, 34 biogas collection and recovery systems were in operation, reducing total GHG emissions from landfills by 11%. Thus, despite its insignificant contribution to national GHG emissions, the Waste sector is important and specific due to the growing volume of waste that is being deposited in landfills and dumps, which are sources of long-term (over 50 years) GHG emissions.

In 2020, Ukraine supported the European Green Deal, which aims to achieve climate neutrality by 2050, and set a national goal of climate neutrality by 2060. The Strategy for Environmental Security and Adaptation to Climate Change until 2030 (2021) and the Law of Ukraine ‘On the Basic Principles of State Climate Policy’ (2024) contain tasks for efficient waste management to reduce the impact on the climate system. These and other regulatory documents state that the main way to achieve climate goals in the context of MSW is to reduce its volume and implement a circular economy.

Table 1. GHG emissions from different waste management approaches.

Category	GHG	Dynamics 1990-2022, %	GHG generation, t/t of MSW
Solid Waste Disposal	$\underline{CH_4}$, CO_2, N_2O, NMOC	16,5 ↑	0.0019 CH_4
Incineration and Open Burning of Waste	$\underline{CO_2}$, $\underline{N_2O}$, $\underline{CH_4}$, C_mH_n	68,8↓	0.07 CO_2 0.0002 N_2O 0.0005 CH_4
Biological Treatment of Solid Waste	CO_2, $\underline{N_2O}$, $\underline{CH_4}$, H_2O, C_mH_n	31,4 ↓	0.004 CH_4 0.0003N_2O

Note: underlined are substances whose emissions are calculated in the Inventory

Obviously, the solution to the problem of reducing GHG emissions from the Waste sector lies primarily in reducing the amount of waste generation. The main source of GHG emissions is fractions containing biodegradable carbon (almost 60% by weight). 50% of this is food waste, 22% – is paper and cardboard, and 15% is green waste. Today, not only food waste, but also other types of waste containing biodegradable carbon remain outside the scope of MSW management systems in Ukraine. The resource potential of such waste can only be used when the flow of easily-decomposed organic waste is separated at the beginning of the MSW life cycle. As a result, we obtain clean raw materials for anaerobic fermentation, as well as an uncontaminated ‘dry fraction’ of MSW. The best option for green waste is composting.

The U.S. Environmental Protection Agency's (EPA) Waste Reduction Model (WARM) is a tool allows estimating and comparing GHG emissions for different methods of MSW management by components, including changes in the consumption of material and energy resources. The WARM model considers the following approaches of reducing waste generation and waste management [2]: 1) reduction of consumption of source materials or reduction of production volumes (source reduction); 2) waste recycling; 3) landfilling (land disposal); 4) combustion with energy recovery; 5) anaerobic digestion; 6) composting.

By comparing the baseline and alternative MSW management scenarios, WARM allows for the assessment of energy impacts and GHG emissions. Therefore, it is necessary to take into account the relevance of the climate aspects of the waste problem, which include the generation of GHG, which can become an indicator of environmental impact or a criterion for choosing the optimal waste disposal technology in developing modern waste management systems at national and regional level.

REFERENCES

1. Ukraine’s Greenhouse Gas Inventory Report 1990-2022 / Ministry of Ecology and Natural Resources of Ukraine. Kyiv, 2024. 581 p. URL: https://unfccc.int/sites/default/files/resource/Ukraine_NIR_2024.pdf
2. Waste Reduction Model. URL: https://www.epa.gov/warm

CLIMATE RISK PROJECTIONS AND ADAPTATION STRATEGIES IN UKRAINE

Iryna Rusyn, Sc.D., As.Prof., Prof.

Lviv Polytechnic National University, Ukraine

Research conducted by the Berkeley Earth Foundation indicates that between 1880 and 2017, the average air temperature in Ukraine increased by approximately 1.5°C. The most significant warming was observed in the second half of the 20th century. A study by Balabukh (2017) further reveals that during the period 1991–2010, the mean annual temperature in Ukraine rose by 0.8°C compared to 1961–1990. Notably, the climatological norm for 1961–1990 in Ukraine's northeasternmost regions was characterized by an isotherm of -6°C, which had shifted to -4.0°C by 1991–2010 (CFE, 2014).

Over recent decades, Ukraine, along with the broader East-Central European region, has experienced more pronounced warming than many other areas of the world. As outlined in the United Nations report, the effects of rising temperatures are not uniformly distributed across the globe. This uneven impact raises concerns, as even minor temperature increases in Ukraine could lead to severe environmental and socio-economic consequences, including anomalously high temperatures.

Future projections indicate that by 2050, Ukraine's average air temperature is expected to rise by 1.2–3.0°C relative to the 1981–2010 baseline under a moderate emissions scenario (RCP 4.5). Under a high greenhouse gas concentration scenario (RCP 8.5), this increase could reach 1.7–4.1°C (Wilson et al., 2021). By 2080, temperatures are projected to increase further, ranging from 1.6–3.5°C under RCP 4.5 and 3.4–6.2°C under RCP 8.5. The most significant warming is expected in Ukraine's eastern and northeastern regions, while the western part of the country is projected to experience the least temperature increase. These climatic changes are anticipated to result in water shortages in the southern and eastern regions, and up to a 25% increase in extreme precipitation events and a rise in flood occurrences (Wilson et al., 2021).

Given the current rate of warming, agricultural viability in parts of Ukraine may be compromised within the next 10–15 years, particularly in Zaporizhzhia, Kherson, Mykolaiv, and Odesa regions, where increasing drought frequency poses a major threat. Conversely, some positive effects may emerge, such as an extended growing season, which could benefit the Polissia agro-climatic zone. However, water scarcity is already evident in Vinnytsia, Volyn, Zhytomyr, Rivne, and Khmelnytskyi regions. In Mykolaiv, Odesa, and Kherson regions, declining groundwater levels, prolonged droughts, increased forest fire frequency, and heightened storm activity have been observed. At the same time, Sumy, Poltava, and Kharkiv regions are experiencing more frequent heavy rainfall events, leading to a rise in flood occurrences (Ivaniuta et al., 2020, Pichura et al., 2022).

To mitigate these escalating risks, the rapid implementation of carbon neutrality principles is essential. This entails the greening of all production stages, from product creation and utilization to disposal, alongside the efficient use of energy resources and a transition to renewable energy sources. Accelerating the adoption of green technologies across transport, industry, energy, land use, and agriculture could slow climate change progression and alleviate its predicted consequences.

However, conventional carbon reduction strategies, such as enhancing energy efficiency, shifting to renewable energy, and developing clean technologies, while critical, may not be sufficient to meet climate targets. Significant residual emissions persist, particularly in industrial sectors, where reducing the carbon footprint remains a formidable challenge.

In response, stratospheric aerosol injection (SAI) has been proposed as a potential geoengineering solution (Smith & Wagner, 2018). This technique involves injecting aerosols into the upper atmosphere to scatter solar radiation, thereby altering the Earth's heat balance and mimicking the cooling effects observed following large volcanic eruptions (Witt & Hornigold, 2019). Another proposed method involves enhancing marine cloud reflectivity by spraying sea salt particles into the air (Song et al., 2024). These approaches could rapidly and cost-effectively reduce global temperatures. Nevertheless, despite their potential effectiveness, they pose significant risks. The localized introduction of low aerosol concentrations in various regions, combined with advanced computational modeling to predict geoengineering outcomes, could serve as a temporary measure to delay temperature rise while fundamental climate mitigation strategies - emission reductions and clean technology transitions - continue to be implemented.

REFERENCES

1. Balabukh V. O., Malytska L. V. 2017: Assessment of current changes in the thermal regime of Ukraine, Geoinformatics, 4 (64), pp. 34-49.

2. Smith W., Wagner, G. 2018: Stratospheric aerosol injection tactics and costs in the first 15 years of deployment, Environmental Research Letters, 13, pp. 124001.

3. Song Z., Yao N., Chen L., Sun Y., Jiang B., Li P., Rosenfeld D., Yu S. 2024: The effectiveness of solar radiation management for marine cloud brightening 1 geoengineering by fine sea spray in worldwide different climatic regions 2, EGUsphere preprint repository, pp. 1-40.

4. Wilson L., New S., Daron J., Golding N. 2021: Climate Change Impacts for Ukraine, Met Office, pp.1-34.

5. Witt C.S., Hornigold, T. 2019: Stratospheric Aerosol Injection as a Deep Reinforcement Learning Problem, ArXiv, abs/1905.07366.

CONSEQUENCES OF CLIMATE CHANGE IN UKRAINE: DROUGHT AND WILDFIRES

Inna Semenova, Sc.D.

Instituto Pirenaico de Ecología (IPE/CSIC), Spain

The territory of Ukraine is affected by droughts of different intensity and duration almost every year. The economic impacts of drought are most often seen in the agriculture and water sector, causing reduced or total crop damage, including through impacts on irrigation systems during hydrological drought. On the other hand, hundreds of fires occur annually in all Ukrainian's landscape zones, from the steppe in the south to the mixed forests in the north.

The relationship between droughts and fire weather conditions is relatively clear. Under drought conditions, more of the total fuel complex is available for combustion. For example, in 2020, under a severe drought, 209 forest fires occurred, the most significant of them were in the Chernobyl zone in April (Boychenko et al., 2025). Wildfire activity is significantly dependent on weather and climate conditions, so, current changes in temperature and moisture regimes, observed both globally and in Ukraine, potentially lead to an increase in the risk of wildfires (Gincheva et al., 2024).

The analysis of the time series of drought indices (SPEI and SPI) showed that during the period from 1946 to 2020, there were at least 20 episodes in which more than 25% of Ukraine's territory was affected by droughts of varying intensity (Semenova & Vicente-Serrano, 2024). The comparison between SPEI and SPI revealed that the increase in drought severity was mainly driven by significant rise in atmospheric evaporative demand in recent decades. Trends indicating an increase in the duration and intensity of droughts were primarily observed in the southwestern, central, and northern regions of Ukraine. Also, it was found that, in recent decades, droughts have become more frequent but less intense and of shorter duration.

Wildfire activity in Ukraine during the period from 2001 to 2021 was assessed using MODIS hotspot and burned area products. Time course of the annual number of hotspots (HSN) showed strong interannual variability with two maximum during the study period: in 2008 and 2014-2015. The spatial distribution of hotspots shows that the greatest number of ignitions occur in the central and north-eastern regions of Ukraine. In the seasonal distribution, two maxima of HSN were identified: a primary one in August and a secondary one in April. The maximum annual burned area (BA) is observed in the southern and south-eastern regions of Ukraine. Time course of BA demonstrated that every year, BA covers an average of 6-7% of the country; in 2008 it was about 20%.

Droughts can positively affect fire conditions by drying out vegetation fuel and soil. However, they can also reduce the amount of available combustible material by limiting vegetation growth. As a result, the impact of drought on fire conditions is vary across different seasons. An assessment of this relationship showed (Semenova, 2025) that droughts in winter and early spring contribute to an increase in the number of ignitions in spring and summer (Fig. 1, a). Conversely, the absence of drought in spring leads to the accumulation of vegetation fuel, which potentially increase the number of fires in summer.

The use of fire weather indices that incorporate essential climate variables (ECVs) is useful not only for assessing fire risk but also for monitoring changes in fire danger conditions due to climate change. Spatiotemporal analysis of the Ångström index (based on air temperature and relative humidity) from 1960 to 2023 confirmed that the risk of fire ignition increased across Ukraine in all seasons, particularly in the southwestern regions and the Carpathian region (Fig. 1, b).

a) b)

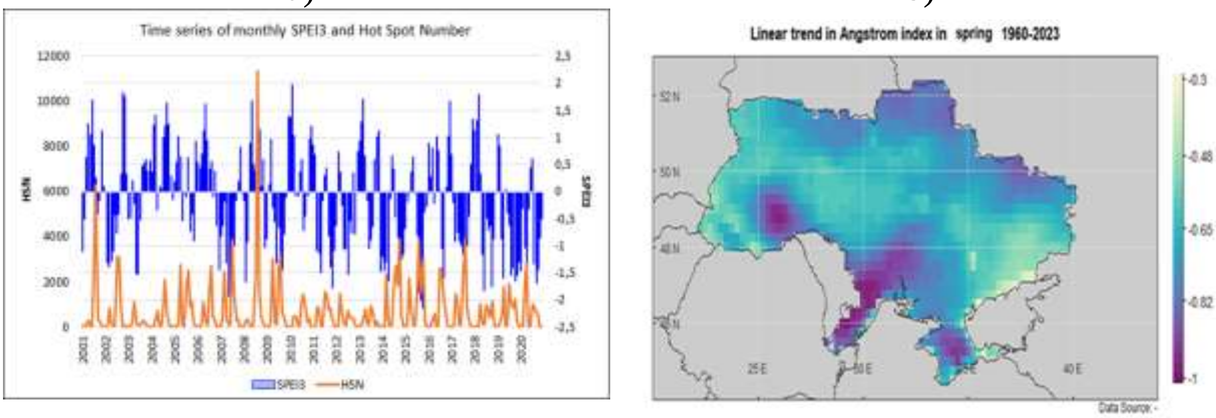


Fig. 1. Time series of monthly SPEI3 and HSN in period 2001-2020 (a); spatial distribution of AI linear trends in spring 1960-2023 (b).

REFERENCES

1. Boychenko, S., Kuchma, T., Karamushka, V., Maidanovych, N., Kozak, O., 2025: Wildfires and Climate Change in the Ukrainian Polissia During 2001–2023. Sustainability, 17, 2223. https://doi.org/10.3390/su17052223

2. Gincheva, A., Pausas, J.G., Torres-Vázquez, M.Á., Bedia, J., Vicente-Serrano, S.M., Abatzoglou, J.T., et al., 2024: The interannual variability of global burned area is mostly explained by climatic drivers. Earth's Future, 12, e2023EF004334. https://doi.org/10.1029/2023EF004334

3. Semenova, I., & Vicente-Serrano, S.M., 2024: Long-term variability and trends of meteorological droughts in Ukraine. International Journal of Climatology, 44(6), 1849–1866. https://doi.org/10.1002/joc.8416

4. Semenova I., 2025: The Influence of Seasonal-Scale Moisture Conditions on Wildfire Dynamics in Ukraine. ESS Open Archive. January 28, 2025. DOI: 10.22541/essoar.173809899.90228093/v1

THE IMPACT OF CLIMATE CHANGE ON THE HYDROLOGICAL REGIME OF RIVERS IN THE UKRAINIAN POLISSIA

Zhannetta Shakirzanova, Prof., Sc.D.,
Denys Sivaiev, PhD

Odesa I. I. Mechnikov National University, Ukraine

Studies by leading Ukrainian and international scientists indicate significant climate changes that affect the formation of river water regimes. There is considerable variability in the frequency and scale of river floods: in some regions, their number and intensity are increasing, while in others, on the contrary, they are decreasing. At the same time, the timing of their occurrence and the duration of their passage are changing. Additionally, a decline in river water levels is increasingly being recorded, leading to low-water conditions and, in some cases, the complete disappearance of small water courses.

Such changes in the hydrological regime have significant socio-economic consequences. They lead to an increase in economic losses associated with both floods and droughts, which negatively affect agriculture, industry, and residential infrastructure.

In recent years, in Ukraine, due to global climate changes, there has been a trend toward the redistribution of water resources. A decrease in spring runoff and a shortening of flood duration are observed, while the risk of catastrophic snowmelt-rainfall floods remains high, particularly on the rivers of Ukrainian Polissia.

The object of this study is the rivers of Ukrainian Polissia, which are characterized by a specific hydrological regime, where the maximum runoff is primarily formed due to the melting of the snow cover and the occurrence of intense rainfall during the winter-spring period. These processes often lead to a rise in water levels, resulting in the flooding of adjacent areas, including industrial facilities and settlements.

The hydrological regime of the rivers in this area is significantly influenced by climate changes, which manifest in the alteration of the frequency and intensity of water runoff. An important aspect of the study is the assessment of the factors that determine the nature of the formation of maximum snowmelt-rainfall runoff and the establishment of trends in its dynamics over a multi-year period and under current climate change conditions.

Analysis of recent studies. Recent research shows that climate change significantly affects the water regime of rivers, particularly the nature and frequency of floods in Europe. In Northwestern Europe, increased precipitation in autumn and winter has led to intensified flooding, while in Eastern Europe, particularly in the Pripyat River basin, their intensity has decreased due to the reduction in snow cover and its melting. Studies by Ukrainian and international scientists indicate a shift towards earlier floods and a reduction in the scale of flood synchronization. In Ukraine, the impact of climate change has been especially noticeable since 1989, which has been reflected in hydrological calculations and forecasts of maximum spring flood levels.

Research results. The study of multi-year trends in the maximum snowmelt-rainfall runoff of rivers in Ukrainian Polissia was conducted using the hydrological-genetic method. To examine the homogeneity and stationarity of the maximum snowmelt-rainfall runoff of the rivers in Ukrainian Polissia, cumulative curves, differential integral curves, chronological graphs of runoff layers, and maximum water discharge were constructed.

The cumulative curves of the maximum snowmelt-rainfall runoff layers of the rivers in Ukrainian Polissia showed homogeneity, as deviations from the straight line were almost absent. However, the cumulative curves of maximum water discharge indicate heterogeneity, with an inflection point after which the trend of maximum runoff changes. The reasons for the disruption of the homogeneity of the time series of maximum water discharge in snowmelt-rainfall runoff are meteorological factors, anthropogenic activity, and climate change.

Chronological graphs of the maximum snowmelt-rainfall runoff of the rivers in Ukrainian Polissia show fluctuations in water flow with a pronounced tendency for decreasing runoff, especially the maximum water discharges. There is also a noticeable trend towards shifting the timing of maximum runoff formation to earlier dates in the context of current climate warming.

The analysis of the differential integral curves of the snowmelt-rainfall runoff of the rivers in Ukrainian Polissia indicates the presence of hydrological cycles. The high-water phase was observed from the beginning of observations and lasted nearly ten years, until 1971-1981, when high water levels in 1979 and 1980 occurred. The low-water phase began in 1972 or 1982 and continued until 2020. It is difficult to determine the exact start of the high-water phase due to insufficient data.

The coefficients of variation for maximum water discharge range from 0.52 to 1.41, while for runoff layers, they range from 0.47 to 1.27, with an average ratio of 2.0. For further justification of forecasting methods, the statistical characteristics are summarized based on average values and geographical features of the catchments.

Conclusion. The analysis of the chronological course of the maximum snowmelt-rainfall runoff of the rivers in Ukrainian Polissia showed that they are synchronous and exhibit hydrological cycles, which cause pronounced trends in the time series of maximum runoff. The direction of the runoff trends is decreasing, which is related to the impact of climate change on the hydrological regime of the rivers in Ukrainian Polissia — unstable winter temperature conditions, low snow reserves, and uneven snow accumulation.

THE IMPACT OF GLOBAL WARMING ON HURRICANE ACTIVITY IN THE NORTH ATLANTIC OCEAN

Victoriya Shepel [1,2], PhD student
Alina Semerhei-Chumachenko[1], PhD, Associate Professor

[1]Odesa I. I. Mechnikov National University, Ukraine
[2]National University Odesa Maritime Academy, Ukraine

The North Atlantic shipping route runs over a wide range of latitudes in the North Atlantic Ocean, and the safety of shipping can be determined by the possibility of the formation of tropical cyclones, which in the North Atlantic are called "hurricanes".

Hurricanes pose a serious threat to shipping in the North Atlantic, and their impact can be reduced through the development of early warning systems and adjustments to ship routes. Sometimes ships are forced to avoid the hurricane zone, which leads to changes in routes, increased time and fuel consumption, and affects the logistics and economics of maritime transport.

Global warming affects hurricane activity in the Atlantic Ocean by warming the water, which increases evaporation and the energy supply for hurricane formation and intensification. Studies show [1, 3] that a 1°C increase in surface water temperature can increase hurricane intensity by 5–10%.

In recent years, hurricanes have become more powerful and longer-lasting as they draw more energy from the ocean, leading to an increase in the number of Category 3-5 hurricanes on the Saffir-Simpson scale. There has also been an increase in the number of "sudden intensification" storms, where hurricanes can rapidly gain strength within 24 hours.

Global warming is changing the paths of hurricanes, and they may reach more northern latitudes more often, threatening new regions. Due to increased humidity, hurricanes can bring record rainfall and cause catastrophic flooding. Storm surges (storm waves) are increasing, which raises water levels along the coast, causing greater destruction in coastal areas.

Global warming is therefore contributing to the formation of stronger, wetter and longer-lasting hurricanes in the Atlantic Ocean. The frequency of higher category hurricanes is increasing, leading to greater destruction, increased risks to coastal areas and increased economic losses.

Based on a 30-year climate period from 1991 to 2020, the average Atlantic hurricane season includes 14 storms [2], 7 hurricanes, and 3 major hurricanes (Category 3, 4, or 5 on the Saffir–Simpson Hurricane Wind Scale). The first storm (TS) typically forms in mid- to late June, the first hurricane (H) typically forms in early to mid-August, and the first major hurricane (MH) forms in late August or early September.

The 2023 Atlantic hurricane season was above normal in terms of storm activity, but normal in terms of hurricane and major hurricane activity. 21

tropical storms formed in 2023 (Fig. 1), of which 7 became hurricanes and 3 became major hurricanes (Category 3 or higher on the Saffir-Simpson Hurricane Wind Scale). The strongest in 2023 was Hurricane MH Lee, which formed as a result of the movement of a strong tropical wave off the west coast of Africa on September 1, 2023, with a large area of showers and thunderstorms.

The 2024 Atlantic hurricane season had near-average storm and hurricane activity, with 15 tropical [2] storms forming, 6 of which became hurricanes and 4 became major hurricanes. Compared to 2023, this season was less active.

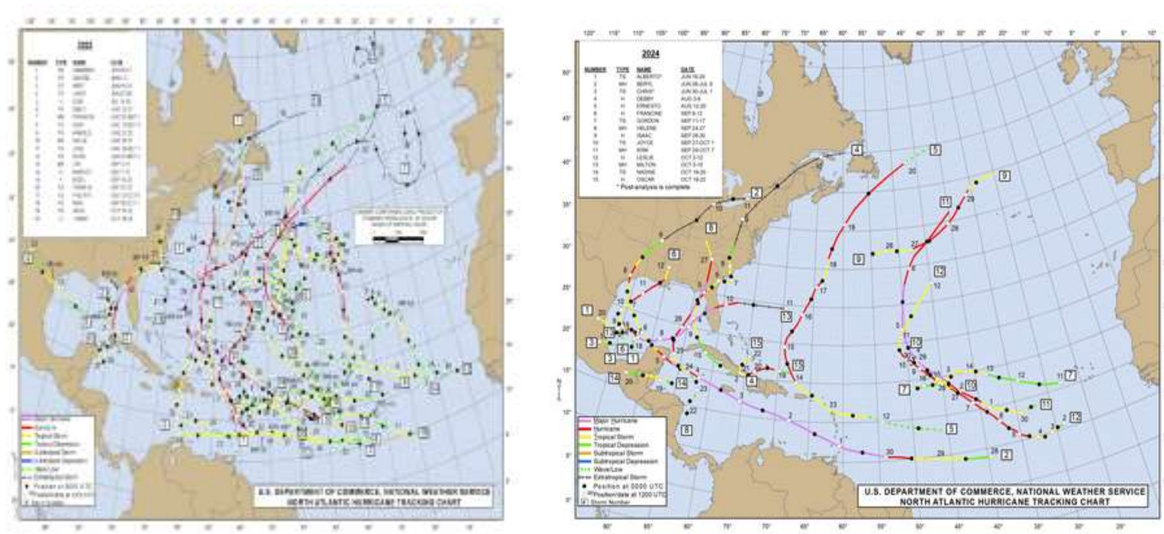


Fig.1 – Dates, maximum wind speed (knots) and track map [2] of tropical cyclones (TS) and hurricanes (H, MN) in the North Atlantic in 2023 and 2024.

In 2024, hurricanes (H) formed from early August (H Debby) to late October (H Oscar), and maximum wind speeds reached 35 to 68 knots (18 and 35 m/s). Major hurricanes (MH) did not form at the peak of the typical season, i.e. from mid-August to mid-September, but in the last decade of September - the first decade of October, with maximum wind speeds of 60-73 knots. Also, one major hurricane (MH Beryl) formed in late June and persisted until July 9, 2024.

In terms of accumulated cyclone energy (ACE), which measures the strength and duration of tropical storms and hurricanes, activity in the basin in 2023 was about 20% above average compared to the long-term [2] average for 1991-2020.

REFERENCES

1. Anthes, R., Corell, R., Holland, G., Hurrell, J., MacCracken, M., and co-authors. 2006. Hurricanes and global warming—potential linkages and consequences. Bull. Amer. Meteor. Soc. 87, 623–628.
2. https://www.nhc.noaa.gov/data/tcr/index.php?season=2023&basin=atl
3. Tropical Cyclone Climatology. https://www.nhc.noaa.gov/climo/

CLIMATE CHANGE AND FORECASTS IN UKRAINE AND METHODOLOGICAL ASPECTS OF EDUCATIONAL PROCESS

Vladyslav Timofeyev, Dr. Sci.*, Svitlana Savchuk, Research Fellow*

Ukrainian Hydrometeorological Institute, Ukraine

Climate change is one of the most urgent problems facing humanity, which is receiving more and more attention due to the consequences and the need for adaptation. At the same time, research on climate change detection and forecasting is carried out at the global, regional and national levels, with special attention to extreme meteorological phenomena (EMP), with the main task of predicting socio-economic consequences, with the development of national development strategies. The evolution of threat ratings unequivocally indicates the increasing importance of the hydrometeorological factor in sustainable development, while about 90% of significant economic losses worldwide fall on the extreme weather.

Climate forecasts show a further increase in the near-surface air temperature (SAT) and an expansion in the arid areas, which already cover up to 1/5 of the entire earth's surface. Moreover, the observed trends in climate change are highly likely to intensify. The severity, frequency and intensity of periods of hot weather, and with them dry weather, is increasing most dramatically over the next decade in most 7regions of the Earth. Large-scale droughts affect not only crops, but also world grain and food reserves. Before the period of modern warming, the climate of Ukraine was generally considered favorable for agriculture, due to the favorable level of insolation and sufficient moisture in most of the territory. At the same time, earlier severe droughts were mainly observed in the south and east of Ukraine, as in 1968, 1972, 1975, and in the north, they were observed rarely.

After 1980s, an increasing trend of the frequency of droughts in Ukraine was noted, almost doubling, a dangerous feature was the northward expansion of droughts to areas that have always belonged to the zone of sufficient moisture - Polissya and the northern regions of the Forest-Steppe. Due to the change in the nature of the EMP, including increase in the frequency of droughts, the degree of climate extremeness and vulnerability increased. In droughty conditions, the energy capabilities of the underlying surface increase, which causes an increase in photosynthetically active radiation.

Certain combinations of agroclimatic conditions can cause adverse phenomena in the summer season, due to droughts, heavy precipitation or their combination, which negatively affects development during the growing season and future harvest. E.g., intra-seasonal variability increased, when some regions receive a lot of precipitation, while others experience a deficit

Increasing degree of aridity is accompanied by persistent changes in the complex of meteorological variables, namely, in addition to the growth in the SAT, decrease in the atmospheric precipitation, increase in direct solar radiation, and sunshine duration, together with the decrease in cloudiness. This is consistent with changes in most areas of central and Eastern Europe, against the predominance of the anticyclones, especially in the middle troposphere. This led to the greater time residence of

Atmospheric Circulation patterns throughout the year. New parameters and indices have been invented that can be used to improve weather forecasts, including longer-range.

However, numerical modeling, even with an ensemble approach, cannot always be successfully applied for seasonal forecasts, due to the existing threshold of predictability; therefore, the personal experience of the forecaster remains important.

There is still much unexplored in the interaction of planetary and regional climate systems, such as, the El Nino-S.Oscillation - NAO – Thermohaline circulation - regional weather, or stratospheric-tropospheric interaction, connections with geophysical parameters, parameters of the earth's rotation solar activity etc.

Climatic service for this region consists of seasonal forecasting, as well as climate forecast, to support local agriculture, taking into account ongoing warming and aftereffects. As stronger variability of ENSO episodes is predicted by models, we should be ready for regional climatic consequences as snowless winter, dry and hot summer, and other extremes and their combinations, such as droughts, heatwaves, and fires.

Special attention is paid to the forecast of droughts and accompanying phenomena at the medium- and longer-range interval, especially during the growing season, as well as knowledge of possible consequences and Transitions between different scales and environment. In educational programs it is important to study, from simple conceptual models to neural networks, e.g., large-scale – regional circulation – local extreme weather – consequences in Environment, economy, agriculture/other risks, Changes in the hydrological regime of river runoff, Watersupply,

Developing adaptation methods is important in the conditions of climate change and the associated global water and food crises. The adaptive potential of Ukraine, given the size of the territory and the diversity of the climate, allows us to hope for successful adaptation to climate changes and the associated consequences. Despite the increasing degree of aridity, in recent years Ukraine has managed to harvest record yields of grains, legumes and oilseeds, as in 2021 But the actual acuteness of the "deficit" of adaptation to extreme weather impacts was sufficiently demonstrated by the heat waves of 2010, 2015, 2018, floods of 2008 and 2012.

To review all the climate information to make it a tool for human welfare is not easy, it requires a holistic vision, inter-and trans-disciplinary dialogue and, above all, it requires breaking several paradigms.

Science is the key tool for effective adaptation. In order to adopt effective preventive adaptation measures, long-term action plans based on scientifically based prospective assessments of climate change are required. The development of adaptation plans should be carried out using modern methods that allow taking into account the uncertainties of climate change scenarios, including changes in the statistics of extreme weather phenomena, distinguishing anthropogenic signal, the deepening analysis of natural changes, the expansion of predictors and the corresponding external impacts and climate-making agents.

The study and understanding of climate changes is an urgent task of modern meteorology and climatology, the solution of which will contribute to the long-term effective planning of the economic development of the regions of Ukraine.

LIGHTNING DETECTION SYSTEM AS A TOOL FOR SHORT-TERM FORECASTING OF NATURAL DISASTERS

Olena Zabolotna, researcher, *Oleksandr Kryvoshein, PhD, Oleksii Kryvobok, PhD*

Ukrainian Hydrometeorological Institute, Ukraine

Climate change has significantly impacted the frequency and intensity of natural disasters such as severe thunderstorms, squalls, hailstorms, hurricanes, and tornadoes. Specifically, climate change has led to an increase in average temperatures, resulting in greater evaporation and humidity, as well as the accumulation of more energy in the atmosphere. This contributes to more frequent formation of powerful thunderstorm clouds, intense squalls, hail, and hurricanes. The turbulence of jet streams and the increasing contrast between warm and cold air masses create favorable conditions for extreme weather events. These phenomena can cause large-scale damage to infrastructure, emergency situations in the energy sector, and threats to human life. In Ukraine, fatalities, injuries, and significant material losses due to these phenomena are recorded annually. Timely detection of thunderstorm activity and forecasting its consequences are essential for effective emergency response.

One of the key tools for monitoring thunderstorms is the lightning detection system, which allows real-time recording of lightning discharges. The Ukrainian segment of the ENTLN (Earth Networks Total Lightning Network) lightning detection system was established in 2016 through cooperation between the Ukrainian Hydrometeorological Institute (UHMI) and Earth Networks. It includes 12 sensors located in different parts of the country. The sensors were installed at meteorological stations as part of an agreement with the Ukrainian Hydrometeorological Center. The system enables real-time detection and tracking of electromagnetic pulses caused by lightning. The detection efficiency of the system for cloud-ground (CG) flashes and for intercloud (IC) flashes is shown in Figure 1. A more detailed description of the Ukrainian segment of the system is provided in the article [1].

The main capabilities of the system include:

- Real-time detection of lightning discharges with a spatial resolution of 200–400 meters;
- Recording both cloud-to-ground and intra-cloud discharges;
- Integration with geographic information systems for visualizing thunderstorm activity;
- Determination of the current strength of lightning discharges;
- Access to data through secure protocols and standardized formats (GeoJSON, WGS-84, ISO 8601);
- Real-time monitoring: ensures continuous observation of thunderstorm activity, allowing rapid response to changing weather conditions.

The use of the lightning detection system enables:

- Timely hazard warnings: receiving data on an approaching thunderstorm or storm allows for early notification of the population and relevant services about potential threats.
- Reduction of fatalities and injuries: due to prompt alerts, people can take necessary safety measures.
- Minimization of material losses: warnings about possible lightning strikes help protect power grids, buildings, and other infrastructure objects.

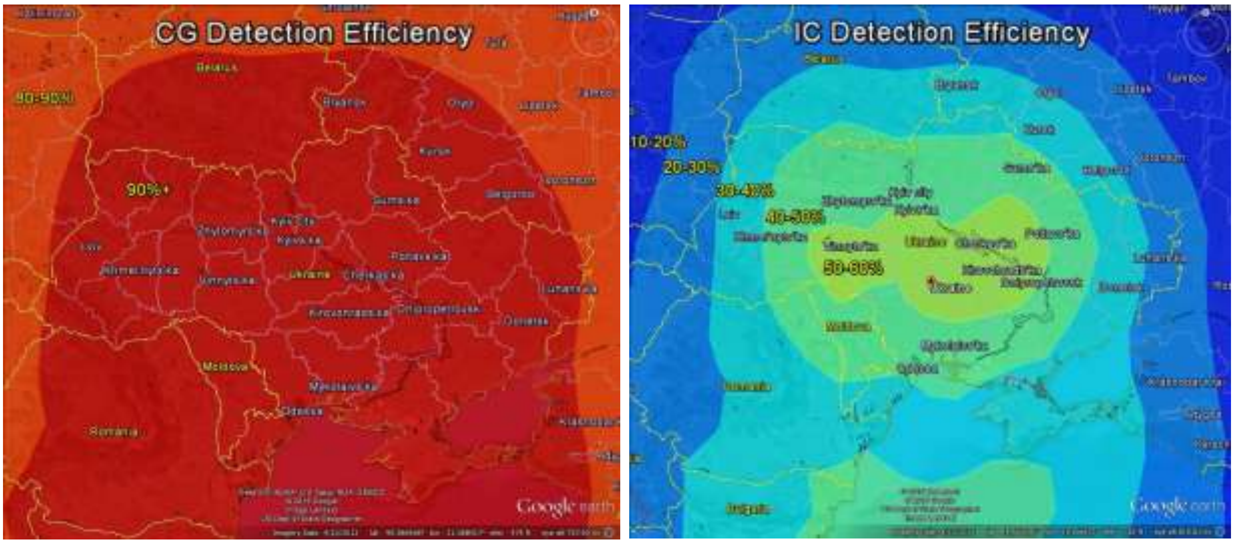


Fig. 1. Lightning flashes detection efficiency.

Integration of the lightning detection system with national emergency services allows for:

- Automated notification: through SMS, mobile applications, or media channels to inform the population about approaching hazardous weather conditions.
- Development and implementation of action protocols: for various scenarios such as mass events or outdoor activities near water bodies.
- Public education and awareness: conducting information campaigns on appropriate behavior during thunderstorms and other natural disasters.

Thus, the lightning detection system is a crucial tool for short-term forecasting and warning of natural disasters. Its implementation and integration with national safety systems will help save lives by providing timely warnings of hazardous weather conditions; reduce infrastructure damage by protecting energy networks, transportation systems, and residential buildings; and ensure effective emergency response through real-time analysis of thunderstorm activity and adaptation of actions by relevant services.

REFERENCES

1. Kryvobok A. A., Kryvoshein A. O., Koman M. M., Krupa E. O. Ukrainian Segment of the ENTLN Lightning Detection System. Ukrainian Hydrometeorological Journal, 2018, No. 21.

REVIEWING CLIMATE SCENARIOS AS ANALYTICAL PROJECTS IN THE CONTEXT OF IPCC ASSESSMENT REPORTS

Ruslana Zadorozhna, PhD

Bila Tserkva National Agrarian University, Ukraine

The scenario approach is a key tool for assessing possible future climate change in the Assessment Reports of the IPCC.

Climate scenarios are neither predictions nor forecasts. They are scientifically based versions of what the Earth's future climate might look like depending on a number of factors. The different scenarios may contradict each other because they are alternative development options.

The creation of climate scenarios is a classic example of a project activity because it fulfills the key characteristics of a project:

- clearly defined goal – design of scientifically based scenarios describing possible future climate changes depending on the level of anthropogenic greenhouse gas emissions and other factors;
- uniqueness of the result – each set of climate scenarios is unique as it reflects the latest scientific knowledge, socio-economic and technological trends;
- time constraints – creation of scenarios takes place within the framework of certain research projects with a specific timeframe for implementation;
- limited resources – project activities on scenario development are financed by governments, international organizations, scientific foundations;
- interdisciplinary approach to the formation of the project team – climate scientists, economists, sociologists, ecologists, energy specialists and others are involved in the scenario development process.

The elaboration of climate scenarios is closely linked to the publication phases of the IPCC Assessment Reports and the growing understanding of climate change processes and improved forecasting methodologies.

The first three generations of scenarios were developed directly under the auspices of the IPCC, starting with Representative Concentration Pathways (RCPs) – by independent scientific groups.

The IPCC's First Assessment Report of (1990) used the first standardized greenhouse gas emission scenarios based on simplified assumptions about economic growth and demographic change and did not take into account regional differences or social factors. These scenarios ranged from the pessimistic scenario A (Business-as-Usual) with a 3°C temperature rise to the optimistic scenario D with a rapid transition to renewable energy.

These scenarios were replaced in 1992 by the more detailed IS92a-f, which took into account changes since the Montreal Protocol. The IS92a-f differed in terms of level of economic development, fossil fuel availability, and regulatory measures to reduce emissions.

The IPCC AR3 and AR4 used scenarios from the Special Report on Emissions Scenarios (SRES), which are organized into four families: A1 (globalization with technological progress), A2 (regional development), B1 (eco-efficiency), and B2 (local sustainability). The SRES scenarios considered socio-economic dynamics but not specific climate protection measures.

The IPCC AR5 introduced RCPs that focused on levels of radiative forcing (2.6; 4.5; 6.0; 8.5 W/m²) rather than emissions. The stringent RCP8.5 reflected a fossil fuel-intensive world, while RCP2.6 reflected a rapid decline in emissions.

The IPCC AR6 linked the RCPs to the Shared Socio-Economic Pathways, where each SSP describes a qualitative societal scenario (Riahi et al., 2017):

- SSP1 – Sustainability: Taking the Green Road – the most climate-friendly narrative, focusing on sustainable development and emission reductions;
- SSP2 – Middle of the road – a compromise option where trends mostly follow their historical patterns;
- SSP3 – Regional rivalry: A rocky road – a rather problematic option where the challenges for both mitigation and adaptation are the greatest;
- SSP4 – Inequality: A road divided – a world where rich countries can adapt to climate change but poor countries remain vulnerable;
- SSP5 – Fossil-fueled development: Taking the highway – also a problematic option due to dependence on fossil fuels.

The scenarios have no probability, i.e. they are uncertain.

Scenario uncertainty is imperfect knowledge about socio-economic and technological development in the future, resulting in different amounts of greenhouse gas emissions (Chen et al., 2021, p. 196).

In scenarios, future emissions depend largely on the collective outcome of choices and processes related to population dynamics and economic activities, or choices that affect the energy intensity of these activities and the intensity of emissions. Therefore, there is an opportunity for humanity to influence global processes. Active efforts to reduce emissions, innovative technologies and adaptation measures can change the trajectory of negative climate change.

REFERENCES

1. Riahi, K., van Vuuren, D.P., Kriegler, E., et al., 2017: The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview, Global Environmental Change, 42, pp. 153-168

2. Chen, D., Rojas, M., Samset, B. H., et al., 2021: Framing, Context, and Methods, In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 147–286

CHANGES IN AGROMETEOROLOGICAL CONDITIONS OF THE AUTUMN PERIOD IN THE SOUTH OF UKRAINE

Serhii Zaiets*[1], *Prof., Sc.D., *Serhii Yuziuk*[1], *Sc.C.,*
Oksana Volvach[2], *Ass. Prof., Sc.C., Yurii Kiriyak*[3], *Sc.C.*

[1]Institute of Climate-Smart Agriculture, NAAS, Ukraine
[2] Odesa I. I. Mechnikov National University, Ukraine
[3]Kherson Regional Centre for Hydrometeorology, Ukraine

Climate change has made adjustments to the rather complicated and ambiguous issue of sowing winter crops, which is one of the main factors of the technological process, which significantly affects the production processes and the formation of the harvest. Since 2001, there has been a significant change in the temperature regime of the autumn growing season of winter crops. Thus, on average, in 1971–1990, during the autumn period, the sum of average daily air temperatures was 498 °C, and in 2001–2005 it reached 608 °C, in 2006–2010 – 689 °C, in 2011–2015 – 720 °C, and in 2016–2020 – 718 °C, or by 110, 191, 222 and 220 °C more, respectively (Table 1).

Table 1. Changes in temperature regime and duration of the autumn vegetation period of winter wheat by years (data from the regional centre for hydrometeorology, Kherson)

Indicator	Value	Years				
		1971–1990	2001–2005	2006–2010	2011–2015	2016–2020
Sum of average daily temperatures, ⁰C	actual	498	608	689	720	718
	±	-	+110	+191	+222	+220
Average daily air temperature, ⁰C	actual	8,1	8,6	9,6	9,9	9,5
	±	-	+0,5	+1,5	+1,8	+1,4
Duration of autumn vegetation, days	actual	63	71	73	78	76
	±	-	+8	+10	+15	+13

During these periods, the average daily air temperature also increased by 0,5–1,8°C and the duration of the autumn vegetation period by 8–15 days.

During 2013–2019, in most cases, longer and warmer periods of autumn vegetation of winter crops were also observed. From July to the end of September 2014 and 2018, as well as from mid-October 2015, 2017 and 2019, extremely difficult agrometeorological conditions characterized by prolonged air conditions were observed in the pre-sowing period of winter crops in southern Ukraine. Vegetation irrigation of soybean crops as a precursor to winter crops was completed in the first to third decade of August. To ensure friendly germination and the required level of moisture, pre-sowing irrigation was carried out at a rate of 500 m^3/ha in 2014, post-sowing irrigation (450 m^3/ha) in 2015, and pre-sowing (500 m^3/ha) and seedling-inducing irrigation (250 m^3/ha) in 2017.

In 2013 and 2016, no pre-sowing irrigation was required, as there was sufficient rainfall in September to ensure friendly germination: 43,7 mm in 2013 and 33,2 mm in 2016. The pre-sowing and germination irrigation carried out in 2015 and 2017, as well as precipitation against the background of high temperatures in November, contributed to the improvement of winter crops. In October-November 2015 and 2017, 62,8 and 52,6 mm of precipitation fell, which was 98 and 82% of the long-term average for this period. In addition, the average monthly temperature in September and November 2015 was 4,5 and 2,9 °C above the long-term average, and in September-October 2017 it was 3,5, 1,5 and 1,0 °C above the long-term average.

In autumn 2016, the temperature was 1,6°C higher in September alone, and 1,4°C and 0,4°C lower in October and November. In the autumn of 2018 and 2019, before sowing winter crops, the productive moisture reserves in the sowing layer of the soil were only 6–8 mm, which was not enough to get friendly germination. Therefore, in 2018 and 2019, pre-sowing irrigation was carried out at a rate of 400 and 500 m^3/ha, respectively. In general, autumn 2019, as well as 2018, was characterized by elevated temperatures, which were 2,1 and 2,3 °C higher than the long-term average. The amount of precipitation in autumn 2019 was 113 mm (109% of the seasonal norm), and in 2018 – 84 mm (81% of the norm). The amount of precipitation that fell during the period 'sowing – end of autumn vegetation' varied significantly during the years of research and ranged from 4,3–63,9 mm in 2013, 27,9–87,0 mm in 2014, 57,2–65,3 mm in 2015, 23,7–98,0 mm in 2016, 93,3–96,0 mm in 2017, 6,1–22,1 mm in 2018 and 60,8–131,2 mm in 2019.

Wet conditions were observed in 2016, when from 20 September, 1, 10 and 20 October until the end of the growing season, precipitation was 42,1 mm, 56,0 mm, 28,9 mm and 0,7 mm higher than the average for the period 1945–2010, respectively. In 2013, 2015, 2017 and 2018, the amount of precipitation during all sowing periods was below normal. At the same time, in 2013, the largest precipitation shortfall was observed during sowing on 20 October (-39.7 mm), and in 2015, 2017 and 2018, the largest precipitation deficits were observed during sowing on 20 September and 1 October: 50,7 and 36,7 mm, 36,3 and 23,0 mm, 31,5 and 30,0 mm, respectively.

In 2019, the precipitation during the autumn growing season when sowing on 20 September and 1 October exceeded the norm by 16,2 mm and 18,1 mm, respectively, and when sowing on 10 and 20 October was less than the norm by 26,2 mm and 21,2 mm. In 2014, the amount of precipitation for sowing on 20 September and 10 October was 20,2 mm and 3,2 mm above normal, while for sowing on 1 and 20 October it was 6,8 mm and 5,9 mm below normal. Thus, there have been significant changes in agrometeorological conditions and a noticeable warming trend.

AUTHOR INDEX

Наукове видання

КЛІМАТИЧНЕ ОБСЛУГОВУВАННЯ: НАУКА І ОСВІТА

Матеріали Другої міжнародної
науково-практичної конференції

м. Одеса, 16-18 квітня 2025 р.

Електронне видання мережевого використовування

В авторській редакції
(*англійською мовою*)

Затвердж. авт. 05.04.2025. Шрифт Times New Roman
Системні вимоги: операційна система сумісна з програмним
забезпеченням для читання файлів формату PDF.
Обсяг 5,7 МБ. Зам. № 2946

Видавець і виготовлювач:
Одеський національний університет імені І. І. Мечникова
вул. Університетська, 12, м. Одеса, 65082, Україна
Свідоцтво суб’єкта видавничої справи ДК № 4215 від 22.11.2011 р.
Тел.: (048) 723 28 39, E-mail:druk@onu.edu.ua