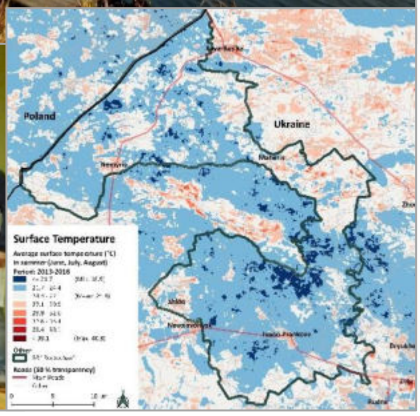
Climate Change and Land Use Impacts on Ecosystems and Human Well-being in Roztochya Biosphere Reserve

Situation Analysis for Ecosystem-based Adaptation



in the frame of the project:

"Ecosystem-based Adaptation to Climate Change and Regional Sustainable Development by Empowerment of Ukrainian Biosphere Reserves"

Implemented by:
Eberswalde University for Sustainable Development
Centre for Econics and Ecosystem Management
Succow Stiftung

Under the auspices of:
biosphere.center
a partnership between
Nationale Naturlandschaften
Succow Stiftung
Hochschule für nachhaltige Entwicklung Eberswalde

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Suggested citation:

Mack, K., G. Stryamets, A. Schick, I. Kruhlov, A. Smaliychuk, A. Dichte & P.L. Ibisch (2021) Climate Change and Land Use Impacts on Ecosystems and Human Well-being in Roztochya Biosphere Reserve: *Situation Analysis for Ecosystem-based Adaptation*. Centre for Econics and Ecosystem Management (CEEM), Eberswalde, Michael Succow Foundation, Greifswald, Germany.

Acknowledgments

The here presented contents, concepts, methods, analyses, maps, and recommendations are the result of contributions by several authors and would not exist in this form if it were not for their dedicated work, participation, and openness to share their findings, experience, and knowledge.

Special thanks to the supportive Biosphere Reserve staff, and all the participants at the citizen and expert workshops and EbA training.

Eberswalde and Greifswald, 2021

International Project:

"Ecosystem-based Adaptation to Climate Change and Regional Sustainable Development by Empowerment of Ukrainian Biosphere Reserves"

https://eba-ukraine.net/

The project is part of the International Climate Initiative (IKI) and financed by the German Federal Ministry for Environment, Nature Protection and Nuclear Safety based on a decision of the German Bundestag. The project is technically supported by the Ministry of Environmental Protection and Natural Resources of Ukraine.

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

based on a decision of the German Bundestag

Contents

1 Introduction

This document provides a summary of the situation analysis and the diagnosis. It is the cumulative result of the findings, discussions, and excursions during a. the citizen workshops[1] b. GIS-based analysis and mapping c. MARISCO (adaptive **MA**nagement of vulnerability and **RIS**k at **CO**nservation sites) expert workshops[2] d. EbA training[3] and recent developments since these events.

The aim is to highlight socio-ecological system components, their functions and services, and their vulnerabilities, especially connected to climate change-related impacts and anthropogenic drivers.

The two coupled and integrated ecosystem-based management approaches of Ecosystem-based Adaptation to climate change (EbA) and the MARISCO method and toolbox are powerful tools to:

1. Analyze the situation, vulnerability, and potentials of the respective socio-ecological system on a holistic and systemic level, permitting a better understanding and visualization of cause-effect chains, feedback loops and for the identification of leverage points to facilitate the right choice of strategic entry points.

2. Guarantee participation of the local and regional population, stakeholders, land-users, experts, professionals, and decision-makers, thus striving for a holistic approach (diverse sectors and points of view) and understanding of diverse necessities, limitations, and framework conditions. EbA can be successful and applied in the long run if it is structurally rooted in the regional and local administrations, decision-making, and land users' mental models, awareness, and knowledge systems.

Applying an adaptive management approach to climate change adaptation – please note!

Due to the complexity and variability of ecosystem processes and functions, which is even increased by the interaction with social systems and constructs, the here applied approach to Ecosystem-based Adaptation is adaptive by nature.

The approach is itself a learning process, helping to adapt methodologies and practices according to how the relevant systems are being managed and monitored. The aim is to reach workable preliminary conclusions based on the best available and accessible data (which is mostly not peer-reviewed and site-specific). Based on such conclusions the most fitting strategy and implementation programs can be designed, yet in ways to always allow for adjustment to the unexpected, contrary to making rigid assumptions and taking steps based on the false belief of certainties. Such flexibility is also necessary for policymaking and implementation because long-term inflexible decisions are likely to become outdated, inadequate, or even detrimental for the system.

At both spatial and temporal scales climate change impacts, biodiversity loss, and ecosystem malfunctioning become evident to local stakeholders. Irrespective of scale, it is important that people are considered as part of, rather than actors external to the ecosystem. It is crucial to recognize the diversity of social and cultural factors affecting natural resource use. Thus, the concept of a 'socio-*ecological system'* is used throughout the document. It requires considering the specialties and uniqueness of local and traditional knowledge, regional expertise and combining and triangulating these knowledge systems with available scientific studies and research on the local, regional, and wider spatial scales.

Thus, ecosystem management and the here applied approaches, need to be envisioned as a long-term experiment that builds on its results as it progresses, a 'learning-by-doing', a source of information, and a shared gaining of knowledge and progress towards mutually agreed goals.

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[1] The citizen workshops took place in November 2018 and involved a variety of local participants of different age, gender and background.

[2] The MARISCO expert workshops were conducted from 3 to 5 June 2019 in Ivano-Frankove village.

3 The training on Ecosystem-based Adaptation to Climate Change with 28 Ukrainian and German participants took place in December 2019, Eberswalde, Germany.

2 Situation Analysis

One central component of the situation analysis is the MARISCO method. Its output is a comprehensive diagnostic of the area, including ecological stresses diminishing ecosystem functionality and their drivers such as climate change and anthropogenic factors. Both human affectedness and stake in such processes were analyzed and depicted systemically. Besides, a basic portfolio of potential ecosystem-based strategies for adaptation to climate change was developed.

A short introduction to the MARISCO method in frame of the EbA Ukraine project

MARISCO method is an approach and toolbox to adaptive ecosystem-based management. It facilitates the integration of dynamic risk and vulnerability perspectives into the management of conservation projects and sites[4].

To gather existing and new knowledge and to analyze the complex socio-ecological system of Roztochya BR, the project team applies this method, a stepwise process to identify and map both essential and strategically relevant elements of the system. The involvement and active participation of diverse groups of stakeholders, including local and regional citizens, land users, professionals, and scientists were ensured to make the model and analysis as site-specific and robust as possible. The findings are being extended and substantiated by excursions, spatial analyses, and desktop research.

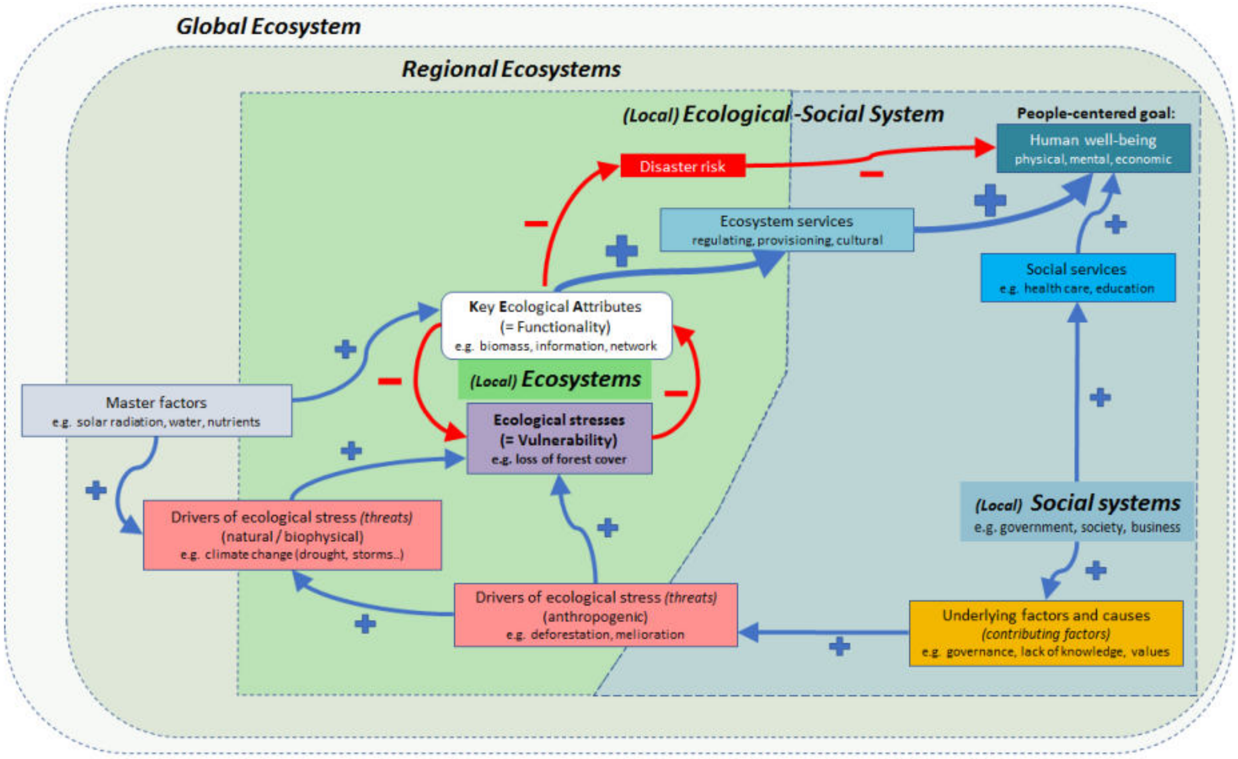

Figure 1 Conceptual model for the MARISCO situation analysis approach; Illustration by K.Mack

This situation analysis comprises the **ecosystems of the Roztochya BR area**, their respective **key ecological attributes (KEA),** and the **ecosystem services (ES)** they provide to people. A high functionality (availability of KEAs) of the ecosystems secures the quality and quantity of ecosystem services, thus contributing to **human well-being in the Biosphere Reserve and beyond**. The **ecological stresses** (e.g. loss of forest cover) describe degraded or even destroyed KEAs (biomass, information, and network), thus indicating the increased vulnerability of the ecosystems. The **drivers of such ecological stresses** can both be of natural/biophysical (e.g. climate change) and anthropogenic origin (e.g. deforestation, melioration). Nowadays, such drivers of stress mostly stem from human **underlying factors and causes** (e.g. governance, lack of knowledge, values), which are driven by the government, societal, economic, and other sectors, constituting the **social systems**. The social systems also contribute (or not) to human well-being via the so-called **social services** (e.g. health care, education).

[4] MARISCO (**MA**nagement of vulnerability and **RIS**k at **CO**nservation sites), Source: https://www.marisco.training/

2.1 Ecosystems, their Functions, and Services

Nature is the basis of all life. Ecosystems, i.e., the habitats and organisms inhabiting them, are the natural structures in which the various components interact particularly intensively and perform different services. They consist of complex, dynamically interacting functional units with emergent properties. From a functional point of view, ecosystems are self-organizing bioreactors through the interaction of their living components, in which energy is captured, passed on, converted, stored, and above all, used to perform work.

Thus, ecosystems are complex systems that use energy and perform work in the physical sense. They result from the fact that living organisms interact as system components with each other and with inanimate resources and thereby develop emergent properties, such as temperature regulation. This guarantees or promotes their continued existence.

Main ecosystem classes of the Roztochya Biosphere Reserve

The following images show the four general ecosystem classes selected for the Roztochya BR.

Forest ecosystems

Water- and Wetland ecosystems

Grassland ecosystems

Agro- and Settlement ecosystems

Images by - Top left: Roztochya BR / Top right: J. Kloiber / Bottom left: Roztochya BR / Bottom right: J. Kloiber

Ecosystem map with ecotope classes

The existing functional ecosystem classes in the Roztochya BR were identified and defined during the MARISCO workshop and in course of the spatial analysis commissioned by the project group.

The map includes data based on landcover classification made within the framework of this project using current sentinel satellite images and manually mapped hydrological and other physiotope conditions, including publicly available data.

The ecosystem map (based on ecotope classes) is **attached to this document series in printed A1 format** and can be accessed online via the project website: https://www.eba-ukraine.net/maps.html

2.1.1 Ecosystem classes and their functions

Results of ecosystems performing work include all physical, chemical, and biological processes and interactions that take place in the various ecosystems. For example, ecosystems produce biomass, filter, and store water, ensure the pollination of plants and thus their survival (also in agriculture), convert and decompose organic and inorganic substances and thus maintain soil fertility. Emergent properties of these systems are for example temperature regulation, which is a precondition for the survival and well-being of many species, including humans. Thus, ecosystems fulfill several important functions and significantly influence many of the life-enabling processes.

Ecosystem Functionality

The functionality of an ecosystem describes a certain state of an ecosystem. It is characterized by inherent structures, ecological functions, and dynamics, the so-called **Key Ecological Attributes** that provide an ecosystem with the following conditions:

- The necessary (energetic, material, and hydric) efficiency
- The flexibility to demonstrate the development of resilience without abrupt changes in system properties and geographical distribution, and to respond flexibly to external change.
- The adaptive capacity to adapt to perturbations and shocks (e.g. caused by climate change)

Thus, the decisive criteria include the nativeness or naturalness of the respective ecosystem, the degree of self-regulation, the amount and type of vegetation or plant biomass, the complexity and diversity, and the proportion of the unsealed area.

The following table introduces the semi-quantitative ranking (levels) of (self-) regulating capacity to reduce climate change vulnerability and risk according to the availability of functional ecological structures and processes.

Level of (self-) regulating capacity based on ecosystem functionality		**Definition**
1	Very high	The ecosystem is **in a (near-) natural state, almost undisturbed** such that **all functional ecological structures and (self-) regulating capacity** are **fully available and maximal**. The conditions are highly beneficial for local and regional climate regulation and buffering.
2	High	The ecosystem is in a **largely natural state** and **negligibly impaired** such that many **functional ecological structures and (self-) regulating capacity** are **available to a high degree**. The conditions are beneficial for local and regional climate regulation and buffering.
3	Rather high	The ecosystem is **partly artificial** and **relevantly impaired** such that **some functional ecological structures and (self-) regulating capacity** are available to **a moderate degree**. The conditions are somewhat beneficial for local and regional climate regulation and buffering.
4	Rather low	The ecosystem is **mostly artificial**, **impaired, and disturbed** such that **functional ecological structures and (self-) regulating capacity are limited**. The conditions are marginally beneficial for local and regional climate regulation and buffering.
5	Low	The ecosystem is **highly artificial**, **significantly impaired, and disturbed** such that **functional ecological structures and (self-) regulating capacity are low**. The conditions are not beneficial or even detrimental for local and regional climate regulation and buffering.
6	Very low	The ecosystem is **completely artificial, heavily impaired, and disturbed** such that **functional ecological structures and (self-) regulating capacity are minimal**. The conditions are harmful to local and regional climate regulation and buffering.

The following tables (2.1.1.1-2.1.1.4) describe the ecosystems´ functional classes according to their general site conditions and ranked level of ecological functionality.

2.1.1.1 Forest Ecosystems

Forest ecosystem (Functional classes)	Site condition	Description	Approx. Area Size in ha (% of total territory)	Ranked level of functionality (Scale 1: highest – 6: lowest)
Broadleaved and Mixed	Roztochya forms part of the broadleaved forest zone and includes a variety of tree communities of beech (fagus sylvatica), admixtures of maple-beech (acer pseudoplatanus) and ulmus glabra; Hornbeech-beech (carpinus, fagus); Pine-beech; Pine-oak-beech; Black alder (alnus glutinosa); Ash (Fraxinus excelsior); Birch			
	On low interfluves (hygric-mesic)		2,083.79 (2.79%)	
	On elevated interfluves (mesic)		16,971.77 (22.69%)	
		Natural and near natural (Conservation and protected forests)		1
		Artificial (Plantations and intensively exploited)		3
Needle-leaf (coniferous)	Including mostly Scots pine (Pinus sylvestris), Common spruce, and Douglas fir			
	On low interfluves (hygric-mesic)		5,207.84 (6.96%)	
	On elevated interfluves (mesic)		13,774.32 (18.42%)	
		Natural and near natural (Conservation and protected forests)		2
		Artificial (Plantations and intensively exploited)		4

Functionality of forests at Roztochya BR

The area encompasses various forest ecosystems that are differently limited in their functional capacity (Maps 11-14: Cooling capacity map as an indicator of the level of regulating functionality). Depending on the degree of use and change, the different forest ecosystems show more or less (self-) regulating capacity. In the overall forest area, a balanced share of about 50% is covered by pure and mixed pine stands. The remaining, equal of about 50% consists of the broad-leaved and mixed broad-leaved forests, such as pure beech (fagus sylvatica) and mixed stands including admixtures of maple-beech (acer pseudoplatanus) and ulmus glabra, Black alder (alnus glutinosa), Ash (Fraxinus excelsior) and Birch.

The near-natural broad-leaved and mixed broad-leaved stands with native main tree species, including bog and fen forests, are home to the main tree species beech, birch, oak, or black alder. They occur with and without mixed and secondary tree species such as Hornbeech (carpinus), maple, ulmus, and have a very high functional capacity. Anthropogenic influence, i.e. ecosystem stresses directly caused by humans, are comparatively low. Due to the high diversity of species and structures and the high proportion of native broad-leaved trees, these stands have sufficient (self-) regulating capacity that climate change impacts are buffered, and climate change-induced stresses can occur rarely or only in a weak form.

Mixed pine-broad-leaved stands are usually older stands with scots pine as the main tree species and broad-leaved trees such as beech, oak-beech, or birch and late blossoming secondary tree species. Due to the mixture of species and age classes as well as the comparatively high proportion of broad-leaved trees, the functional efficiency can be classified as high, although not very high, since these stands were mostly established or actively influenced by humans.

Pure pine stands, mixed pine-needle stands, and other coniferous stands are relatively unnatural forest ecosystems with conifers such as the scots pine, the common spruce, or the Douglas fir from North America as main tree species. None or very little admixture of secondary tree species of the mostly industrial forests is present. Thus, the functional efficiency can be classified as medium to low. Permanent human interventions characterize these ecosystems; self-regulation can hardly take place. Many essential ecosystem structures and processes are missing in these forests, which also makes them vulnerable to climate change impacts in the long term.

Clearcut areas, pioneer forests, and young forests exist due to human activities. These include young afforestations, bare areas, clearings, and patches with overstory on dry sites. Often these areas undergo further maintenance and development interventions such as weeding, planting, and later thinning. However, these highly transformative ecosystems have a high potential to build ecological functioning if allowed to develop in a primarily self-regulated manner in the future. They have intermediate functional capacity.

2.1.1.2 Water- and Wetland Ecosystems

Ecosystem	Site condition	Functional classes / with … vegetation	Approx. Area Size in ha (% of total territory)	Ranked level of functionality (Scale 1: highest – 6: lowest)
Wetlands				
	… in valley bottoms… (hydric-hygric)	All main kinds of mires, in particular eutrophic (most common), mesotrophic and oligotrophic (most rare) mires; bogs…		1
		…with broadleaved and mixed forest	1,977.28 (2.64%)	1
		…with coniferous forest	1,773.78 (2.37%)	2
		…with grassland (incl. flooded meadows, peat and wet types, also included drained wetland with grass and meadows)	3,171.12 (4.24%)	3
		…with cropland (mainly on drained wetlands)	3,017.64 (4.04%)	5
Water bodies and running waters		**Description**		
Lakes		Undisturbed and (near-)natural, protected		1
		Highly frequented and intensively used also artificial (e.g. flooded sulphur mines)		2
Ponds and puddles (natural)				1
Large (artificial) ponds		Highly frequented and intensively used (also regularly drained)		3
Springs			**Sum of all:** 1,338.17 (1.79%)	1
Rivers		Natural and undisturbed		1
		Modified with transversal and longitudinal shoring, intensely used		3
Smaller streams		Natural and undisturbed		1
Drainage Systems /Channels				6

The **hydrography map** (based on ecosystem data) is **attached to this document series in printed A1 format** and can be accessed online via the project website: https://www.eba-ukraine.net/maps.html

Functional classes of wetland and water ecosystems

The availability of mires, in particular eutrophic (most common), mesotrophic, and oligotrophic (most rare) as well as bogs play a significant role in the Roztochya area. They are important as they represent a transitional form between water bodies and terrestrial habitats. The use and alteration of sites where wetlands are present vary greatly, which also has different effects on their functional capacity. Only (semi-)natural mires and bogs have a very high ecological functional capacity. As semi-terrestrial sites, they combine the water storage capacity of water bodies with the ability of terrestrial systems to produce plant biomass that additionally stores and evaporates water. Farmed and degraded wetlands, on the other hand, tend to match their environment in functional capacity. For example, agriculturally used fen sites have intermediate functional capacity. In the past, the drainage of fens created species-rich wet meadows. However, often complex nature conservation measures are necessary to preserve these, as natural succession would lead to scrub encroachment or reed buildup. Then, the ecological functionality is also only moderate.

In this classification, water bodies include continuously flowing freshwater bodies above ground (such as Vereshchytsya River) and smaller tributaries as well as still waters (e.g. small lakes, puddles, or ponds). These have grown and developed naturally, but can also be artificially created (e.g. large fishing ponds along the course of Vereshchytsya River or pools in the settlement area or for agricultural or forestry use). Ponds or pools are not bound to a specific section of the landscape in any characteristic way. Due to their ability to absorb, supply, and evaporate water, they play a significant role in ecosystem-based adaptation to climate change but can also disturb the overall hydrological regime thus negatively impacting the overall functionality of the systems.

Flowing waters include primarily the Vereshchytsya River and its tributaries, including piped streams and small creeks. In the Roztochya region, smaller flowing waters are in part strongly influenced by humans. This includes not only the many changes in river courses caused over centuries and the construction of flowing waters but more recently also measures of renaturation and revitalization. Locally, these effects manifest themselves in part very differently and are often also spatially displaced. Similar to still waters, streams are central to ecosystem-based adaptation to climate change because of their ability to absorb, store, remove, and evaporate water. Their spatial dispersal and connectivity are particularly important to the networking between different ecosystems.

2.1.1.3 Grassland Ecosystems

Functional class	Site condition	Approx. Area Size in ha (% of total territory)	Ranked level of functionality (Scale 1: highest – 6: lowest)
Meadows (terrestrial, dry types)	On low interfluves	1,611.49 (2.15%)	3
	On elevated interfluves	3,927.42 (5.25%)	3

2.1.1.4 Agro- and Settlement Ecosystems

Ecosystem	Site condition	Functional classes	Approx. Area Size in ha (% of total territory)	Ranked level of functionality (Scale 1: highest – 6: lowest)
Agricultural land	On low interfluves		5,361.7 (7,17%)	
	On elevated interfluves		7,736.92 (10.35%)	
		Pastures		3
		Hayfields		3
		Cropland (intensively used)		4
Settlements			6,831.4 (9.13%)	
		Cemeteries		4
		Allotment gardens		4
		Settlement (housing) areas (Buildings and yards)		5
		Mineral mining areas		6
		Waste polygons		6
		Sewage and waste pits		6
		Technical infrastructure & facilities		6
		Roads		6

2.1.2 Ecosystem services

Ecosystems are not only 'nature' out there, beautiful, and simply given. For us humans they are also the indispensable basis of our well-being and economic activity: they provide food, clean water, living space, and a source of income. They also provide recreation and a sense of home. These ecosystem services are essential for human well-being. In addition to these more obvious provisioning and cultural services we receive from ecosystems, they also regulate water balance and water quality, influence air quality, and local climate, protect against soil loss or degrade pollutants. These regulating services are seemingly inexhaustible and free for everyone to use which is why they are often neglected in economic and development considerations.

According to the *Common Classification of Ecosystem Services* (CICES) developed by Haines-Young & Potschin, these services obtained from ecosystems for human benefit can be ordered into the following three classes:

Regulating Ecosystem Services

In current times of accelerating climate change, regulating ecosystem services are coming to the fore. They are the key services when it comes to adaptation to climate change. These include services that result from the fact that the work of ecosystems positively influences the quality of the environment such as air and water purification, pollination, fertile soils, flood prevention (e.g. through soil- and plant water retention), and climate regulation. Further examples are the storage of greenhouse gas carbon dioxide or biological control of pest infestation.

The regulating services can be understood as fundamental services, themselves guaranteeing a sufficient and qualitative provision of material and cultural services.

Provisioning Ecosystem Services

Provisioning ecosystem services are the goods (biomass and genetic materials) that are produced by ecosystems and used by humans. For example, food (such as fruit and vegetables), drinking water, timber (e.g. as construction material), and fuel materials (firewood, peat) are provided by ecosystems.

Cultural Ecosystem Services

Cultural ecosystem services are of high relevance, especially in modern, technology-oriented societies. Varied and semi-natural landscapes offer high recreational, educational, and adventure value. The typical features and the condition of ecosystems have a complex effect on the human psyche. In this way, they also create an identity and contribute to people feeling connected to their habitat.

On the following page, a non-exhaustive list of ecosystem services of the Roztochya BR is depicted. They were identified and discussed by a group of local citizens, experts, and stakeholders.

**Images by - Top: Pierre L. Ibisch / Middle: J. Kloiber / Bottom: Roztochya BR*

Regulating Ecosystem Services	Provisioning Ecosystem Services	Cultural Ecosystem Services
Regulation of physical, chemical, biological conditions **Regulation of baseline flows and extreme events** ▪ Wind erosion reduction and prevention ▪ Hydrological cycle and water flow regulation (Including flood control) ○ Regulation of surface water level and runoff ○ Regulation of groundwater level ▪ Water accumulation and retention (incl. flood protection) ▪ Protection from soil erosion ▪ Reduction of wind speed; wind protection ▪ Fire protection **Lifecycle maintenance, habitat, and gene pool protection** ▪ Pollination* ▪ Seed dispersal* ▪ Maintaining nursery populations and habitats* ▪ Biotic production **Pest and disease control** ▪ Pest control and reduction of the spread of invasive species* ▪ Prevention and reduction of diseases* **Regulation of soil quality** ▪ Soil formation ▪ Soil purification and fertility ▪ Soil moisture regulation ▪ Mediation of weathering processes* ▪ Decomposition and fixing processes* **Regulation of water quality** ▪ Regulation of the chemical and physical quality of freshwater in surface waters (standing and flowing) ○ Water purification ▪ Regulation of the chemical and physical quality of groundwater **Regulation of air/atmosphere quality and climate regulation** ▪ Microclimate regulation (e.g cooling) ▪ Filtration and purification of air ▪ Air humidity regulation ▪ Carbon sequestration (reduction of anthropogenic CO2 emissions) ▪ Oxygen production **Transformation of biochemical or physical inputs** **Mediation of wastes or toxic substances of anthropogenic origin** ▪ Bioremediation/cleaning by (micro-) organisms* ▪ Filtration, accumulation, storage by (micro-) organisms* **Mediation of nuisances of anthropogenic origin** ▪ Smell reduction* ▪ Noise attenuation* ▪ Visual screening*	**Biomass** **Nutritional use** ▪ Non-timber forest products (berries, mushrooms, medical herbs) ▪ Fishery products (both private and business) ▪ Organic products ▪ Honey (beekeeping) ▪ Agricultural produces (crops/grains/vegetables) ▪ Meat and dairy products by livestock breeding **Materials** ▪ Timber ▪ Construction wood ▪ Hay ▪ Cosmetics ▪ Flowers ▪ Gardening and horticulture products **Energetic use** ▪ Fuelwood / Firewood **Fundamental goods** ▪ Fresh and clean air ▪ Fresh and clean water **Genetic material from all types of organisms*** ▪ Seeds, spores, and other plant materials collected for maintaining or establishing a population* ▪ Individual plants used to breed new strains or varieties* ▪ Individual genes extracted from plants for the design and construction of new biological entities* ▪ Animal material collected to maintain or establish a population* ▪ Wild animals (whole organisms) used to breed new strains or varieties* ▪ Individual genes extracted from organisms for the design and construction of new biological entities*	**Direct outdoor interactions with living/ecological systems in their natural setting** **Physical and intellectual interactions with biota, ecosystems, and landscapes** ▪ Tourism ▪ Recreation (e.g in the forest) and sports (swimming etc.) ▪ Health treatment and therapies – aroma and hydro ▪ Ecological education (researching and studying nature) ▪ Bird/animal watching ▪ Source/Place of inspiration ▪ Arts (photography/painting) **Spiritual, symbolic, and other interactions with biota, ecosystem, and landscapes** ▪ Aesthetic value ▪ Spiritual value ▪ Traditional, and cultural value ▪ Wood-based traditional crafts (willow branches, wooden toys) ▪ Decoration for fests and holidays

Table 1: Roztochya BR Ecosystem Services; Classification based on CICES, Haines-Young & Potschin (2017), contents by workshop participants **added by the author based on CICES*

2.2 Ecosystem Vulnerability, Risks, and Human Affectedness

In the Millennium Ecosystem Assessment, vulnerability is defined as:

> *Exposure to contingencies and stress and the difficulty in coping with them. Three major dimensions of vulnerability are involved: **exposure** to stresses, perturbations, and shocks; the **sensitivity** to the stress or perturbation, including their capacity to anticipate and cope with the stress; and the **resilience** of the exposed ecosystems in terms of their capacity to absorb shocks and perturbations while maintaining function.*[5]

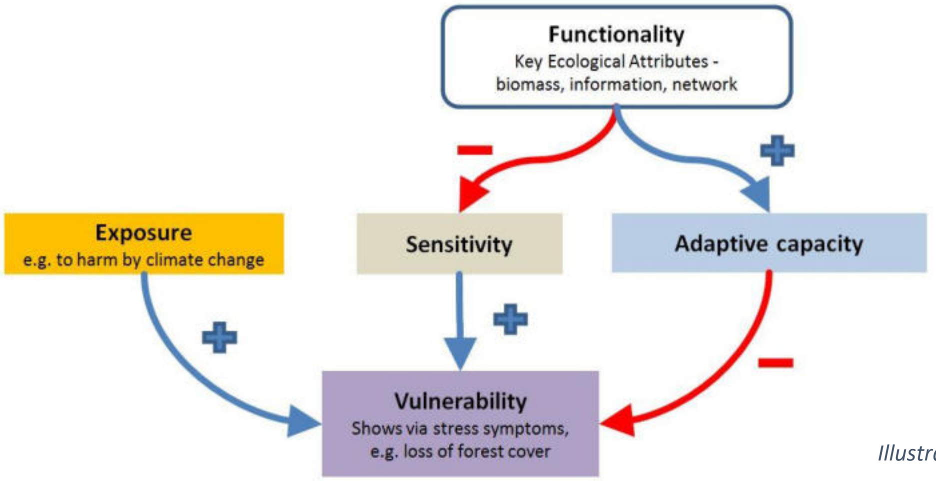

Illustration by K.Mack

Exposure to e.g. climate change causes stress in the ecosystems (e.g. by extreme temperatures or absent precipitation), indicating the increased overall vulnerability.

The **ecological stresses** are the visible symptoms and manifestations of the degradation of key ecological attributes. They indicate how stressed, i.e. vulnerable an ecosystem is. This includes the loss of minimum levels of biomass (e.g. trees, mosses, flowers, fungi, dead matter, etc.), information (gene pool, nutrient uptake, nutrient provision, etc.), and network (e.g. mycorrhizal symbiosis, nutrient exchange, etc.) due to insufficient availability or quality of master factors (e.g. energy input, moisture, temperature, nutrients, etc.)

The result is that, under certain conditions, the ecological attributes begin to degrade, which then impacts the resilience, adaptive capacity, and efficiency of biodiversity elements, such as species or ecosystems. If stress (or a mix of stresses) is sustained, shifts or changes in the ecosystem occur. Ecological stresses are **caused by the "drivers of ecological stress"** (as explained in chapter 2).[6]

The drivers of the ecological stress (also *threats*) can be natural events, for example, droughts and tornados, as well as anthropogenic activities such as deforestation or draining of landscapes. These threats damage and degrade the Key Ecological Attributes, i.e. decrease functionality, and increase vulnerability. The underlying factors and causes (also *contributing factors*) originate both from direct and indirect natural/biophysical processes as well as from anthropogenic origins.

2.2.1 Exposure to climate change in Roztochya Biosphere Reserve

Roztochya Biosphere Reserve represents the most western part of the broadleaved forest zone in Ukraine. The local climate is extensively influenced by westerlies, which cause the highest annual precipitation at this location compared to the entire plain part of the country. Therefore, Roztochya is a north-eastern frontier for natural beech forests in Ukraine. Variations in surface topography

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[5] Adapted from Millennium Ecosystem Assessment (2005), p. 605

[6] Ibisch P. L. and Hobson P. R. (eds.), *MARISCO: Adaptive MAnagement of vulnerability and RISk at COnservation sites: A guidebook for risk-robust, adaptive and ecosystem-based conservation of biodiversity* (Eberswalde: Centre for Econics and Ecosystem Management, 2014).

(both in elevation and morphology) cause uneven distribution of solar radiation and precipitation causing a distinct pattern of microclimate in Roztochya. The summer seasons are humid and often with thunderstorms, whilst winter tended to occur with a permanent snow cover until recent years.

There are permanent facilities for the collection of climatological data within the biosphere reserve, namely in the town Ivano-Frankove. Being set up only in the late 1980ies, it cannot provide long-term datasets which explains why the here presented data is from three weather stations of the Ukrainian Hydrometeorological Service situated nearby. The data comes from the weather stations of Lviv, Yavoriv, and Rava-Ruska, which are situated to the east, south, and north respectively. They are no more than 15 km distant from the reserve's edge.

Changes in air temperature

During the climatic normal period between 1961 and 1990 (standard reference) the average annual air temperature was about 7.4 °C. It reached a maximum of 9.0 °C (Rava-Ruska) and 9.1 °C (Yavoriv) in 1989. In the last 28 years (1991-2018) the mean annual temperature increased to 8.4 °C, i.e. by 1.0 °C. It has been particularly high since 2014 with a peak of 10.0 °C in 2015 for Yavoriv. The mean monthly temperature of the coldest and hottest months (i.e. January and July) in the periods of 1961-1990 and 1991-2018 were -4.4 vs -2.4 °C and 17.5 vs 19.2 °C respectively.

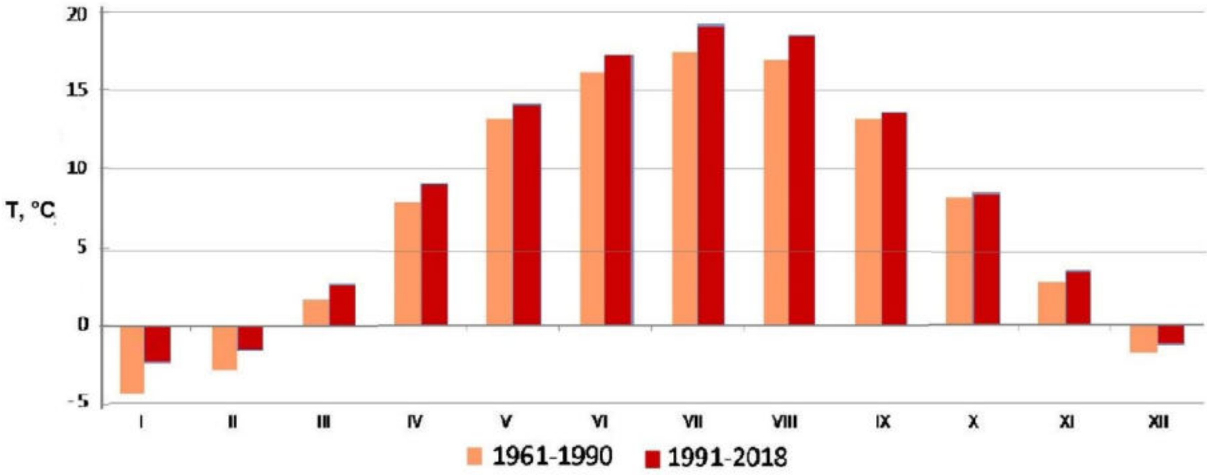


Figure 2 Monthly average temperatures for periods 1961-1990 and 1991-2018; Graph by A. Smaliychuk

The highest increase in mean monthly temperatures in comparison to the climatic normal was observed for the winter (January & February) and summer months (July & August) (see figure 3). Moreover, this trend has accelerated in the years (2014-2018) when the highest temperature rise was calculated as more than 2.5°C for December, August, and February. It was particularly hot in August 2015 and July of 2014, when the average air temperature reached 21.5 and 20.5°C respectively, which corresponds to the past long-term average of Central-Eastern Ukraine within the steppe zone. In 2018, the summer days (maximum daily temperature exceeding 25 °C) were observed as earliest as April, which is additional evidence of the recent climate change in the region.

The meteorological station located within the biosphere reserve provided the following data:

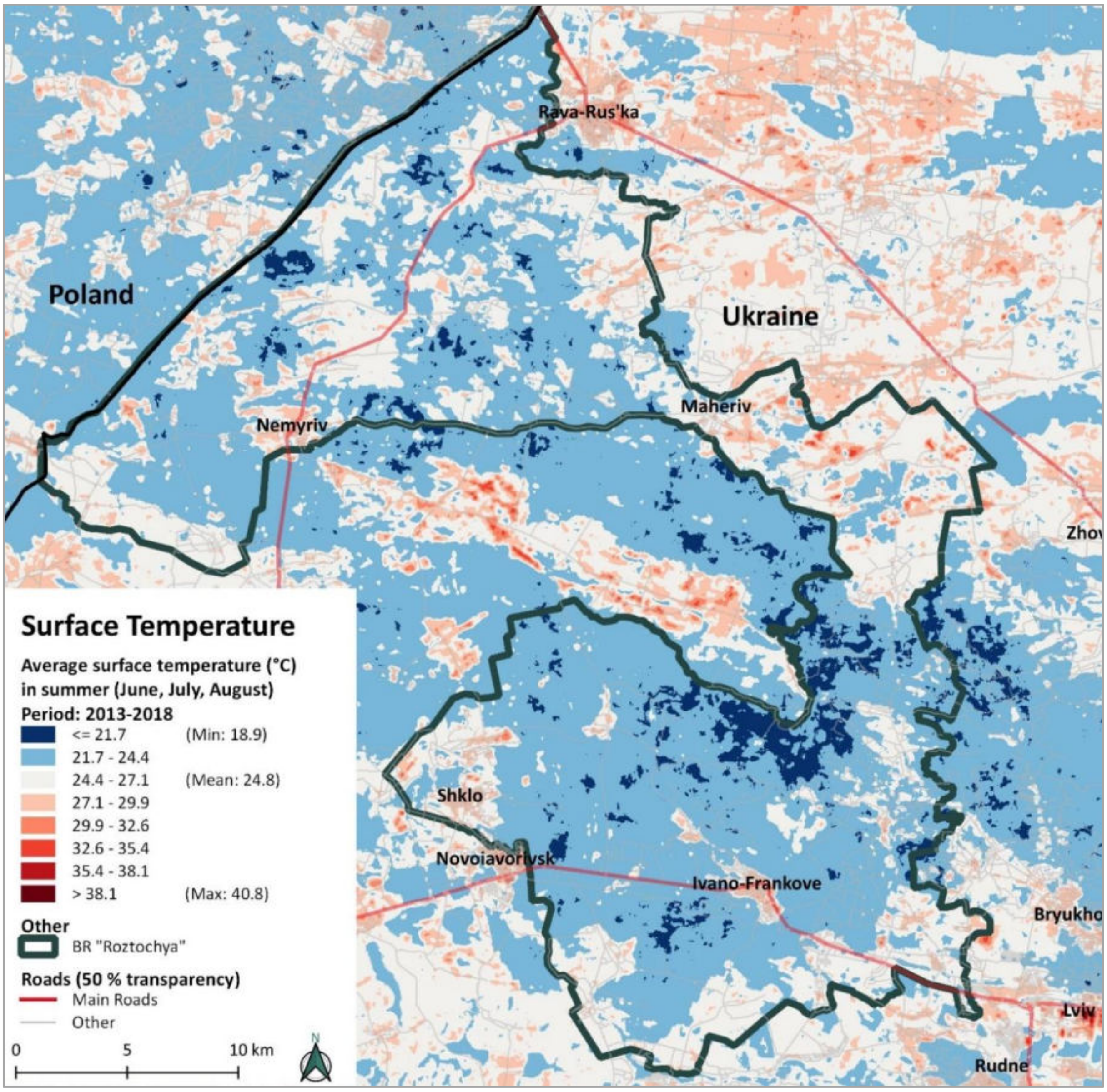
- During the last 30 years, the average annual air temperature increased by 1-1.7°C. In the summer period by approx. 1.9°C and in the winter period by 1.5°C.
- The average annual air temperature increased by 1.4 °C over the last 10 years (2010-2019) and by 1.7 °C for the last 5 years (2015-2019).
- Additionally, the summers of 2013-2019 are characterized by high maximum temperatures between 32,0 - 36.0°C. Also, the number of warm and hot days has increased.

Projections for the future

According to the most probable climate development scenarios for the Roztochya region (B1 and A2 scenario of IPCC) the mean annual temperature is expected to increase by 2.1 and 4.6 °C respectively by the end of the 21st century in comparison to 2000-2010 average. They also indicate an increasing variability of the amount of precipitation, which might be challenging for the development of sustainable and adapted agriculture and forestry in the region.

This increased number of warm and hot days also causes an incline in surface evaporation, having a significant effect on water bodies and the general hydrological situation of the region. In subsequent dry and warm years, the future cooling capacity of lake-, forest-, wetland-, and grassland areas through evaporation and evapotranspiration is can be diminished significantly.

Satellite-based remote sensing data for the reflection of heat radiation now makes it possible to assess surface temperatures on a global, regional, and local scale. The surface temperature map (see figure 4) shows average surface temperature (°C) patterns in the summer months (June, July, August; day-time) at Roztochya BR and adjacent regions. They were recorded by the Landsat 8 satellite every two weeks from 2013 till 2018 with a spatial resolution of 30 m. Compared with the ecosystem map on page 6, it appears that settlement and arable land show the warmest (red) areas and the large areas of forest, wetlands, and water bodies the coolest areas (light and dark blue) of the region.



Map 1 Surface temperature map, Landsat 8 OLI & TIRS: US Geological Survey, Roads & settlements: OSM 2019; Data processing and analysis by S. Kriewald (PIK); Map by A. Dichte

Hence, the map also allows interpretations about the work capacity of different ecosystem types, their functional state, and regulating capacity to handle increased incoming energy (solar radiation), buffer and transform it, and thereby cool themselves and surrounding areas. This (micro-) climate regulating capacity of the different ecosystem types refers to chapter 2.1.1 and is partly included in the rankings of ecosystem functionality.

[7]Rising temperatures are one of the most dangerous consequences of climate change, threatening socio-economic systems (Chen et al. 2020), ecosystem functions (Fisher et al. 2017) and human health (Vicedo-Cabrera et al. 2021, Luber & McGeehin 2008; Mora et al. 2017). These findings increase the importance of regulating ecosystem services, such as mitigating local temperatures and temperature peaks. While the positive influence of forests and wetlands or water bodies on (micro)climate is widely known and acknowledged (e.g. Blumröder et al. 2021, Alkama and Cescatti 2016, Bonan, 2008, Bright et al. 2017, Frenne et al. 2019; Zellweger et al., 2019), their concrete contribution to regional landscape cooling has not been accurately assessed so far. For a study in north-eastern Germany, a satellite-based method was developed to quantify the effect of different land use types on surface temperatures in the landscape (Gohr et al. 2021).

An area of about 11,000 km2 in the northeast German lowlands was chosen for the analyses. The area encompasses a land use gradient that includes the metropolis of Berlin in the south and the Mecklenburg Lake District in the north, thus covering various forest ecosystems of different sizes, water bodies, but also agricultural areas as well as other urban areas in more rural regions.

When considering the hottest days (days with daily maximum temperature ≥ 30 °C in the study period, for the years 2002-2020), temperatures in forests were on average almost 4 °C below temperatures in urban areas and on average about 3 °C below temperatures in agricultural areas. Modeling a theoretical conversion of 10% of the agricultural land in the study area into 'average forest' showed that the average temperature on heat days would be reduced by 0.9 °C.

Furthermore, a clear correlation between the vitality of the vegetation and the cooling effect could be established. The more vital a forest ecosystem is, the more pronounced its cooling capacity, with effective cooling in turn helping to mitigate heat stress under extreme summer temperatures, which can thus have a positive effect on vegetation vitality. Thus, climate change effects can be counteracted at the local level. Risks associated with them are reduced.

The study of Gohr et al. (2021) shows that landscape temperature depends on the composition of land use types. The cooling function of forests and water bodies in the landscape on hot days can be explained by their ecohydrological functions, which support the uptake, processing, and storage of water in ecosystems (Ellison et al. 2017). Evaporation, transpiration, and shade (in forests) ensure local cooling during the day (Ellison et al. 2017, Maes et al. 2011, Shen et al. 2020). However, reduced soil moisture due to heat extremes can impair temperature regulation functions (Teuling et al. 2010). In summary, the temperature regulation of forests and water bodies in the landscape depends on different local and regional factors such as evaporation, albedo, and energy conversion, as well as on supra-regional functions such as land use type composition and clouds (Wu et al. 2021, Shen et al. 2020, Bright et al. 2017, Zeng et al. 2017, Bonan 2008, Benayas et al. 2008, Zaitchik et al. 2006, Schneider & Kay, 1994). The thermal effects of forests and water bodies can be understood as a potential for ecosystem-based adaptation to climate change-induced heat stress (e.g. Kupika et al. 2019, Nanfuka et al. 2020). The relevant ecosystem functions need to be integrated into landscape management target systems. Targets and incentives should be created to support these functions

[7] The following paragraphs have been extracted and translated from the document: *Pierre L. Ibisch, Charlotte Gohr, Deepika Mann & Jeanette S. Blumröder (2021). Der Wald in Deutschland auf dem Weg in die Heißzeit. Vitalität, Schädigung und Erwärmung in den Extremsommern 2018-2020. Centre for Econics and Ecosystem Management an der Hochschule für nachhaltige Entwicklung Eberswalde für Greenpeace. Eberswalde* (in German language).

(Lusiana et al. 2017). The quantification of landscape cooling with satellite-based surface temperature data can be readily adopted for analyses in temperate landscapes.

For the description of the used datasets and method, please refer to the Toolbox document in frame of this publication series.

Changes of seasons

In Roztochya BR, the following changes in seasons have been observed:

- Warmer and dryer summers and unusually mild winters without frost and snow become more frequent on the territory of the Biosphere Reserve for several years in a row.
- The duration of the spring season is shortened. This is accompanied by lower levels of air humidity, cold nights, warm days, cold exhaustive winds, and relatively small amounts of precipitation.
- Anomalies in phenomena such as the repeated blossoming of flowers, individual trees, and bushes are occurring more frequently.
- Unusually hot summers with periodic disastrous rainfalls and storms increase.

Changes in wind directions

The prevailing vectors of wind directions of the Roztochya have started to change significantly:

- In the past, south-western winds dominated. In recent years, the north-western and even north-eastern winds started dominating. Such fact specifies new trends in the movement of atmospheric waves, it affects the balance of precipitation and air pollution in the lower strata of the atmosphere.

Changes in precipitation quantity and patterns

The average annual amount of precipitation in the region of the biosphere reserve compared to the reference period and the last three decades increased by almost 6 % – from 719 to 765 mm. However, eight out of ten years between 2009 and 2018 had an amount of precipitation close to the long-term average of 1961-1990. Most precipitation still falls during the summer season, but there are some changes in volume throughout the year. Between 1991 and 2018, a substantial decrease in the amount of rainwater was recorded for June and December, while in March, May, and September a substantial surplus of water was recorded compared to the climatic normal. The lowest changes in precipitation patterns showed in July and August.

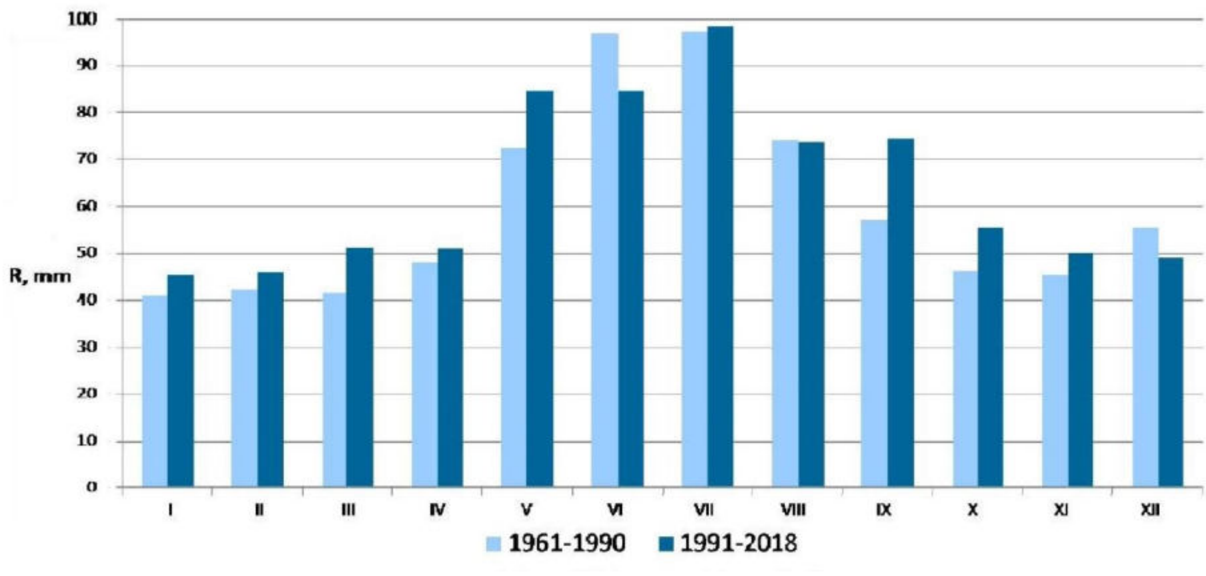


Figure 3 Monthly average sum of precipitation during the periods 1961-1990 and 1991-2018, Graph by A. Smaliychuk

During the period 2014-2018, the average duration of a dry period was 9 days per month, with the longest consecutive period of 35 days in August - September 2015. The highest one-day precipitation usually falls in May - July and September - October with an average amount of 20-30 mm over 24 hours. Its absolute maximum was recorded in October 2016 with 69 mm/day, which was 146 % of the long-term average for that month. An average number of days with extremely heavy rains (R>20 mm) in Roztochya BR is the highest amongst other reserves and equals six. Due to the air temperature developments last winter seasons featured by the absence of stable snow cover while most of the precipitation occurred as rain rather than snow.

Meteorologists at the biosphere reserve, the local population, land users, especially farmers, notice a change in the amounts and patterns of precipitation:

- A site-specific decrease of average annual precipitation by 5-18% in recent years. However, other sources report rather insignificant changes in precipitation which would correspond with the above-presented findings from the stations located outside the BR territory.
- Generally small amounts of precipitation, especially during the spring period having relevant effects on agricultural activities.
- A decline in the total amount and frequency of precipitation causes drying of springs and small water bodies, thus driving the disappearance of flora and fauna species.
- Precipitation increasingly occurs during short-term heavy, torrential rains such that the mean monthly precipitation within one single day leads to flooding, crop damage, and erosion.

2.2.2 Climate change-related impacts, disasters, and human risks

The above-described altered temperatures and drought periods, precipitation patterns, and seasonal shifts cause high levels of stress for the ecosystems and make the need for adaptation palpable. For humans, being embedded and forming an active part of these systems, this need for adaptation to climate change becomes drastically visible through the related natural disasters posing direct and indirect risks to human well-being.

The **human well-being in Roztochya BR** can be defined by a multi-dimensional interrelation of:

- Physical well-being factors such as physical health, sufficient and good nutrition as well as safety from environmental and human harm.
- Mental well-being factors such as mental health, personal fulfillment, sense of belonging, freedom of choice and action, knowledge, spirituality, and social relations.
- Economic well-being, including secured income, and material livelihood.

In the face of climate change, these aspects are threatened, as essential regulating functions and ecosystem services are at stake and might be insufficiently supplied by ecosystems.

Anthropogenically driven harm and destruction of ecosystems are further strengthening these effects. This includes examples as forest clear-cutting, inadequate land management, pressure from uncontrolled recreation, and low ecological awareness of the local population.

Several climate change-related risks affecting the ecosystems´ and human well-being both directly and indirectly have been identified as relevant for Roztochya BR:

Changes in the hydrological regime

Higher average and total temperatures combined with changing precipitation patterns, unsustainable land-use practices, and other factors affect the hydrological regime of Roztochya BR:

- A general disturbance and alteration of the water balance are observed, including the drying of soils and the gradual disappearance of hygrophilous species of plants and animals.
- The changed seasonal small river runoffs are lower in summer (by 5-20%) and higher in winter. Local small rivers suffer severe water stress due to these shifts.
- A decrease of groundwater level, drying of springs and marshes, shallowing of rivers, and wells. Also, anthropogenic activities, such as flooding of sulfur mines and the above-described drainage systems play a relevant role in such processes.
- The decrease in groundwater level and subsequent shallowing of wells and reduced drinking water quality complicates and worsens the qualitative and quantitative water supply of local

inhabitants as the region relies mostly on non-centralized water supply, especially in the countryside. This will have an effect on the health and well-being of the local population as well as on ecological sustainability and the biological productivity of natural ecosystems.

- As winters are getting warmer and snowfall rather occurs as rainfall, a lack of sustainable snow cover in winter is noticed, impacting the hydrological balance and thus flora and fauna.
- An additional factor driving the negative development of the hydrological regime is the historic land reclamation conducted between 1960-1980. In this period, most of the peatland was drained and covered by monocultural meadows and grasslands. The thick network of reclamation canals resulted in a sharp lowering of groundwater level and change of surface water drain. Natural lakes and water spills disappeared. Hydrological, hydrochemical, hydrobiological performance of ecosystems have changed. The area of open peat fields, water bodies, peat swamps has decreased.

Increasing number and risk of meadow-, peat bog-, and forest fires

Due to the increasingly dry conditions, groundwater decrease, and periodical absence of precipitation, especially in spring, there is an increasing risk of fires in peat bogs and meadows. The risk of forest fires is also elevated while the occurrence is still low. Usually, irresponsible and ill-advised humans trigger these types of fires, e.g. by burning agricultural residues, waste, and recreational activities.

Changes in flora and fauna

The changing climatic and hydrological conditions lead to an altering composition and decrease in numbers of native plant and animal species due to a variety of morbidity causes. Meanwhile, the emergence of new invasive species of plants and animals, as well as pests and allergens is noticed. Overall, a reduction in biodiversity is observed which is accelerated by pressure from human land use.

Pests, diseases, and insect calamities

The increasing temperatures, heat, and drought stress besides other relevant anthropogenic drivers enable and accelerate the occurrence and spread of (new kinds of) pests including diseases, insect calamities, weeds, and abiotic factors. This is observed mostly in forest and agricultural ecosystems.

However, here a **fundamental rethink is necessary**. From an ecosystem perspective, bark beetle infestations also support the “restoration” of a damaged system. The beetle, disease, or plague is a symptom that indicates the level of stress, for example, that a monoculture forest is not healthy and functional. Such a structurally weakened forest is not able to fight the “disease” by its defense mechanisms. To protect the forest from so-called “bark beetle infestations” would necessitate a natural decay and regrowth cycle with as little human influence as possible.

Extreme and hazardous weather events

- **Heat:** A larger number of hot days (>30°C in air temperature) in the Roztochya BR are recorded. Consequences of increasing heat and heat stress are for example raised levels of mortality of flora and fauna and soil degradation processes. The extinction of certain species may occur at an accelerated pace. Heat also drives elevated evaporation rates leading to faster drying of water bodies and wetlands.
  Humans are also directly affected by heat stress, especially more vulnerable groups within the local population. The centers of the so-called “heat stress” are mainly residential areas with a high percentage of sealed surfaces and an insufficient quantity of, green spaces, shrubs, and trees. The situation is worsened due to air pollution and intensive territory development and construction.
- **Increase of duration and intensity of droughts** in summer, especially in August and partly in spring. This combined with a general groundwater decrease leads to the drying of springs, creeks, small water bodies, wells for humans, and watering places for animals. In this context, the fire risk in peat bogs and forests also increases.

- **Strong squalls, winds, and storms** especially during thunderstorms (especially in summer) causing:
  - Wind erosion of the fertile soil layer causing economic losses for farmers.
  - **Soil dust storms** due to topsoil wind drift directly affect human health.
  - Destruction of forests leading to harvest losses.
  - Damage to homes and infrastructure.
- **Heavy, short torrential rainfall**, especially in summer, with precipitation amounts that sometimes equal the average monthly precipitation. This causes flooding, crop loss, and damage to infrastructure and buildings.
- **Thunderstorms with lightning and hail** which harm humans and destroy crops, infrastructure, and buildings are occurring more frequently. Especially in residential areas, they are destructive.
- **Frosts and icing** occur in spring (still in May) causing damage to blossoming gardens, flourishing warm-season vegetation, tree branches, and crops. This also happens in autumn (early October).

All the described climate-change-related contingencies and risks have a significant influence on the diverse ecosystems and the whole network within the Roztochya BR. Thus, humans are directly and unsparingly affected by these developments, physically, mentally, and economically.

Affectedness of economic well-being

Diverse economic sectors relevant to the Roztochya BR region, such as forestry, agriculture, pisciculture, and tourism are facing challenges due to climate change impacts.

Agricultural sector

Most of the residents live in rural areas (about 70%) and maintain a traditional system of self-sustaining households with small fields and allotment gardens for growing their own produces. The agricultural sector of the region specialized in the growing of cereals, vegetables (potato, cabbage, cucumbers), and stockbreeding (mainly cattle, pigs, poultry). The infrastructure of agricultural producers includes mills and enterprises producing sausages, pasta, oil, pastry, and confectionery.

Increasing average monthly temperatures, warmer summers and winters, dry springs and winters (frostless, with little or no snowfall), and changing precipitation patterns cause a reduction of humidity and groundwater level and a decrease of air humidity. This all results in a water deficit for agriculture and impacts the agricultural sector significantly. The dry autumn of 2019 was problematic for the sowing of winter crops. Natural disasters such as heavy rainfall with floodings, storms, and thunderstorms with hail cause direct damage to crops, farming infrastructure, and put farmers themselves in danger.

The farms located within the territory of the biosphere reserve face the challenge to retain water in the soil and prevent erosion caused by strong winds in valleys. Heavy, short-term rains with large amounts of water are causing flooding and waterlogging and lead to processes of washing out of the topsoil.

Anomalies within the region occur, such as the repeated blossoming of gardens, individual trees, and bushes, which decrease subsequent amounts of harvest.

A very hazardous phenomenon occurring more frequently during the last years are fires which resulted from the dry conditions and the farmers' habit to burn sections of dry vegetation and waste.

Forestry sector

The forestry sector within the Biosphere reserve faces several challenges driven by climatic changes such as higher average temperatures, altered precipitation patterns, a shift of season, driving insect calamities, changes in flora and fauna, and extreme events such as heat, drought, heavy storms. These drive a variety of stresses such as mechanical damages to trees, drying and dieback, windthrow, early defoliation, and others. The fire risk is generally elevated during dry seasons and missing water retention capacity. Especially pine monocultures are vulnerable.

A considerable area of the Biosphere Reserve Roztochya features forest plantations, which do not correspond to the composition and age structure of natural forests. Forest plantations growing on these formerly arable lands, due to low humus content, have reduced biological stability and are more vulnerable and susceptible to pests, diseases, and storms.

Such anthropogenically altered forests, plantations, and transformed lands increasingly suffer from climate change. It is disrupting the links between the components of forest ecosystems. Forest phytocoenosis is depending on the structure, composition, and shape structure and thus is impacted and reacts differently to critical climatic and anthropogenic factors.

Changes in weather and climatic conditions lead to deterioration of growth conditions, reduction of biological stability of stands, weakening, and death of individual trees and whole stands. For example:

- Excessive drought periods stress forests and lead to the death of artificial pine, spruce, and Douglas fir stands.
- Changes in precipitation amount and patterns, as well as groundwater level decrease, are altering the hydrodynamic regime and water balance.
- Considerable areas of forest are damaged and destroyed by storms in recent years.

- Increasing occurrence of forest fires
- The forests´ resistance to pests and diseases has decreased
- A general decrease in biodiversity is the result of such developments.
  - The number of plant species is decreasing
  - Changes in forest fauna composition are occurring
- Soil degradation and changes in the species composition of soil flora and fauna
- Flooding and waterlogging cause damages to vulnerable stands

The Biosphere Reserve staff observes that in (near-) natural plantations, most consistent with the native forests, outbreaks of pests and diseases occur much less.

Fishery sector

The valley of the river Vereshchytsya has almost over 6 square kilometers of ponds that were created for cultivated fish farms and a specialized enterprise for fish salting and smoking. Changes in hydrological conditions, water availability, and its chemical composition increase the risk for negative implications on these sectors.

Tourism sector

The Roztochya area is a relevant tourism destination, located close to the metropolis of Lviv. Within and near the biosphere reserve there are sanatoria and spa resorts in the villages of Ivano-Frankove, Bryukhovychi, Nemyriv, Shklo. Tens of thousands of tourists receive health treatment every year, make pilgrimages to monasteries and special touristic destinations within the area. People seeking recreation and sports activities, providing ecological education, and weekenders from Lviv visit the area and its diverse ecosystems, large ponds, and villages with traditional crafts and woodwork. The diverse ecosystem services allowing for these activities are threatened by the above-described climatic developments and the overall increased vulnerability of ecosystems in the region.

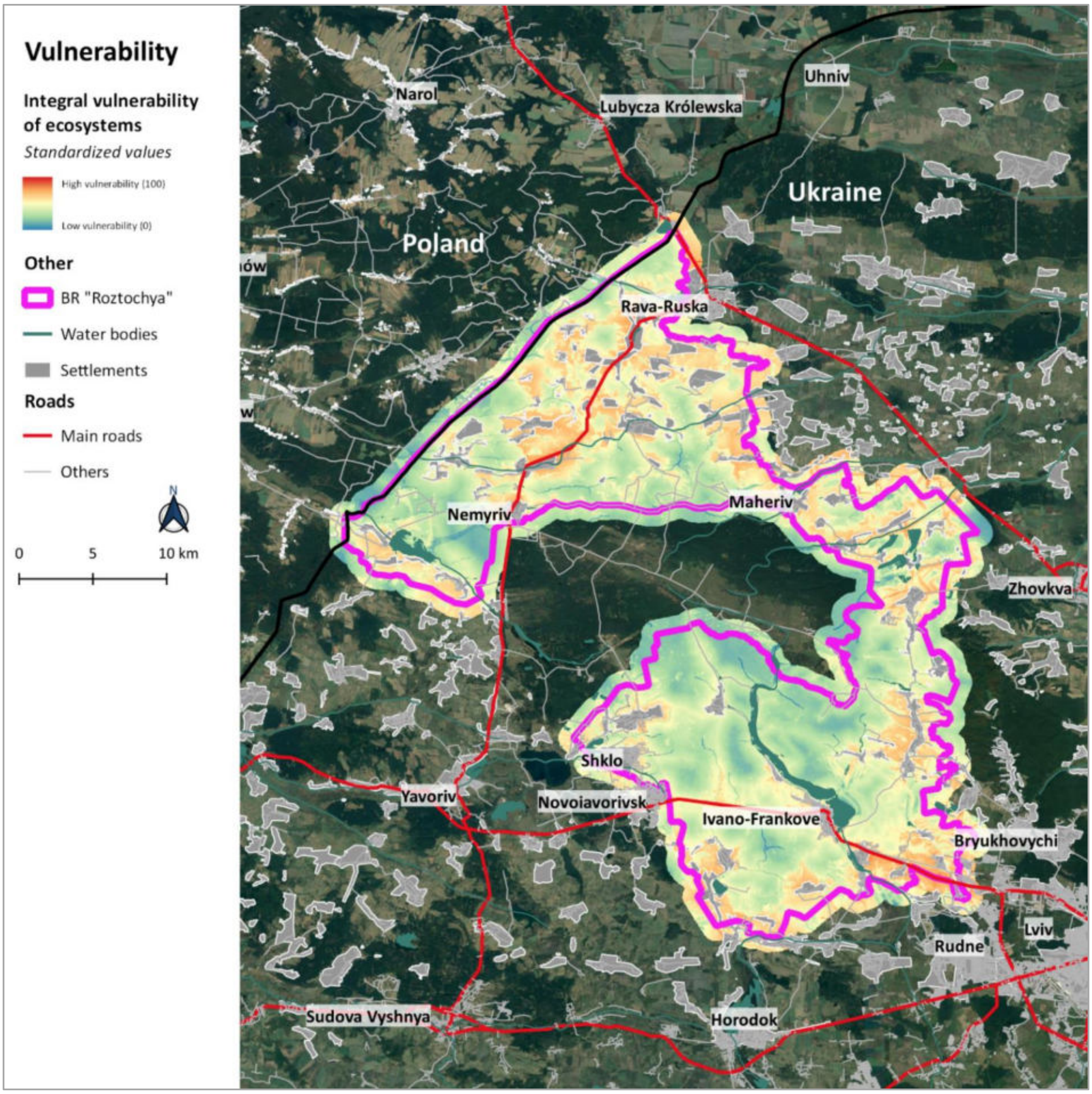
How is EbA related to such impacts and events?

EbA measures have the potential and goal to proactively reduce all the above-described risks by decreasing vulnerability and enhancing (self-) regulating capacity by restoring natural ecological structures and processes. For the EbA measures, please consult the separately printed *EbA measure and activity catalogs* annexed to this document series. The catalogs can also be accessed via the project website (https://www.eba-ukraine.net/Publications.html). The following sections will describe other ecological stresses, their drivers, underlying factors, and causes that were identified during the MARISCO stakeholder and expert workshops.

Map 2 depicts the vulnerability of ecosystems based on the following stress indicators:

Forest ecosystems	**Wetland ecosystems**	**Grassland ecosystems**
a. Management intensity (expressed in structure and species composition) – coniferous/broad-leaved, freshly logged, recently gained + forest change data b. Logging intensity or forest loss intensity (% of logged area) – expressed in a generalized 1 km grid c. Fragmentation by roads and other transport infrastructure, differentiated by impact, expressed in a buffer size d. Patch metric indicators (size, connectivity, edge density, neighbor analysis (e.g., forest-field, forest-wetland) e. Soil parameters (water retention capacity, etc.) – taken from ecosystem map as a site moisture index f. Artificial drainage – continuous buffers along artificial canals g. Human population density – as a chance of human impact on the forest (related to the settlement population and distance)	a. Artificial drainage b. Peat extraction sites c. Human population density d. Fragmentation by roads and other transport infrastructure e. Patch metric indicators (size, connectivity, edge density, neighbor analysis) **Lake ecosystems** a. Buffer around the shoreline to analyze its structure and impact on the lake (incl. patch metrics) b. Population density c. Size (area, form) d. Depth (bathymetry)	a. Patch metric indicators (size, connectivity, edge density, neighbor analysis e.g., wetland-field, forest-wetland) b. Population density c. Fragmentation by roads d. Soil parameters (water retention capacity, etc) e. Artificial drainage **Arable/Cropland ecosystems** (same criteria as grassland) a. Size can indicate management mode (e.g., machinery, chemicals)

The outcomes of this analysis were used to make evaluations for separate ecosystem types. Then they were harmonized and weighted with the evaluation results. Only afterward, the neighborhood analysis was applied. For a detailed method description, please consult the Toolbox document, chapter *Spatial Analysis and Mapping – Part I*.



Map 2 Map of ecosystem vulnerability in the region of the Biosphere Reserve Roztochya (area of the BR + 1 km buffer)
Sources: Data processing and analysis by I. Kruhlov;
Base map: Google Satellite 2016;
Roads, settlements, water bodies: OSM 2020; Produced by A. Dichte

2.2.2.1 Relevant ecological stresses in Roztochya BR

The rating scale is from 1 (dark green) – low strategic relevance to 4 (red) – high strategic relevance.

Sphere	Ecological stress	Ecosystem affected (direct)				Strategic relevance (based on criticality ratings)
		Forest	Water bodies and Wetland	Grassland	Agricultural and Settlements	
Energy input	Changed solar radiation intensity*	X	X	X	X	?[8]
Atmospheric	Changed seasonal precipitation patterns	X	X	X	X	3
	Shift of natural seasons	X	X	X	X	3
	Freezing / Icing	X		X	X	1
	Polluted air	X	X	X	X	1
	Changed (micro-)climatic conditions (e.g. increasing heat)*	X	X	X	X	?
	Changed air humidity*	X	X	X	X	?
Hydrosphere	Pollution (by plastics and other)	X	X	X	X	4
	Pollutant accumulation in bottom sediments		X			4
	Changed pH of water due to pollution	X	X	X	X	3
	Decrease in water level	X	X	X	X	2
	Changed hydrological regime	X	X	X	X	2
	Water eutrophication	X	X	X	X	2
	Silting		X			2
	Accumulation of erosion products		X			2
	Decreased dissolved oxygen	X	X	X	X	2
	Decreasing quality of drinking water (in wells)				X	2
	Floods (water & dirt/mud floods)	X	X	X	X	1
	Changed stream velocity		X			1
	Changed chemical composition of underground water	X	X	X	X	1
	Decreased groundwater level*	X	X	X	X	?
	Seasonal disappearance of springs and small streams*	X	X	X	X	?
Lithosphere	Eroded soils	X		X	X	2
	Soil eutrophication	X		X	X	2

[8] The boxes marked with a '**?**' are issues which were not completed, rated, and prioritized by the participants during the situation analysis workshops.
Elements marked with '*****' added by author based on indication outside of MARISCO expert workshop

Sphere	Ecological stress	Ecosystem affected (direct)				Strategic relevance (based on criticality ratings)
		Forest	Water bodies and Wetland	Grassland	Agricultural and Settlements	
	Decreased land aeration by excessive moisture during precipitation	X		X	X	2
	Accumulation of washed-out soil from cropland (located above grassland)		X	X	X	2
	Compacted soils	X		X	X	1
	Changed chemical composition of soil	X		X	X	1
Matter cycles	...					?
Biomass	Loss of grassland			X		2
	Decreased crop yield				X	2
	Damaged crops				X	2
	Decreased productivity			X		1
	Encroachment of shrubs and trees		X	X		1
	Loss of water bodies (due to reed/plant regrowth)		X			?
	Reduced extent of ecosystems*	X	X	X		?
	Loss of forest cover*	X				?
Information	Appearance of new kind of insects	X	X	X	X	4
	Decreased biodiversity	X	X	X	X	3
	Decreased plant biodiversity	X		X	X	1
	Species and habitat extinction	X	X	X	X	1
Network	Changed bird migration			?	?	3
	Ecosystem fragmentation	X	X	X		2
	Damaged trophic chain	X	X	X	X	2
	Excessive development of certain species´ populations					1
	Changed species composition	X	X	X	X	?
	Reduced land management practices			X		?
	Internal fragmentation of stands*	X				?
	Canopy gaps*	X				?
	Edge effects*	X	X	X	X	?
	Dissection of mushroom and root plants*	X		X	X	?
Species-specific	Disturbed/altered life cycles	X	X	X	X	3

Sphere	Ecological stress	Ecosystem affected (direct) Forest	Water bodies and Wetland	Grassland	Agricultural and Settlements	Strategic relevance (based on criticality ratings)
factors						
	Mechanical damages	X		X	X	3
	Dieback of trees	X				2
	Windthrow	X				2
	Windbreak	X				2
	Wet crops				X	2
	Changed color of needles (brown discoloring)	X				1
	Drying of forests	X				1
	Dry grass			X		1
	Second blossoming in autumn	X		X	X	1
	Early fall of leaves	X				1
	"Empty" spawning		X			1
	Second blossoming within one year				X	1
	Browning of (crop) plants					?
	Reduced health of populations	X	X	X	X	?
	Reduced health of individuals	X	X	X	X	?
Energy, matter, and water efficiency	Dryness (increased fire risk)	X		X	X	2
	Elevated rate of evapo(transpi)ration*	X	X	X	X	?
Resilience and resistance	Impaired forest recovery in monocultures	X				1

Ecological stresses for forests

Especially the south and southeastern part of Roztochya BR is home to a relatively large, predominantly contiguous forest area, with a significant proportion of broad-leaved and mixed forest and minor fragmentation. Further, towards the southeast, the regional capital of Lviv, and more urban areas, the forest is more fragmented and replaced by cropland and settlements.

In the north and northwestern part of the BR, forests are highly fragmented mainly due to cropland and settlements. Outside of the BR boundaries but located right in the center of the BR area, a large military training ground dissects forest continuity in a line of wide-open land from north-western towards the south-eastern direction. Broad-leaved and mixed broad-leaved forests occupy a significant area. Yet, they are also partly fragmented and have sharp forest edges, thus increasing edge effects.

The mosaic of different types of use (including settlement areas, traffic routes, energy lines) causes fragmentation and islanding of forest areas that would naturally be contiguous. Resulting forest ecosystem fragments are increasingly separated from each other and limited in their functional capacity. Increased fragmentation leads to downsizing and islanding of populations, genetic impoverishment, and possibly local disappearance of species. Abrupt transitions between forests and other areas without functional forest edges increase edge effects; among other things, it is easier for substances foreign to the ecosystem to enter, e.g. through emissions from road traffic or agriculture.

Due to agricultural use and construction projects, there may be a further loss of forest area. Access roads cause additional internal fragmentation and microclimatic changes. Additional disturbances are caused by the development and operation of forestry areas. Not only the construction and driving of forest roads and trails but also of so-called skid trails for the corresponding machines, result in the loss of areas for tree growth and thus in biomass losses. Linear forest aisles lead to sharp forest edges in the middle of the forest and thus change light and climate conditions.

Stands potentially become thinner, warmer, and drier. Originally non-native species may invade the forest along trails and in disturbed areas, sometimes displacing other species and contributing to further homogenization. Soil is compacted, at least around logging roads; underground, fungal root networks important for water and nutrient uptake (mycorrhizae) may be disrupted. Soil and regrowth vegetation on the skid trails (and beyond) are often damaged during timber harvesting. With heavier logging and lowering of the stocking level, more or less large gaps are created in the canopy. This, together with biomass removal, in turn, affects the microclimate. Among other things, biomass in the forest also stores water and cools. Trees that stand more freely are also moved more during storms and may be more susceptible to windthrow. The wind susceptibility of trees is high for a certain period if larger protective trees have previously been removed from a stand.

Particularly problematic in heavily used forests is the poverty of dead and old wood. Dead wood is, for example, a habitat for many species and a substrate for regeneration. It is a nutrient and water reservoir, protects the soil from drying out, and has a favorable effect on soil formation.

The intensive management of coniferous forests and woodlands that are not in their natural state has the effect of severely limiting the age and decay phases, as less old and dead wood is found in these areas. As with all ecosystem uses and any human infrastructural or industrial activities, forestry activities result in the degradation of ecosystems and their ability to function at all stages of operation. Fundamental choices are made when establishing forests and selecting the tree species that will be allowed to grow.

The selection of few species (compared to natural succession) and the cultivation of predominantly even-aged trees results in the severe simplification of stands, loss of biodiversity at all levels, and reduced self-regulation. Among other things, pests can more easily establish themselves and cause economically relevant damage. The risk for windthrow and forest fires may increase. If non-native trees are planted on a larger scale, fewer resources may be available for native species. Certain tree species have an unfavorable effect on the soil in monoculture (e.g., acidification by needle litter, reduction of soil microorganisms, and available nutrients by red oak, for example). Furthermore, in coniferous forests, evaporation is increased even in the recently more frequent mild winters and groundwater recharge is greatly reduced.

Decades and centuries of settlement and use of the former and remaining forest areas, including the loss of predators such as wolves, have increased the population density of, in particular, cloven-hoofed game to such an extent that this disturbs the forest in its development and regeneration.

If the functional capacity of forests is reduced, they become significantly more susceptible to climate change impacts. In heavily modified stands, mainly in those where pine dominates and the understory is very sparse, there is also a changed forest interior climate, which is far from the typical balancing microclimate of a mixed broad-leaved forest. Lower evaporation and stronger or unrestrained solar radiation lead to lower humidity and higher temperatures on hot days. Soils dry out and trees suffer drought and heat stress, which can lead to higher mortality rates. Higher temperatures and less moisture in the forest coupled with highly flammable tree species such as pine also increase the risk of wildfire. Higher winter temperatures also favor the reproduction of insects and other creatures that live in and on wood. Trees are increasingly weakened by pathogens and insect calamities, and mortality rates are increasing. Aisles, sparse stands, and abrupt forest edges promote the effects of wind or storms, which can lead to an individual to areal injury and toppling of trees. The resulting clearings increase edge effects in the forest and provide new targets for storms and strong solar radiation.

2.2.2.2 Relevant natural and anthropogenic drivers of ecological stress in Roztochya BR ecosystems

Sphere	Drivers of ecological stress	Strategic Relevance (based on criticality ratings)
Climate change and severe weather	Long periods of drought	1
	Extreme rainfall in a short time	1
	Floods (water & dirt/mud floods)	1
	Increase of mean annual temperature	?
	Extreme temperature events	?
	Temperature anomalies*	?
	Heavy winds / Storms	?
	Late frost	?
	Heavy snowfall	?
	Icing	?
	Frost in late spring (on peaks)	?
	Heavy thunderstorms with hail*	?
Energy production and mining	Extraction of natural gas	1
	Sulfur mining activities	1
	Land conversion	?
Agriculture and aquaculture	Increase of chemical and fertilizer use in agriculture	4
	Cultivation of grasslands (conversion to cropland)	3
	Burning of agricultural remains and weeds	2
	Succession planting / Multiple cropping (in agricultural lands)	1
	Monoculture cropping	?
	Use of agricultural machinery	?
	Agricultural land abandonment	?
	Deforestation*	?
	Soil erosion*	?
Biological resource use	Clear-cutting	2
	Overharvest of berries and mushrooms	2
	Establishment of monoculture forests of	1

	azonal types	
	Illegal logging	?
	Overhunting	?
	Poaching	?
Human intrusions and disturbances	Soil erosion on forest & road edges	2
	Noise pollution, disturbance	?
Natural system modification	Drainage	2
	Fires	2
	Forest fires	?
	Peat-soil fires	?
	Increased water extraction	?
Invasive and other problematic species	Expansion of pathogens and pests (more frequent)	3
	Alien species expansion (shrub and forest encroachment)	3
Pollution	Chemical pollution of waters	?
	Spontaneous landfills	?
Hydro-Geological events	?	?
Transportation and service corridors	Land conversion (road construction etc.)	?
Residential and commercial development	Land conversion	?

Climate change and biological resource use by forestry

Climate conditions currently perceived as "extreme" (Büntgen et al., 2021) could be considered "normal" in the near future (Hari et al., 2020; Scharnweber et al., 2020). It is therefore of great interest to what extent forest management (especially thinning and thinning of forest stands) has the potential to increase the negative effects of heat waves in forest stands[9].

It has been partly concluded from recent studies that thinning can reduce the impacts of drought (Ameztegui et al. 2017, D'Amato et al. 2013, DelRío et al. 2017, Gebhardt et al. 2014, Giuggiola et al. 2013, 2016, Ma et al. 2010, Primicia et al. 2013, Simonin et al. 2007, Sohn et al. 2016). However, the corresponding findings are by no means as clear-cut as sometimes presented. The benefits of thinning depend on local climatic conditions and cannot be generalized (Ameztegui et al. 2017). It

[9] The following paragraphs have been extracted and translated from the document: *Pierre L. Ibisch, Charlotte Gohr, Deepika Mann & Jeanette S. Blumröder (2021). Der Wald in Deutschland auf dem Weg in die Heißzeit. Vitalität, Schädigung und Erwärmung in den Extremsommern 2018-2020. Centre for Econics and Ecosystem Management an der Hochschule für nachhaltige Entwicklung Eberswalde für Greenpeace. Eberswalde* (in German language).

needs to be reflected more critically in times of frequently recurring dry and hot years, namely when rainfall is absent for prolonged droughts. Then, potential advantages of thinning can turn into a disadvantage because higher water losses through evaporation become the decisive stressor in forests exposed to more intense heat. It is also known that forest openings and clearings increase ambient and ground temperatures, which in turn negatively affect water availability, especially during periods of low precipitation (Redding et al. 2003). The larger the canopy openings, the higher the air and soil temperatures (Latif & Blackburn, 2010). At forest edges, soil moisture can be similar to that in open areas (Erdős et al., 2019).

The microclimatic regulation capacity of forests is therefore of central importance. This is mainly a matter of mitigating peak summer temperatures, lowering average temperatures, and buffering temperature fluctuations. An open question was to what extent forest properties that are directly influenced by forest management (e.g. thinning, timber harvesting intensity, and nature conservation) affect microclimatic regulation under extreme climatic conditions in exceptionally hot periods. To this end, a study in northern Germany (Blumröder et al. 2021) investigated temperature indicators in the two extremely hot and dry summers of 2018 and 2019 (see e.g. Buras et al. 2020, Kornhuber et al. 2019, Vogel et al. 2019) in forests of northern Germany. In addition, temperature measurements were collected and analyzed in pine and beech forests along a utilization gradient.

In both years, the highest maximum temperatures were measured near the ground and at a height of 1.3 m in a pine stand with a relatively low supply (177 m3 ha-1). At the same time, maximum temperatures were 9 °C lower in a beech stand with a relatively high stock (>565 m3 ha-1). In 2019, when data on crown closure were also included in the analysis, crown closure was also a significant factor influencing maximum temperature, as was the number of felled trees. Across both study years and all sample plots, the temperature increased by 0.21-0.34 °C near the ground and by 0.09-0.17 °C at 1.3 m per 100 trees per hectare felled in the past. In 2019, when crown closure was also considered in the analysis, it showed a significant influence on maximum temperature (in all datasets studied). Between forest stands differing in crown closure by 10%, there was a difference in maximum temperature of 0.46 °C (including pine and beech stands, measured at 1.3 m) and 0.35 °C (pine stands only, measured at 1.3 m). Near the ground, the maximum temperature was 0.53 °C (pine and beech stands) and 0.41 °C (in pine stands) higher.

The biomass stock also influences the temperature regime. Sample circles with a difference of 100 m^3 less stock per hectare showed a 0.31-0.33 °C and 0.15-0.27 °C higher maximum temperature near the ground at 1.3 m (including all sample plots). In pure pine stands, it was found that the more densely stocked a forest stand, the lower the maximum temperature.

A closed forest has a better cooling capacity (preventing relatively high temperatures) and also greater buffering capacity (reducing temperature fluctuations). Considering all study plots (beech and pine stands), it was found that temperature fluctuations (at 1.3 m) were higher than average when the crown closure was below 65 %.

Forest management has a significant influence on the ability of forests to mitigate temperature peaks, average temperatures, and temperature fluctuations. For the mitigation of maximum temperatures in the forest interior, the openness of the canopy is the decisive factor, but the amount of felled trees are also of great importance, and both variables are directly controlled by forest management (in terms of reducing timber harvesting activities and developing denser, multi-layered forest stands). Other studies also show that a reduction in canopy closure leads to an increase in forest internal temperature (e.g. Thom et al. 2020, Kong et al. 2014).

In the two record heat years of 2018 and 2019, denser and less thinned forests showed better microclimate regulation. Effective forest management aiming at continuous forest cover and more complex structures instead of homogeneous monocultures of the same age thus enables stabilization of microclimatic conditions inside the forest and counteracts extreme macroclimatic conditions that will occur more frequently in the course of climate change. The cooling property of forests contributes to climate regulation in the wider landscape and positively influences water and carbon cycles (Ellison et al. 2017). The regulation of microclimate can therefore mitigate climate change effects (Thom et al. 2020).

Based on the results, it is recommended to minimize warming and evaporation effects in the forest interior by reducing or avoiding the creation of artificial gaps in the canopy through silvicultural measures, including intensive thinning and clear-cutting, as well as the establishment of roads and skid trails. In this context, the fragmentation of forests by roads and infrastructure as well as the opening of the canopy by the construction or maintenance of skid trails and forest roads must be discussed. Regular and regular thinning or timber harvesting in German commercial forests usually takes place every 5 years, with skid trails being cut into the forest at a distance of 20-40 m from each other. The associated opening of the canopy creates internal forest edges and potential edge effects within a forest area, which can reduce microclimatic regulation capacity and increase the risk of heat and drought stress from the edges into the forest interior (Duncan et al. 2019, Reed et al. 1996). Road infrastructure causes higher air and canopy temperatures and saturation deficits (Delgado et al. 2007, Pohlman et al. 2007). Increased tree mortality at forest edges indicates higher stress levels in times of water scarcity and heat (Brun et al. 2020).

Adapting forest management to climate change primarily means reducing the sensitivity of trees to drought events as much as possible. Extremely low precipitation and high temperatures, depleted soil moisture, and increased evaporation were responsible for the recent spring droughts in Central Europe and are likely to persist in the long term due to climate change-induced atmospheric circulation phenomena (Ionita et al. 2020). According to the results of the study (von Blumröder et al. 2021), high stock and dense canopy provide insurance against heat and drought events. This is in contrast to promoting thinning as a management strategy to adapt forests to climate change and reduce the associated impacts of droughts.

Forest microclimate management, with the aim of producing cooler and less variable forest interior temperatures, is a critical element of ecosystem-based adaptation to climate change.

It is recommended to keep the canopy as dense as possible, at least at 80 % cover. This can be achieved through low intervention intensities, intermediate layers (e.g., native deciduous tree species in intermediate and understory), with the aim of creating multi-layered, uneven-aged stands.

The trade-off between sufficient light availability for tree regeneration growth, which is necessary for the forest to develop into a more resilient ecosystem, and the need to maintain protective shade is increasingly evident under climate change conditions, especially in extremely hot and dry years. Of key importance is the risk that extreme heat, soil dryness, or even direct sunlight (which can lead to sunburn in exposed beech trees) can jeopardize the success of forest development.

The regulation of micro-and mesoclimate by forest ecosystems is an important function and service, which in turn influences other ecosystem services (Tuff et al. 2016). The socio-economic importance of forests goes far beyond timber production and is also highly relevant for human health and recreation. Therefore, forest management should assume greater responsibility for regulating the microclimate in order not to further exacerbate the negative impacts of the macroclimatic climate crisis, but to counteract it.

2.2.2.3 Relevant underlying factors and causes

Sphere	Underlying factor and cause	Strategic Relevance (based on criticality ratings)
Biophysical factors	Favorable conditions for increase of insects´ number and diversity	3
	Global climate change[10]	1
	CO_2 emissions*	?
Institutional factors	…?	
Governance-related factors	Lack of appropriate waste management	?
	…?	
Socio-economic factors	Tourism and recreation	?
	Uncontrolled religious tourism	?
	Demand for building materials	?
	…?	
Socio-demographic factors	…?	
Infrastructure-related factors	Communications engineering	2
	Settlement / urban development	?
	Road infrastructure	?
	…?	
Socio-cultural factors	Technological reasoning	?
	Desire for more living space	?
Spatial factors	Proximity of the military area	?
	… ?	
Natural resource-use related factors	Biospecies introduction	3
	Forestry (e.g., monocultures)	1
	Agricultural activity	1
	Technology (agricultural machinery)	?
	Grass burning	?

? - To be determined/assessed

[10] Itself natural and biophysical processes but today mostly driven by past and current anthropogenic activities

2.3 Diagnosis

Roztochya Biosphere Reserve, its nature, and humans are already and increasingly will suffer a regime of climatic and anthropogenic pressure. It is mostly driven by increasing temperatures, changing wind direction, uneven precipitation patterns, and shifts in seasons causing increased exposure to extreme events and a diverse array of ecological stress.

The climate change-related impacts, disasters, and direct and indirect risks for humans are perceptible and visible: changes in the hydrological regime are affecting all ecosystems and humans alike. It causes decreasing surface and groundwater levels as well as drying of ponds, peat bogs, forests, and wells. Meanwhile, it increases the number and risk of meadow-, peat bog-, and forest fires. Climate change also prompts alterations in flora and fauna, namely of pests, diseases, and insect calamities.

Extreme and hazardous weather events driven by climate change include heat stress for flora and fauna, an increase of duration and intensity of droughts in spring and summer, squalls, strong winds, and storms, short torrential rainfall, thunderstorms with strong lightning and hail, as well as icing. These events increasingly cause crop failures, damage homes, and put human health at risk.

Anthropogenic activities and unsustainable land use (draining of wetlands. monocultures, clear-cut areas, sealed surfaces, compacted and intensively used soil, etc.) degrade Key Ecological Attributes, making the ecosystems vulnerable and less resilient to exposure to climate change impacts. This in turn raises the risks of direct climate change effects on human well-being, including physical, mental, and economic spheres.

Thus, the Roztochya BR has an urgent need to protect and restore (self-) regulating, functional ecosystems, while limiting harmful and destructive land use and behavior to a minimum extent. Only then there is a chance that human well-being and a qualitative and quantitative provision of ecosystem services can be guaranteed in the long term. This is also a vital requirement for sustainable regional development which is mainly based on natural resources and tourism (attracted by natural beauty and functionality).

The objectives to counter climate change and its negative impacts are based on the findings of the situation analysis and the necessity to protect and restore (near-)natural ecosystems.

These goals shall safeguard that the ecosystems of the Roztochya Biosphere Reserve:

- **maintain their ecological functionality** even under the influence of climate change including long-term local climatic changes and an increase in extreme weather events.
- can **buffer and reduce the effects of climate change on themselves** as much as possible.
- **continue to provide the ecosystem services needed for human well-being**, including most importantly the regulating services (e.g. local climate and water balance) mitigating negative effects of extreme events on humans, the provisioning services (e.g. food and energy), and the cultural services (such as recreation and cultural identity).
- **reduce climate change-related disaster risks to human well-being**.

Thus, the overarching aim is to **reduce Roztochya BR´s vulnerability to climate change**. Since vulnerability is caused at different levels (cf. chapter 2.2), these different levels must also be addressed to reduce vulnerability holistically.

For the Roztochya BR, the following four climate change relevant and both ecosystem and human well-being centered goal-dimensions can be reached by EbA:

A. Cooling and buffering of temperature fluctuations
B. Water retention potential, water runoff- and flood regulation
C. Pest and disease control
D. Buffering of extreme and hazardous weather events

EbA measures have the potential and goal to proactively reduce the above-described risks by decreasing vulnerability and enhancing (self-) regulating capacity by restoring natural ecological structures and processes. For the EbA measures, please consult the separately printed *EbA measure and activity catalogs* annexed to this document series. The catalogs can also be accessed via the project website (https://www.eba-ukraine.net/Publications.html). The map "Priority Areas for Ecosystem-based Adaptation" provides a spatially explicit orientation of where what kind of action is primarily needed.

2.4 Spatial Analysis and Maps

In preparation for the local citizens' workshops and the MARISCO workshops, GIS experts carried out spatial analyses of the Biosphere Reserves Desnianskyi, Roztochya, and Shatskyi as well as their surroundings. Innovative maps were produced that take the ecosystem-based approach into account and incorporated first information on climate change impacts as well as land use.

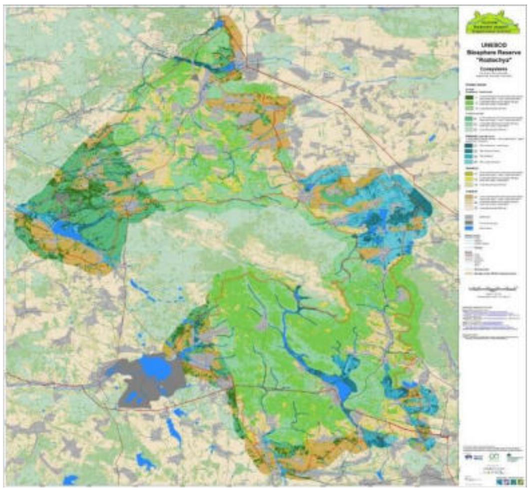
The spatial analysis enables statements to be made on the distribution and condition of relevant ecosystems and their services. Through citizen participation and stakeholder workshops, existing knowledge of the participants and their wishes and ideas are incorporated into the situation and target maps. They help to prioritize areas of conservation value and to localize EbA measures.

2.4.1 Situation Maps

The situation maps included: Ecosystems, Hydrography, Threats, Vulnerability, and Thermo

For more information on the method and geodatasets used to produce these maps, please refer to the Toolbox document and project website.

Ecosystems - Based on current satellite imagery, a land cover classification was developed, which depicts the ecosystem complexes of the region. In addition, information on topography, soil, and drainage was added manually (only inside the borders + 5 km buffer of the Biosphere Reserve areas).

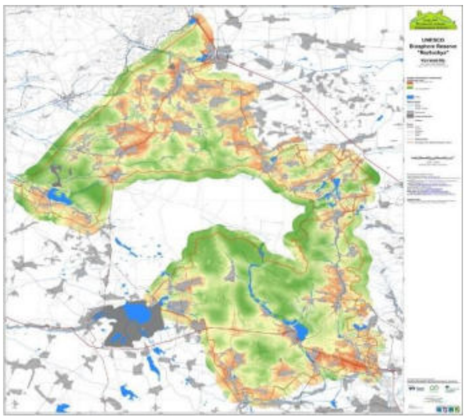


Map 3 Ecosystem Map of the Roztochya BR

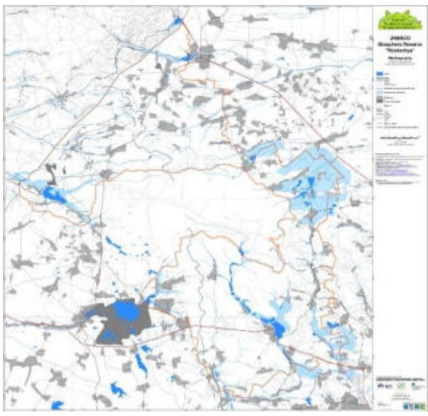
The ecosystem maps represent relatively small and homogeneous ecosystems of a local geographical scale – ecotopes. An ecotope can be viewed as a combination of the two sets of ecological components: (1) a physiotope encompassing abiotic characteristics such as local landform, climate, hydrologic regime, and soil; (2) a biotope as a plant community with microorganisms and animals (biocenosis) within defined geographic boundaries.

The Hydrography maps focus on the representation of the hydrological regime including watersheds, surface waters, and wetlands. The Vulnerability maps show the spatial distribution of stress impacts in the ecosystems, based on an assessment of stress indicators carried out beforehand.

The plotted maps were already handed out to the biosphere reserve administration and staff during



Map 5 Vulnerability Map for the Roztochya BR



Map 4 Hydrography Map of the Roztochya BR

the MARISCO expert workshops in May and June 2019. All maps are included as A1 printouts to this document series and will be also downloadable from the project website.

2.4.2 Demand and Target Maps

Map types:

1) Deviation from Mean Surface Temperature
2) Ecosystem Cooling Capacity for the summer months 2002-2018

In the *mean surface temperature deviation maps*, geospatial distribution of temperature (T) deviations from mean for different weather conditions were calculated and visualized. In the *ecosystem cooling capacity maps,* zonal statistics were used to describe each ecotope class surface T values for the four weather conditions. Both sets of maps are annexed at the end of this document.

The method and steps for the creation of these maps are explained in more detail in the *Toolbox document*, chapter "Spatial Analysis and Mapping" – part II.

The four weather conditions cover:

1) Mean T for June-August

2) Mean T for cozy days (with max air T of 20 – 25 deg. C)

3) Mean T for summer days (with max air T of 25 – 30 deg. C)

4) Mean T for heat days (with max air T over 30 deg. C)

These four different conditions show one significant pattern over the entire study period (2002-2018). Water bodies with intact riparian zones, wetlands and the areas covered with forest as well as forest-shrub transition stages are the coldest areas in the study area. They sharply contrast with warmer agriculturally managed areas as well as urban and industrial areas. Sealed settlement or urban areas such as Ivano-Frankove and towards the north-eastern part as well as the south-eastern part towards Lviv city. These and the direct, often agricultural, and non-forested areas show elevated temperatures. The difference in average surface temperatures between the coolest and forested areas and the warmest urban areas is over 10°C.

For example, on hot summer days with maximal air T > 30°C, the more functional and natural ecosystems, such as wetlands as well as mixed and mostly unmanaged forests constitute the coolest areas with down to -5,5°C from the mean (see map 10). Their cooling potential (see map 13) is thus significantly higher than that of intensively managed or altered ecosystems such as agricultural and settlement (up to +12,8°C).

It becomes evident that different ecosystems and land use areas which are, for example, heavily modified, biomass-poor, drained, and sealed by humans, feature a significantly higher positive deviation from the mean temperature. Thus, temperatures differ significantly between the different ecosystems and land use classes.

Maps of Priority Areas for Ecosystem-based Adaptation Action

The project also aimed at indicating spatially explicit *Priority Areas for Ecosystem-based Adaptation Action.* To support targeted, urgent action and efforts to prevent and reduce climate change and its impacts, ecosystem degradation, and biodiversity loss, a map was elaborated with the following color gradient indicating:

1. Green - Conservation (mainly in (near) natural, i.e., rather functional, less stressed, and damaged ecosystems)
2. Yellow - Reduction of human influence/pressure (modified and (intensively) used and stressed ecosystems)
3. Red - Restoration (destroyed, heavily used, damaged, and stressed ecosystems)

It is important to note that the transitions of the three lines of action (conservation, reduction of human drivers of stress/pressure, restoration) are fluid, meaning that in areas of restoration (e.g., rewetting drained wetlands) also reduction of human influence (e.g. peat extraction, agricultural use) needs to be pursued, while conservation efforts are still relevant (e.g. preserving individual trees or tree communities that remained as functional structures). This applies to both directions of the gradient and is very site-specific. At this level of analysis, available data, and area section, the maps cannot provide further detail. Ground truthing and further research and monitoring are needed to clearly define the area, and which actions are most needed and efficient. For the selection of more concrete action, the EbA measure and activity catalogs can provide first guidance. They are attached to the document series and can be downloaded via the website.

For this map, thermal datasets standardized on the scale 0-100 were merged with integral vulnerability datasets for each BR, which also contain standardized values 0-100. The method is explained in more detail in the toolbox.

The maps are attached to this document in the annex (cf. map 7-15) and part of the printed materials within the series of documents.

3 Conclusions and Outlook

Roztochya Biosphere Reserve, its ecosystem, and social system complexes have been and increasingly will **face significant climatic changes** causing alterations in the physical, chemical, and biological conditions. This includes the alteration of the hydrological regime affecting all ecosystems and humans alike. It causes decreasing surface and groundwater levels leading to drying of ponds, peat bogs, forests, and wells. Meanwhile, it increases the number and risk of meadow-, peat bog-, and forest fires. Climate change also prompts alterations in flora and fauna and drives the spread of pests, diseases, and insect calamities.

Extreme and hazardous weather events driven by climate change include, inter alia, heat stress for flora and fauna, an increase of duration and intensity of droughts in spring and summer, squalls, strong winds, and storms, short torrential rainfall, thunderstorms with strong lightning and hail, as well as icing. These events increasingly cause crop failures, damage homes, and infrastructure, and put human health at risk.

To buffer such climate change impacts and to adapt to them, the self-regulating and self-organizing functions of ecosystems, and thus the guaranteeing of regulating ecosystem services are fundamental. However, they are impaired, reduced, or partly lost due to a **variety of harmful anthropogenic activities**. These include especially land-use practices, having their origins both in the past (e.g. land reclamation via draining of wetlands for grass- and cropland, monoculture forestry), and continue in the present (deforestation by clear-cutting, surface sealing, artificial water abstraction, compacted and intensively used soil, and the like).

These degraded Key Ecological Attributes make the ecosystems more vulnerable and less resilient to exposure to climate change impacts. This in turn raises the risks of direct, negative climate change effects on human well-being, including physical, mental, and economic spheres.

Thus, the adaptive management approach of Ecosystem-based Adaptation to climate change aims at:

- **Protection, maintenance, and restoration of ecological functionality** even under the influence of climate change.
- Maximal capacity of ecosystems to **buffer and reduce** climate change **effects on themselves.**
- **Continued provision of ecosystem services** needed for human well-being.
- **Reduction of climate change-related disaster risks** for humans.

For Roztochya BR, four climate adaptation goal dimensions are proposed:

1. **Cooling and buffering of temperature fluctuations**
2. **Water retention** potential**, water runoff- and flood regulation**
3. **Pest and disease control**
4. **Buffering of extreme and hazardous weather events**

To achieve this, the EbA approach proposes four lines of action to increase ecosystem functionality and decrease vulnerability through heightened self-regulating and -organizing capacity. This will enable ecosystems to cope with the challenges and climatic uncertainties ahead:

I. **Conservation** of existing functional ecological structures and (self-) regulating capacity
II. **Reduction of human-made stresses and factors** that limit and disturb (self-) regulating capacity
III. **Restoration and targeted support** of (self-) regulating capacity
IV. **Development of enabling factors** supporting lines of action I – III

Outlook

The strategy development process played a central role in the continuation of the EbA and MARISCO approaches. The discussion of existing and additional strategies for each ecosystem complex and the ecosystem network of the Roztochya Biosphere Reserve led to the elaboration of five concrete work and monitoring plans. Both the spatial and temporal dimensions were addressed and considered in this process. These complementary strategies aim at filling strategic gaps and include relevant information for operationalization and implementation of the most viable EbA measures and actions. Based on these final results of the strategy development process, the strategies are included in the upcoming annual planning and discussed with regional and national decision-makers.

4 Annex

4.1 Workshop Series at Roztochya BR and Training in Eberswalde

Since the project started in August 2018, the team and partnering biosphere reserve staff conducted two multi-day workshops and excursions at each biosphere reserve. These workshops form part of the MARISCO adaptive management approach, described in the previous section.

The first visit during November 2018 was aimed at familiarizing the German project team with the biosphere reserves, meeting with administration staff, local actors, and land users. With the involvement of the local population the question of "in which nature do we want to live?" was addressed. These so-called *citizen workshops* were designed to get a first-hand insight into the residents' relationship to their natural surroundings and allowed for the first assessment of Ecosystem Services.

The second journey to the Biosphere Reserves took place from May-June 2019 and aimed at a situation analysis based on the inputs of local and regional experts as well as excursions in the region. Furthermore, the insights of the citizen workshops were introduced and integrated into the considerations and systemic model.

Due to the COVID-19 pandemic, the third workshop trip to the Biosphere Reserves had to be canceled. Instead, a web-based process was developed and conducted to elaborate Ecosystem-based Adaptation strategies, measures, and activity catalogs, as well as working and monitoring plans.

4.1.1 Citizen Workshops

The citizen workshops included a series of three workshops within the area of each biosphere reserves, involving diverse actors from school children to foresters, land-users to administration staff. The participants exchanged knowledge and discussed views on the local ecosystems and their services.

Process

Firstly**,** the biosphere reserve introduces itself to the participants and gives some general insights into both work and purpose. Like this, the workshop also provides a platform to familiarize the audience with the biosphere reserve, its activities and to raise awareness.

Image 1 Workshop with Roztochya BR staff, Ivano-Frankove, 05.11.2018, Credit: K.Mack

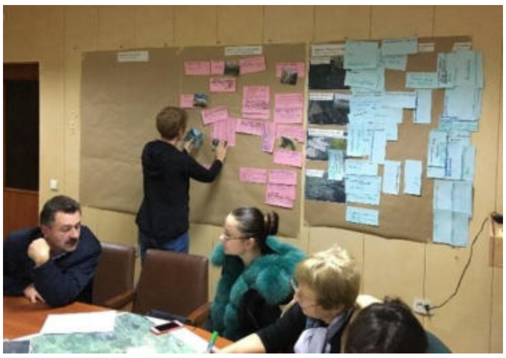


Image 2 Results presentation and clustering, Credit: K.Mack

The project staff introduces the citizen workshop. The "why" and "how" are explained to the audience. Smaller working groups of 4-6 people are formed.

Session 1: Nature and humans

The previously formed groups work on a set of simple questions and write the answers on moderation cards. The concept of Ecosystem Services and ecosystem classification is explained.

Afterward, they are presented by the groups and directly clustered into the scheme shown below. The guiding questions were:

- **How does nature contribute to your well-being?**
- **How do you use nature in the biosphere reserve, where?**

Services of nature (ecosystems)	**Forests** (Natural and managed)	**Water bodies and wetlands** (Lakes /rivers/mires etc.)	**Open land** (Agricultural land/ grassland etc.)	**Settlements and urban green areas**
Provisioning				
Regulating				
Cultural				

Session 2: Nature & (Climate) Change

What kind of changes and threats in nature do you perceive in the biosphere reserve?

- ➢ General changes are written down
- ➢ The group discusses for about 10 min.

Is climate change occurring?
The group adds more observed features of climate changes

If so, how is climate change affecting nature?

- ➢ Locate visible effects on the map
- ➢ Create small result ordered by the affected type of nature

Image 3 Young participants at climate change impact mapping exercise, 09.11.2018, Credit. K.Mack

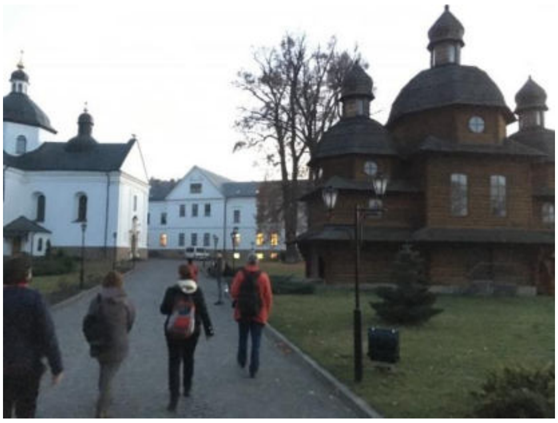


Image 4 Excursion to Krekhiv monastery cultural heritage site, Credit: K.Mack

Image 5 Group work session in Lozino, 08.11.2021, Credit: K.Mack

Session 3: View to the future

How can nature and people be better prepared to deal with climatic changes?

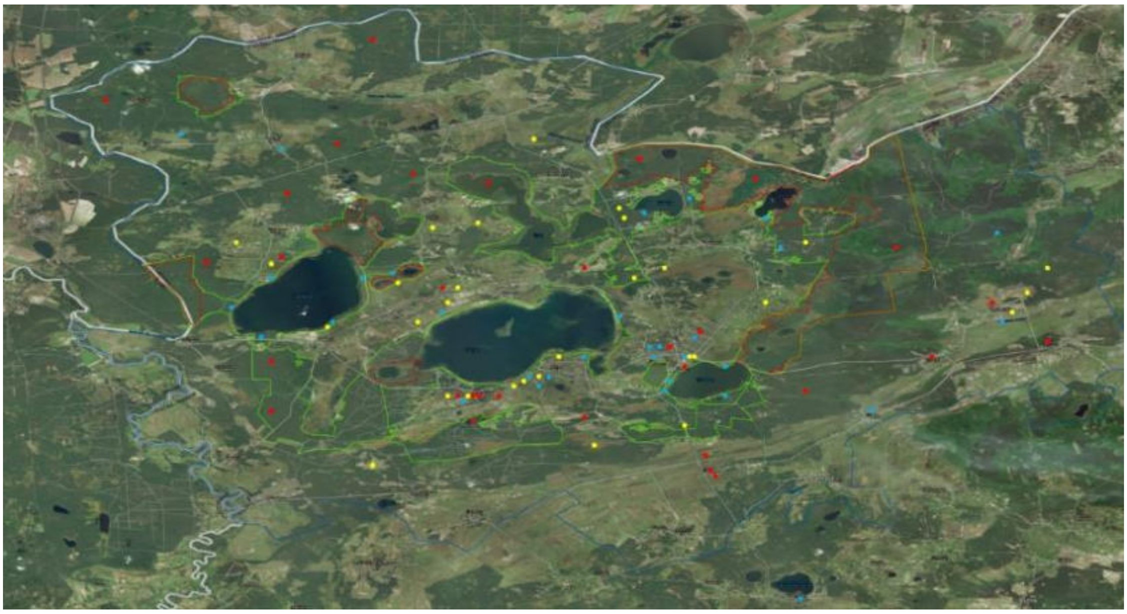
- ➢ 3 main ideas are noted down

How do you wish that the future landscape and its use in the biosphere reserve will look like? What should be changed where?

Finally, the participants received a certificate of participation.

Results

During the citizen workshops, the participants considered a variety of ecosystem functions and services contributing to their wellbeing and livelihood. Ecological stresses, drivers of stress, and climate change impacts in the area were listed and indicated spatially explicitly on printed versions of the area´s satellite image provided during the workshops.



Map 6 Climate change-related events in the Shatskyi BR indicated by the workshop participants, Credit: CEEM

During the citizen workshop, a broad array of climate change-related impacts and threats was mentioned by the participants, including:

- Increase of mean annual temperature
- Temperature anomalies (e.g., extremely low temperatures in spring with frost)
- Seasonal changes of precipitation patterns
- Rainfall anomalies (torrential rain in short periods)
- Flooding
- Hailstorms
- Strong winds, storms, and tornados
- Drought
- Desertification
- Forest fires
- Peat-soil fires
- Soil erosion
- Increase of forest parasites

The full list of the situation analysis results can be found in chapter 2.2.2.1

4.1.2 MARISCO I - Stakeholder and Expert Workshops

From May to June 2019, expert workshops were held in Ivano Frankove. Here, the MARISCO method was applied to elaborate a first comprehensive diagnostic of the area. Both challenges to ecosystem functionality as imposed by climate change, as well as the first inventory of potential Ecosystem-based Adaptation strategies, were gathered. Some of the previous workshop results were considered and further developed.

Roztochya Biosphere Reserve

On 30.05.2019, the workshop kicked off with an introduction by the deputy director of the biosphere reserve, Galyna Stryamets, and scientific project lead Prof. Pierre Ibisch.

After the presentation and discussion of the maps, 4 groups produced a list of ecosystems in BR. The groups were formed by competency and interest in the relevant ecosystem complexes including forests, grasslands, agricultural & settlements, and water ecosystems. In continuation, the key ecological attributes (KEAs) of previously defined ecosystems were defined in groups, presented, and added to the conceptual model.

Image 6 Group work situation at MARISCO workshop; Credit: P. Ibisch

After a break, the thermo-map was discussed, and the focus was put on the ecological stresses of the regional ecosystems. The already available ecological stress cards from the citizen workshop were introduced, afterwards, each group continued defining missing elements. The criticality ratings followed, current, past, trend, future was assessed. Then, the working groups rated manageability & knowledge.

At the end of this workshop day, the project team presented the identified drivers of ecological stress (threats) recorded at the citizen workshops and gave a general review of the day´s results.

After a recap and revision of the conceptual model on the wall, the second workshop day, 31.05.2019, continued with the identification and placing of drivers of ecological stress and underlying causes and factors. Having finished this step, the focus moved to strategy formulation and rating. In the previously formed ecosystem groups, strategies were rated according to four (color-coded) ecosystem functions relevant in climate change: water retention and stabilization of hydrological regime, temperature buffering and cooling, reduction of diseases, pests, and invasive species, reduction of natural hazards. Then, each strategy with a direct effect on the functionality of an ecosystem got a colored sticker. All cards are then given to the next table. This evaluation of the direct impact on functionality according to the four categories is done till the cards from the beginning are back at the same table where they started. The cards that received any kind of color are separated from the ones without any stickers.

This step allows for the first prioritization in the question of functionality enhancing strategies/measures. The impact of some strategies might be overestimated by the smaller groups, thus the plenary does a final double-checking when the results are placed within the conceptual model and discussed.

The final step is the rating of strategies on the wall model concerning possible acceptance by 4 different stakeholder groups in the BR area: forestry, tourism industry, farmers, and conservation sector.

Image 7 Participants in front of the conceptual model; Credit: CEEM

On the excursion day, 01.06.2019, the group of experts, land users, and project team visited several relevant sites, including the world heritage beech forests, a post Sulphur mining site with an artificial lake adjacent to the city of Novayavorivsk, the village of Yavoriv, the protected area "Nemyriv", and the artificial fishing ponds close to the city of Ivano-Frankove.

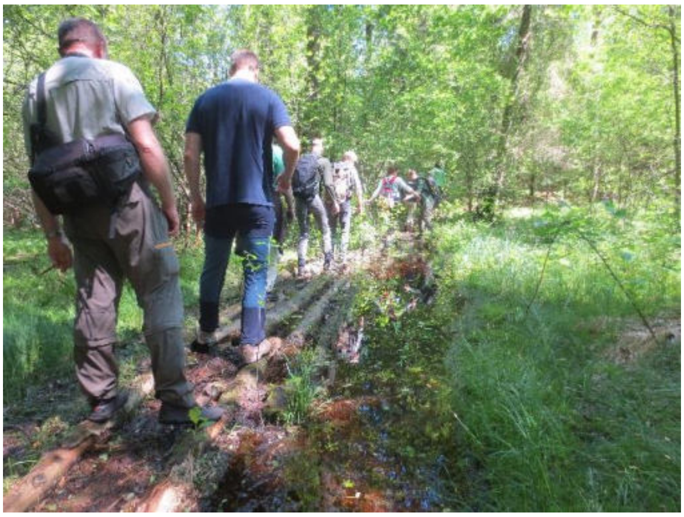


Image 8 Excursion Day at Roztochya BR; Credit: A. Dichte

Feedback of workshop participants:
Pro:

- Gaining of and systemization of knowledge concerning the region, climate change, and adaptation
- Effective group brainstorming method for complex issues
- Good for understanding problems, threats, and driving factors
- Sharing of ideas and awareness-raising
- Productive and interesting system of information collection and processing for the development of the climate change adaptation strategy.
- The methodology of the seminar is very good as for the interdisciplinary approach.
- The thoughts of various specialists and scientists on one particular territory and being in one place is very important and good for the results.

Cons:

- Very theoretical, challenge to move to concrete implementation steps
- Complex approach – not enough time to proceed and discuss the complicated elements and problems sufficiently.
- Method (at this stage) neglects or underestimates resistance or obstacles of stakeholder or lobby groups when strategies come to an implementation level.
- The speed of the group work situations might lead to misunderstanding and overruling of crucial and essential impulses if they are not strongly promoted in due time
- Establish a closer link of elaborated strategies to ecosystem classes and maps
- Involve more local people knowing the region
- The applied approach for information gathering is quite subjective. It is hard to interpret and evaluate stresses, if they are mentioned by other teams (misinterpretation possible)

Results and conclusion:

- **The participants gained more clarity of what kind of role, functions, and services ecosystems play in climate change.**
- **Understand systemically, where the problems and challenges lie, how human activity contributes to them, and how they can be overcome.**
- An important goal was to **harvest the first appropriate strategies for the region**, which form a good base for the elaboration of strategies of Ecosystem-based Adaptation to climate change.

The participation of the biosphere reserve representatives was valuable, as this allowed for networking and learning together about climate change and adaptation options. Like this, the areas can inspire each other and share their solutions.

The project team expresses gratitude to all the workshop participants. The conceptual model represents walls full of “knowledge” and regional insight. The idea contest, as well as the implementation phase of the project, shall provide an opportunity for action on the local scale, to move from theory to practice, and implement parts of the Ecosystem-based Adaptation strategies and measures. It is very important to not only produce paper stacks but implement something, thereby inspiring people and making a change.

Biosphere Reserves are the right places for experimenting with such “revolutionary” new strategies and measures. The mission of BRs is to inquire, implement and monitor such people-centered and ecosystem-based approaches to changes in management, land use, and education. In this aspect, they can be the drivers of change and serve as role models.

4.1.3 Training and dialog in Eberswalde: Ecosystem-based Adaptation in Biosphere Reserves

From December 09-13, 2019, 15 representatives of 5 Ukrainian UNESCO Biosphere Reserves met in Eberswalde and initiated a dialogue to mutually support the understanding of Ecosystem-based Adaptation to climate change. The training was organized and conducted by the Centre for Econics and Ecosystem Management with the support of the Michael Succow Foundation.

Image 9 Group photo at Lower Oder Valley National Park, Credit: EbA Ukraine

The participants and organizers set out to mutually explore, discuss, and understand practical options for the implementation of corresponding measures.

Image 10 Workshop session at Eberswalde University for Sustainable Development, Credit: K. Mack

The training week comprised diverse formats – from lectures and excursions to workshop-like group work, the elaboration of a common statement paper, and the co-creation of own criteria for effective ecosystem-based measures in biosphere reserves.

Image 12 Guided excursion at Treuenbrietzen forest fire site; Credit: A. Dichte

Image 11 Guided excursion at Sernitz valley spring fen, Credit: K. Mack

December 9, 2019

Lecture day

After a welcome by the organizers, participating biosphere reserves, and a Ministry representative, presentations covered the topics of:

- The Biosphere Reserves Concept
- Adaptive Management under the Ecosystem Approach
- Participation and governance
- Climate change and developments in Ukraine
- Ecosystem-based Adaptation and Mitigation: Climate management with forest ecosystems
- Regional sustainable development and justice

Image 13 Uli Gräbener, head of the Biosphere Reserves Institute presenting the functional zonation concept; Credit: K. Mack

December 10, 2019

Forest ecosystems day

Excursion 1:

Glassy Forest Project,
Schorfheide-Chorin Biosphere Reserve
Gollin, Reiersdorf, Brandenburg

- Visiting the project site with a best practice approach from an EbA perspective
- Examples of measures positively affecting and securing regulating, provisioning, and cultural ecosystem services

Image 14 Dietrich Mehl (Brandenburg State Forestry Service), Pierre Ibisch, and Jeanette Blumröder (both Centre for Econics) guiding the excursion at Reiersdorf forest, Schorfheide-Chorin Biosphere Reserve; Credit: A. Dichte

Excursion 2:

CleverForest Project,
(**CL**imate-adaptive, **E**cosystem-based, **VE**rsatile and **R**esilient Forest)
Treuenbrietzen, Brandenburg

- Recent forest fire site
- Research on vulnerability and climate change impacts
- Project area with a new management approach
- Self-regulated and natural regeneration of the area

Image 15 Jeanette Blumröder and Pierre Ibisch (both CEEM/HNEE) guiding the excursion to the post-fire excursion site at Treuenbrietzen, Germany

December 11, 2019

Open land and settlement ecosystems day

Excursion 1:
Bernau – Project Bernau.Pro.Klima

Vulnerability and climate change impacts in semi-urban ecosystems and surrounding ecosystems

- Participatory adaptation approach for Bernau
- EbA best practice and management approaches including the topics of renaturation of a small river, urban greening, and surface unsealing

Image 16 Excursion to small river renaturation site - Panke, Bernau, Brandenburg; Credit: K. Mack

Excursion 2:
Ökodorf Brodowin, Schorfheide-Chorin BR
Ecological/Organic (Demeter certified) agriculture as an example of best practice approaches in agriculture and livestock breeding.

- Support of species and structural diversity
- Extensive forms of livestock breeding and agricultural production

Image 17 Ludolf v. Maltzan, CEO of the Ökodorf Brodowin explaining the concept, challenges, and benefits; Credit: A. Dichte

December 12, 2019

Water and wetland ecosystems day

Excursion 1: Lower Odra Valley National Park

- Vulnerability and climate change impacts on river and floodplain landscape
- EbA best practice approaches: Renaturation of Odra river meanders
- Support of structural landscape diversity
- Protection of biodiversity

Image 18 Dr Michael Tautenhahn, deputy director, guiding the excursion in the national park; Credit: A. Dichte

Excursion 2: **Sernitz marshland**

Schorfheide-Chorin Biosphere Reserve
Project: Revitalization of one of Northern Germany's largest spring bogs

- Options of Ecosystem-based Adaptation in land-use of wetlands (Paludiculture)
- Wetland nature protection activities
- Preservation and restoration of wildlife habitat

Image 19 Dr Benjamin Herold (Schorfheide-Chorin BR) and Andreas Haberl (Succow Foundation) guiding the excursion at Sernitz marshland; Credit: A. Dichte

December 13, 2019

Strategy and EbA criteria day

Elaboration of a **statement paper** concerning Ecosystem-based Adaptation and biosphere reserves.

Identification and selection of **criteria for Ecosystem-based Adaptation measures**

- for the planned idea contest
- for project proposals

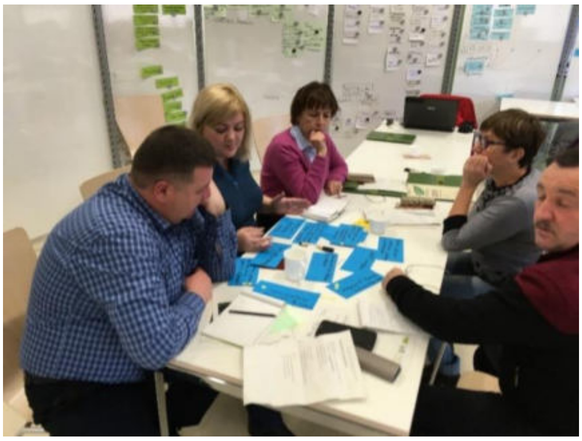


Image 20 Group work for the elaboration of the statement paper and criteria for EbA measures/projects. Credit: K. Mack

Results of the training:

- Improved understanding of the **concept and measures of Ecosystem-based Adaptation**
- **Networking** and **strengthening of the cooperation** between Ukrainian Biosphere Reserves and German partners.
- **Criteria** for the selection of EbA measures and projects
- Elaboration of a **statement paper** regarding Ecosystem-based Adaptation and biosphere reserves aimed at regional and state decision-makers.

4.1.4 MARISCO II – Strategy Development Process

The process consisted of different working steps, covering the identification of strategies, measures, and actions (SMA) relevant for restoring, increasing, and protecting ecosystem functions such as water retention and storage, filtration of solar radiation, and soil formation. These functions generate indispensable services urgently needed by humans to reduce climate-change-related threats like heat, drought, floodings, storms, forest- and wetland fires, etc. It furthermore provided an opportunity to assess and discuss the effectiveness and viability of strategies together with stakeholders to support the selection of key strategies for each of the BRs' upcoming work and monitoring plan development.

MARISCO and adaptive management expert Axel Schick guided through the process and, together with the whole project team and partners, took on the challenge to moderate all sessions via video-conferencing from Lima, Peru. Thus, the project operated on a global level, in different time zones, progressing amidst the challenges due to Covid-19-related travel and meeting restrictions. Positive side-effects were lower Greenhouse gas emissions, reduced travel time, and material use. The flipside of the adapted method was the missing possibility to further elaborate on and work with the conceptual model within the original group, the valuable in-person discussions, and the informal gatherings which used to complete the long working sessions in past on-site meetings in both Ukraine and Germany.

Part I: EbA Strategy identification and gap analysis

In Block A, the strategy identification was conducted for each biosphere reserve. Here, the task was to look through all existing strategies elaborated in the SMA catalog as well as in the available management plans of the BRs. Additionally, strategic gaps were identified based both on the participants´ expertise as well as the MARISCO conceptual model.

Table 1 Online sessions conducted for strategy identification and gap analysis

Date	Biosphere Reserve	Ecosystem considered
13.07.2020	Opening session / ceremony – 46 participants	
14.07.	Roztochya	Open land and settlement
16.07.	Shatskyi	Open land and settlement
17.07.	Roztochya	Forest
20.07.	Desnianskyi	Open land and settlement
21.07.	Roztochya	Grassland
22.07	Shatskyi	Forest
24.07	Roztochya	Water-& Wetland
28.07.	Desnianskyi	Forest
29.07.	Shatskyi	Wet-& Grassland
10.08.	Desnianskyi	Wetland
11.08.	Shatskyi	Waterbody
14.08.	Desnianskyi	Waterbody
26.08.	General summary and presentation of results	

The strategy process was met with great interest from a variety of participants. On 13.07.2020 up to 46 persons participated during the session ranging from biosphere reserves, local land users, universities, NGOs, to ministry representatives.

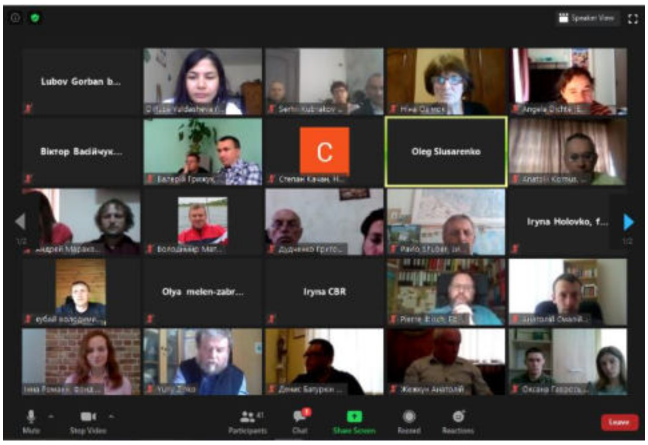


Image 21 Participants at the web-based opening session of the Strategy Development Process on 13.07.2020

As a result of the sessions shown in table *6, from **July to September 2020***, experts and staff of the three partner Biosphere Reserves together with the project team **developed an extensive Ecosystem-based Adaptation strategy portfolio.**

Part II: EbA Strategy evaluation, rating, and prioritization

11.09.2020

- 15 participants at the offline workshop
- 3 hours session was quite short – conducted about 400 ratings
- Everything was discussed in one large group
- Issue of rating – majority agreeing with ratings, had to make quick decisions (15 seconds per item)
- The discussion took longer
- Time constraints impacted the results
- The BR merged similar strategies

Image 22 Strategy rating and prioritization session at Roztochya BR on 11.09.2020, Credit: Roztochya BR

Especially environmental education was very relevant for the region

14.09.2020

Presentation and discussion of the ranking results as well as of the final strategy selection by the Roztochya BR.

Image 23 Physical strategy rating table elaborated by Roztochya BR, Credit: Roztochya BR

15.09.

In the general summary and closing session, all biosphere reserves and the project team got together.

This didn´t mark the end of the whole process, but a milestone of having finished the SMA workshops for each ecosystem cluster, the offline workshops, and strategy ratings.

The process continued with the focus on the most viable and necessary goals, SMAs, and the development of concrete operational and monitoring plans

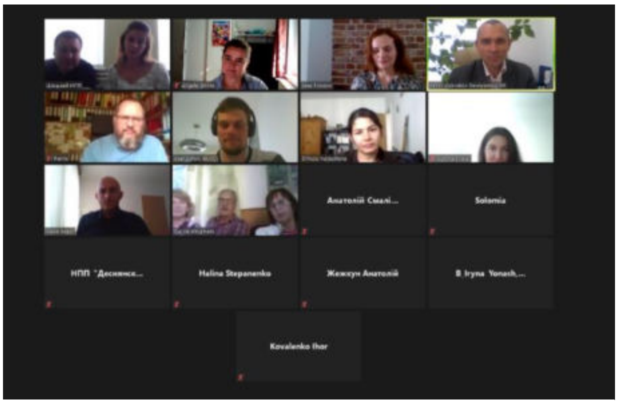


Image 24 Participants at the closing session on 15.09.2020, Credit: K. Mack

Conclusions and necessities:

- It is important to develop an Ecosystem-based Adaptation strategy on the national level.
- The 3 Biosphere Reserves are working at the forefront, doing groundbreaking work on these topics. So far, the BRs in general (also globally) haven´t stood up in favor of Ecosystem-based Adaptation.

The development of a shared vision on EbA in biosphere reserves: Is both a big challenge and a chance for finding workable ways and answers to climate change.

Part III: Elaboration of Work- and Monitoring Plans for 5 Key Strategies

From ***October to December 2020,*** **detailed work and monitoring plans for strategies (five per BR) of Ecosystem-based Adaptation to climate change were prepared**. The strategies were developed during months of cooperation and 22 online workshops and meetings as well as regularly discussed, independent work on behalf of the Biosphere Reserves.

After the introduction session, the BRs were invited to elaborate in total 5 strategies which the BR will work on after the session:

<table>
<tr>
<td>The tasks for the BRs encompassed the following:
1. Define goals for each ecosystem (-cluster)
2. Select strategies most likely to achieve these goals
3. Take strategies & start to divide them into concrete tasks & actions
a. Who is going to implement each task
b. Define concrete timeline
c. Define what resources are needed for implementation
4. Make use of the conceptual model to evaluate and conduct a plausibility check
a. Do we achieve the change we want in the system?
5. Write concise work and monitoring plans</td>
<td>Further filtering and priority setting are required to advance to strategies that allow for adequate action. Here, two criteria are especially relevant:
• Effectiveness (will the measure contribute to the goal?)
• Feasibility (Will such a measure be accepted by the stakeholders?)
• Socio-economically
• Culturally appropriate
• Financially viable (is there money to implement?)
Further criteria had to be defined by the biosphere reserves and other participants</td>
</tr>
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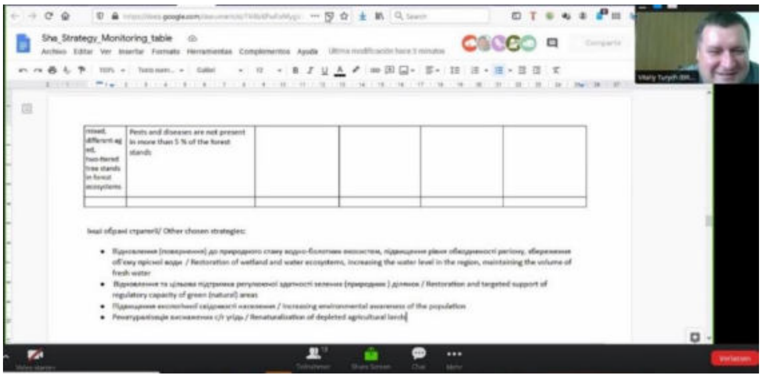
<table>
<tr><td>24.09.2020</td><td>1st revision session for the working and monitoring plans</td><td rowspan="5">
Image 25 Shatskyi BR´s Vitaliy Turych discussing the EbA work and monitoring plan - online session on 24.09.2020; Credit: K. Mack</td></tr>
<tr><td>08.10.</td><td>Goals and strategy revision</td></tr>
<tr><td>21.10</td><td>2nd revision session for the working and monitoring plans</td></tr>
<tr><td>16.12.</td><td>Closing event</td></tr>
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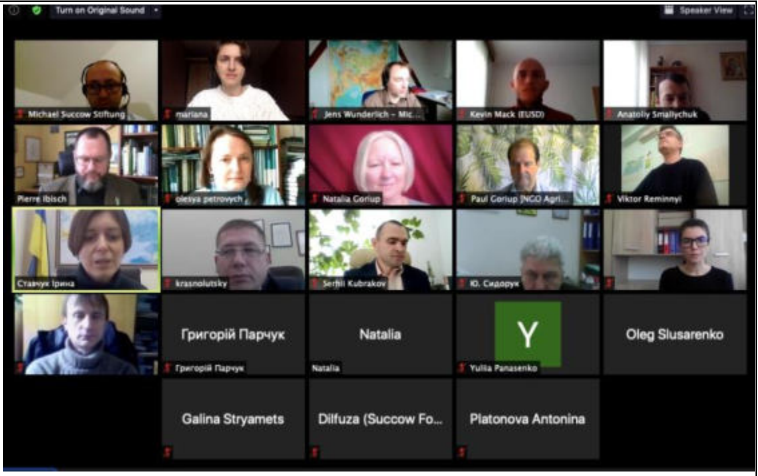
02.03.2021	*Web-based presentation of updated results for the steering committee and Ministry of Environmental Protection and Natural Resources of Ukraine*	 *Image 26 Participants during the results presentation session* *Credit: K. Mack*

Based on the elaboration and collection of EbA strategies and measures (five catalogs per BR for the main ecosystem complexes), a criteria-based selection of 5 'key EbA-strategies' per region was completed. The work and monitoring plans for the strategies are ready for implementation. The results have already been presented to the project steering committee with the participation of Ukrainian ministry representatives and various documents have been distributed among the participants.

Results of the Strategy Development Process

1) An extensive portfolio of EbA, measures, and actions for the present ecosystem clusters of the biosphere reserves and regions was developed (cf. attached catalogs in this documents series or via the project website: https://www.eba-ukraine.net/Publications.html).
2) Strategy evaluation and rating schemes were elaborated during offline work sessions by the BRs and partners by which the prioritization of strategies and final selection process was informed: The final selection of strategies was the following:

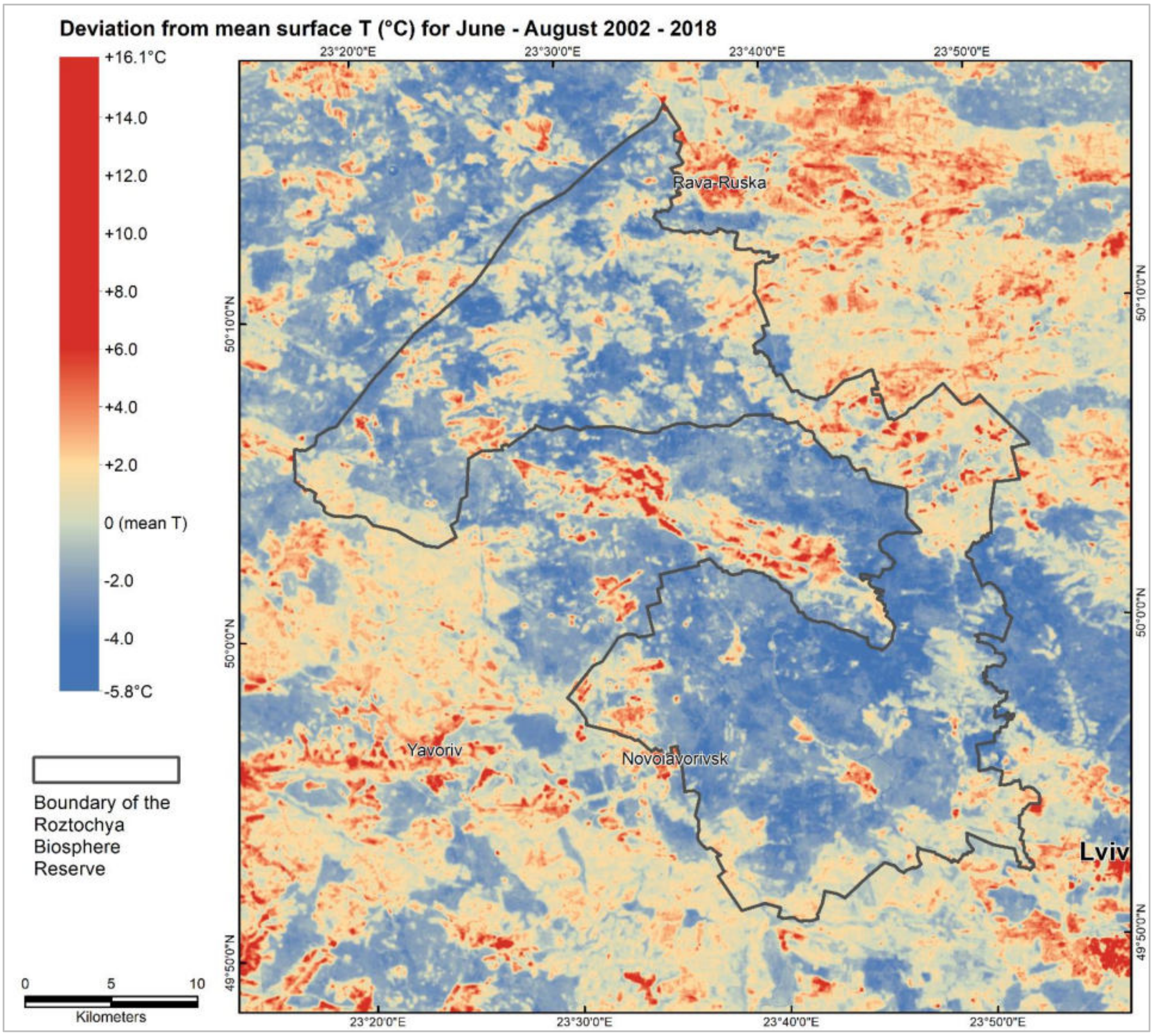
Roztochya BR (5 out of 18 strategies):

- Re-cultivation of anthropogenically disturbed lands
- Sustainable forest management
- Wetland restoration
- Conservation and protection of existing natural grasslands
- Ecological education as a tool of ecosystem-based adaptation to climate change

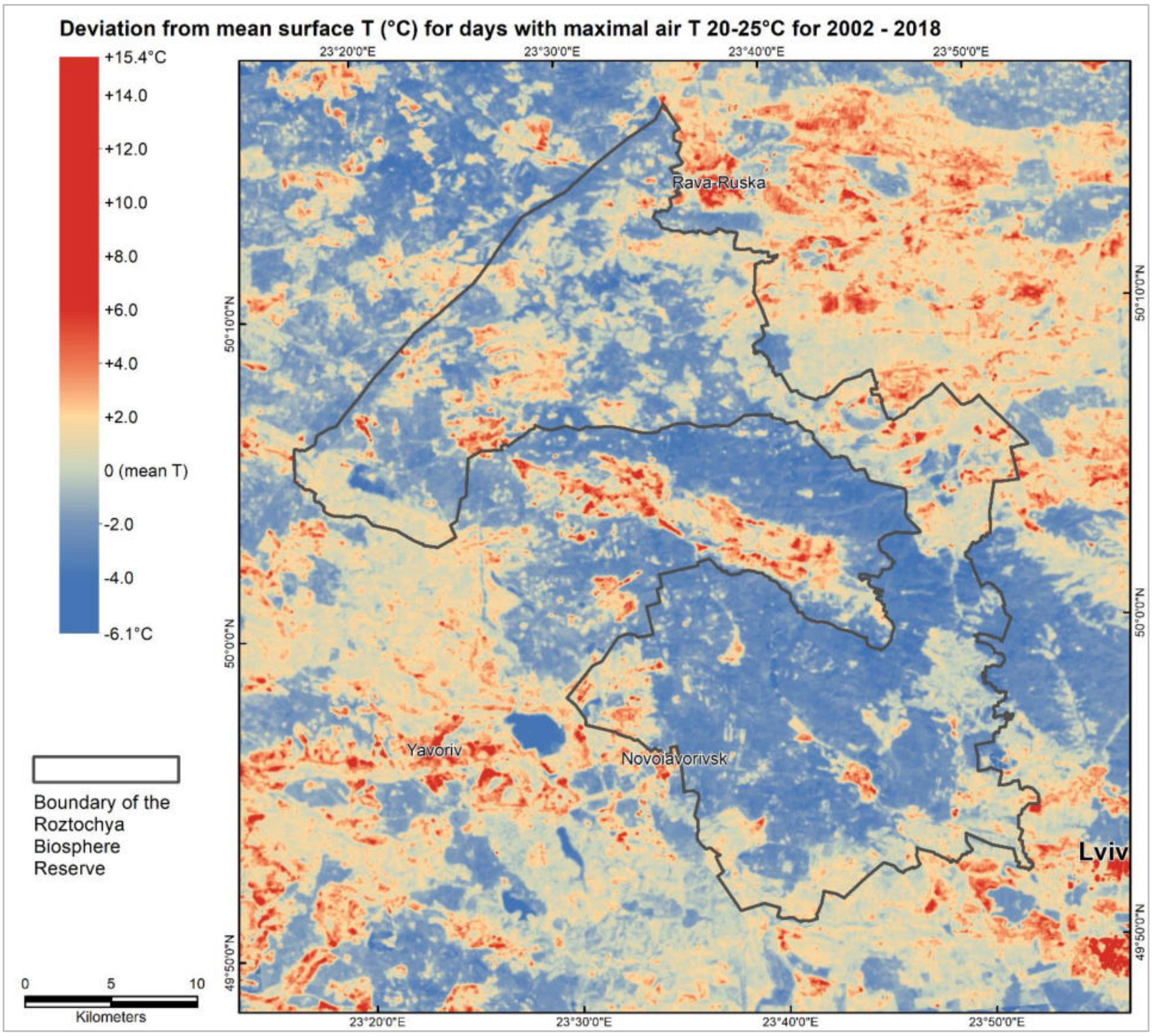
This process showed that Ecosystem-based Adaptation needs to address different levels of management:

- Direct protection and renaturation activities by the BR staff.
- Land-use changes with stakeholders in all zones of the biosphere reserves and beyond.
- Influence on regional and national strategies, policies, and laws.
- Showing presence and highlighting the importance of the UNESCO MAB program nationally and internationally.

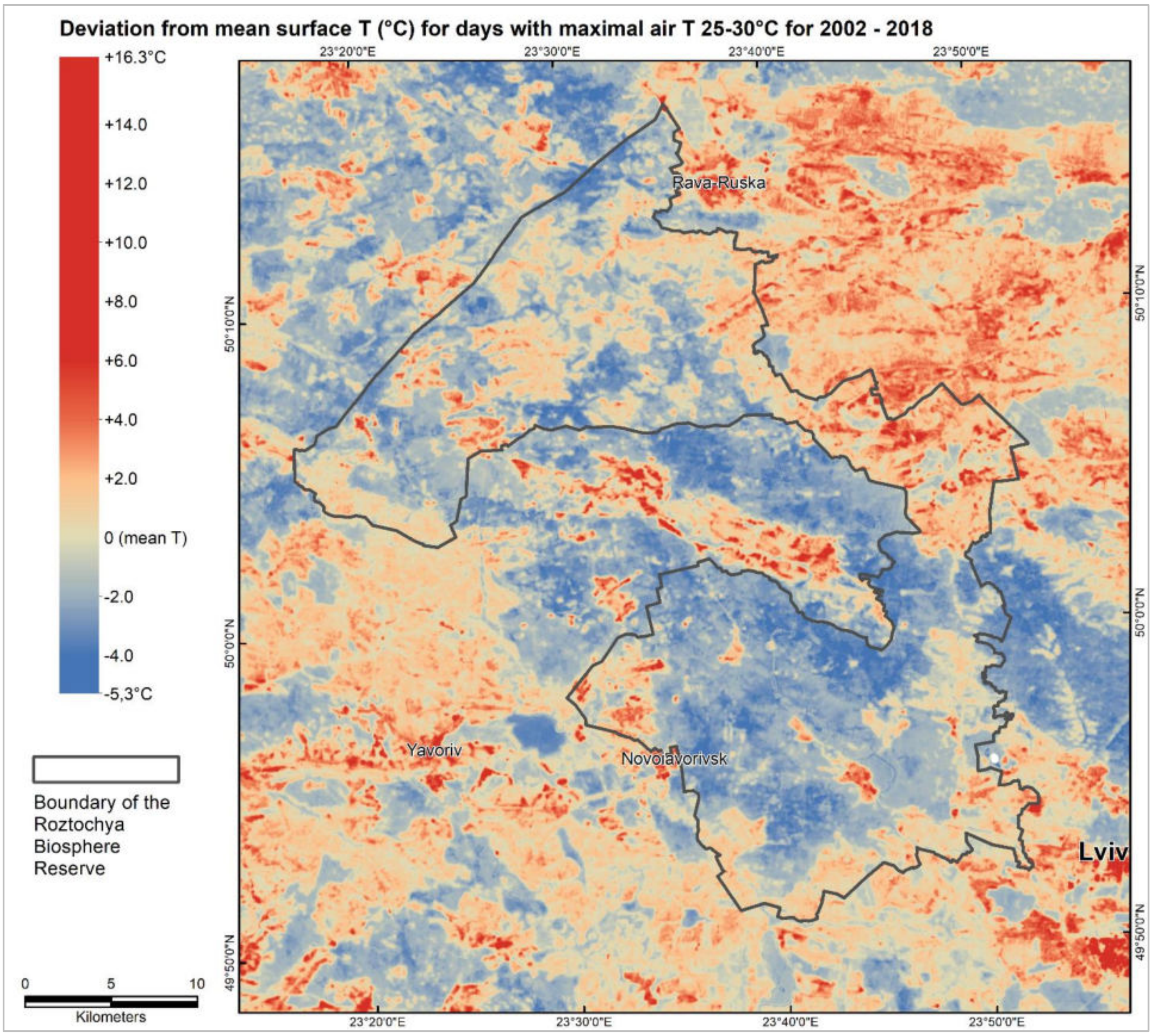
4.2 Maps: Deviation from Mean Surface Temperature - Summer Months 2002-2018



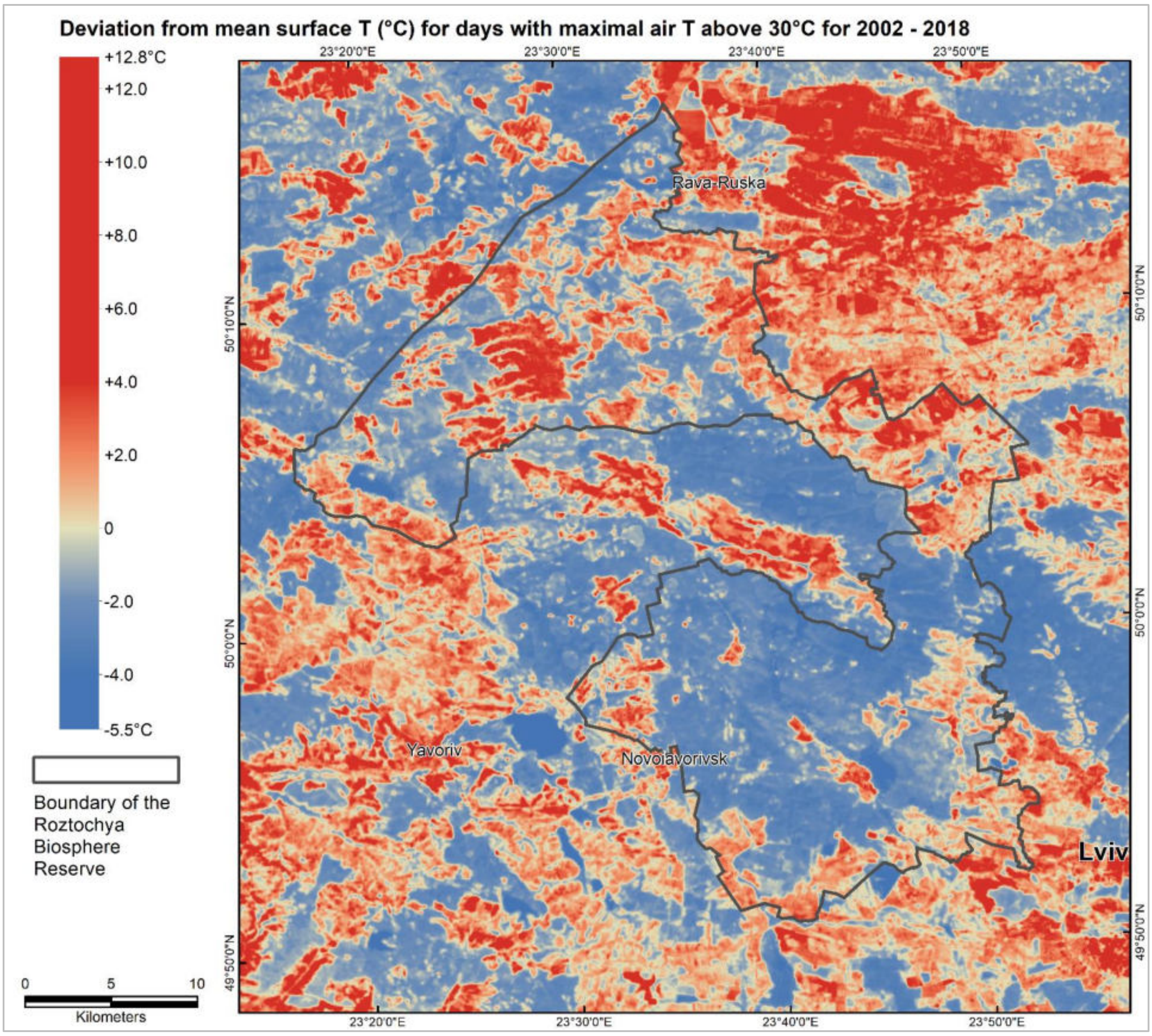
Map 7 Deviation from mean surface T (°C) for June-August (2002-2018)



Map 8 Deviation from mean surface T (°C) for June-August (2002-2018) - max air T 20-25°C

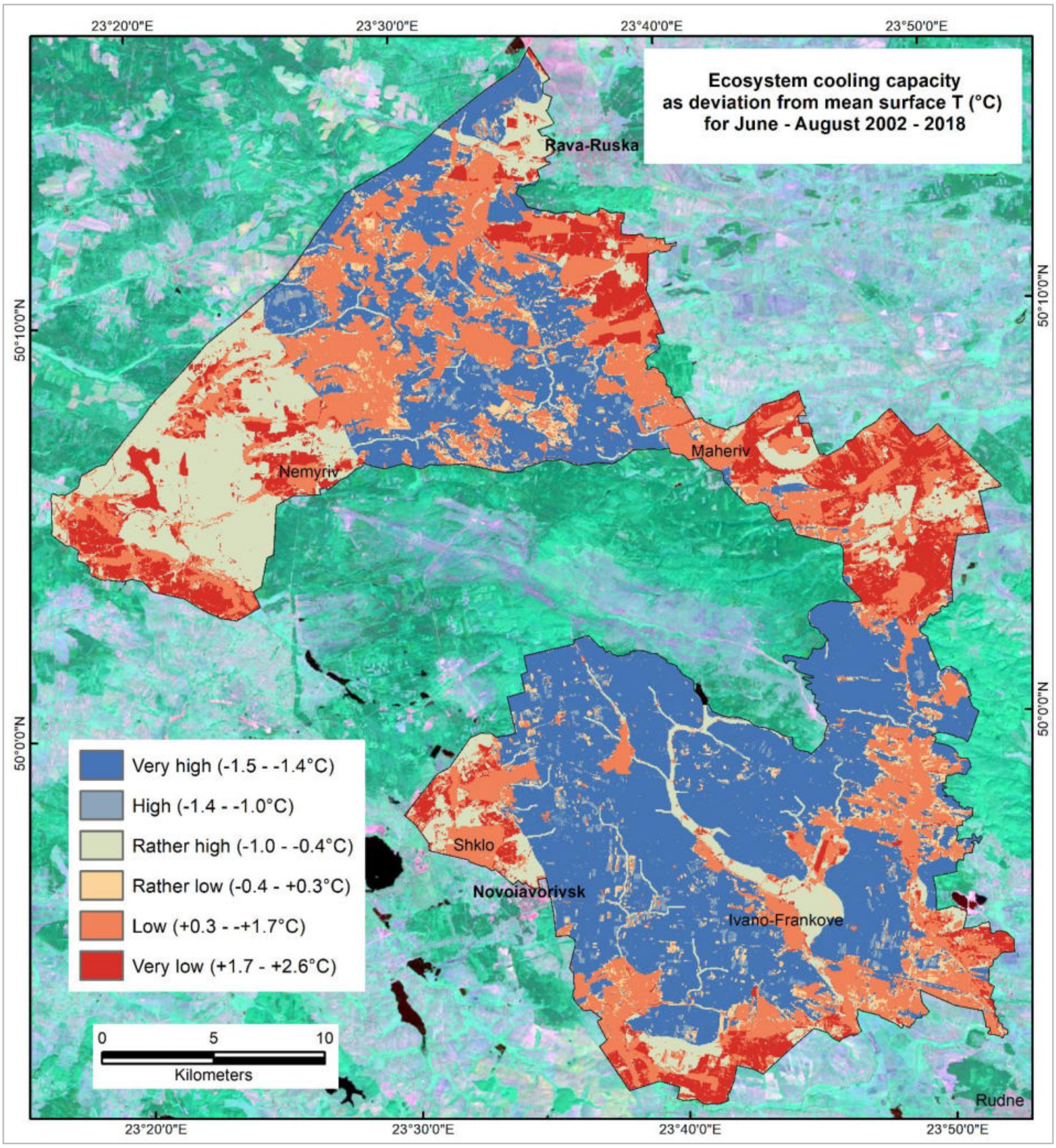


Map 9 Deviation from mean surface T (°C) for June-August (2002-2018) - max air T 25-30°C

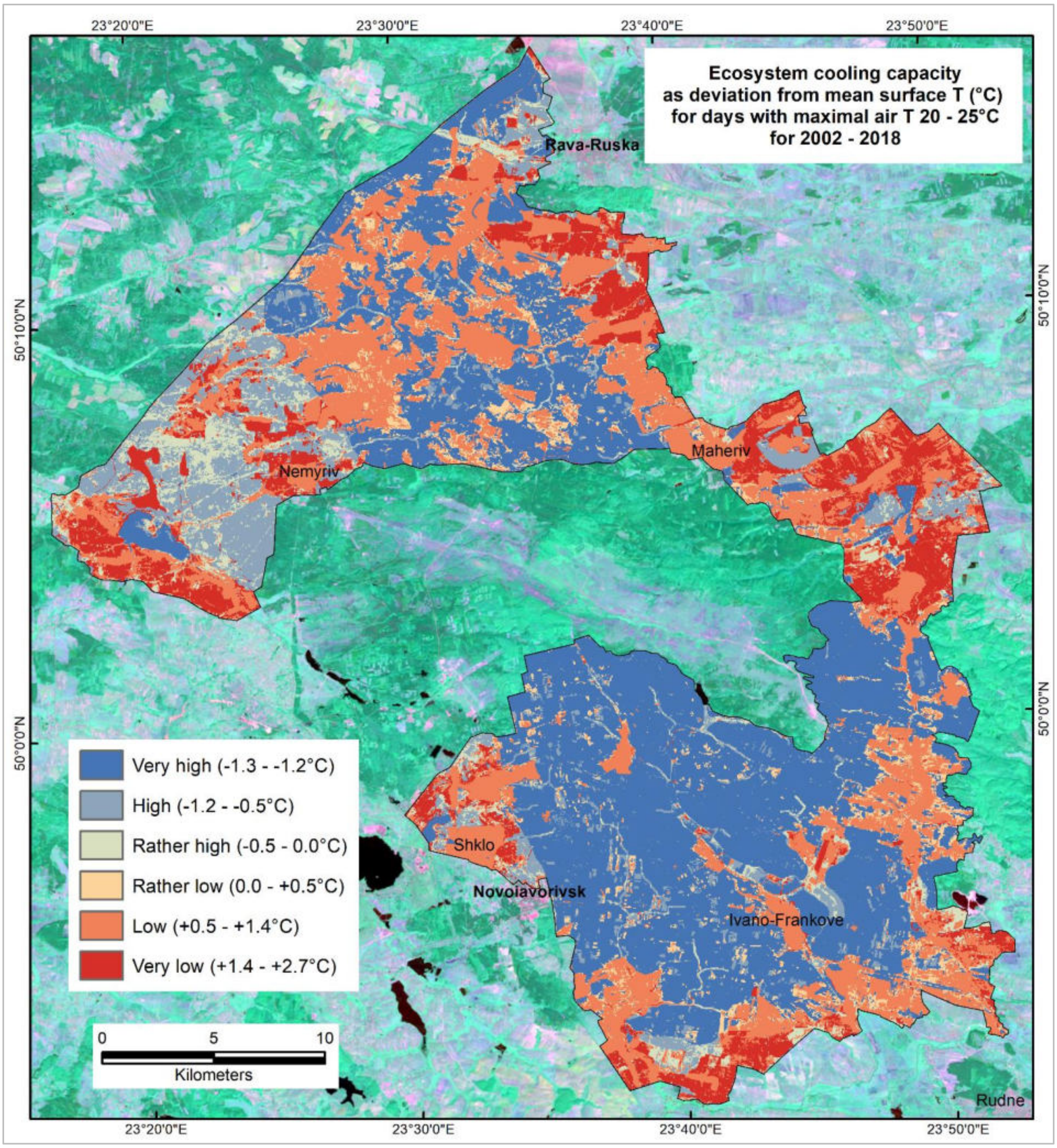


Map 10 Deviation from mean surface T (°C) for June-August (2002-2018) - max air T >30°C

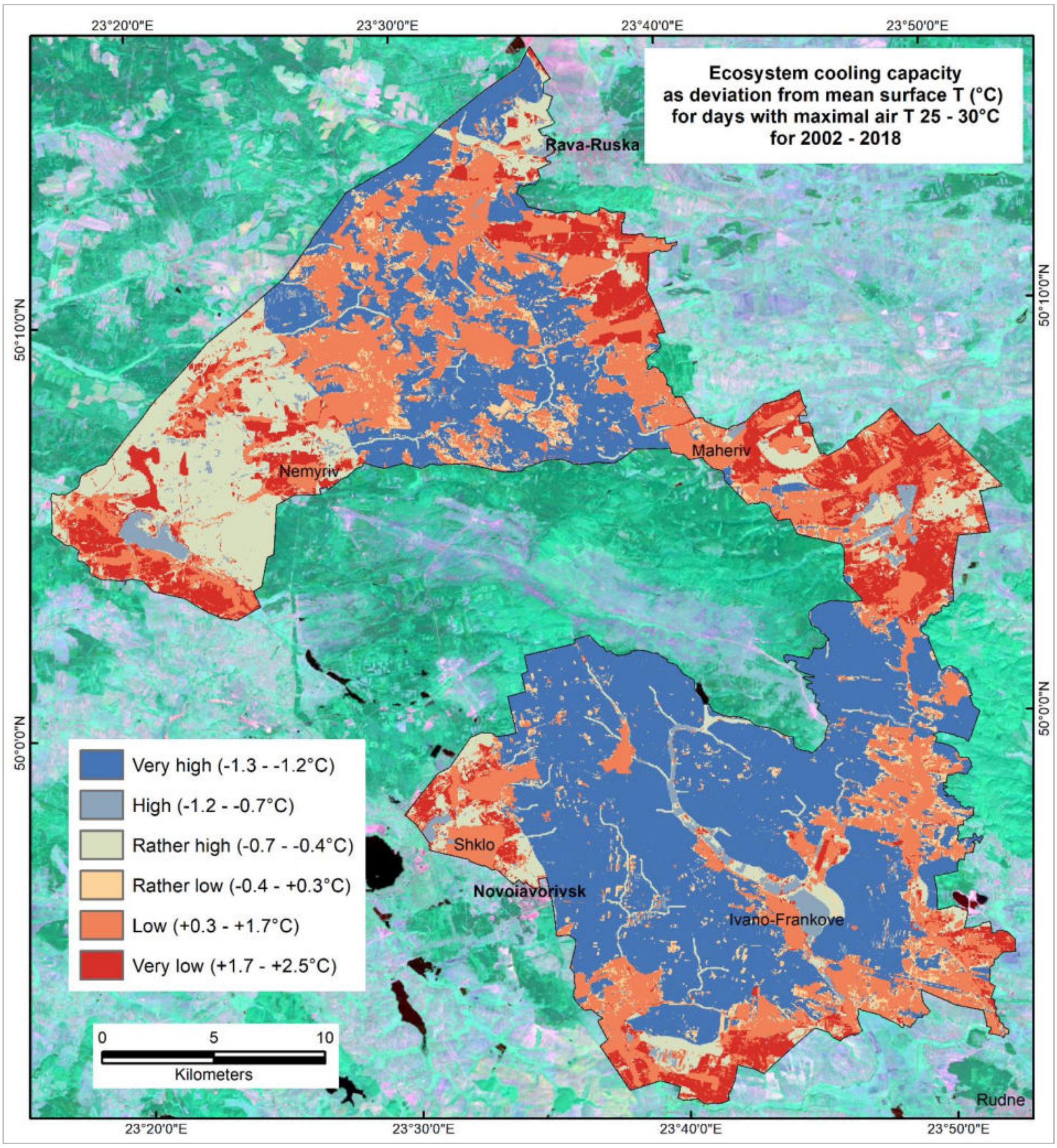
4.3 Maps: Ecosystem Cooling Capacity – Summer Months 2002-2018



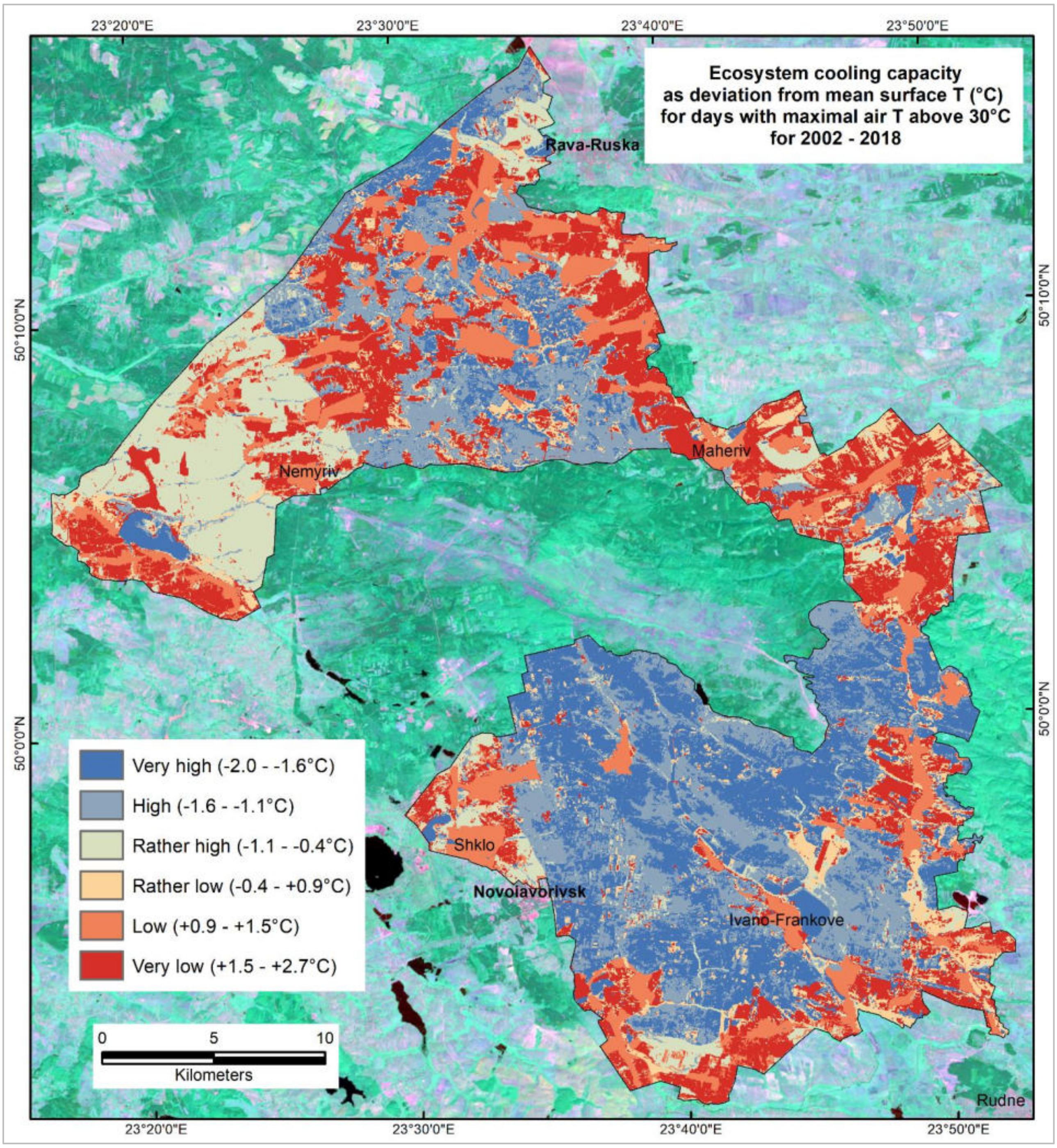
Map 11 Ecosystem Cooling Capacity – based on deviation from mean surface T (°C) June-August (2002-2018)



Map 12 Ecosystem Cooling Capacity – based on deviation from mean surface T (°C) June-August (2002-2018) for max T 20-25°C

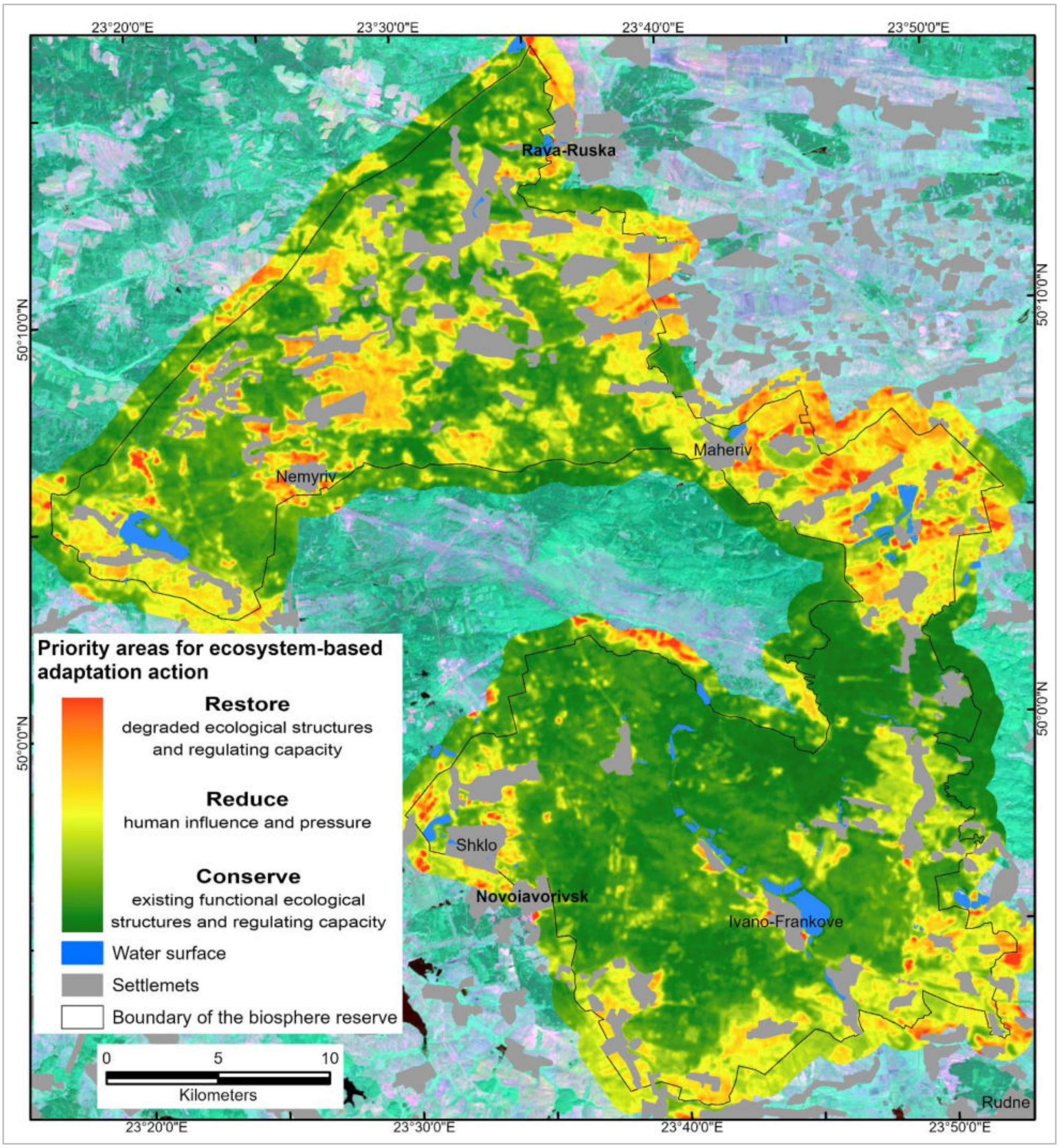


Map 13 Ecosystem Cooling Capacity – based on deviation from mean surface T (°C) June-August (2002-2018) for max T 25-30°C



Map 14 Ecosystem Cooling Capacity – based on deviation from mean surface T (°C) June-August (2002-2018) for max T >30°C

4.4 Map: Priority Areas for Ecosystem-based Adaptation Action



Map 15 Priority Areas for Ecosystem-based Adaptation Action - Restore, Reduce, Conserve

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