# Biosphere Reserves and Climate Adaptation

## Ecosystem-based Adaptation in Ukraine based on three UNESCO Biosphere Reserves




## Toolbox


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Шацький національний природний парк

West Polesie

## Cover pictures:

1. **Functional ecosystems** - providing manifold essential services for human livelihood and well-being.
   Shading, water retention, evapotranspiration, and cooling by a forest – physical work performed with both local and global impacts. Image credit: Pierre L. Ibisch

2. **Human land-use** as a driver of ecological stress, vulnerability (to climate change) and loss of ecosystem services.
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   Protecting, restoring, and enhancing ecosystem functions and services – biomass, water retention – cooling, buffering, and adverting of negative climate change impacts.
   Reforestation and agroforestry schemes in Pechau, Germany
   Image credit: Pierre L. Ibisch

## International Project:

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

https://eba-ukraine.net/

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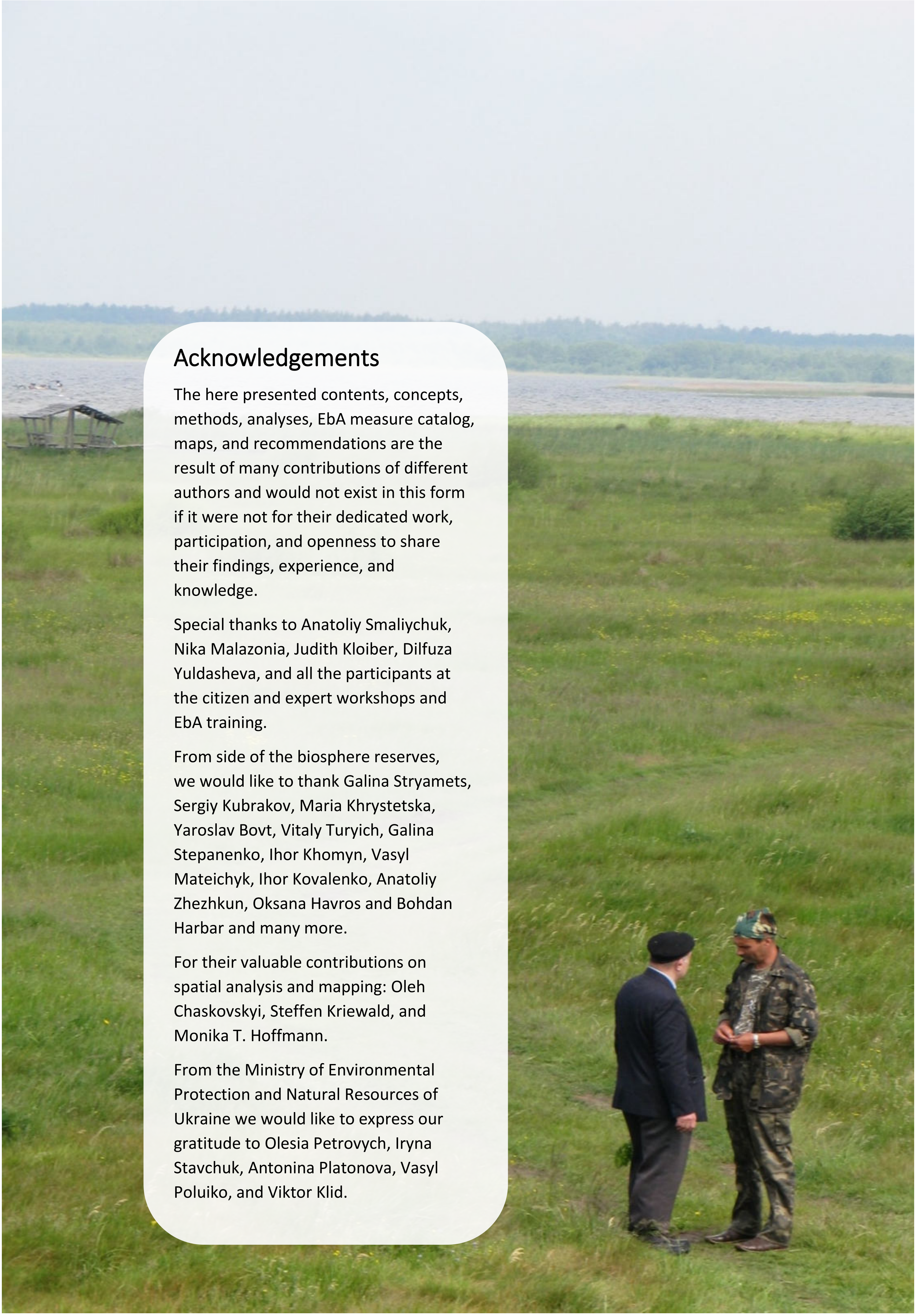


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# Ecosystem-based Adaptation in Ukraine based on three UNESCO Biosphere Reserves

# Toolbox

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# ABOUT

The here presented document is part of a collection of outputs comprising:

1. Toolbox for Ecosystem-based Adaptation to climate change including an introduction to a participatory, adaptive vulnerability assessment and management method (MARISCO), spatial analysis, and mapping method, as well as first drafts of EbA measure and activity catalogs (attached in separate printouts)
2. Situation Analysis (separate for each partnering biosphere reserve)
3. Annexes including several printed maps in A1 format and further additional documents

These documents were elaborated within the project "Ecosystem-based Adaptation to Climate Change and Sustainable Regional Development by Empowerment of Ukrainian Biosphere Reserves" funded by the International Climate Initiative (IKI) of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The goal of the three-and-a-half-year project was to introduce an Ecosystem-based Adaptation approach to climate change. It intended to ensure active public participation in three pilot regions - Roztochya and West Polesie in the Western part and Desnianskyi in the northeast of the country - according to the UNESCO program "Man and Biosphere", as well as raising awareness for the impacts of climate change.

Via close cooperation, the project aimed at working out adaptation strategies and their exemplary application. For that purpose, activities like baseline studies, workshops with citizens and experts, a training week, legal recommendations, and a project idea contest were conducted. The most promising ideas are being implemented in the frame of mini-grant pilot projects. A wide range of stakeholders is involved in the process, including local land users and residents of the biosphere reserves, regional experts, and national decision-makers. Diverse methods of stakeholder participation were applied, assessed, and implemented to achieve long-term benefits for all parties involved.

**Ecosystem-based Adaptation seeks to preserve and enhance ecosystem functionality and buffers climatic and weather extremes.** By decreasing vulnerability, human livelihood is protected, and the impacts of extreme weather events are reduced. Functional ecosystems are the key to counter climate change and warming. They are the most effective cooling elements, as via biophysical processes, e.g. water retention and evaporation, filtration, and energetic transformation of solar radiation, the water and temperature balance are regulated. The approach is **human-centered, as humans are the benefactors and recipients of ecosystem services** depending on functional ecosystems.

The **biosphere reserves are doing valuable "pioneer" work** by presenting and testing ecologically and socially more sustainable land-use and ecosystem management approaches to counter and adapt to a present and future with accelerating climate change and biodiversity loss:

1. **The introduction of EbA in the partnering biosphere reserves is a "beginning". It is a new approach, a process that requires re-thinking, willpower, and effort to work toward a livable and worthwhile future. For their implementation, the developed strategies and their respective measures require time, resources, and upscaling.** Ecosystems, "nature", need time to restore, grow, diversify, develop, and become more functional. Humans need time to learn and adapt to change. Furthermore, there are many obstacles that regulations, policies, laws, and real-world cultural, as well as resource restrictions (financial, personnel, etc.), pose for the successful application of EbA in Ukraine.
2. Due to the systemic complexity, it is inevitable to approach the challenges from several sides. Thus, the plans and catalogs deal with all ecosystem complexes and consider underlying social factors

and drivers of ecological stresses. This is supposed to be **a holistic approach, nothing should be dealt with in isolation**.

3. The plans provide a **basis for writing and initiating new projects in the frame of international (and national) climate change adaptation and mitigation programs as well as biodiversity conservation and restoration initiatives.** We assume that funding opportunities will increase as climate change pressure and impacts intensify. For this, the biosphere reserves will be prepared with plans for the timely application. It is an **opportunity to access new funding and resources.**
4. In the strategic documents as well as the pilot project implementation there are **still contents that are not fully in line with an Ecosystem-based Adaptation approach** (this also relates to the implemented mini-grant pilot projects). Ongoing revision and discussion are needed. Yet, these documents are **an important and valuable step forward by the biosphere reserves** – EbA strategies, implementation of mini-grant projects, as well as raising awareness and interest on both regional and national government sides are a set of activities that have been initiated.

With these efforts, the Biosphere Reserves strengthen their societally and environmentally important role of **reconciling the human-nature relationship and making valuable contributions in countering climate change and biodiversity loss** on a local and global scale.

**Image 1 Raising the water level in frame of Zalyvky Bog restoration at Roztochya BR; Credit: CEEM**

**Image 2 Monitoring the progress of forest conversion to broad-leaved and mixed forests; Credit: A. Smaliychuk**

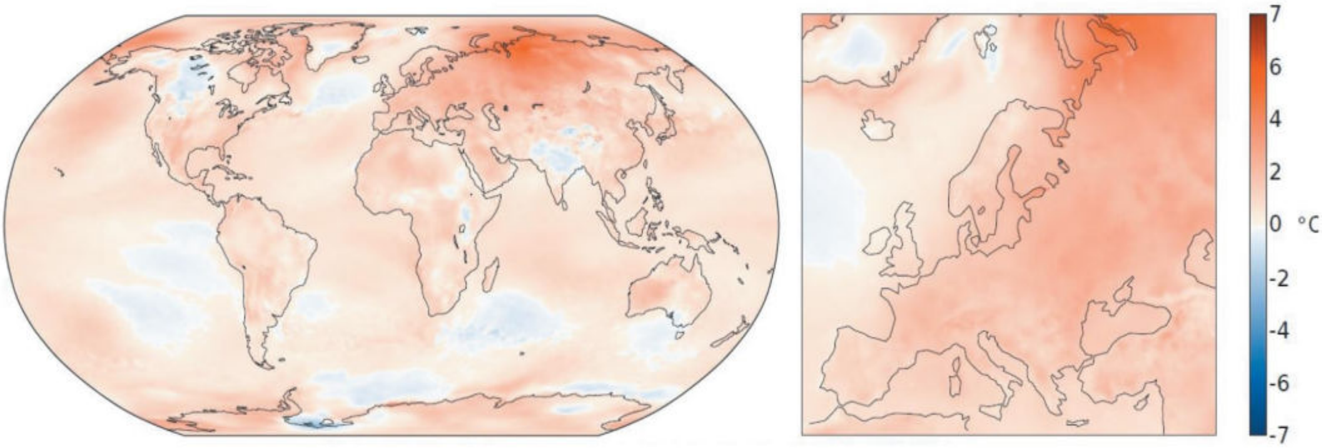
**Image 3 Development of a field protection strip at Roztochya BR; Credit: A. Smaliychuk**

**Image 4 Restoration of degraded post sulfur mining soil; Credit: A. Smaliychuk**

# BACKGROUND

## Climate Change

Global climate change is one of the greatest challenges of our time. It impacts all areas of life. It manifests in very different ways locally. In some regions, it brings too much water, in others too little. New heat extremes and prolonged drought periods become more frequent. Many people lose their livelihoods, others may gain new land to use for agriculture. Despite the many climate models, projections, and scenarios that attempt to predict the evolution and impacts of climate change, dealing with climate change involves many uncertainties and a great deal of non-knowledge. The smaller the scale of the region under consideration, the less precise calculations become, and uncertainties increase.



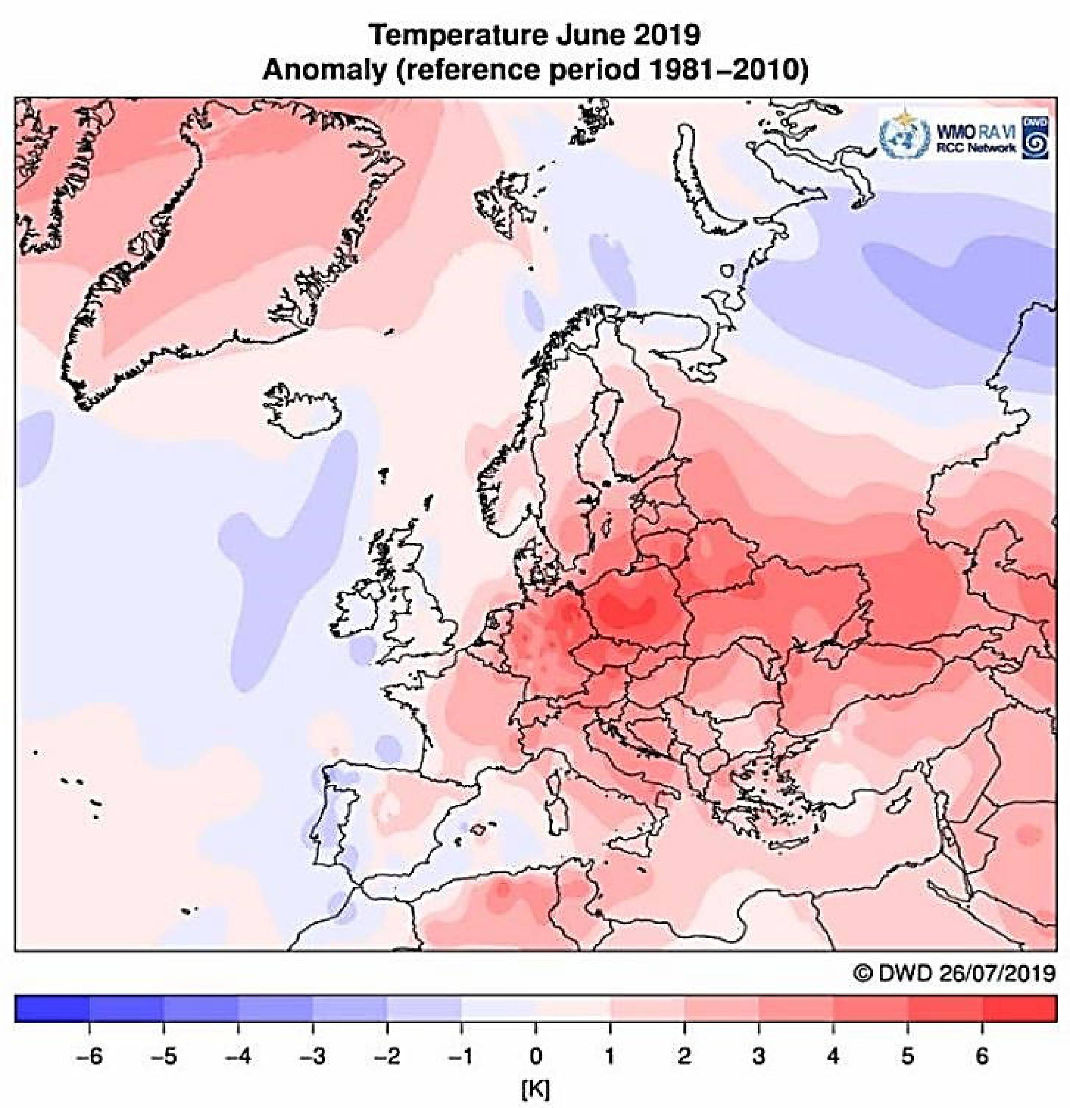

**Map 1 Surface air temperature anomaly for September 2019 to August 2020 (Reference period: 1981-2010)**

In any case, global climate change brings changes that we must face in all forms of social organization. New demands will also be placed on different administrative levels - state, regional, and municipal. A need to apply adaptive planning and management in times of advancing global climate change arises. In this context, biosphere reserves as learning sites for sustainable development and management units of changes and interactions between social and ecological systems can play a crucial role in strengthening climate action locally and sharing best practices and lessons learned globally.

**Example: Heat wave in Eastern Europe, June 2019**

The recorded average monthly temperature in June 2019 was above normal (1981-2010 average). The temperature increase was particularly observed over Central and Eastern Europe with anomalies around +3 to +6°C. The warm to hot temperatures dominated during the whole month, additionally experiencing short, but intense heat waves. In Poland, Ukraine, Belarus, and Eastern Germany, for example, temperatures exceeding 30 °C during several days were recorded.

More frequent heat waves endanger the health of people, especially of sensitive groups. Not only humans but also plants and animals are stressed by heat, can weaken, or even die. Respiratory and cardiovascular diseases can result from heat or thermal stresses while risks of fire and waterborne diseases rise. The diminishing quality and quantity of drinking water can lead to water supply shortages.




**Map 2 Temperature anomaly in Eastern Europe June 2019; Credit: German Meteorological Service (DWD), 26.07.2019**

## Thinking climate change mitigation and adaptation together

The two main societal responses to global climate change are mitigation and adaptation. Mitigation is about reducing the impact of humans on the climate system. The focus is on strategies for reducing the emission of greenhouse gases and increasing the sequestration of carbon in so-called carbon sinks (productive ecosystems can store a lot of carbon, e.g. forests or peatlands). Today, the solutions are mostly technical - e.g. use of regenerative energy sources through wind turbines and photovoltaic systems, the expansion of public instead of private transport, or the production and energetic utilization of so-called energy crops in intensively used monocultures[1]. The potential for land-use conflicting with nature conservation goals is consequently very high. Often, less attention is paid to the fact that vegetation loss also has an impact on the climate system, firstly because carbon can be released and secondly because regional or small-scale hydrological cycles are disturbed, albeit in a more regional context[2-3].

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[1] NASA (2021) Responding to climate change, https://climate.nasa.gov/solutions/adaptation-mitigation/, accessed 21-12-07

[2] Kravčík, M., J. Pokorný, J. Kohutiar, et al. (2007) Water for the Recovery of the Climate - A New Water Paradigm. Municipalia http://www.waterparadigm.org/, accessed 21-12-07

[3] Schmidt, M. (2010) A new paradigm in sustainable land use. Topos 7099-103

Despite increasing climate change mitigation efforts, climatic changes have already occurred and are more likely to intensify in the future. Humanity has not yet succeeded, not even partially, in changing its economic and lifestyle patterns to achieve emission reduction and more absorption of $CO_2$ (-equivalents). In the last decade, it became obvious that the goal of preventing climate change is no longer sufficient. It is also necessary to adapt to it. There is a societal need to cope with and adapt to these changes in the climatic and ecological systems. Thus, both objectives – climate change mitigation and adaptation – should simultaneously be pursued and offer manifold synergies.

**Adaptation to climate change**

Generally, adaptation refers to the process of adjusting to a current or expected changed condition, e.g. climate and its effects. People and nature have been adapting to the variability of climate for millions of years, but current rapid changes seem to outpace their coping mechanisms.

Adaptation to climate change involves initiatives and actions in ecological or human systems that reduce the susceptibility (vulnerability) of these systems to actual or expected impacts of climate change, avoid or mitigate impairments, and realize the beneficial potential in the process[4-5]. Adaptation is an ongoing, iterative process because complete adaptation to progressive, even accelerated, climate change will hardly be possible.

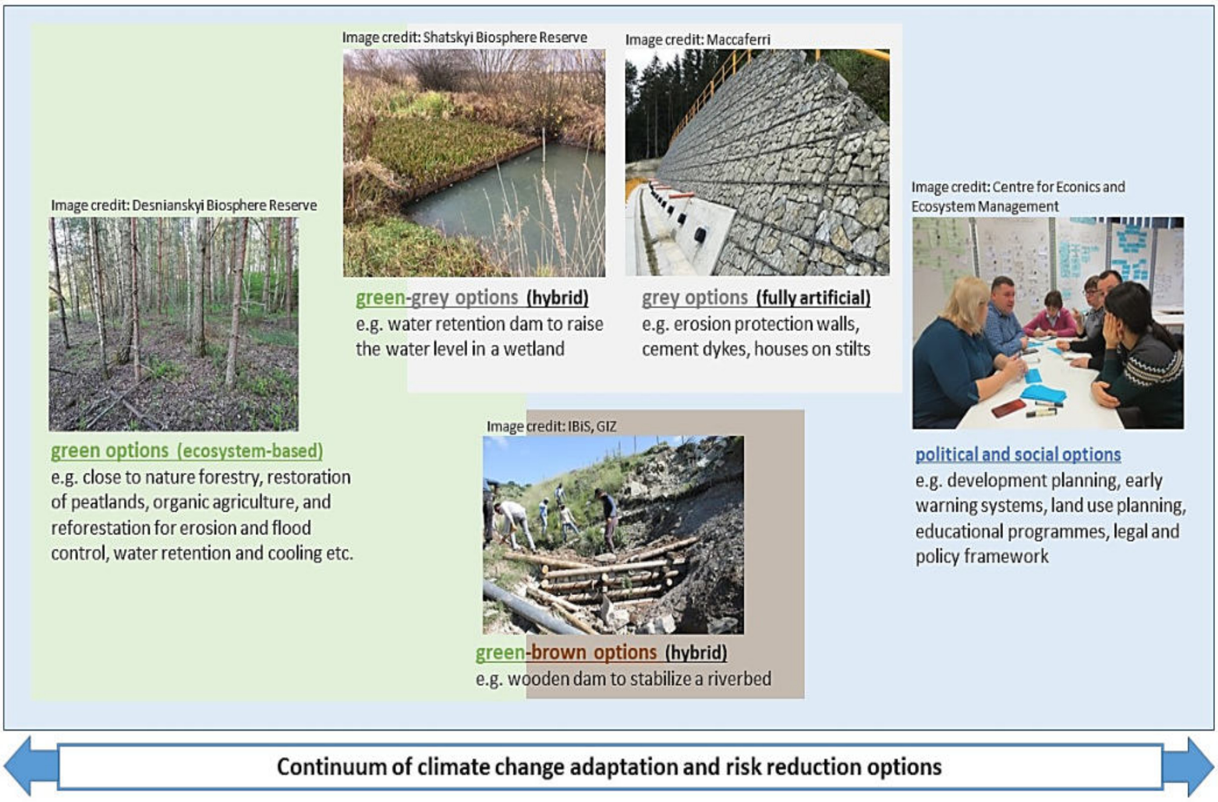


**Figure 1 Continuum of climate change adaptation and risk reduction options adapted from GIZ (2021). Integrating Ecosystem-based Adaptation and Integrated Water Resource Management for climate-resilient water management. Based on Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Bonn, Illustration by D. Yuldasheva, K. Mack**

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4 IPCC (Intergovernmental Panel on Climate Change) (2007) Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Ed.: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Cambridge, UK.

5 Convention on Biodiversity (2009) Connecting biodiversity and climate change mitigation and adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Technical Series No. 41, Montreal, Kanada.

Adaptation measures taken by society can be very diverse and range from ecosystem-based to institutional or purely technical approaches. The latter is particularly relevant in disaster management (e.g. structural flood protection). Many nature conservation measures already contribute to climate protection, e.g. the protection of forests and peatlands as water and carbon reservoirs. These approaches and synergies arising from them are an important component of Ecosystem-based Adaptation.

The creation of protective structures, such as dikes or water collection basins, is often chosen as an adaptation option. For adaptation and risk reduction, they appear more effective at first glance. However, these "hard" or "grey" measures involve high financial and ecological costs, and adverse effects are more probable. Such measures are often riskier and carry more potential regret. Yet, in the current climate adaptation debate, they are more popular as they often also serve particular (economic) interests. An ecosystem-based, "green" approach, in distinction, uses the natural properties and processes of ecosystems by protecting, sustainably managing, or restoring them. These measures are significantly less expensive, considered “No Regret options”, and in the best case, more effective than "grey" measures, since strengthening ecosystems simultaneously promotes a greater number of ecosystem functions and services[6].

**The role of ecosystems in climate change**

Nature is the basis of all life. Natural structures in which the various components interact particularly intensively, transform, and store energy and thereby perform different services and work, are referred to as ecosystems[7]. These are complex functional units with emergent properties and processes that are nested and interact.

Ecosystems are not just “nature”, beautiful and simply given. For us humans, they are also the basis of our lives and economies: they provide food, clean water, are habitat and source of income, provide recreation and a sense of home. These ecosystem services are essential to human well-being. However, in addition to the obvious services we derive from ecosystems, they also regulate water balance and quality, influence air quality and local climate, protect against soil loss, or break down pollutants. These regulating services are seemingly inexhaustible and free for everyone to use and are therefore often neglected in economic considerations.

It is precisely the regulating effects of ecosystems that are so valuable and crucial in society's approach to counter climate change. Ecosystems have a regulating influence on the global, regional and local climate system and its changes, depending on whether they act favorably or unfavorably.

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[6] IUCN (2014) Ecosystem based Adaptation: Building on No Regret Adaptation Measures, Technical Paper, 20th session of the Conference of the Parties to the UNFCCC, Lima

[7] Ibisch, P. L. (2018) Die Grundlage: Ökosysteme und Ökosystemmanagement. S. 129-154 in P. L. Ibisch, H. Molitor, A. Conrad, H. Walk, V. Mihotovic, and J. Geyer, editors. Der Mensch im globalen Ökosystem - Eine Einführung in die nachhaltige Entwicklung. oekom, München.

| Provisioning Ecosystem Services | Regulating Ecosystem Services | Cultural Ecosystem Services |
|---|---|---|
| - Supply of materials (timber, raw materials)<br>- Supply of water<br>- Supply of food<br>- Supply of energy sources<br>- Supply of seeds, spores and plant material to maintain and build up populations | - Regulation of the water cycle and discharge<br>- Regulation of water quality<br>- Regulation of micro and mesoclimate<br>- Air filtration and purification<br>- Protection against fires<br>- Wind protection<br>- Erosion control<br>- Regulation of soil quality<br>- Maintenance of offspring populations and habitats<br>- Pollination, gamete and seed dispersal<br>- Pest and disease control | - Recreation<br>- Nature experience and education<br>- Place of residence/living space<br>- Workplace<br>- Self-awareness<br>- Exercise and sport<br>- Resting place<br>- Joy and entertainment<br>- Intrinsic value<br>- Aesthetic stimulation and inspiration<br>- Cultural identity and belonging<br>- Spiritual, religious and symbolic significance |

**Table 1 Overview of selected Ecosystem Services (based on Ibisch 2018 referring to Haines-Young & Potschin 2018)**

Firstly, ecosystems carry carbon and sequester this precursor to the greenhouse gas carbon dioxide in soil and plants. Some ecosystems can sequester more carbon than others. This depends, for example, on productivity, plant growth, or disturbances. Near-natural wetlands and forests can absorb and store a comparatively large amount of carbon, while intensively managed agricultural land can store less. Secondly, ecosystems have a balancing effect on the regional and local climate as well as on the water balance to different degrees and in different places. By storing and evaporating water, ecosystems rich in vegetation and/or water have a cooling effect on hot days. Many ecosystems generate their small water cycle, in which at least part of the evaporated water is directly returned as precipitation (rain or dew) (e.g. forest areas in the Amazon, but also on a smaller scale such as in vegetation-rich wetlands in the Biosphere Reserves of Ukraine).

**Image 5 Water retention and evaporation as functions of a forest ecosystem; Credit: P. Ibisch**

This can buffer climatic extremes, regulate changes over the longer term, and ultimately reduce risks to human well-being. Diverse types of risks are influenced to different degrees by several ecosystems, their interrelation, and conditions. Here, this risk-reducing effect can be very local, or it can have a more widespread impact on the landscape. This potential of ecosystems plays a crucial role in Ecosystem-based Adaptation and offers beneficial opportunities in dealing with climate change.

Ecosystems can only provide this regulating effect in sufficient quality and quantity if they are functional. That is, they must have certain properties and processes that perform work in a web of relationships, organizing themselves, and becoming more efficient in that process to allow the ecosystem to mature as a whole. If these properties and processes are compromised, the regulating capacity of ecosystems is also diminished. Without this ability, however, the ecosystems themselves and their environment become more vulnerable to change, such as climate change.

**Vulnerability to climate change**

For the development of adaptation strategies for a socio-ecological system such as a biosphere reserve, it is important to understand its vulnerability. Vulnerability describes the susceptibility of a system to external influences, such as climate change. Three factors significantly influence how vulnerable a system is (see Figure 2). One factor is the respective exposure of the system, e.g. its exposure to climate change or anthropogenic disturbance. The more exposed a system is to climate change, e.g. because local impacts are particularly strong or highly variable, the higher its vulnerability. The functional capacity (functionality) determines the second and third factors, a system´s sensitivity and adaptive capacity to change[8]. Preserving and restoring the functionality of a system can therefore reduce its vulnerability by decreasing its sensitivity and enhancing its adaptive capacity.

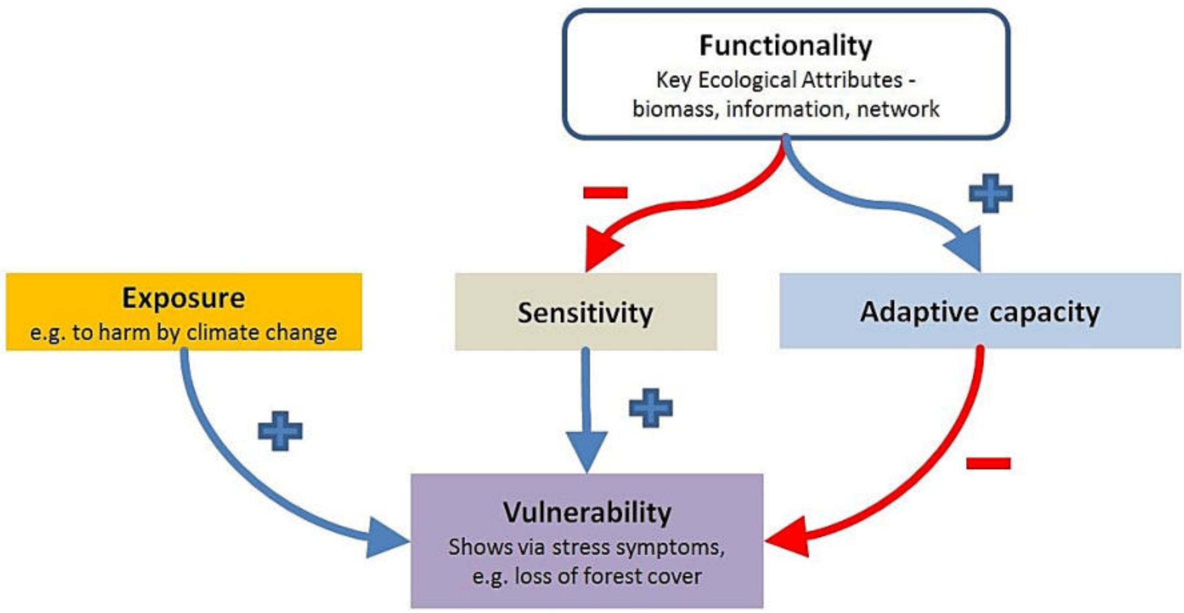



**Figure 2 Factors influencing the vulnerability of systems to climate change**

*The **functionality** of a system largely determines how **sensitive** and how **adaptable** it is to change. Consequently, preserving and restoring a system's ability to function can reduce its vulnerability.*

***Vulnerability** describes the level of exposure, sensitivity, and adaptive capacity of a system to external influences, such as climate change.*

[8] P. Weißhuhn; F. Müller; H. Wiggering (2018) Ecosystem Vulnerability Review: Proposal of an Interdisciplinary Ecosystem Assessment Approach, Environmental Management (2018) 61:904–915

Ecosystems do not only have a key role in climate regulation, they are at the same time affected by the advancing climate change itself. Climatic conditions are a component of ecosystems around which and with which the respective elements and processes of ecosystems organize themselves. An abrupt or long-term change in these climatic conditions inevitably brings about changes in the natural structure. However, the extent of these changes and how much they affect the respective ecosystem itself also depends on how functional (i.e. "healthy" and "self-sustaining") these ecosystems are. Consequently, the vulnerability of ecosystems to climate change depends strongly on their functional capacity. Functioning ecosystems that are less influenced by humans are less sensitive to climate change impacts and have a higher capacity to adapt.

The functional capacity of ecosystems depends on the (self-)regulating and organizing capacity of ecosystems. This arises primarily in the interaction of supporting ecosystem functions - ecosystem processes that characterize, underpin, and sustain the system (see Table 2). These processes can only take place if certain characteristic elements and properties are present in the respective ecosystem (Key Ecological Attributes), as well as the following conditions:

1. there must be a steady supply of energy from outside (sunlight);
2. there is a certain availability of water - a basis of life;
3. the system is not disturbed seriously;
4. the system can increase biomass, information content (including the information stored in genes), and internal interconnectedness, so that more and more parts can work together effectively.

| **Functional Group** | **Ecosystem Function** |
|---|---|
| Water cycle | - Water absorption<br>- Water retention<br>- Water storage<br>- Evaporation<br>- Infiltration<br>- Reduction of (surface) runoff |
| Productivity and Reproduction | - Photosynthesis<br>- Primary production (plant growth and biomass build-up)<br>- Pollination<br>- Seed and spore dispersal |
| Physical effect | - Shading/filtering of solar radiation<br>- Reduction of wind effect<br>- Ventilation<br>- Air filtration<br>- Water filtration |
| Nutrient cycle | - Decomposition & humus formation<br>- Soil formation (incl. mineralization) |

**Table 2 Examples of supporting ecosystem functions as the basis of (self-)regulating capacity of ecosystems**

Consequently, if critical ecosystem properties (Key Ecological Attributes) are altered and functions are disrupted, their ability to function is impaired. These ecosystem changes or impairments, e.g. reduced biomass, are referred to as ecosystem stresses. Human activities, use, and interventions, such as surface sealing, drainage of wetlands or agricultural use, are significant causes and drivers of such ecosystem stresses.

Ecosystems can thus be defined as dysfunctional when they are affected by multiple stresses, i.e. when key properties and processes are disrupted or destroyed. Dysfunctional ecosystems are more vulnerable and provide diminished quality and quantity of ecosystem services, thus affecting human well-being - health, nutrition, income, and livelihood. Climate change is particularly dangerous where ecosystems are exposed and cannot function properly due to human overuse, modification, destruction, and fragmentation.

Often, human interventions do not just happen once, but many ecosystems are used and regulated continuously, such that sometimes they cannot recover. This not only significantly impairs the functioning of ecosystems, but also makes them more vulnerable to climate change and exacerbates climate change impacts in the ecosystem (climate change-induced stresses) such as heat or drought.

In addition to direct ecosystem interventions, the underlying factors, i.e. societal processes and structures that enable and require these interventions, also play a role in ecosystem functioning and vulnerability. This includes, for example, the political and legal framework as well as regional planning and administration or concrete land use. However, socio-demographic, cultural, and socio-economic factors also determine human actions and thus the extent to which ecosystems are restricted in their ability to function.

Another factor influencing functional efficiency is the respective embedding of the individual ecosystem in the ecosystem network. Subsystems and the superordinate ecosystem influence the functional efficiency just as much as neighboring systems. If the discrepancies between the systems and their properties are very large or even too large, the functional efficiency is reduced accordingly.

The higher the functional capacity of the ecosystems in the respective biosphere reserve, the lower their vulnerability to the effects of climate change and the better they can regulate change processes and extreme events in the ecosystem network.

**Changes of ecosystem services and risks to human well-being**

Ecosystems whose functionality is disturbed can no longer adequately provide ecosystem services that ensure human well-being. Thus, risks to human well-being can arise: health is endangered, security can no longer be guaranteed, material supplies are limited.

Due to a reduced functional capacity, especially and initially above all, the regulating services can no longer be provided to the full extent, and there are directly noticeable consequences for humans. Extreme events such as heavy rainfall are no longer adequately buffered, resulting in increased frequency, severity, and unpredictability. This poses risks and sometimes even serious hazards.

When basic ecosystem functions are no longer provided and certain ecosystem processes are no longer adequately regulated, provisioning services very quickly become limited. Food, water, materials, and energy can no longer be provided locally in sufficient quantities. This leads, for example, to water shortages, crop failures, and bottlenecks in the supply of wood. Local income and livelihoods are reduced, and in extreme cases livelihoods (e.g. farms) are threatened.

Last but not least, ecosystems also change their cultural services and values. The recreational value of open land decreases due to increased development of heat, drought, and dust. The recreational value of the forest is reduced by hazards and damage from storms and wildfire. Regionally typical or previous forest and landscape images and associated values change and in some cases may be lost altogether. The cultural identity or sense of belonging can be disturbed or changed, which can lead to conflicts between groups and generations.

**Climate change demands re-thinking of regional management and planning**

Climate change brings new challenges for the state-, oblast-, regional-, and municipal administration and intensifies existing ones. In particular, the more frequent and more severe occurrence of extreme events such as droughts, heatwaves, or heavy rainfall and the associated risks to human welfare require a new form of public good that must be developed and implemented accordingly in planning and administration. The same applies to ecosystem degradation due to climatic changes with ever-increasing human demands on ecosystems. In this context, we are facing an accelerated change that is associated with strong uncertainties. The complexity of change processes is steadily increasing; manageability and predictability are declining. Changes are becoming more diverse, influencing and reinforcing each other directly and indirectly; ultimately, such feedback effects occur unforeseen and make adequate adaptation efforts more immediate, challenging, and costly.

Climate change affects all areas, sectors, and levels of society, and adaptations are necessary everywhere. At the same time, the climate is to be "protected" with a variety of approaches. Corresponding measures are not always equally considered and coordinated with each other, which can lead to new conflicts. Not only within the municipalities is it necessary to coordinate strategies and measures with all actors and stakeholders to adequately address climate change. Climate change also places new demands on transboundary cooperation with neighboring regions and land users.

This realization that human actions influence one's well-being not only through social systems and processes but also, and above all, through changes in ecosystems as the basis of life, should create a new awareness in municipal planning and administration in dealing with climate change. It must be an essential task of a municipality to ensure human well-being by preserving and restoring the natural basis of life, i.e. ecosystems and their ability to function. This results in a new form of municipal provision for the public good, even disaster preparedness, with a new awareness of climate change-related risks and their origins. What is needed is a debate and an active approach to climate change adaptation that focuses on the importance of functioning ecosystems, to reduce vulnerability and the potential risks and impacts for humans. This corresponds to the concept of ecosystem-based adaptation to climate change.

At the same time, human society is the main actor in Ecosystem-based Adaptation to climate change because it is itself a dependent subsystem of ecosystems as well as a factor significantly influencing the ecosystem. Society, in turn, consists of various social systems. They all have their roles in the adaptation process. Therefore, it is important to involve the whole society in the process and to lead decision-making processes together. In the end, it is primarily the smallest social units, i.e. the basic population or civil society, that claim the right to human well-being. To meet this, contemporary participation and inclusive communication should accompany, guide, and advance an Ecosystem-based Adaptation process.

Guidelines for Ecosystem-based Adaptation (EbA) to climate change emerge from this process (based on Ibisch et al. 2014[9]):

1. The functionality of ecosystems should be the primary goal;
2. Synergies between climate change adaptation and climate change mitigation result from an ecosystem-based approach;
3. EbA must be understood as a cross-cutting task in a landscape or ecosystem use geared towards sustainability;
4. Ecosystem-based development and effective climate change resilient municipal management require adapted (nature conservation) sectoral planning and action programs;
5. EbA is accompanied, shaped, and driven by timely communication, inclusive public outreach, and civil society participation.

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

**Ecosystem-based Adaptation**

Ecosystem-based Adaptation (EbA) to climate change is defined as 'the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. (…) It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people.'[10]

The approach aims to conserve existing functional ecosystems, reduce human stress and pressure on ecosystems, and restore ecological structures and processes to increase overall system functionality and health. Thus, in times of accelerating anthropogenic climate change and ever more devastating impacts, it aims at protecting human lives, livelihood, and wellbeing by conserving and restoring fundamental ecological functions and services.

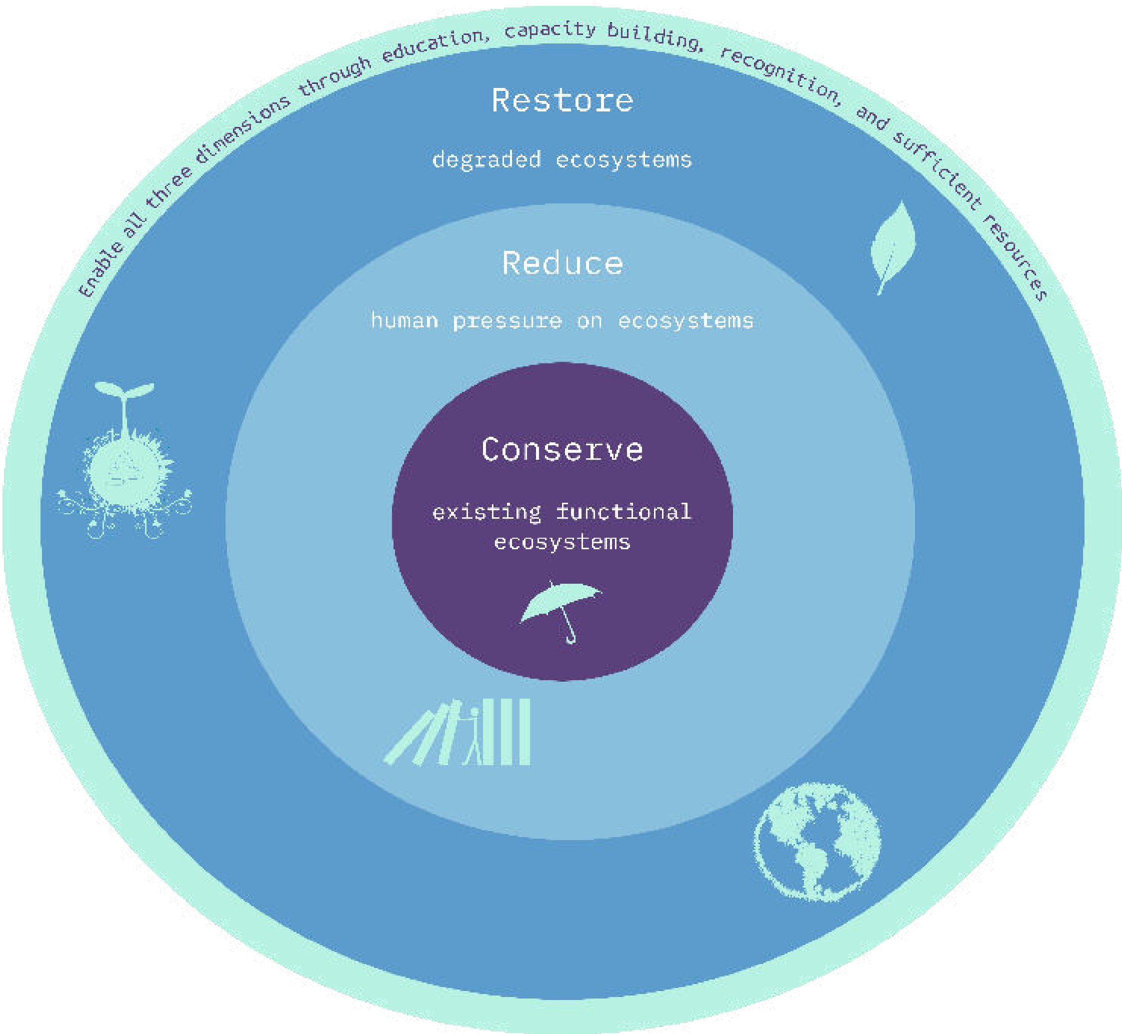



**Figure 3 The three dimensions of Ecosystem-based Adaptation plus the enabling conditions. Illustration by A. Dichte**

[10] Secretariat of the Convention on Biological Diversity. 2009. Connecting biodiversity and climate change mitigation and adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Montreal, Canada: Technical Series No. 41.

The EbA approach is at the interface of the sustainable development targets[11]. By reducing and buffering climate change impacts, conserving and restoring biodiversity and ecosystem functions, it aims at safeguarding and enabling socio-economic benefits on a local scale contributing to the global situation.

An ecosystem-based, «green» approach uses the natural properties and processes of ecosystems by protecting, sustainably managing, or restoring them. These measures are significantly less expensive and, in the best case, more effective than «grey» measures, since strengthening ecosystems simultaneously promotes a greater number of ecosystem services.

Part of the ecosystem approach is promoting the no-regret measures, which provide a useful way of dealing with uncertainties. They are worth implementing, no matter the actual developments, because the resulting improvements still bring benefits or at least do no harm.

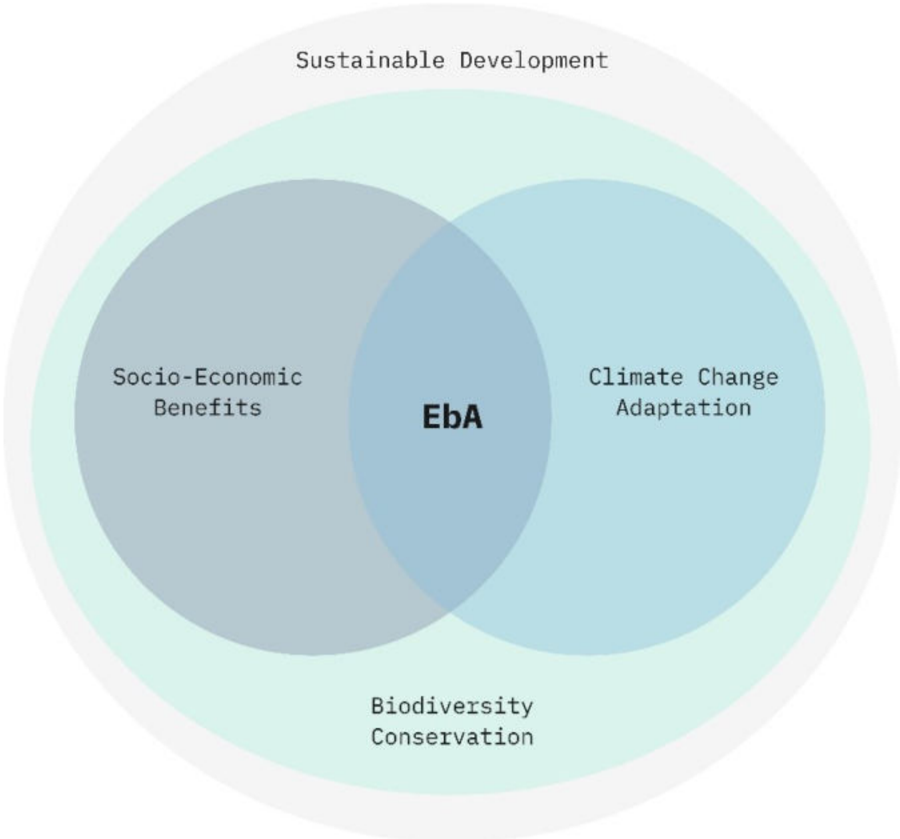



**Figure 4 EbA in the context of sustainable development (adapted from Midgley et al. 2012)**

Ecosystem-based Adaptation to climate change must become a central pillar of nature conservation and holistic ecosystem management. Absolute priority must be given to such measures as water retention, cooling and buffering of microclimatic fluctuations, and slowing down or stopping drying winds. These measures will lead to success if they are accompanied by an increase of biomass in near-natural vegetation in the landscape, soil care, and humus formation.

[11] Midgley et al. 2012. Biodiversity, Climate Change and Sustainable Development – Harnessing Synergies and Celebrating Successes

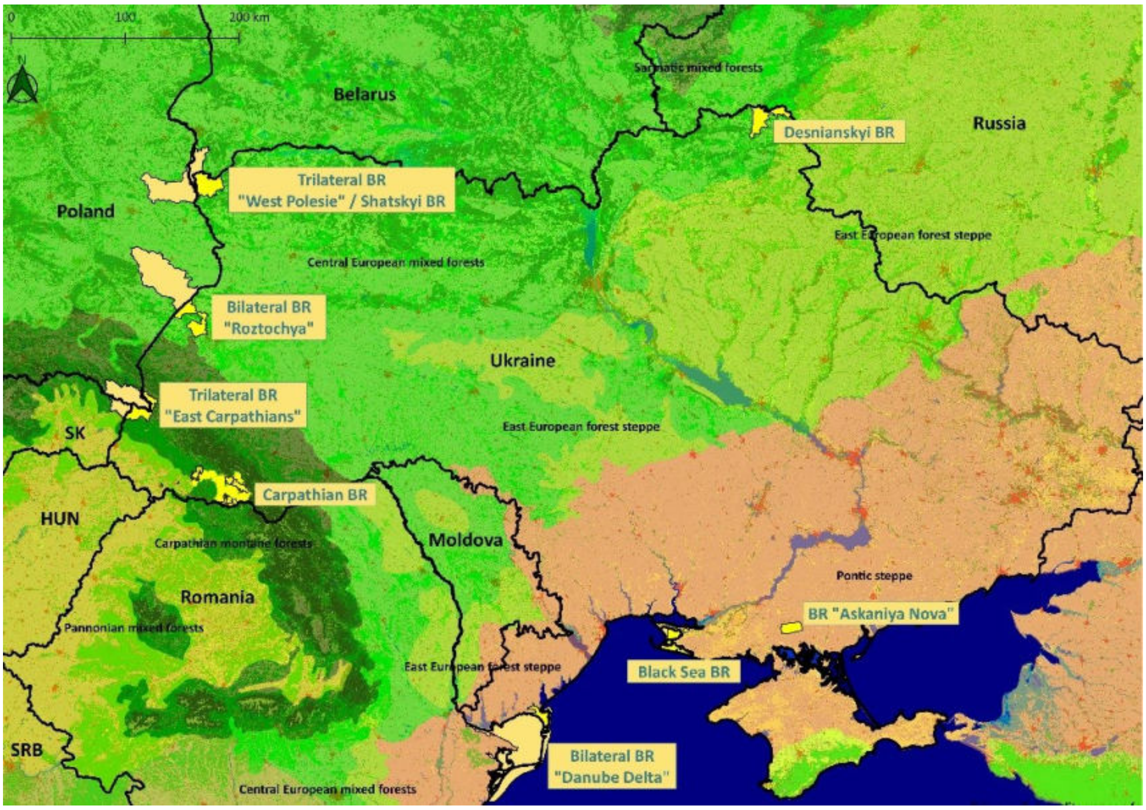
**Biosphere reserves are learning sites for sustainable development**

Biosphere reserves are "*sites for testing interdisciplinary approaches to understanding and managing changes and interactions between social and ecological systems, including conflict prevention and management of biodiversity*"[12]. They are regions where nature and culture connect and are internationally recognized for their biodiversity and cultural values. As "living laboratories" they are important for the preservation of ecosystems by promoting eco-sustainable human and economic development approaches. Furthermore, they promote continued research, education, and the provision of information.

**A dynamic worldwide network**

As early as 1971, the United Nations Educational, Scientific and Cultural Organization (UNESCO) established the Man and the Biosphere Programme (MAB) as an international, interdisciplinary program to create a scientific basis for improving relations between people and their environment. In 1974, a Task Force of the MAB program developed the concept of biosphere reserves, recognizing that the conservation of biological diversity, the promotion of economic development, and the preservation of the associated cultural values are often contradictory objectives.

Since the 1970s, UNESCO has designated areas all around the world for the establishment of biosphere reserves. When designated, these regions are commissioned to serve as learning sites and role models for sustainable development, crafting local solutions to global challenges. As a result, a network of biosphere reserves was established, which is constantly growing, currently comprising 714 areas in 129 countries of the world (as of 2021), including 21 transboundary sites.




**Map 3 Overview map of all Ukrainian UNESCO Biosphere Reserves and, if available, the corresponding transboundary areas in neighbouring countries.** **Terrestrial Ecoregions of the World 2.0: World Wildlife Fund (WWF) - US 2004; Landcover data: Copernicus Global Land Service 2015: Land Cover 100m; Data on Biosphere Reserve areas: WDPA 2018; Produced by: A. Dichte**

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[12] UNESCO (2021), https://en.unesco.org/mab, accessed 21-12-07

**The Ukrainian network of sites of excellence**

In Ukraine, there are currently eight UNESCO biosphere reserves, of which four are created together with neighboring countries as Transboundary BRs. More are in the planning stage. During times of the Soviet Union, two biosphere reserves existed inside the territory of Ukraine. The Ukrainian biosphere reserves cover a wide range of ecological and cultural conditions - from alpine and wooded ecosystems to steppe areas with relatively intensive land use to lowland river, floodplain, and delta areas. This also means that very different challenges and development opportunities emerge depending on the area. Nevertheless, a constant exchange between the areas is very fruitful, as different possible solutions can be tried out and best-practice experiences can be exchanged - the best prerequisite for fresh ideas and new perspectives by learning from each other.

**What does a biosphere reserve do?**

As a *living laboratory* and *special place for joint learning*, a UNESCO Biosphere Reserve has the mission to support innovative ideas and projects that aim towards sustainability by promoting:

- **Development** – Fostering a sustainable economy and society for people living and working in the region
- **Learning** – Facilitating education, training, and research to support conservation and sustainable development
- **Conservation**: Protecting biodiversity and cultural diversity

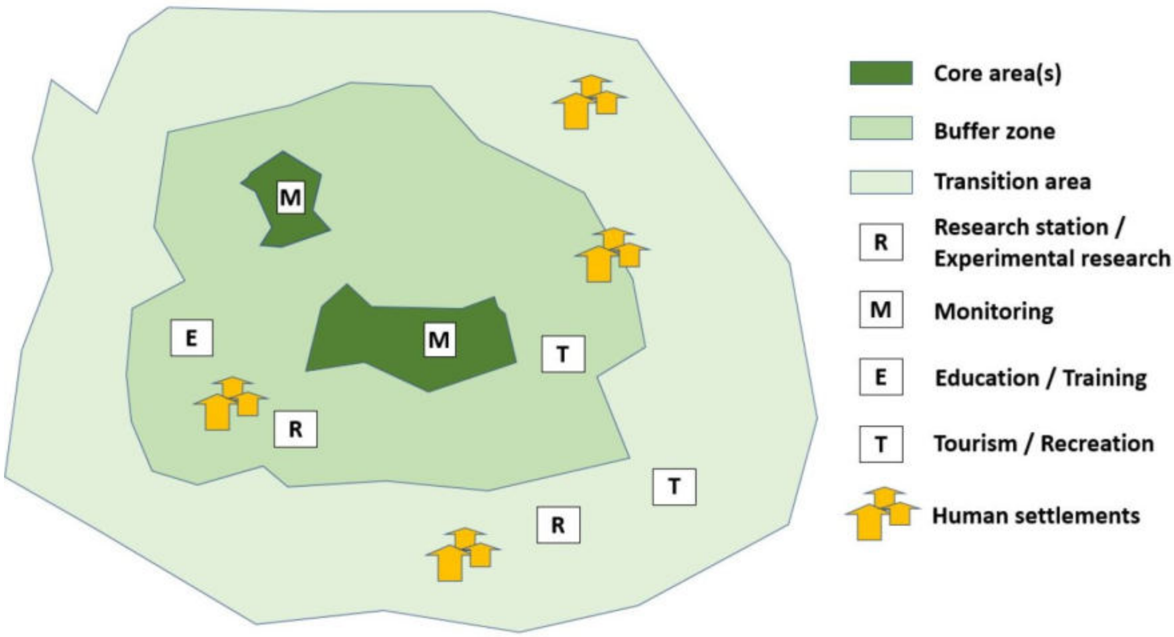



**Figure 5 Biosphere Reserve Zonation Scheme, Illustration by K. Mack**

For the purpose of addressing its mission and functions, a biosphere reserve-specific zonation system was developed, encompassing:

- **Core zone** - A zone with strictly protected ecosystems / non-usage
- **Buffer zone** - Surrounds the core areas – used for scientific and educational activities
- **Transition zone** – Usually covering the largest area of the biosphere reserve, promoting and supporting socio-ecologically sustainable land-use practices

## The project areas

### Desnianskyi Biosphere Reserve

| Designation date: | 2009 |
|---|---|
| Total area: | 70,749 ha |
| Core zones: | 2,397 ha |
| Buffer zones: | 13,156 ha |
| Transition zone: | 55,195 ha |

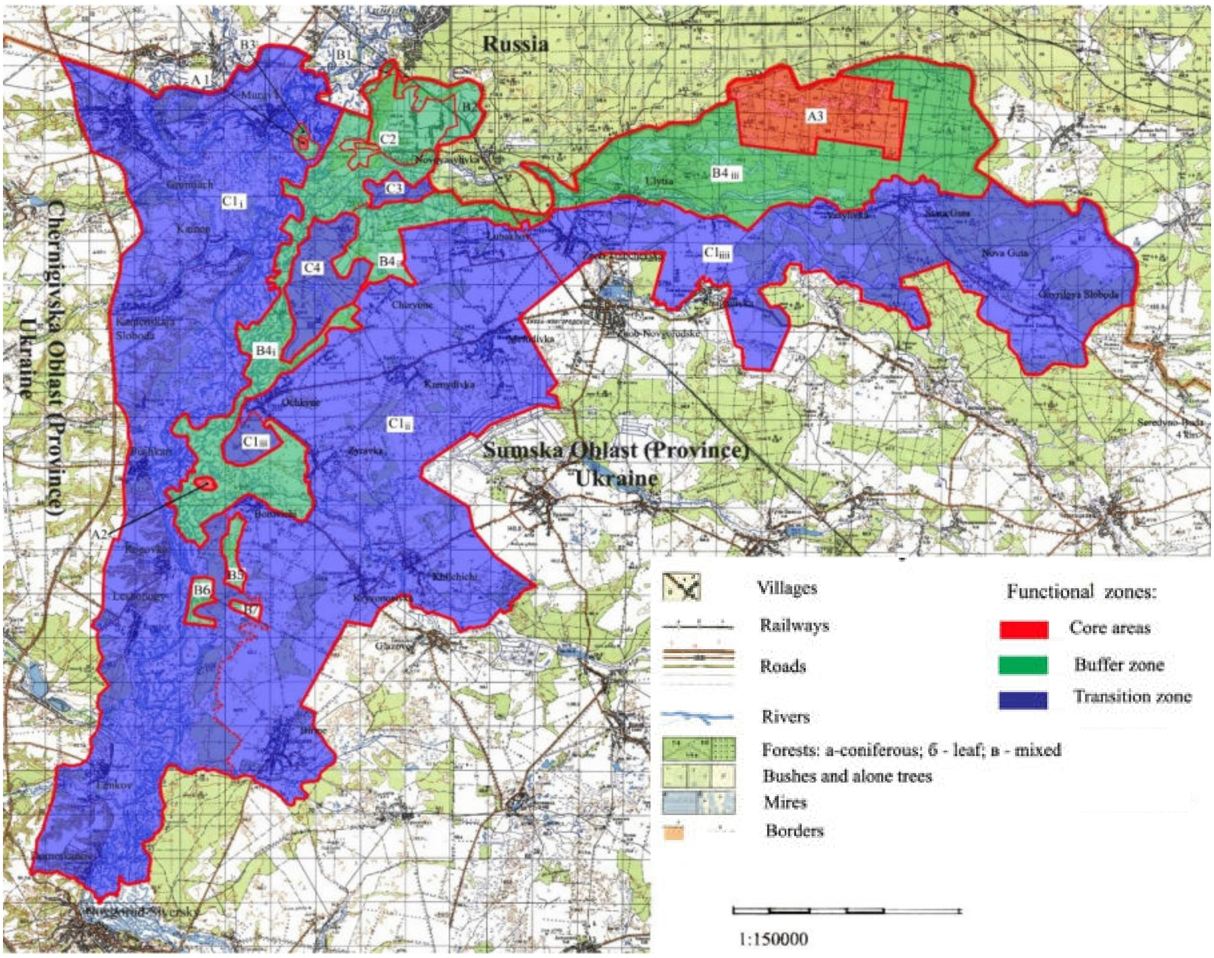
Desnianskyi Biosphere Reserve is located both in Sumy and Chernihiv oblasts. Geographically, it is situated in Eastern Polesia, in the middle stream of Desna River - one of the largest arms of the Dnipro and one of the last large unregulated watercourses in Europe.

The area of the biosphere reserve represents the basic landscape types of the eastern Polesiane lowlands: 33% forests (38% incl. forested wetlands), 2% water ecosystems (rivers, lakes), 25% wetlands (swamps, marsh meadows, bogs), 14% grasslands, 20% agricultural, and 6% settlement area.

The territory has a low population density and is mainly non-industrial (rural). Agriculture and forestry are the typical economic basis with a considerable part of traditional nature use.

The biosphere reserve includes other protected areas, such as, “Desniansko-Starogutskyi” National Nature Park, three wildlife reserves, three nature monuments, and the Ramsar site “Desna River Floodplains.”

The work with the public focuses on recreational and educational activities. Exhibitions, seminars, conferences as well as thematic events for schoolchildren constitute some of these regular events.




**Map 4 Functional zonation of the Desnianskyi Biosphere Reserve; Credit: Desna BR**

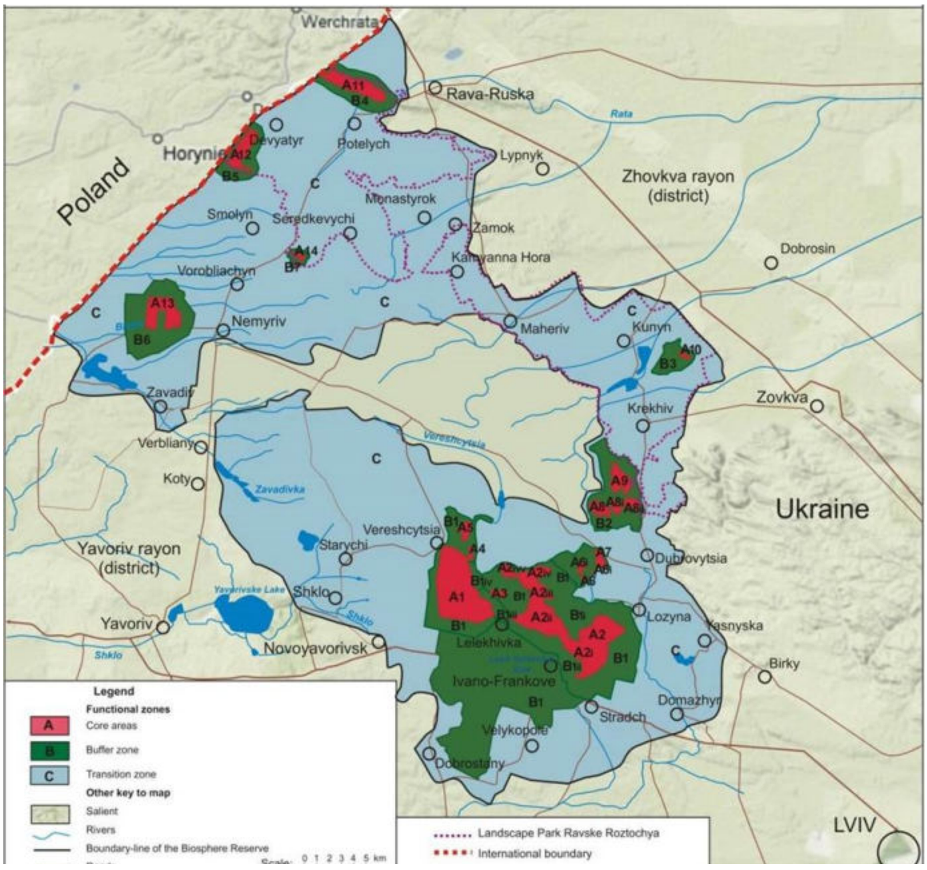
**Biosphere Reserve `Roztochya`**

| Designation date: | 2011 |
|---|---|
| Total area: | 74,416 ha |
| Core zones: | 3,314 ha |
| Buffer zones: | 10,874 ha |
| Transition zone: | 60,227 ha |

The Roztochya region forms an ecological corridor enabling the movement of plants and animals. The Roztochya Biosphere Reserve belongs to the ecoregion of the Central European mixed forests bordering in the south of the Carpathian montane forest region. Due to its location, plant species of the three regions – Polesia, Podillia, and the Carpathians – occur. The area consists of 50.8% forests (broad-leaved, mixed, and needle-leaved), 7.4% grasslands (meadows), 1.8% waterbodies, 13.3% wetlands (mires, bogs, flooded meadows), 17.6% agricultural lands, and 9.1% settlements.

The population of the area is mostly rural. Subsistence farming, stockbreeding, fish farming, and woodworking are common. Additionally, the BR attracts visitors to its sanatoriums and the growing health tourism sector.

The BR Roztochya includes other protected areas, namely, Nature Reserve “Roztochya”, the Yavorivskyi National Nature Park, and the Regional Landscape Park “Ravske Roztochya”. BR Roztochya is managed by the Coordination Board which consists of the directors of protected areas, scientists, head of local authorities, head of forestry, agriculture enterprise, and NGOs. Meetings of the Scientific-Technical Board, as well as other regular meetings and workshops with local authorities, keep a strong relationship with local citizens which led to the mainly positive attitude towards the establishment of the biosphere reserve. In July 2019, the commission of the MAB Programme of UNESCO decided to create a Ukrainian-Polish Transboundary Biosphere Reserve “Roztochya” on the area of 371,902 ha.



**Map 5 Functional zonation of the Biosphere Reserve Roztochya; Credit: BR Roztochya**

## Shatskyi Biosphere Reserve

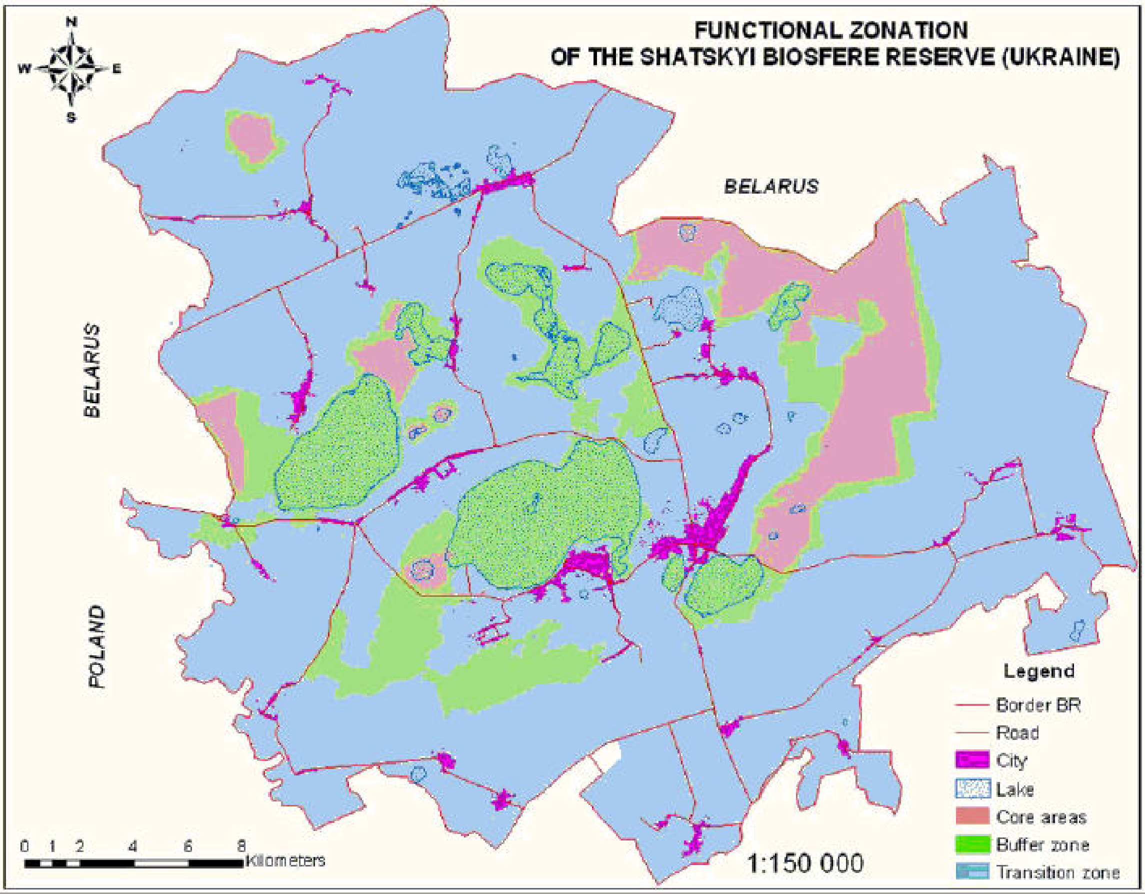
| Designation date: | 2002 |
|---|---|
| Total area: | 75,075 ha |
| Core zones: | 5,732 ha |
| Buffer zones: | 12,325 ha |
| Transition zone: | 57,018 ha |

Shatskyi Biosphere Reserve is part of the Volynska oblast. The territory is situated in the watershed between the rivers Western Bug and Pripyat and lies in the north-western part of the Polesia region. The biosphere reserve was created based on Shatsk National Nature Park, which is existing since 1983, and since 2012 is a part of the international biosphere reserve "Western Polissya".

Shatskyi Biosphere Reserve has a unique and the largest swamp-lake-forest landscape complex throughout the whole Polissya ecoregion within Ukraine. The area consists of 44.3% forests (59% including forested wetlands), 29.2% wetlands (marshes, bogs, fens, mires including forested and grassy), 7.7% dry grasslands (e.g. heathland), 8.7% water bodies, 5.8% settlements, and 4,3% cropland areas. The Ramsar Convention recognizes the lakes of the biosphere reserve as important nesting and breeding places for migrating waterfowls. The area is recognized as an Important Bird Area (IBA).

About 17,000 people live in the area of the biosphere reserve. The main economic activities are forestry, agriculture, tourism, and services. Around 100,000 tourists visit the biosphere reserve annually for recreational purposes. The area has several recreational centers and sanatoriums.

The director of Shatskyi National Nature Park is head of the Coordinating Council. Further members are the representatives of local authorities, forest and agricultural enterprises, sanatoriums, NGOs, and private persons.




**Map 6 Functional zonation of the Shatskyi Biosphere Reserve; Credit: Shatskyi BR**

# TOOLBOX FOR ECOSYSTEM-BASED ADAPTATION

The here presented toolbox introduces the method of a participatory and adaptive management process applied in the frame of the EbA Ukraine project. It also includes an outline of the methodology used for spatial analysis and mapping. Furthermore, it provides the first version of Ecosystem-based Adaptation measures, and actions catalogs for the five main ecosystem clusters of the three considered biosphere reserves.

**Image 6 Monitoring the development of a field protection strip at Roztochya BR, Credit: M. Verbovska**

## Participatory, Adaptive Management of Vulnerability and Risk

One central component of the project was the application of the **MARISCO** (Adaptive **MA**nagement of vulnerability and **RIS**k at **CO**nservation sites) **method**. The 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.

The MARISCO method as a management tool for Ecosystem-based Adaptation is providing the opportunity to:

1. Analyze the situation, vulnerability, and potentials of the respective socio-ecological system on a holistic and systemic level.
2. Permitting a better understanding by visualization of cause-effect chains, feedback loops, and for the identification of leverage points to facilitate the right choice of strategic entry points.
3. Assess and visualize the potential effects of planned or implemented EbA strategies and measures on the whole system and thus allow for risk assessment and strategic planning.
4. Guarantee participation of the local and regional population, stakeholders, land-users, experts, 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 itself is also a learning process, helping to adapt methods 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.

**Executive summary**

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[13].

To gather existing and new knowledge and to analyze the complex socio-ecological system of the biosphere reserves, a stepwise process to identify and map both essential and strategically relevant elements was carried out. The involvement and active participation of diverse groups of stakeholders, 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 substantiated and strengthened by excursions, spatial analyses, and desktop research.

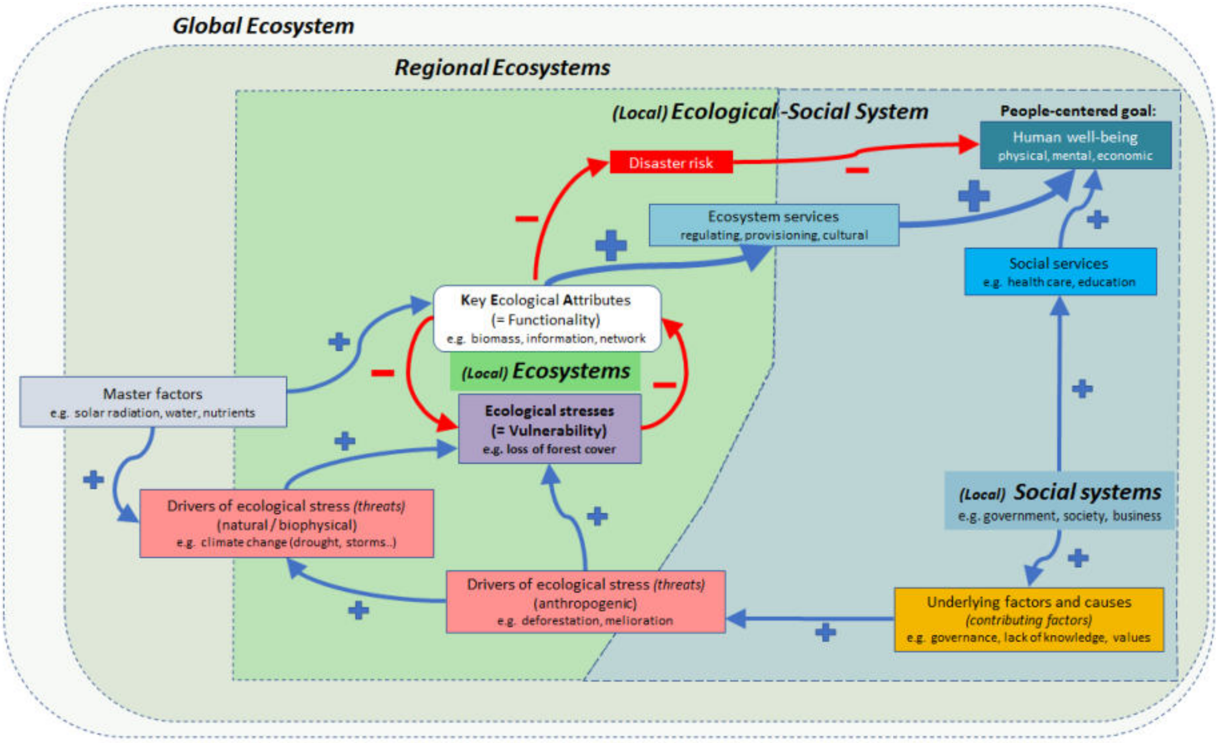



**Figure 6 Conceptual model for the MARISCO approach; Illustration by K. Mack**

This analysis comprises the **ecosystems of the biosphere reserve areas**, their respective **key ecological attributes (KEA – biomass, information, network),** 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, 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 stresses 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).

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13 MARISCO (**MA**nagement of vulnerability and **RIS**k at **CO**nservation sites), Source: https://www.marisco.training/, accessed 21-12-07

## Method

**Introduction**

The exposure to the risks of climate change and the inherent vulnerability of the multiple stressed landscapes requires an ecosystem-based management approach. The MARISCO (Adaptive **MA**nagement of vulnerability and **RIS**k at **CO**nservation sites) method provides a toolbox that can be used for the participatory development of such management plans. In the context of this project, management is understood as the ongoing implementation of measures and actions to accomplish the vision of the biosphere reserves with their overall goals and objectives. The strategies that have been developed can be incorporated into the current management plans. This way, the biosphere reserves can serve as regional models for the rest of the country on how to combine biodiversity and ecosystem conservation with sustainable development.

The development of the adaptive management plans is based on a thorough systemic and systematic situation analysis, which focuses on a comprehensive assessment of conservation objects and their status followed by a systemic derivation of stresses, stress drivers, and underlying factors and causes that endanger the viability and functionality of the ecosystems. In addition, essential information about the political and socio-cultural framework, the main stakeholders, as well as the present management approaches are outlined. The outcomes of these processes are long-term adaptive management plans. The systemic situation models provide the general strategic framework for the operative planning, which should be revised and adapted during participatory processes in certain time intervals in the future.

During the application in the context of this project, the MARISCO method underwent a substantial update. To allow the readers to follow the made changes, this document adopted the updated version of the steps and phases for the description of the toolbox. A short description of the phases and steps of the MARISCO method will follow.

Originally, the method was designed to be applied during physical participatory workshops and if sanitary conditions allow for it we would still strongly recommend using this approach. However, due to the restrictions that were caused by the global Covid-19 pandemic, these physical meetings had to be abandoned and were substituted with online workshops. The online sessions are described in the corresponding situation analysis document. Given that technical requirements and assistance are available, online works sessions are a valid alternative to physical meetings.

**Please note: This chapter is not a guidebook for the planning and execution of participatory workshops. For detailed descriptions of the first version please consult the MARISCO guidebook (Ibisch, P.L. & P.R. Hobson (eds.) 2013. MARISCO. Adaptive MAnagement of vulnerability and RISk at COnservation sites. A guidebook for risk-robust, adaptive, and ecosystem-based conservation of biodiversity. Centre for Econics and Ecosystem Management, Eberswalde (ISBN 978-3-00-043244-6). http://www.marisco.training/resources/manual).**

**In the near future, a software will be made available that will facilitate the application of the (then updated and enhanced) methodology.**

**The Seven Main Phases of the MARISCO Method**

The toolbox presented in this document is based on the MARISCO method. It is a visualized systematic process designed for collecting, ordering, and documenting both knowledge and non-knowledge related to biodiversity, stress drivers and drivers of change, as well as the (previous) management approaches for a given site. It reflects the perceptions, assumptions, and knowledge of people who participate in the exercise. The method employs an ordered, stepwise approach to planning and, ideally, all stages of the process should be completed by management teams that are working towards producing a risk-robust strategy for designated protected areas or landscapes.

The updated and enhanced MARISCO method comprises seven interrelated phases (see figure 7):

| | |
|---|---|
| **Phase I**<br>**Motivation and geographical scope** | Comprises steps 1. and 2. Even though not part of the methodological cycle, the exercise often starts with an **Ecosystem Diagnostics Analysis** (EDA). Other activities involve: defining the **motivation**, **expectation,** and **vision** for the project; as well as defining the geographical **scope.** |
| **Phase II**<br>**Human wellbeing and social systems** | Aims to identify the social components of the socio-ecological systems that are found within the project scope and comprises steps 3. to 7. Even though the steps of this phase are non-mandatory, it is recommended to dedicate some time to these tasks, since a better understanding of the social framework will enable the project team to develop more feasible and effective management solutions. |
| **Phase III**<br>**Ecosystem functionality** | Covers step 8. and 9. and is dedicated to the assessment of the **ecosystems** and their requirements for functionality, the **key ecological attributes**. This phase is of utmost importance since functional ecosystems are the basis for any sustainable development. |
| **Phase IV**<br>**Stresses and risks** | Encompasses steps 10. to 19. involving the carrying out a complex situation analysis to establish a sound understanding of the status quo for the conservation objects, and to identify existing and potential **stresses**, **drivers of stress,** and **underlying factors and causes**. All these elements are assessed according to states of **criticality**, dynamics, and levels of **knowledge** and **manageability**, and their **systemic activity**. |
| **Phase V**<br>**Strategies** | Comprises steps 20. to 25., including an analysis of **existing strategies** and the systematic development of new **complementary strategies** that allow for the effective enhancement of the objects' functionality; the abatement of stress drivers, and the avoidance or reduction of vulnerability and risk. It also includes a check for strategic consistency and complementarity. |
| **Phase VI**<br>**Plausibility and effectiveness** | Dedicated to step 26., the development of **result webs**. The result webs are visualizations of the theory of change of the management strategies within the complex situation model. |
| **Phase VII**<br>**Operational planning and implementation** | This covers step 27. to 30., dedicated to the implementation of the strategic plan and includes the elaboration of **monitoring** and **operational plans**, strategic knowledge management, and the evaluation of the implementation process. |


**Figure 7 Phases and steps of the MARISCO cycle (updated and enhanced methodology). Credit: A. Schick**

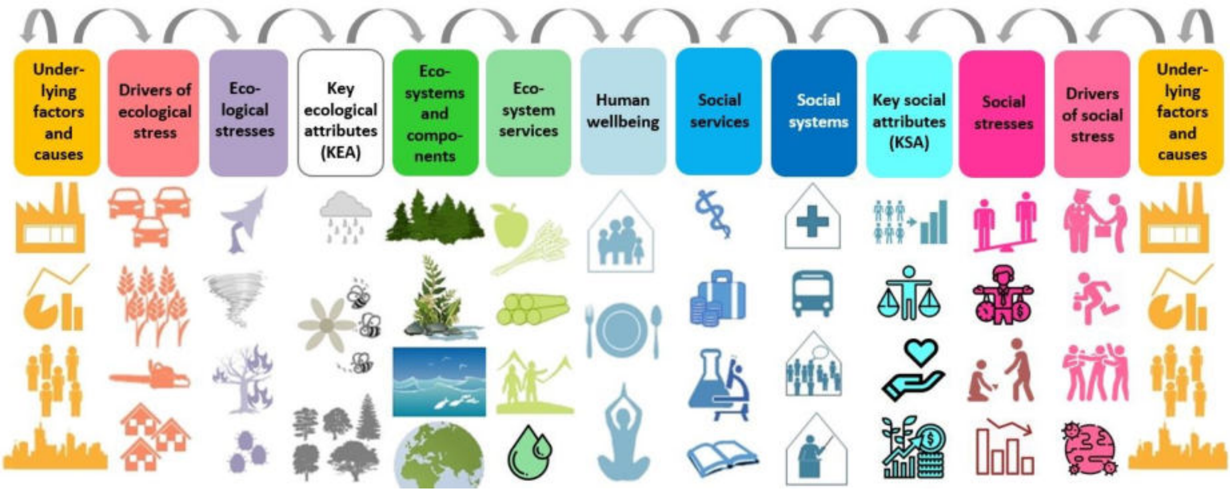



**Figure 8 Step sequence of the MARISCO conceptual model. Credit: CEEM**

## Step 0: Ecosystem Diagnostics Analysis (EDA)

Even though the 'Ecosystem Diagnostics Analysis' (EDA) is not part of the MARISCO cycle, it is strongly recommended to conduct such an assessment at the beginning of the process. The EDA describes a process of characterizing and evaluating land-use change that has direct relevance to the sustainable management of the area. Working at a coarse grain resolution or landscape scale has the advantage of greatly increasing the extent of coverage but at the expense of losing the ecological detail at the local scale.

To carry out an effective EDA, it is necessary to allocate sufficient time and resources for the corresponding tasks. Field surveys provide the relevant fine-grain information that would otherwise go undetected and unrecorded. Relying solely on spatial data and desktop information can quickly lead to false assumptions and blind spots. Ground-truthing is just that, a means of verifying what is observed remotely. This stage of the EDA requires time and effort if it is to be effective. Rather than take a broad-sweep approach to ground-truthing, a more productive study can be performed by targeting specific areas identified in the first stage of the EDA – the spatial analysis.

This is where accurate identification of ecosystem typology is important as it provides a focal point for ground-truthing. Where rivers, streams, and surface water are present, they should be targeted in a field survey as they are one of the driving forces of landscape patterns and change. In most cases, they also show evidence of any substantial human disturbance. Similarly, because of the services they provide, forests and wooded landscapes should be investigated. Often, the first stages of soil erosion occur in areas that have experienced significant removal of tree cover. The effects can also be far-reaching – in some cases, many kilometers from the point source.

The EDA has two main outcomes. The first is the provision of a baseline for the conceptualization process in MARISCO. Before a systemic situation analysis is undertaken by stakeholders, a broad understanding of the project site is needed to ensure that all members share a common knowledge of the landscape character and the potential risks and stress drivers to the area. The second outcome is the provision of a process reference point based on the objective analysis of impartial scientists.

The EDA's findings should be cross-referenced with the outcomes of the situation analysis. In this instance, the EDA not only serves to validate the findings of the situation analysis but also reveals any gaps in the process that can then be revised at a later stage.

The following structure provides the basic outline of an EDA:

a) Use of Google Earth images to scope the project site.

b) A desktop study based on existing reports, local scaled maps, photographic images, historical accounts/ notes, specific socio-ecological or biological/ environmental studies.

c) A field survey: targeted, in-the-field observation; a ground-truthing exercise.

d) Final analysis of the gathered evidence.

## Phase I - Motivation and geographical scope (steps 1-2)

### Step 1 Motivation, expectation, and vision

**Motivation**

Motivation is the process that initiates, guides, and maintains goal-oriented behaviors. It is what causes you to act. Working on a project can be exhausting. Therefore, it is good to be able to remind yourself what motivated you to start the project in the first place.

> Examples:
> The goal is to contribute to the conservation of the local ecosystems and their biodiversity and to enable the local population to manage the natural resources in an equitable, participatory, and sustainable fashion.
>
> This exercise aims to gain a better understanding of the status and dynamics of the complex socio-ecological systems of the study area and to develop an adaptive management plan for the project area based on this knowledge.

**Expectation**

Expectations are your personal beliefs in the effect of an action on achieving a particular outcome. In the beginning, it is always helpful to ask yourself what you want to achieve by doing this exercise. What are the expectations of the other people involved? A good understanding will help you to manage their expectations and to avoid frustration in the end. When you are working in a team, it might become necessary to manage the expectations by communicating so that all involved have a clear understanding of what to expect - and when to expect it. Expectations can change over time, so it can be necessary to adapt your expectations. First attempts at listing down the expectations can always be revised later on as the process unfolds.

> Examples:
> At the end of this exercise, I want to have a better understanding of the status and dynamics of the complex socio-ecological systems of the study site, as well as a detailed work plan for the adaptive management of the ecosystems of the project area.
> Through this participatory process, we want to foster cooperation with local stakeholders and authorities, sensitizing the population for the needs and importance of ecosystem-based management of natural resources.

**Vision**

The vision is a general statement of the desired state or ultimate condition that a project is working to achieve. A management vision helps to orientate activities, management goals, and objectives. It is important to formulate this vision before moving on to the detailed situation analysis because the vision stimulates consensual strategic thinking and sets a baseline for goal formulation.

A good vision statement should meet the following criteria:

- Relatively general – Broadly defined to encompass all project activities
- Visionary – Inspirational in outlining the desired change in the state of the targets toward which the project is working
- Brief – Simple and succinct so that that all project participants can remember it

> Example:
> The Biosphere Reserve is a highly preserved natural area with a unique biological, landscape, ethnic and cultural diversity, providing a large range of ecosystem services, which are important to local communities as well as to humankind at the regional and global levels. It is created to conserve and study its biotic and abiotic features and to enhance both the material as well as the spiritual wellbeing of local communities.

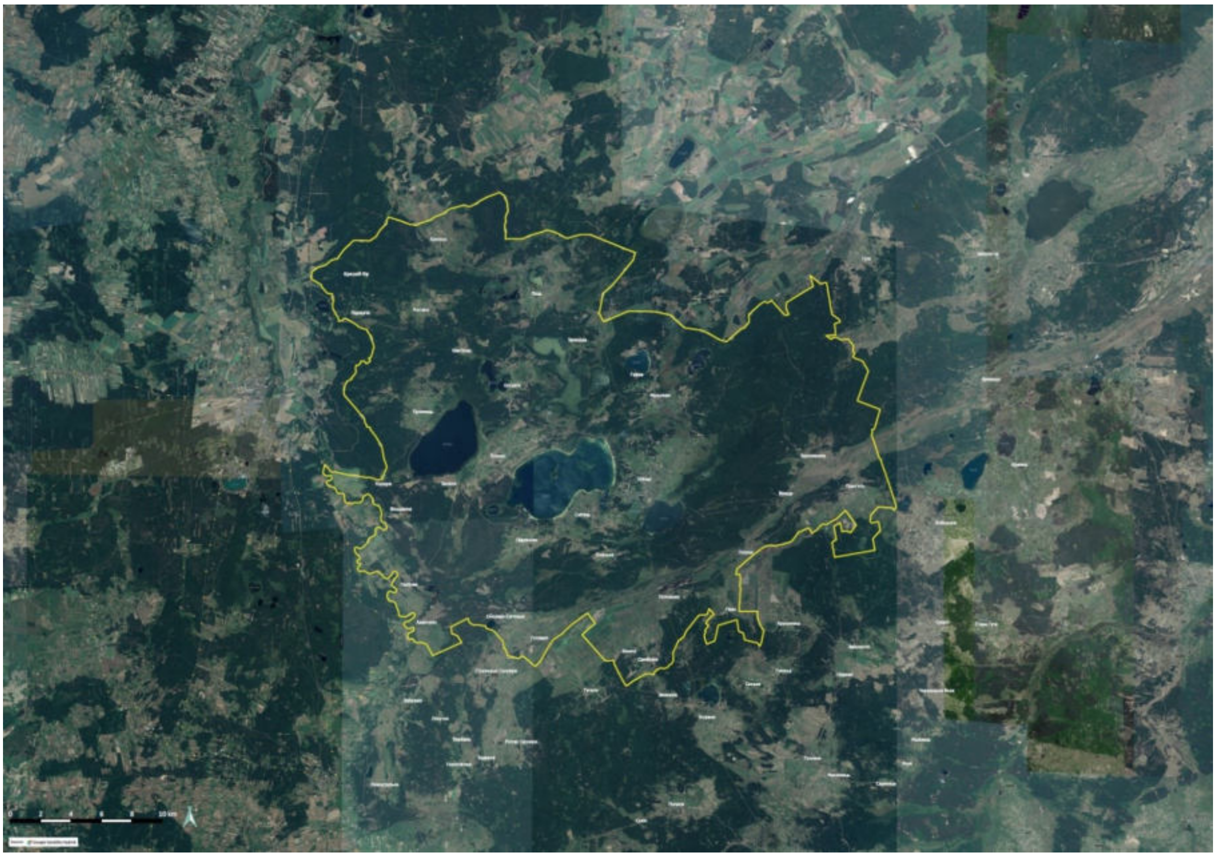
## Step 2 Geographical Scope

The scope defines the management area of a project or conservation site and includes all those features of biodiversity identified as in need of protection. When using an ecosystem-based approach, it is important to identify, where possible, whole systems that represent not just the compositional elements of an ecosystem, but also the processes, structures, and dynamics that govern them.

In most cases, the management area already exists as a designated protected site or is soon to become one. However, decisions made to designate a site as protected are often based on socio-political factors or economic reasons and have very little to do with the ecological needs of biodiversity. Consequently, the areas are usually too small to ensure adequate conservation. There are other issues related to human impacts occurring in the wider landscape that may influence biodiversity on-site but may remain undetected. Only a landscape perspective that puts the site in a wider context is likely to capture these sorts of problems.

The following questions offer some guidelines for this process:

- Is the existing area coverage of the site large enough to allow for the effective functioning of the relevant ecosystems?
- Does the projected scope take into account wider landscape features or ecosystems that may influence the biodiversity of the existing site?
- Does the area coverage of the current scope ensure/support the existence of a viable population of an important species?
- Does the scope include relevant stakeholders and/or communities close to the conservation site?



**Map 7 Draft scoping map for the Shatskyi BR, Google Satellite Hybrid; Credit: M. Hoffmann**

## Phase II - Human wellbeing and social systems (steps 3-7)

The ecosystems are the basis for sustainable development in your project area, including the adaptation to environmental change. Their functionality must be guaranteed to enable the local population to inhabit this specific part of the globe. Nonetheless, any specific strategy proposed for inducing change and transformation in the complex socio-ecological systems of the project site must also adequately address people’s needs and attitudes. Otherwise, it will likely be ineffective. It is particularly important to reflect social conflicts and (assumed) reasons for certain habits and actions. In this context, we must remember that people are part of the complex ecosystems that they live off and change. As a key element of these systems, the human subsystem deserves a careful analysis.

### Step 3 Human well-being


Conservation does not take place in a vacuum. Consequently, all your actions will ultimately affect the humans within your project scope and even beyond. A good understanding of the elements that comprise the human well-being of the people in your project scope will enable you to sensitize the local population on how they benefit from functional ecosystems in form of ecosystem services.

It will also help you to understand potential conflicts of interest and risks that might arise from different interests regarding the use of natural resources.

Examples of human well-being factors:

- Freedom and choice
- Health
- Good social relations
- Personal security

Human well-being comprises all the key components that people need for a good life. The constituents of wellbeing, as experienced and perceived by people, are situation-dependent, reflecting local geography, culture, and ecological circumstances.

Ecosystems are essential for human well-being through their services. Evidence in recent decades of escalating human impacts on ecological systems worldwide raises concerns about the consequences of ecosystem changes for human well-being.

Human well-being includes tangible elements such as access to clean water, nutritious and healthy food, and good physical health. Other important elements are related to mental and emotional well-being and social relationships.

## Step 4 Social services


**Goal: Identification of social services**

Humans are social beings, so it comes as no surprise that our well-being is strongly influenced by our social environment. Social systems contribute to human well-being through social services. They describe a range of public services provided by the government, private, profit, and non-profit organizations. These public services aim to create more effective organizations, build stronger communities, and promote equality and opportunity.

> Examples of social services:
>
> Include the benefits and facilities like education, food subsidies, health care, police, fire service, job training and subsidized housing, adoption, community management, policy research, and lobbying.

## Step 5 Social systems


The social services that you have identified during the last step are produced by one or more social systems. Unless you have a specific focus on a particular social system it is recommendable to concentrate on the larger social systems. Social systems can comprise systems such as the government, civil society, as well as profit and non-profit organizations.

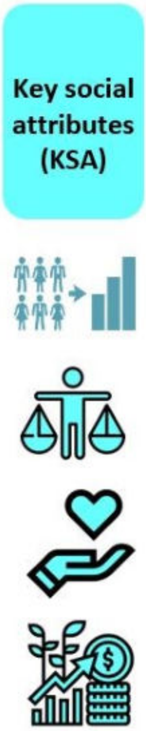
The social system is the patterned network of relationships constituting a coherent whole that exists between individuals, groups, and institutions. It is the formal structure of role and status that can form in a small, stable group. An individual may belong to multiple social systems at once. The organization and definition of groups within a social system depend on various shared properties such as location, socioeconomic status, race, religion, societal function, or other distinguishable features.

> Examples of social systems:
> - Nuclear family units
> - Communities, cities, nations
> - Corporations, and industries

**Option: Add subsystems to the identified systems**

If you want, you can add subsystems that are of special importance for the functionality of the social systems such as specific groups, actors, or stakeholders to one or more social systems. These can be relevant stakeholders for the implementation of your projects, such as farmers, hunters or miners, specific institutions, or important key actors, which are known to play a relatively large role in the system.

## Step 6 Key social attributes




The ultimate goal of sustainability management is to ensure the functionality of the systems. To be functional, social systems need a certain set of components and conditions. These are the key social attributes. They comprise tangible factors such as access to resources, information, and energy, as well as intangible factors related to the interactions of diverse social components such as cooperation, coordination, and trust.

A detailed description of key social attributes will increase your understanding of the current status of social systems and enable you to make better management decisions.

Key social attributes are best described as integral elements and properties of social systems that maintain function and provide the necessary adaptation and resilience to cope with perturbations. As with the social systems, the organization and definition of key social attributes are subject to strong cultural differences and even might vary within members of the same group according to their socioeconomic status, race, religion, or societal function.

Examples of key social attributes:

- *Tangible factors* such as access to resources, information and energy
- *Intangible factors* related to the interactions of diverse social components such as cooperation, coordination and trust

## Step 7 Ecosystem services


The identification of ecosystem services is essential for working with stakeholders, understanding their needs and perspectives, and also communicating the benefits of conservation to the public. The depiction of ecosystem services reflects the potential of a given site for ecosystem-based sustainable development. When this step is completed, the way people use or depend on the scope's biodiversity can be understood and visualized.

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as the regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other non-material benefits. Ecosystem services are based on emergent ecosystem properties, and a distinction is made between direct benefits provided by certain species – e. g. related to the production of plant or animal biomass – and indirect ones that exist because of the (inter)action of system components (e.g. pollination, climatic regulation). For more details on ecosystem services, see page 7.

Examples of ecosystem services:

- Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes
- Hydrological cycle and water flow regulation (including flood control, and coastal protection)
- Wind energy

## Phase III – Ecosystem functionality (steps 8-9)

### Step 8 Ecosystems and components




Functional ecosystems are the basis for sustainability. Hence, a good understanding of the ecosystems is fundamental to the development of any management plan. When using an ecosystem-based approach, it is important to identify, where possible, whole systems that represent not just these compositional elements of an ecosystem, but also the processes, structures, and dynamics that govern them.

Identify a sufficiently large spatial unit that encompasses the most important ecological processes in the region. In most cases, this means ecosystems at the landscape scale and can include smaller aquatic and terrestrial subsystems. A large spatial system may represent a certain type of landscape – e. g., forest landscape, lake scape (around a large lake and including surrounding mountains and [lower] catchment areas), seascape, coast scape, etc. This may well be the highest-order ecosystem object to conserve, and it is likely to extend beyond the boundaries of the established protected area.

List the smaller ecosystems that are included and are assumed to contribute significantly to the larger system's functionality – e. g., rivers, water bodies, forests, mires.

Ecosystems operate as 'bioreactors', capturing and using radiation energy from the sun and converting it into chemical energy or, rather, 'eco-energy'. The result of this conversion process is the manufacture of elaborate and complex molecules with biomass and function. These also have the capacity to store remaining energy and even transfer it through and between systems. At the most basic level, energy is the driver for all of the phenomena in nature. This captured eco-energy can be stored away in long-living organisms like trees or organic compounds in the soils, or fossil sediments. But it can also be used for maintaining food webs, including so-called producers, consumers, and decomposers or destruents.

The species in ecosystems are continuously interacting, producing forces and emergent properties that do not equate to the sum of the parts of a system. In other words, it is not possible to accurately characterize an ecosystem by simply describing it in terms of its species. It is rather the interactions of these species that make an ecosystem. These interactions are related to the exchange of energy, matter, and information.

> Example: Beaver dams are subsystems within river and lake ecosystems where many representatives of the functional group of herbivores can be found, including the beaver, a keystone species, and ecosystem engineer.

## Step 9 Key ecological attributes

**Key ecological attributes (KEA)**

The ultimate goal of ecosystem-based management is to ensure the functionality of the ecosystems. To be functional, ecosystems need a certain set of components and conditions. These are the key ecological attributes. They comprise abiotic factors such as temperature regimes, precipitation patterns, and soil conditions, as well as biotic factors related to the presence and interaction of diverse biological components.

Examples of key ecological attributes:

- Stable climatic conditions
- Hydrological regimes
- Species diversity
- Viable population size

You can either identify specific key ecological attributes for each ecosystem, or you can insert generic key ecological attributes and afterward connect them to one or more ecosystems. However, the identification of specific key ecological attributes for each ecosystem will provide you with a more precise understanding of the current status of the ecosystem, as well as its dynamics, and enable you to make better management decisions.

Key ecological attributes are best described as integral elements and properties of ecological systems that maintain function and provide the necessary adaptation and resilience to cope with perturbations. Underpinning the biological ‘template’ of ecosystems are the ‘master factors’, the physical skeleton primarily made up of energy input, moisture, temperature, and nutrients.

The living systems themselves are best characterized in terms of biomass, networks, and information, which represent fundamental key ecological attributes. For example, in this context, the abundance, and diversity of species matter, as does a certain level of connectedness, so that energy, matter, and information can be exchanged between system components. In line with the concept of vulnerability, the key ecological attributes are very much related to the sensitivity of the biodiversity objects. Biodiversity objects with a lot of ‘demanding’ key ecological attributes would be more sensitive to changes in exposure to stress drivers (e. g., narrow bands of preferred temperature, low variability of environmental conditions, the highly specialized dietary preferences of animals). The key ecological attributes might also be related to traits that are relevant in terms of the adaptive capacity of conservation objects. Whenever a conservation object requires a high degree of connectivity or a continuous range of occurrence, this may imply a lower adaptive capacity.

## Phase IV – Stresses and risks (steps 10-19)

### Step 10 Ecological stress analysis

**Eco-logical stresses**

A detailed analysis of the stresses for ecosystems is important to understand how the ecosystems and their components are affected by the negative effects of direct and indirect human activities. It is the starting point for identifying and understanding the drivers of stress, and for creating hypotheses about interrelated cause-effect chains', which will eventually be treated by the implementation of strategies. The number of stresses gives further insights into the vulnerability of an ecosystem, since highly stressed ecosystems are, in general, expected to be more vulnerable.

There are two ways to conduct an ecological stress analysis. You can either assess the stress level of each key ecological attribute that you have identified specifically for the ecosystems and their components, or you can work with a set of generic stresses that can be connected to the key ecological attributes afterward. The first option will provide you with a detailed understanding of the status of each of your ecosystems and their components but will take some extra time. The second option will be faster, but less specific. However, you can always come back and revise this step if needed.

Ecological stresses describe the symptoms and manifestations of the degradation of key ecological attributes caused by the insufficient availability or quality of master factors and manifesting as the loss of minimum levels of biomass, information, and network. Stresses imply that, under certain conditions, the ecological attributes begin to degrade, which then impacts the resilience and adaptive capacity of biodiversity elements, such as species or ecosystems. Over time, the systems will shift or even collapse. Stresses describe a certain state, reaction, or symptoms of a system or any of its components to anthropogenic 'forcing factors' – the so-called drivers of stress. If sustained, the impact will lead to shifts or changes in the system.

The identification of these changes is the first step in a thorough diagnosis of the ecological stress, which will eventually be treated by the implementation of strategies. To start this exercise, revise the key ecological attributes. Those that are degraded or might become degraded within the time frame of your planning horizon can be classified as stresses. Whenever a complete functionality analysis has been carried out, it should be a little clearer from the status given to the attributes which of these are likely to translate into stresses. Once this exercise is completed, reflect on the health of the ecosystems and their components; this can lead to the identification of further stresses, which might have been neglected when determining the key ecological attributes.

In general, guiding questions to help in the process of identifying stresses are:

- What kind of negative changes of the key ecological attributes can be observed?
- What are the signs of 'disorder' and 'illness'?
- Are there any critical changes to the status of environmental master factors, such as climate, soils, or water?
- Is there a loss of biomass, information, or network within the system?
- Is there a loss of network/connectedness with other systems?

Example:
For instance, changes to the pH status of seawater in oceans alter the buffer capacity of water and its ability to regulate temperature fluctuations. Physical changes of this kind interfere with the ability of calcareous organisms to lay down an exoskeleton and, in the case of corals, to autotrophically feed, resulting in bleaching.

In some cases, one stressor can cause or promote another stress. In many cases, symptoms arise in organisms and systems as a result of the accumulative effects of several stresses, which may lead to an escalation in the degradation of an ecosystem.

## Step 11 Drivers of ecological stress


Drivers of ecological stress are considered to be any human-induced forcing or pressing factor that is likely to directly or indirectly impact the natural structure and dynamics of an ecosystem. They represent processes of change that negatively affect ecosystems and their components by causing stress and increasing their vulnerability, ultimately inducing a state change connected with degradation (which means the loss of master factors, biomass, information, or network). There are both obvious and subtle examples of drivers of stress. Usually, the indirect or imperceptible effects are hardest to observe or identify, yet they may cause the greatest disruption in the ecosystem. We see evidence of this in the complex dynamics of human-induced climate change.

Guiding questions for the identification of drivers of ecological stress are:

- Which human activities are negatively affecting the viability of the different ecosystems or components?
- Which other processes are degrading the functionality of the key ecological attributes by causing stresses?

Examples:
- Extractive activities like logging or hunting.
- Consequences of altering the physical or chemical conditions of the environment like increased water run-off, soil erosion, and water pollution.

## Step 12 Underlying factors and causes

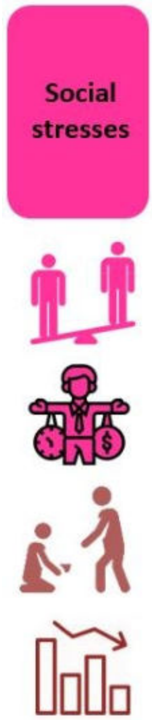

Underlying factors and causes are best described as a human action or activity that directly or indirectly results in the emergence of a driver of stress, which then goes on to induce stress or stresses in one or several components in an ecosystem. Often, underlying factors and causes act synergistically, but they may also produce antagonistic effects. Many of these underlying factors and causes represent risks because they can unforeseeably appear or change in the future and can contribute to impacts on biodiversity objects.

Guiding questions for this process are:

- What are the reasons for the appearance of a driver of stress or an underlying factor?
- Which relevant actors and stakeholders are involved in causing a driver of stress? What are their reasons for doing so?
- Are there any factors from those listed that have a positive influence on another underlying factor and causes or drivers of stress?

> Example: The excessive use of fossil fuels causes increased $CO_2$ levels in the atmosphere, which is one underlying factor behind global climate change.

## Step 13 Social stress analysis




In case the project team has identified key social attributes for the social systems, it can decide to conduct a social stress analysis, similar to the ecological stress analysis detailed in step 10.

To start this exercise, revise the key social attributes. Those that are degraded or might become degraded within the time frame of your planning horizon can be classified as stresses. Whenever a complete functionality analysis has been carried out, it should be a little clearer from the status given to the attributes which of these are likely to translate into stresses. Once this exercise is completed, reflect on the health of the social systems and their components; this can lead to the identification of further stresses, which might have been neglected when determining the key social attributes.

In general, guiding questions to help in the process of identifying stresses are:

- What kind of negative changes of the key social attributes can be observed?
- What are the signs of ‘disorder’ and ‘illness’?
- Is there a loss of mass, information, or network within the system?
- Is there a loss of connectedness with other systems?

> Examples:
> - Overpopulation
> - Loss of traditions
> - Lack of communication

## Step 14 Drivers of social stress


Social stress is caused by direct and indirect human activities that negatively impact one or more key social attributes.

Guiding questions for the identification of drivers of social stress are:

- Which human activities are negatively affecting the viability of the different social systems?
- Which other processes are degrading the functionality of the key social attributes by causing social stresses?

| Examples: Discrimination, Terrorism, Corruption |
|---|

## Step 15 Underlying factors and causes (Part II)


In case you have added drivers of social stress it is recommendable to revise and complete the identified underlying factors and causes.

Guiding questions for this process are:

- What are the reasons for the appearance of a driver of social stress or an underlying factor?
- Which relevant actors and stakeholders are involved in causing a driver of social stress? What are their reasons for doing so?
- Are there any factors from those listed that have a positive influence on another underlying factor and causes or drivers of social stress?

| Examples: 'Lack of transparency' and 'weak governmental institutions' are underlying factors and causes of the driver of social stress 'corruption'. |
|---|

## Step 16 Revision and completion of systemic relationships

The behavior of complex systems is usually determined by a limited set of elements, the so-called systemic drivers. An important attribute of these drivers of change is their influence on other elements of the complex system. For this purpose, the systemic activity is calculated for the elements of the systemic situation model. Elements with high systemic activity will have a higher influence on the system. They are drivers of change and may play a key role in the cause-effect relations pictured in the systemic situation model. An analysis of the level of systemic activity is important to improve the understanding of these cause-effect relations within the situation analysis. Furthermore, these drivers of change can be used as leverage points to change problematic cause-effect relations. Therefore, they should be given special attention when designing management strategies to generate changes at the level of root causes.

The identification of the connections between the elements of the systemic situation model is a fundamental step to gaining a better understanding of the behavior of the complex system. The connections can be between elements of the same category, or between neighboring categories. Sometimes, these connections create feedback loops. The connections will be used to calculate the systemic activity of the elements.

The systemic activity is calculated in the first instance by counting the number of incoming and outgoing connections for every element and then classifying them according to the categories. Secondly, the activity of each element is calculated according to the number of influenced elements. Finally, the overall systemic activity of each element is determined.

## Step 17 Element rating

The strategic relevance of a stress, stress driver, underlying factor, or cause refers to the perceived importance of those elements for the state of vulnerability of the target system. As is to be expected, any element with a high rating for strategic relevance is likely to be targeted in the final prioritization process. However, it is important to keep in mind, that the strategic relevance is a derived value and should not be seen as a replacement for the individually derived outcomes for each element.

There are two ways to assess the current criticality of the elements. You can either make a detailed assessment by rating the scope, severity, and irreversibility of the elements, or you can assess the current criticality using override criteria. The first option will provide you with a detailed understanding of the current criticality of each element, but it will take some extra time. The second option will be faster, but less specific.

The following criteria can be used to rate the strategic relevance of the elements of the systemic situation model:

**Analysis of criticality**
The criticality of a stress, stress driver, or contributing factor refers to the perceived importance of those elements for the state of vulnerability of a biodiversity object.

a) **Current criticality**
To determine the current criticality every factor/stress driver/stress will be evaluated according to the following descriptors: scope, severity, and irreversibility.
b) **Past criticality**
To determine past criticality, the current situation of every stress/stress driver/factor is compared to the (assumed) situation prevailing 20 years ago.
c) **Current trend of change**
The dynamic behavior or current trend of change of every stress/stress driver/factor is determined.
d) **Analysis of future dynamics, risks, and criticality**
Having completed these future scenario exercises, the participants judge the future criticality of stresses, stress drivers, and contributing factors (occurring over the next 20 years).

e) **Systemic activity**
The systemic activity is calculated by counting the number of connections of every factor and stress driver with other elements of the systemic situation model and its relative importance in the context of the whole model.

f) **Strategic relevance**
The strategic relevance sums up the outcomes of the different ratings undertaken in the previous steps and can be used to identify the most relevant elements in the systemic situation model (stresses, stress drivers, and contributing factors).

g) **Manageability**
Manageability describes the degree to which the evaluated stress/stress driver or factor can be influenced by the planning group, including the necessary financial and human resources.

h) **Knowledge**
The level of knowledge that exists within the planning group about the contributing factors, stress drivers, and stresses, is classified. 'Knowledge' comprises all possible dimensions that can be known about an element, such as its relevance in the cause-effect network, its behavior, its dynamics, etc.

## Step 18 Identification of systemic drivers

The complexity of ecosystems does not emerge from a random association of a large number of interacting factors, but rather from a small set of controlling processes and components that are essential for its functionality. Likewise, the behavior of complex socio-ecological systems is usually determined by some highly influential elements. These are the systemic drivers.

The ranking lists can help you to identify the drivers within the complex system. In general, all elements with high strategic relevance are potential drivers, since they have a strong influence on a large number of elements. These drivers should be considered during the next phase, which is dedicated to the evaluation and the development of strategies.

## Step 19 Revision and validation

Any decision made during any part of the MARISCO process is considered to be preliminary and open to alteration at a later date when more information surfaces. Revising and validating the systemic situation analysis with as many stakeholders and experts as possible is recommended. This will provide you with the opportunity to include further knowledge and expertise beyond that existing in your project team. Such revisions can be performed in mini-workshops, brief sessions with groups of 'external' experts, or directly in this project. The best items to review and validate would be the systemic situation model and the tables containing the rating results. If the results differ significantly, they can be used to inform a critical discussion, which can enhance the process as well as the general understanding of the elements under discussion.

Some guiding questions are:

- Are there some elements missing, or is some information redundant?
- Are all established connections plausible?
- Do the scope and the vision still fit the systemic situation model?
- Has your motivation or expectation changed?

**Be aware that any modifications you make will cause changes within the systemic situation model.**

## Phase V - Strategies (steps 20-25)

### Step 20 Identification and mapping of existing strategies

A strategy comprises a series of decisions related to the deployment of available resources (management) and the establishment of appropriate socio-institutional conditions (governance) that allow for effective action towards achieving desired goals and objectives.

All existing strategies for delivery in the management area are collected, including strategies that are being implemented at the moment, as well as strategies that are planned for the future (for example, as part of a management plan). Once all strategies are identified, they are inserted into the systemic situation model alongside the appropriate elements that they address and linked with arrows to the drivers of stress and underlying factors and causes.

Examples:
- Promoting ecosystem-based forestry
- Renaturation of drained wetlands

### Step 21 Impact analysis

The process of visualizing the actual or potential relationships of the strategies with other elements in the systemic situation model provides a deeper understanding of the complex environments in which strategies are to be implemented and may even lead to the identification of previously overlooked risks. New risks might be those that reduce the feasibility and effectiveness of strategies.

To start the impact analysis, place a transparent overlay sheet over the systemic situation model. Begin with one strategy and systematically draw arrows that connect the strategy with other elements in the systemic situation model, specifically: underlying factors and causes, drivers of stress, stresses, and other strategies. The connecting arrows may be modified to distinguish between different types of connection, e.g. strong vs. weak, or positive vs. negative. If not using an overlay, the visual evaluation can be performed on a separate printed poster of the systemic situation model. This procedure is systematically repeated for every strategy. The results are used for the revision of the strategy evaluation. After the visual evaluation, the overlay is taken down.

### Step 22 Gap analysis

Once the strategies are mapped onto the systemic situation model, the analysis of relationships between strategies and other elements embedded in the systemic situation model is then more straightforward. The next task is to discuss if all elements in the systemic situation model with high strategic relevance are adequately treated by the strategies.

### Step 23 Development of complementary strategies

In case you have identified underlying factors and causes, drivers of stress, and stresses of high strategic relevance that are not addressed by existing strategies, discuss if and what kind of strategies could be applied to address the critical elements.

If deemed appropriate, formulate strategies that would allow for the reduction and mitigation of problems or adaptation to risks. While formulating the strategies, their manageability and knowledge assessment is considered. Less manageable elements call for adaptation strategies rather than change strategies. Strategies that address poorly understood elements could comprise investigative components or precautionary actions.

## Step 24 Impact analysis (Part II)

To complete the visual assessment, conduct impact analysis for the complementary strategies. This visualization process applies the same objectives and procedure as that described in step 22. The analysis should also take the existing strategies into account.

## Step 25 Strategy evaluation

The evaluation of the strategies will help you to adjust the strategy design and prioritize from the portfolio of strategies, improving effectiveness and robustness. It will also help you to avoid negative effects caused by the implemented strategies, which remain unforeseen without proper reflection. Each strategy is evaluated for both feasibility and potential impact factor through a stepwise approach.

**Feasibility** is the degree to which a strategy is likely to be implemented under the prevailing conditions within the management area. Factors likely to influence feasibility include the availability of given resources and also risks, restrictions, and conflicts with or between actors and stakeholders.

The **impact** of a conservation strategy is related to any change within or outside the management area that can be attributed to the strategic action and that influences either directly or indirectly the conservation objects. Positive impacts are ultimately related to the maintenance or improvement of the status of the defined conservation objects. Negative impacts would lead to an increase in stresses, stress drivers, or their contributing factors.

The following criteria can be used to evaluate the strategies:

Feasibility

a) Level of acceptance by relevant stakeholders
b) Supportive legal framework
c) Necessary resources
d) Plausibility of ownership
e) Probability of benefiting from external factors, especially opportunities
f) Probability of harmful risks to the implementation of the strategy
g) Adaptability to change

Impact

a) Creation of social, political, and institutional conflicts
b) Creation of negative impact on the target systems
c) Synergies with other strategies
d) Conflicts with other strategies
e) Effectiveness in reducing stress drivers
f) Direct increase of functionality of the target system
g) Level of potential regret
h) Reduction of social vulnerabilities
i) Generation of societal benefits
j) Support of equitable governance and enhancement of capacities

The results are documented in the form of an evaluation matrix.

## Phase VI - Plausibility and effectiveness (step 26)

### Step 26 Development of result webs

a) **Result webs**

Result webs graphically illustrate systemically and logically linked assumptions that must be made for postulating the effects of strategies. They comprise the logical sequence of intermediate results to be achieved that, ultimately, would imply a positive impact on the biodiversity objects.

The process starts by selecting a strategy from the systemic situation model. Then, translate the underlying factors and causes or drivers of stress likely to be influenced by the strategy into assumed outcomes, reformulating them as positive results. Document each result/outcome on a blue moderation card. With the assumed chains of results that are predefined by the systemic relationships in the systemic situation model, the corresponding results would have to be presented as 'if-then' relationships. For example, an educational campaign would result in increased awareness among certain members of a stakeholder group. Raising stakeholders' awareness about the environment would change their attitudes or habits and lead to the desired outcome for a given ecosystem.

Continue working systematically through the process to convert all underlying factors and causes and drivers of stress that are addressed into assumed outcomes. During the activity, other elements not thought of earlier may be identified. These will need to be included in the results web. During the construction of the 'if-then' results webs, a decision might be made to include other strategies in the web before the final strategy portfolio is deemed to be complete. However, it is best to start the analysis with simple results chains before creating more complex webs. As the results webs are a means of recording the project teams' ideas regarding the effectiveness of their strategies, this step also prepares the way for the design of an effective monitoring system. Some strategies can represent key or 'milestone' strategies that need to be put in place before any further steps are taken.

The construction of a results web is intended to facilitate the next stages in management (including results webs operational planning) as well as help decide on the type of activities to carry out and the order in which these should be implemented. Any information generated at this stage in the process must be documented on new cards and placed next to the strategies.

b) **Goal and objective setting**

Goals are the observable and measurable results having one or more objectives to be achieved within a more or less fixed time frame. Goals and objectives are formulated for all the conservation objects, especially the ecosystems, and should meet the following SMART criteria:

- **Specific** – Clearly defined so that all people involved in the project have the same understanding of what the terms in the goal or objective mean;
- **Measurable** – Definable in relation to some standard scale (numbers, percentage, fractions, or all/nothing states);
- **Achievable** – Practical and appropriate within the context of the project site, and in light of the political, social, and financial context (especially relevant to objectives, goals may be more aspirational);
- **Results-Oriented** – Represents necessary changes in target condition, threat reduction, and/or other key expected results;
- **Time-Limited** – Achievable within a specific period, generally 1-10 years for an objective and 10-20 years for a goal.

## Phase VII - Operational planning and implementation (steps 27-30)

### Step 27 Monitoring design

Within adaptive management, monitoring provides the basis for learning and the purposeful adaptation of your underlying concept. In other words, a sound monitoring design helps to control the (desired or otherwise) outcomes of a strategy, even where other measures have to be taken to achieve the desired impact on the target systems.

**a) Indicators**

The results webs developed in the previous step lay the ground for target-oriented learning. Indicators are developed for impact and process monitoring. An indicator is a measurable entity related to a specific information need, such as the status of a target, change in a stress driver, or progress towards an objective. Indicators can be quantitative measures or qualitative observations.

Good indicators meet the following criteria:

- Measurable: Able to be recorded and analyzed in quantitative or in discreet qualitative terms.
- Clear: Presented or described in such a way that its meaning will be the same to all people.
- Sensitive: Changing proportionately in response to actual changes in the condition or item being measured.

Examples:
- The pH could be used to measure the water quality of a river ecosystem
- The woody biomass in t/ha could be used to measure quantitative growth of forest ecosystems over time

Complete the monitoring plan by transferring the indicators (including the indicators from the viability analysis of key social and ecological attributes in steps 6 and 9) into a table and complete the monitoring plan with the following information for each indicator:

- Monitoring method: How will you measure the indicator/ which method will you use?
- Responsible person: Who will do the measurement?
- Time: When will you collect the data and at what time intervals?
- Place: Where will you collect the data or take the measurement?

b) **Methods**

**Methods** are specific techniques used to collect data to measure an indicator.

Methods do not need to be complex or sophisticated - if you can get information you need using a simple, inexpensive method, it is far preferable to do this than to choose a complex, expensive method.

Use only a relatively small portion of your budget for measuring. Otherwise, you will not have enough money to implement actions and measure the results.

A good **method** meets the following criteria:

- **Accurate**: The data collection method has little or no margin of error.
- **Reliable**: The results are consistently repeatable - each time that the method is used it produces the same result.
- **Cost-Effective**: The method does not cost too much in relation to the data it produces and the resources the project has.
- **Feasible**: The method can be implemented by people on the project team.
- **Appropriate**: Acceptable to and fitting within site-specific cultural, social, and biological norms.

## Step 28 Operational planning

Operational plans provide those within the project team with a clear picture of their tasks and responsibilities over a specified period. It helps to achieve the strategic goals of the project team consistently and coherently. Clearly defining tasks allows for checks to assure that these tasks are in line with the strategic objectives. Strategies and activities are converted into practical and concrete tasks. The required resources – time, money, labor, and others – and the specific responsibilities within the managing entity are defined.

**Development of the operational plan**

1. ***Definition of available resources*** for project implementation such as time, money, personnel, knowledge etc.
2. **Assessment of currently unavailable resources:**
   a) Which resources are necessary for task execution but are currently not available?
   b) Is there a lack of funding?
   c) A lack of political will?
   d) Is it likely that these resources will be available in the future?
3. **Definition of specific responsibilities within the managing entity:**
   a) Who should be responsible for which activities?
   b) Clarify: Define clearly which tasks must be undertaken.
   c) Delegate: Delegate responsibility to a person or group of people for each activity.
   d) Clarify: Have concrete timelines in which tasks must be completed.
   e) Indicate the number of resources that will be dedicated to each task.
   f) Follow good practice guidelines, such as those from the Open Standards Methods.
   g) Clarify: Continue with the logic of the conceptual model to maintain consistency.
   h) Are detailed enough to provide all personnel with a clear idea of what is expected from them.
4. ***Convert strategies and activities into concrete tasks which:***
   a) Define clearly which tasks must be undertaken.
   b) Delegate responsibility to a person or group of people for each activity.
   c) Have concrete timelines in which tasks must be completed.
   d) Indicate the number of resources that will be dedicated to each task.
   e) Follow good practice guidelines, such as those from the Open Standards Methods.
   f) Continue with the logic of the conceptual model and results-webs to maintain consistency.
   g) Are detailed enough to provide all personnel with a clear idea of what is expected from them.
5. ***Follow up with monitoring of results, impacts, and research***

## Step 29 Implementation and monitoring of results and impacts

The ongoing monitoring of operational activities is considered to be an important part of documenting and measuring the outcomes and desired effects of the strategy. The whole process of monitoring is planned and documented through the monitoring plan described and developed in step 27.

## Step 30 (Non-) knowledge management

The management of knowledge and non-knowledge is a crucial task because it provides the basis for developing a learning and adaptable institution. It encompasses not only the collection and storage of information but also the organization and preparation of adequate infrastructure for storing, using, adapting, and further developing available knowledge at any time and by all relevant persons.

Achievements and lessons learned, processed, and made available through monitoring and knowledge management are analyzed to find out what the specific adaptation needs are. The systemic situation model is then adapted according to the findings of this evaluation.

## Participatory Working Process (Physical and Online)

**Physical participatory workshops**

The input to the ecosystem-based management plans should be developed through a participatory process involving various stakeholders. In general, two MARISCO workshops are sufficient to cover the various steps of the phases I to V, which enable the management team to develop the initial management plan. Ideally, these workshops should be conducted with the participation of staff from the management team and various stakeholder groups, including representatives of local and regional authorities, non-governmental organizations, scientists, and land users.

The first workshop usually covers (most of) the steps of the phases I to IV of the MARISCO cycle. During this workshop, the geographical scope of management and analysis are discussed; the natural and anthropogenic ecosystems are identified, and an initial management vision is jointly elaborated. A systemic situation analysis is carried out, to gain a better understanding of the current state of target systems as well as the knowledge about them within the management team. The existing and potential stresses, drivers of stress, and underlying factors and causes are being identified and assessed according to their states of criticality, dynamics, and level of knowledge and manageability. This process results in a systemic situation model, revealing the relationships of the cause-effect dynamics of the ecosystems of the biosphere reserves.

During the second workshop, strategies should be evaluated and selected. If necessary, complementary strategies can be developed to fill strategic gaps. Selected strategies should be further examined by developing results webs, which form the basis for the development of the operational and monitoring plans. Usually, it will not be possible to develop result webs for all selected strategies and this task can, later on, be complemented by the project team. The result webs can be sent to relevant stakeholders for evaluation and revision.

**Online workshops**

Ideally, the participatory process is realized through a series of physical workshops. However, there are situations when this is not possible. It might not be possible to realize physical workshops due to budgetary constraints, or due to travel restrictions, as has been the case during the COVID-19 pandemic in 2020. Instead of centralized workshops, it is possible to execute the various methodological steps during a series of online workshops. These online workshops should be of short duration and should focus on specific tasks. Yet, there are some considerable constraints to this approach, since it requires the necessary equipment and knowledge of the relevant stakeholders to be able to participate. Therefore, the project team should carefully evaluate if this approach is a feasible alternative.

## Supplementary Materials

### Rating criteria

Rating criteria for **ecological stresses** – materials used as printouts at the MARISCO situation analysis

| | | | |
|---|---|---|---|
| 1. Criticality *scope* | 2. Criticality *severity* | 3. Criticality *irreversibility* | MARISCO |
| 4. Past criticality (20 years ago) | 5. Current criticality (→ 1&2&3) | 6. Trend of change (of current criticality) | 7. Future criticality (in 20 years) |
| | | | **11. Strategic relevance** (→ 5&6&7) |
| 12. Manageability | | 13. Knowledge | |

Rating criteria for **drivers of ecological stresses (threats)** and **underlying factors**

| | | | |
|---|---|---|---|
| 1. Criticality *scope* | 2. Criticality *severity* | 3. Criticality *irreversibility* | MARISCO |
| 4. Past criticality (20 years ago) | 5. Current criticality (→ 1&2&3) | 6. Trend of change (of current criticality) | 7. Future criticality (in 20 years) |
| 8. Systemic activity *level of activity* | 9. Systemic activity *no of influenced elements* | 10. Systemic activity (→ 8&9) | **11. Strategic relevance** (→ 5&6&7&10) |
| 12. Manageability | | 13. Knowledge | |

**Element Rating**

**Table 3 Rating Criteria[14] for Systemic Elements**

| | Low = 1 | Somewhat known = 2 | Not known, but theoretically knowable = 3 | Not knowable = 4 |
|---|---|---|---|---|
| **Current criticality: scope** | Local occurrence = 1<br><br>Stress/threat: The stress/threat is likely to have a very limited spatial distribution, affecting the biodiversity object across a small proportion of its occurrence in the area of analysis (1–10%).<br><br>Contributing factor: The factor is likely to be very narrow in its spatial distribution, affecting other elements across a small proportion of the area of analysis (1–10%). | Medium area = 2<br><br>Stress/threat: The stress/threat is likely to be fairly restricted in its spatial distribution, affecting the biodiversity object across a certain part of its occurrence in the area of analysis (11–30%).<br><br>Contributing factor: The factor is likely to be fairly restricted in its spatial distribution, affecting other elements across a certain part of its occurrence in the area of analysis (11–30%). | Large part of the area = 3<br><br>Stress/threat: The stress/threat is likely to be well spread, affecting the biodiversity object across a significant part of its occurrence in the area of analysis (31–70%).<br><br>Contributing factor: The factor is likely to be well spread, affecting other elements across a significant part of the area of analysis (31–70%). | (Almost) omnipresent = 4<br><br>Stress/threat: The stress/threat is likely to be pervasive in its spatial distribution, affecting the biodiver- sity object across all or most of its occurrence in the area of analysis (71–100%).<br><br>Contributing factor: The factor is likely to be pervasive in its spatial distribution, affecting other elements across all or most of the area of ana- lysis (71–100%). |
| **Current criticality: severity** | Light = 1<br><br>Stress: Within the scope, the stress does not imply a reduction in the overall functionality of the biodiversity object.<br><br>Threat: Within the scope, the threat is not likely to degrade or harm the biodiversity object.<br><br>Contributing factor: The factor is not likely to generate a significant impact on the influenced elements. | Moderate = 2<br><br>Stress: Within the scope, the stress may eventually lead to a certain reduction in the overall functionality of the biodiversity object within the next 10 years.<br><br>Threat: Within the scope, the threat may eventually lead to a certain level of degradation of and harm to the biodiversity object within the next 10 years.<br><br>Contributing factor: The factor may eventually generate a certain level of impact on the influenced elements. | Severe = 3<br><br>Stress: Within the scope, the stress is likely to reduce the overall functionality of the biodiversity object within the next 10 years.<br><br>Threat: Within the scope, the threat is likely to degrade and harm the biodiversity object within the next 10 years.<br><br>Contributing factor: The factor is likely to generate a clear impact on the influenced elements. | Extreme = 4<br><br>Stress: Within the identified scope, the stress most likely means a serious reduction in the overall functionality of the biodiversity object, or even its loss, within the next 10 years.<br><br>Threat: Within the identified scope, the threat is most likely to degrade and harm the biodiversity object and even cause its loss within the next 10 years.<br><br>Contributing factor: The factor is most likely to generate a significant impact on the influenced elements and become a driving force that ultimately harms one or various biodiversity objects (at least within the identified scope). |

[14] Based on MARISCO-guidebook

| | Low = 1 | Somewhat known = 2 | Not known, but theoretically knowable = 3 | Not knowable = 4 |
|---|---|---|---|---|
| **Current criticality: irreversibility** | Probably disappearing in the short term = 1<br><br>It is likely that the stress/threat/ factor will disappear spontaneously (without management) in the short term (1 to 5 years), possibly implying nothing more than easily reversible consequences for conservation objects. | Probably not disappearing in the midterm = 2<br><br>It is likely that the stress/threat/ factor will not disappear (without management) in the midterm (6 to 20 years), but this does not imply long-term and irreversible consequences for conservation objects. | Probably staying in the long term = 3<br><br>It is likely that the stress/threat/ factor will stay present (without management) in the long term (21 to 100 years), which also implies long-term consequences for conservation objects that are hard to reverse. | Very high = 4<br><br>It is very likely that the stress/threat/ factor will stay present in the long term (probably for more than even a century), which also implies long- term consequences for conservation objects that cannot be reversed for decades. |
| **Current criticality: overall (or override)** | Slightly critical = 1<br><br>The stress/threat/factor does not play a very important role in generating the overall vulnerability of the conservation objects within the geographical scope of analysis. | Moderately critical = 2<br><br>The stress/threat/factor plays a fairly important role in generating the overall vulnerability of the conservation objects within the geographical scope of analysis. | Critical = 3<br><br>The stress/threat/factor plays an important role in generating the overall vulnerability of the conservation objects within the geographical scope of analysis. It is an important driver of negative change in the analyzed system. | Very critical = 4<br><br>The stress/threat/factor plays an extremely important role in gen- erating the overall vulnerability of the conservation objects within the geographical scope of analysis. It is a major and persistent driver of nega- tive change in the analyzed system. |
| **Past criticality** | Lower than current = 1<br><br>The past criticality (20 years ago) of the stress/threat/factor is lower than the current one. | Equal to current = 2<br><br>The past criticality (20 years ago) of the stress/threat/factor more or less equals the current one. | Higher than current = 3<br><br>The past criticality (20 years ago) of the stress/threat/factor is higher than the current one. | Much higher than current = 4<br><br>The past criticality (20 years ago) of the stress/threat/factor is much higher than the current one. |
| **Current trend of change of criticality** | Decreasing = 1<br><br>Currently, the criticality of the stress/threat/factor tends to decrease. | Stable = 2<br><br>Currently, the criticality of the stress/threat/factor seems to be fairly stable. No change is recognizable | Gradually increasing = 3<br><br>Currently, the criticality of the stress/ threat/factor tends to increase, but it is doing so rather gradually and apparently quite predictably. | Rapidly increasing = 4<br><br>Currently, the criticality of the stress/threat/factor tends to increase in a fast and accelerating way (exponentially). |

| | Low = 1 | Somewhat known = 2 | Not known, but theoretically knowable = 3 | Not knowable = 4 |
|---|---|---|---|---|
| **Future criticality** | Lower than current = 1<br><br>The future criticality (in 20 years) is expected to be lower than the current one. | Equal to current = 2<br><br>The future criticality (in 20 years) is expected to be equal to the current one. | Higher than current = 3<br><br>The future criticality (in 20 years) is expected to be higher than the current one. | Much higher than current = 4<br><br>The future criticality (in 20 years) is expected to be much higher than the current one. |
| **Systemic activity: level of activity** | Passive = 1<br><br>The element within the conceptual model is influenced by more elements than it is influencing. (Difference [influencing – influenced] = < 0). | Inert = 2<br><br>The element within the conceptual model is influenced by as many elements as it is influencing. (Difference [influencing – influenced] = 0). | Active = 3<br><br>The element within the conceptual model is influenced by fewer elements than it is influencing. (Difference [influencing - influenced] = 1–3). | Very active = 4<br><br>The element within the conceptual model is influencing other elements much more than it is influenced. (Difference [influencing – influenced] = >3). |
| **Systemic activity: number of influenced elements** | Modestly influential = 1<br><br>The element is influencing 1 element. | Moderately influential = 2<br><br>The element is influencing 2–3 elements. | Highly influential = 3<br><br>The element is influencing 4–5 elements. | Extremely influential = 4<br><br>The element is influencing >5 elements. |
| **Manageability** | Well manageable = 1<br><br>The element is easily and directly manageable and can be influenced by strategies and activities; usually, these refer to mainly local elements. | Somewhat manageable = 2<br><br>The element is likely to be directly manageable to a certain extent, especially if more resources are made available than at present. | Poorly manageable = 3<br><br>The element is not very likely to be directly manageable. It can be influenced instead in a meta-systemic and indirect way. | Not manageable = 4<br><br>The element is not manageable at all. It is extremely unlikely that local management would cause any change, either directly or indirectly. |
| **Knowledge** | Well known = 1<br><br>The level of knowledge about the factor/threat/stress is very high; the planning team has a precise idea of the element's characteristics, relevance, and dynamics. | Somewhat known = 2<br><br>The level of knowledge about the factor/threat/stress is high; the planning team has a fairly good idea of the element's characteristics, relevance, and dynamics. Some knowledge gaps might have been identified. | Not known, but theoretically knowable = 3<br><br>The level of knowledge about the factor/threat/stress is poor; the planning team does not have a good idea of the element's characteristics, relevance, and dynamics. Some better knowledge might be available, but this is not currently possessed by the team. | Not knowable = 4<br><br>It is impossible to obtain a good level of knowledge about the factor/threat/stress; the planning team can only formulate assumptions about the element's characteristics, relevance, and dynamics. Further research would not provide better knowledge. This non-knowability is related to the fact that the element is complexly influenced by other uncertain ones, or that it represents future risks. |

## Strategies

Table 4: Feasibility criteria[15]

| | Excellent | Good | Problematic | Poor |
|---|---|---|---|---|
| **Level of acceptance by relevant stakeholders** | **Very good acceptance = 4**<br>The strategy is accepted by (almost) all of the relevant stakeholders. | **Good acceptance = 3**<br>The strategy is accepted by a major part of the relevant stakeholders. | **Fairly low acceptance = 2**<br>The strategy is supported by a minor part of the relevant stakeholders, but there is no rejection. | **Extremely poor acceptance = 1**<br>The strategy is supported by only a few of the relevant stakeholders and is rejected by the most relevant ones. |
| **Supportive legal framework** | **Strong binding legal framework = 4**<br>There is a clear, strong, and binding legal framework in place that supports the implementation. | **Non-binding legal framework = 3**<br>There is a non-binding legal framework in place that supports the implementation. | **Weak or missing legal framework = 2**<br>There is a weak or diffuse legal framework in place, or the legal framework is missing. | **Conflicting legal frameworks = 1**<br>There tend to be conflicting legal frameworks in place that might hinder the implementation. |
| **Necessary resources** | **No resource problems = 4**<br>There are sufficient financial, personal, time, and knowledge resources within the managing institution to implement the strategy. | **Some resources available = 3**<br>There are some resources to at least partially implement the strategy, and additional resources are likely to be obtained. | **Only limited resources available= 2**<br>Only a few limited resources are available to implement the strategy, and only very small-scale and fairly isolated activities can be carried out. It will be difficult to obtain additional resources. | **Not enough resources = 1**<br>There are not enough resources within the managing institution to implement the strategy and it is unlikely that additional resources can be obtained. |
| **Plausibility of ownership** | **Strong ownership = 4**<br>The involved stakeholder developed strong ownership of the strategy and will undergo considerable efforts to maintain it in the long term. | **Some ownership = 3**<br>The involved stakeholder developed some ownership of the strategy and will undergo some efforts to maintain the strategy at least partially in the long term. | **Only limited ownership= 2**<br>The involved stakeholder developed only limited ownership of the strategy and it is unlikely that it will make efforts to maintain it in the long term. | **No ownership = 1**<br>The involved stakeholder developed no ownership of the strategy and will not make any efforts to maintain it in the long term. |

[15] Based on MARISCO-guidebook

| | Excellent | Good | Problematic | Poor |
|---|---|---|---|---|
| **Probability of benefiting from external factors, especially opportunities (if yes then state which)** | **Very high = 4**<br>The strategy can very likely make use of existing or arising opportunities such as additional resources or external support. | **High = 3**<br>It is quite probable that the strategy can make use of existing or arising opportunities such as additional resources or external support. | **Low = 2**<br>It is not very probable that the strategy can make use of existing or arising opportunities such as additional resources or external support. | **Very low = 1**<br>It is highly unlikely that the strategy can make use of existing or arising opportunities such as additional resources or external support. |
| **Probability of harmful risks to the implementation of the strategy (if yes then state which)** | **Unlikely to be affected by risks = 4**<br>There is (almost) no probability of risks that (could) complicate the implementation of the strategy. | **Probably not threatened by risks = 3**<br>There is a low probability of risks that (could) somewhat complicate the implementation of the strategy. | **Probably threatened by risks = 2**<br>There is a high probability of risks that (could) complicate or even hamper the implementation of the strategy. | **Extremely threatened by risks = 1**<br>There is a high probability of risks that (could) significantly hamper the implementation of the strategy or even make them completely ineffective. |
| **Adaptability to change** | **Very adaptable = 4**<br>The adaptation of the strategy to changing circumstances or unexpected events can be easily achieved without any additional resources. | **Rather adaptable = 3**<br>The adaptation of the strategy to changing circumstances or unexpected events is likely to be achieved with some additional resources. | **Not adaptable without significant additional resources = 2**<br>The adaptation of the strategy to changing circumstances or unexpected events could possibly be achieved, but significant additional resources will be required. | **Poorly adaptable, if at all = 1**<br>The strategy is (possibly) not adaptable to changing circumstances or unexpected events. |

**Impact criteria**

Table 5: Impact criteria[16]

| | Excellent | Good | Problematic | Poor |
|---|---|---|---|---|
| **Creation of social, political and institutional conflicts (If yes, then state which)** | **Very low risk of conflict generation = 4** There is no or almost no probability that the strategy will give rise to any conflicts between different stakeholder groups. | **Medium risk of conflict generation = 3** It is possible that a certain amount of conflict will be generated between different stakeholder groups and that this will have the potential to influence the conservation project/site. | **High risk of conflict generation = 2** It is fairly likely that relevant conflicts between different stakeholder groups will be generated and that these will have the potential to influence the conservation project/site. | **Very high risk of conflict generation = 1** It is (almost) certain that relevant conflicts between different stakeholder groups will be generated, and that these will influence the conservation project/site. |
| **Creation of negative impact on the target systems** | **No risk of creating negative impact on the target systems = 4** There is no risk that the implementation of the strategy will create a negative impact on the target systems in the management area. | **Low risk of creating negative impact on the target systems = 3** It is not very likely that the implementation of the strategy will create negative impact on the target systems in the management area | **High risk of creating negative impact on the target systems = 2** There is a high risk that the implementation of the strategy will create negative impact on at least one target system in the management area. | **Very high risk of creating negative impact on the target systems = 1** There is a very high risk that the implementation of the strategy will create a negative impact in several target systems in the management area. |
| **Synergies with other strategies** | **Very high probability of synergies with other strategies = 4** The strategy is very likely to develop important synergies with several other strategies. | **High probability of synergies with other strategies = 3** The strategy is likely to develop important synergies with some other strategies. | **Medium probability of synergies with some strategies = 2** The strategy will eventually develop important synergies with a few other strategies. | **Low probability of synergies with other strategies, if at all = 1** The strategy is fairly isolated and is not likely to develop any synergies with other strategies. |
| **Conflicts with other strategies** | **Low probability of conflicts with other strategies, if at all = 4** The strategy conflicts with (almost) no other strategy that is being implemented in the management area. | **Medium probability of conflicts with other strategies = 3** The strategy somewhat – but not problematically – conflicts with other strategies that are being implemented in the management area. | **High probability of conflicts with other strategies = 2** The strategy conflicts with several of the strategies that are being implemented in the management area. | **Very high probability of conflicts with many strategies = 1** The strategy severely conflicts with a substantial number of strategies that are being implemented in the management area. |
| **Effectiveness in reducing stress drivers** | **Very highly effective in reducing stress drivers = 4** The strategy is very effective: it will result in the significant and sustainable reduction, or even eradication, of several stress drivers. | **Highly effective in reducing stress drivers = 3** The strategy is quite effective: it will result in the large-scale reduction of at least one stress driver. | **Somewhat effective in reducing stress drivers = 2** The strategy is not very effective: it will only result in a minor reduction of a stress driver, and this may only be temporary. | **Rather ineffective in reducing stress drivers = 1** The strategy is (almost) not effective: it will not even indirectly lead to the reduction of stress drivers. |

[16] Based on MARISCO-guidebook

| | | | | |
|---|---|---|---|---|
| **Direct increase of functionality of the target system** | **Very positive for target system functionality = 4**<br>The strategy will safeguard or completely restore the long-term functionality of one or more systems. | **Positive for target system functionality = 3**<br>The strategy will contribute to the restoration or maintenance of one or more systems' functionality. | **A small and rather indirect contribution to target system functionality = 2**<br>The strategy will make a minor contribution to the conservation or restoration of one or more systems. | **Not measurably improving target system functionality = 1**<br>The strategy is unlikely to contribute to the conservation or restoration of any of the systems. |
| **Level of potential regret** | **No-regret strategy = 4**<br>The strategy will create clear collateral benefits, even if the originally intended impact is not achieved. | **Medium-regret strategy = 3**<br>The strategy is likely to create some positive collateral effects, even if the originally intended impact is not achieved. | **High-regret strategy = 2**<br>The potential level of regret is high. If the originally intended impact is not achieved, the strategy will not create (significant) positive collateral effects. The strategy will also be difficult to reverse and might end up wasting resources. | **Very high-regret strategy = 1**<br>The potential level of regret is very high. If the originally intended impact is not achieved, the strategy will not create positive collateral effects. The strategy will be impossible to reverse in time and would clearly end up wasting resources. |
| **Reduction of social vulnerabilities** | **Very highly effective in reducing social vulnerabilities = 4**<br>The strategy is very effective: it will result in the significant and sustainable reduction of several social vulnerabilities. | **Highly effective in reducing social vulnerabilities = 3**<br>The strategy is quite effective: it will result in the large-scale reduction of at least one social vulnerability. | **Somewhat effective in reducing social vulnerabilities = 2**<br>The strategy is not very effective: it will only result in a minor reduction of a social vulnerability, and this may only be temporary. | **Rather ineffective in reducing social vulnerabilities = 1**<br>The strategy is (almost) not effective: it will not even indirectly lead to the reduction of social vulnerabilities. |
| **Generation of societal benefits** | **Very high probability of generation of societal benefits = 4**<br>The strategy is very likely to generate important societal benefits for people through the use of biodiversity and ecosystem services fairly and equitably. | **High probability of generation of societal benefits = 3**<br>The strategy is likely to generate some societal benefits. | **Medium probability of generation of societal benefits = 2**<br>The strategy will eventually generate some societal benefits | **Low probability of generation of societal benefits, if at all = 1**<br>It is not very likely that the strategy will generate any societal benefits. |
| **Support of equitable governance and enhancement of capacities** | **Very positive for the governance and enhancement of capacities = 4**<br>The strategy will strongly improve the governance of natural resources with respect to the use of biodiversity and ecosystem services and enhancement of capacities of the implementing institution by following a community-centered, participatory and gender-sensitive approach. | **Positive for the governance and enhancement of capacities = 3**<br>The strategy will contribute positively to the governance and enhancement of capacities. | **A small and rather indirect contribution to the governance and enhancement of capacities=2**<br>The strategy will make a minor contribution to the governance and enhancement of capacities. | **Not measurably improving the governance and enhancement of capacities = 1**<br>The strategy is unlikely to contribute to the improvement of governance and enhancement of capacities. |

## Spatial Analysis and Mapping

An important feature of the Ecosystem-based Adaptation in the project in Ukraine is the elaboration of geographic information system (GIS)-based maps for the visualization of ecosystem features, vulnerability, and priority areas for EbA activities. The results of the spatial analyses and maps reflect another important component of the adaptation process. Based on these, discussions can be held in the participatory process and relevant areas can be localized. The knowledge gained can in turn be fed back into the spatial analysis, enabling its further development and specification. The spatial analyses can support decision-making processes for prioritizing measures and areas. For the EbA strategies, available spatial information was compiled and made accessible together with the newly developed content in a geodatabase and visualized in maps. The data serve to stabilize and further develop the adaptation process. Besides the presentation of existing spatial data in thematic maps, new information was generated.

Together with the project team, the needs and quality of the required data and the products to be created were clarified and agreed upon in constant exchange and a personal meeting in the 1st quarter of 2019. The required maps for the MARISCO stakeholder workshops were prepared and provided by the 2nd quarter of 2019. During three workshops the maps were discussed with the participants. This supported, in an exemplary way, the transfer of knowledge and the exchange between science and practice.

- **General map** (larger section) to show landscape, large-scale relationships, and conditions.
- **Ecosystem map** (data based on land cover classification made within this project using current sentinel satellite imagery as well as manually mapped hydrological and other physiotopic conditions + publicly available data)
- **Hydrology** (focus on hydrological situation, see ecosystem map for data basis).
- **Stress drivers** (threats - esp. fragmentation by roads and settlements, forest loss in 2000-2018 based on data v. Hansen et al. 2013)
- **Vulnerability** (modeling based on ecosystem, land use, and stress driver data using jointly developed criteria and weightings).

**Surface temperature maps** are based on MODIS and Landsat satellite images to determine the averaged daily surface temperatures of the areas in seasonal sections. The imagery used was for longer periods (MODIS 2002-2018, Landsat 2013-2018) and at 30 m resolution. The cartographic representation was for the summer months for each area.

These maps as well as high-resolution satellite images of the respective regions were available as printed A0 maps during the first series of MARISCO stakeholder workshops. They formed an important basis for discussion and orientation for all participants. They were produced in both Ukrainian and English language.

In the second work package, a profound analysis of the thermal data was conducted. Novel types of maps were created showing the **temperature deviations from the mean for different weather conditions** and the **cooling capacity of ecosystems**. Furthermore, PIK thermal datasets and integral vulnerability calculations were merged to indicate **priority areas for Ecosystem-based Adaptation activities**.

**Please note**: Most of the maps are either attached as printed A1 versions to this set of documents or printed in the annex of the situation analysis documents. They can also be accessed and downloaded from: https://www.eba-ukraine.net/maps.html

## Situation and Vulnerability Maps (Part I)

In preparation for the local citizen's workshops and the MARISCO workshops with local actors, the mentioned GIS experts carried out spatial analyses of the Biosphere Reserves Desnianskyi, Roztochya, and Shatskyi and their surroundings. For this purpose, innovative maps were produced that take the ecosystem-based approach into account and incorporate first information on climate change impacts. The spatial analyses thus enable 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.

### Situation Maps

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).

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 Threats maps provide an overview of tree biomass loss and ecosystem fragmentation in the regions.

### Vulnerability Maps

Ecosystem-based Adaptation measures have the potential and goal to proactively reduce climate-change-induced risks by decreasing the vulnerability and enhancing the (self-)regulating capacity of ecosystems. To obtain an overview of the spatial distribution of stress impacts in the ecosystems of the biosphere reserve regions, an assessment of stress indicators was carried out. The results of the individual stress indicator assessments are shown in the stress indicator maps, the combined result in the vulnerability map.

## Methodology

All values of the stress indicators are standardized on a 0-100 scale to ensure compatibility during final integration into the Vulnerability map.

**1. Management intensity**

Basic assumptions:

1) Physiotope class 1 (floodplain) ecosystems are least managed – a natural floodplain regime is dominant here. Grassland (forestless area) is, to a great extent, a result of a natural flood disturbance here.
2) Hygric physiotopes 2 and 4 have experienced fewer management interventions than mesic (3,5-7) owing to lower natural productivity and limited accessibility due to waterlogged soil. Forestless areas here ("grassland" land cover class) bare varying human impact – these may be bogs or fens with close-to-natural structure as well as after-forest grassland used as pasture or for haying. Therefore, a varying assessment score of 10-30 is averaged to 20 points. Artificially drained areas are regarded as one step more intensively managed (+10 points in the assessment).
3) Coniferous forests are mostly cultures of *P. sylvestris* and therefore have more distinct traces of management than deciduous/mixed forests.
4) Intensively managed grassland on drier soils in Physiotopes 3, 5, 6, 7 may be mixed by remote sensing with cropland, or may just be a rotation phase of cropland (as for the situation of 2018). Therefore, its assessment score is closer to cropland.

An ecotope matrix was used to estimate management intensity on a scale 0-100.

| | Phys 1 | Phys 2, 4 | Phys 2, 4 drained | Phys 3,5,6,7 |
|---|---|---|---|---|
| Lndcvr 11 Decid & mixed frst older 20 yrs | 10 | 10 | 20 | 20 |
| Lndcvr 12 Decid & mixed frst yngr 20 yrs | | 20 | 30 | 30 |
| Lndcvr 21 Conif frst older 20 yrs | | 20 | 30 | 30 |
| Lndcvr 22 Conif frst yngr 20 yrs | | 30 | 40 | 40 |
| Lndcvr 31 Mostly unmngd / extnsvly mngd grassland | 10 | 20 (10-30) | 30 (20-40) | |
| Lndcvr 32 Mostly intensively mngd grslnd | | | | 60 |
| Lndcvr 40 Cropland | | | | 80 |
| Settlements | | 100 | 100 | 100 |

**2. Management intensity neighborhood impact**

This stress indicator is a neighborhood analysis within a 1-km circular neighborhood. The input values are from the management intensity assessment (paragraph 1). A mean value of the management intensity is calculated for each cell and standardized.

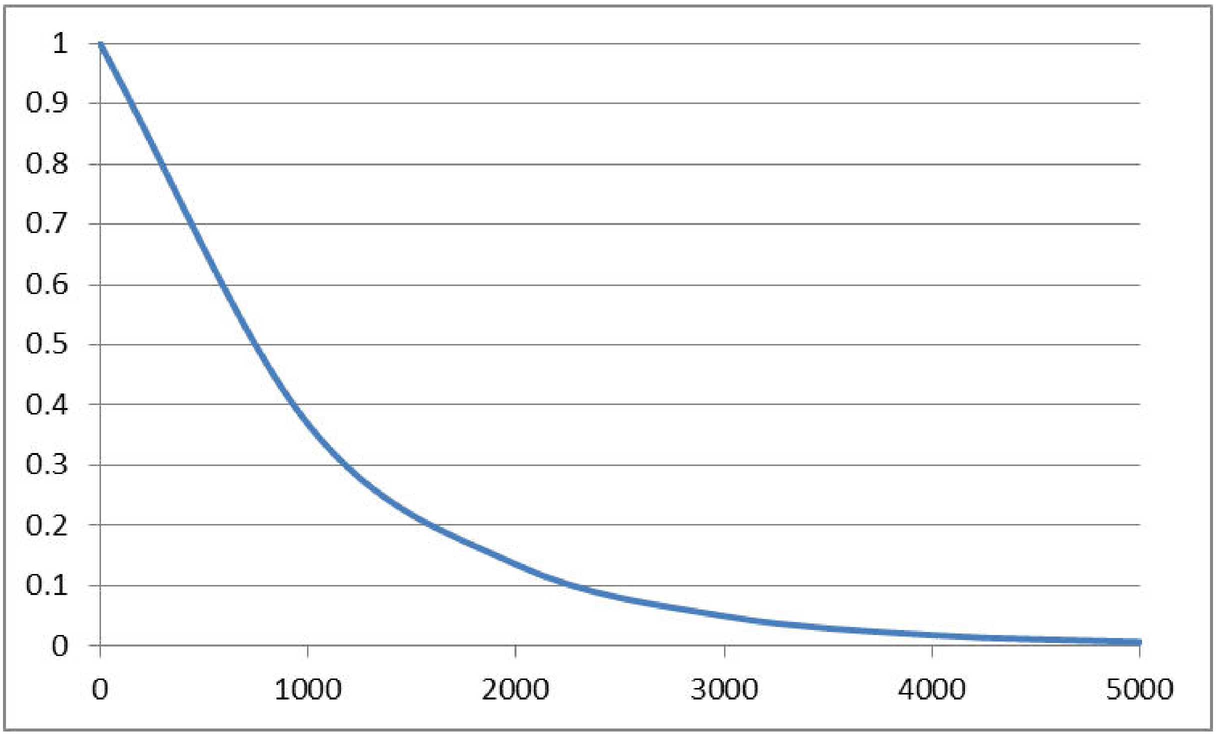
**3. Logging intensity**

The same continuous approach (focal statistics) was applied. The dataset of forest loss 2000-2018 indicating years of disturbances (values 1 to 18) was filtered to eliminate regions of less than 0.5 ha, which mostly are erroneous (slivers). Then, focal statistics were applied to calculate the sum of cell values in a circle neighborhood of 1000m. The obtained values were standardized to the integer scale from 0 to 100.

**4. Road impact**

The roads were grouped according to traffic intensity, which was linked to the OSM road types (1 - trunk, 2 - primary, 3- secondary, 4 – t-rtiary, 5 - other). The traffic intensity was estimated as points on the scale 1-100 using the "0.6" rule (Tribe and Alpine 1986)[17] – i.e. 1 -100; 2 – 60; 3 - 36; 4 – 22; 5 – 13.

The values of the traffic intensity estimations were extrapolated on 5 km buffers (Ibisch et al. 2016)[18] using Probability Density Function (PDF).




$f(x) = e^{-x}$, where x is the distance from a road

The resulting geo dataset was standardized on a 0-100 scale.

**5. Soil water**

Soil water index was estimated for physiotope classes and standardized on a scale 1-100.

| Physiotope classes | Soil water index: 1 (wet) - 5 (dry) |
|---|---|
| 1 | 1 |
| 2 | 1 |
| 3 | 3 |
| 4 | 2 |
| 5 | 3 |
| 6 | 4 |
| 7 | 5 |

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[17] Tribe MA, Alpine RLW (1986) Scale economies and the “0.6 rule.” Engineering Costs and Production Economics 10:271–278 . doi: 10.1016/0167-188X(86)90053-4

[18] Ibisch, P. L., Hoffmann, M. T., Kreft, S., Pe’er, G., Kati, V., Biber-Freudenberger, L., ... & Selva, N. (2016). A global map of roadless areas and their conservation status. Science, 354(6318), 1423-1427.

**6. Artificial drainage**

Assumptions:

1) It is assumed that the impact of artificial drainage extends to about 250 m beyond the drain. This assumption is based on distance measurements between parallel drains (100-500m).
2) Groundwater table (GWT) sensitivity to drainage varies for different physiotope classes. Most sensitive are Physiotopes 1 and 2 (valley bottoms) with a natural high GWT, while Physiotopes 7 (slopes) with naturally fragmented GWT are least sensitive. This sensitivity was expressed as a "cost" parameter in a cost-distance calculation from the drain.

"Cost" values for physiotope classes

| Physiotope classes | Cost value (the smaller the value – the more sensitive GWT) |
|---|---|
| 1,2,4 | 1 |
| 3,5 | 2 |
| 6 | 4 |
| 7 | 8 |

Buffers of 250m were generated along canals/drains and peat extraction sites using the above cost parameters. Then, the cost-distance values were inverted and standardized on a 0-100 scale to reflect the level of technogenic impact on the GWT.

**7. Human population density**

Assumptions:

1) Human presence in the landscape depends on the number of inhabitants in the settlements as well as on the proximity to the settlements.
2) Proximity, or accessibility, of the landscape, depends not only on the Euclidian distance from a settlement but also on the "impedance" of the terrain to human movement – e.g. movement through wetlands is much slower than along a road.

These assumptions determined the methodology.

1. A movement cost dataset was produced from the ecotopes dataset and roads dataset.

Ecotope matrix used to estimate landscape "impedance" to human movement (larger values indicate more difficult terrain).

| | Phys 1 | Phys 2, 4 | Phys 3,5,6,7 |
|---|---|---|---|
| Lndcvr 11 Decid & mixed frst older 20 yrs | 8 | 7 | 6 |
| Lndcvr 12 Decid & mixed frst yngr 20 yrs | | 7 | 7 |
| Lndcvr 21 Conif frst older 20 yrs | | 7 | 5 |
| Lndcvr 22 Conif frst yngr 20 yrs | | 7 | 6 |
| Lndcvr 31 Mostly unmngd / extnsvly mngd grassland | 7 | 6 | |
| Lndcvr 32 Mostly intensively mngd grslnd | | | 5 |
| Lndcvr 40 Cropland | | | 6 |
| Roads | 1 | | |
| Settlements | 1 | | |
| Water | Restrictive | | |

2. A cost-distance surface of proximity to settlements was interpolated using the settlement dataset and the cost dataset.
3. A buffer of 10 "cost-distance" km was generated around settlement outlines.
4. Human density (persons/sq.km) was calculated for the areas inside the settlements and extrapolated outside to the limits of the 10-km buffer using spline interpolation.
5. The obtained dataset of human density was standardized to the 0-100 scale.

**Integral vulnerability assessment**

It is a weighted overlay of the seven stress indicators described above with equal weights (mean values). It is possible to create a separate representation for different ecotope categories (e.g, forest, grassland), however, this was not done as there was no specific need so far.

**Further relevant literature**

Bennett VJ (2017) Effects of road density and pattern on the conservation of species and biodiversity. Curr Landscape Ecol Rep 2:1–11 . doi: 10.1007/s40823-017-0020-6

## Surface Temperature Maps

Dr. Steffen Kriewald with the Potsdam Institute for Climate Impact Research elaborated maps and analyses on surface temperatures (long-term average).

Land Surface Temperature (LST) is an essential variable to observe short time and longtime changes of climate on a regional scale. Additionally, it allows studying the individual reaction of different land cover types to these changes in climate, as a result of a changed surface energy budget. The LST can be obtained by remote sensing data, analyzing the infrared and near-infrared bands.

The analysis was based on two different data sets for a long period (2002-2018) from MODIS with a coarse spatial resolution of 1000m and a short period (2013-2018) from Landsat8 with a high spatial resolution of 30m. MODIS data is available daily, whereas Landsat8 data is only available on a fortnightly basis, which drastically limits the number of images.

Averaged LST and the corresponding standard deviation is available for seasons and different temperature ranges. To avoid a short-time influence of weather, additionally, normalization with the spatial mean was done. Values below 1 indicate areas that are cooler than the spatial mean and values above 1 areas which are hotter than the average.

Explanation of structure:

- 3 regions
  - Roztochya, Shatskyi, and Desnianskyi Biosphere Reserves
- Two satellites
  - Landsat 8; 30m resolution; one shot every 16 days at 9 am
  - MODIS; 1000m resolution; daily overflights at 12 o'clock noon
- Seasons or temperature classes
  - MAM; all measurements from March, April, May
  - JJA; all measurements from June, July, August

- SON; all measurements from September, October, November
- DJF; all measurements from December, January, February
- frost.days; all measurements from days with a maximum air temperature < 0°C
- cosy.days: all measurements from days with a maximum air temperature between >=20 and <25°C
- summer.days; all measurements of days with a maximum air temperature between >=25 and <30°C
- heat.days; all measurements from days with a maximum air temperature >30°C

- Variables
  - temperature; the average surface temperatures for the period in question or the temperature class
  - temperature_sd; the standard deviation of temperature
  - norm_temperature; the averaged normalized (division by the respective daily mean) surface temperatures for the respective period/temperature class
  - standard_temperature_sd; the standard deviation of standard_temperatrue
  - number_of_obs; the number of measurements per pixel for the respective period or temperature class

## Thermal Analysis, Ecosystem Cooling Capacity and EbA Demand Analysis (Part II)

### Output 1 - Thermal analysis of the area and cooling capacity of ecosystems

**Thermal analysis of the area**

The data used was compiled and provided by Steffen Kriewald of Potsdam Institute for Climate Impact Research. This included:

Raster geo datasets on the terrain surface temperature (deg. C) for the BRs and their vicinities were derived from the Landsat 8 thermal band for the observation period of 2002-2018. Spatial resolution is 30*30m. Four geo datasets were used describing different weather conditions (in the PDF version, the interactive thermo maps can be accessed via this link: https://www.hnee.de/ceem/ukr-thermo/index_en.html).

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)

**Processing of the data:** The mean value of each geodata set (available in metadata) was subtracted from the cell values using a map algebra function to produce datasets of surface T deviations from the mean (in deg C). Then, these datasets were visualized as A4 size continuous color maps.

**Results**: Geospatial distribution of temperature deviations from mean for different weather conditions are illustrated by the maps (Fig. 9) with summary tables (provided in the situation analysis docs).

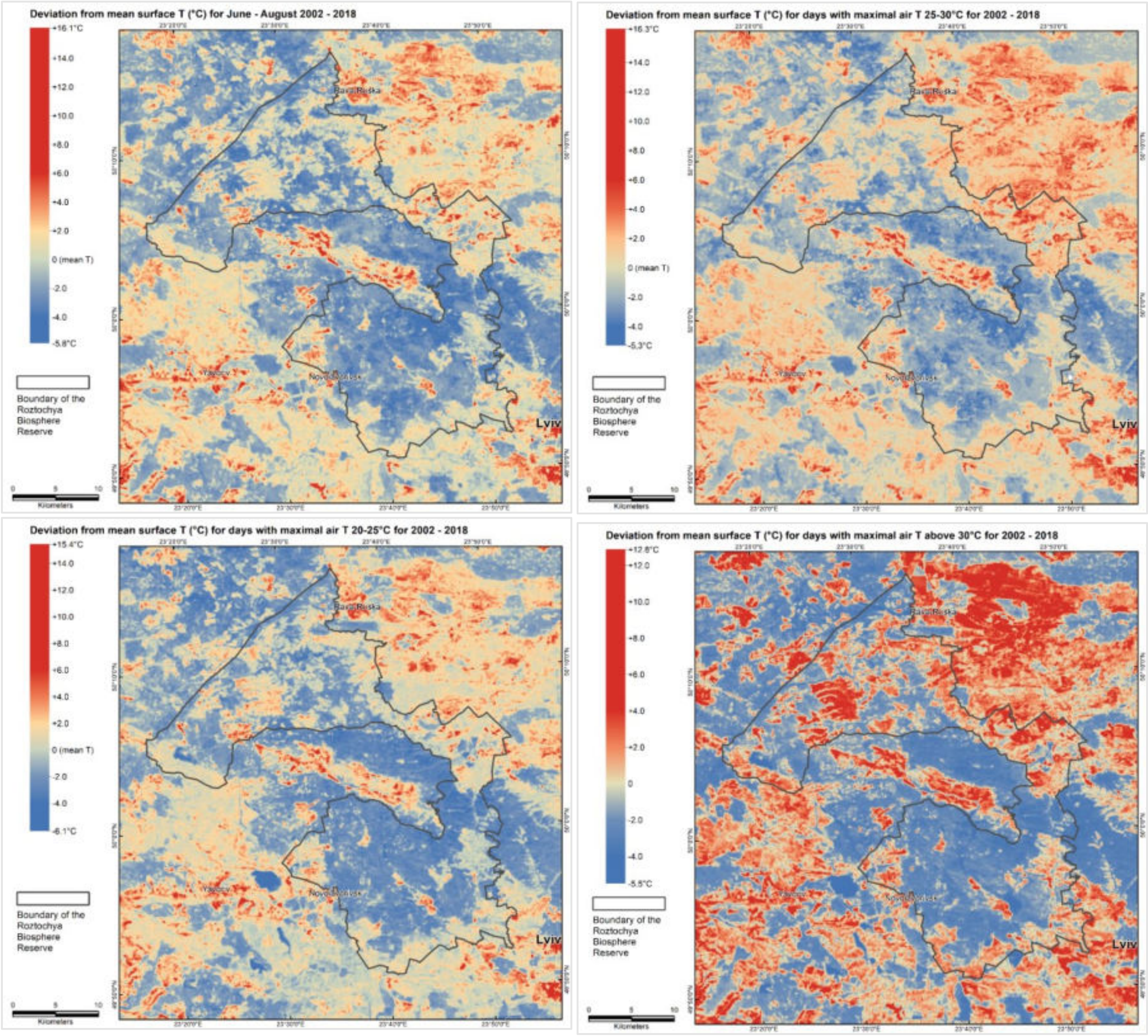



Figure 9 Example: Roztochya BR: Deviations of surface T from the mean values during 2002-2018 summer period

## Cooling capacity of ecosystems

**Data** used in this study:

1) Raster geo datasets representing deviations from the mean terrain surface temperature (deg. C) during 2002-2018 for 1) June-August; 2) cozy days with max air T 20-25 deg C; 3) summer days with max air T 25-30 deg C; and 4) heat days with max air T above 30 deg C. Spatial resolution is 30*30m.
2) Raster geo datasets of ecotope classes. Spatial resolution 10*10 m
3) Raster geo dataset of Tree loss 2001-2019 (Hansen et al. 2013). Spatial resolution 24*24 m

**Processing:** Tree loss patches up to the year 2010 (median of surface T Landsat observations) were extracted and merged with ecotope classes data to produce new geo datasets with 30*30 m resolution containing such categories:

| Id | Description | Id | Description |
|---|---|---|---|
| 110 | Brdlvd/mxd frst hygric-mesic on sand | 320 | Conif frst wet |
| 111 | Brdlvd/mxd frst hygric-mesic on sand logged | 321 | Conif frst wet logged |
| 120 | Brdlvd/mxd frst mesic on loam | 330 | Grassland wet |
| 121 | Brdlvd/mxd frst mesic on loam logged | 410 | Grassland hygric-mesic on sand |
| 210 | Conif frst hygric-mesic on sand | 420 | Grassland mesic on loam |
| 211 | Conif frst hygric-mesic on sand logged | 510 | Cropland hygric-mesic on sand |
| 220 | Conif frst mesic on loam | 520 | Cropland mesic on loam |
| 221 | Conif frst mesic on loam logged | 600 | Settlements |
| 310 | Brdlvd/mixed frst wet | 700 | Water |
| 311 | Brdlvd/mixed frst wet logged | | |

**Table 6 Desna BR: Ecotope classes used for the calculation of cooling capacity**

| Id | Description | Id | Description |
|---|---|---|---|
| 110 | Brdlvd/mxd frst hygric-mesic on sand | 320 | Conif frst wet |
| 111 | Brdlvd/mxd frst hygric-mesic on sand logged | 321 | Conif frst wet logged |
| 120 | Brdlvd/mxd frst mesic on loam | 330 | Grassland wet |
| 121 | Brdlvd/mxd frst mesic on loam logged | 340 | Cropland wet (drained) |
| 210 | Conif frst hygric-mesic on sand | 410 | Grassland hygric-mesic on sand |
| 211 | Conif frst hygric-mesic on sand logged | 420 | Grassland mesic on loam |
| 220 | Conif frst mesic on loam | 510 | Cropland hygric-mesic on sand |
| 221 | Conif frst mesic on loam logged | 520 | Cropland mesic on loam |
| 310 | Brdlvd/mixed frst wet | 600 | Settlements |
| 311 | Brdlvd/mixed frst wet logged | 700 | Former mining areas |
| | | 800 | Water |

**Table 7 Roztochya BR: Ecotope classes used for the calculation of cooling capacity**

| Id | Description | Id | Description |
|---|---|---|---|
| 110 | Brdlvd/mxd frst hygric-mesic on sand | 330 | Grassland wet |
| 111 | Brdlvd/mxd frst hygric-mesic on sand logged | 340 | Cropland wet (drained) |
| 210 | Conif frst hygric-mesic on sand | 410 | Grassland hygric-mesic on sand |
| 211 | Conif frst hygric-mesic on sand logged | 510 | Cropland hygric-mesic on sand |
| 310 | Brdlvd/mixed frst wet | 600 | Settlements |
| 311 | Brdlvd/mixed frst wet logged | 700 | Water |
| 320 | Conif frst wet | | |
| 321 | Conif frst wet logged | | |

**Table 8 Shatsk BR: Ecotope classes used for the calculation of cooling capacity**

Then, the new ecotope dataset was overlaid with the four raster datasets representing surface T deviations of 2002-2018 (see previous section) to calculate zonal statistics for each ecotope class. The zonal statistics of deviations from mean surface T for each ecotope class were presented in natural units (deg. C) as well as in %. Mean surface T values (in deg. C) were used to group ecotope classes into six categories of cooling capacity (very high, high, rather high, rather low, low, very low). For this purpose, Jenks (natural breaks) approach was used.

**Results:** Tables with zonal statistics describing each ecotope class surface T values for the four weather conditions are provided separately in spreadsheet files as well as in attribute tables of respective ecotope geo datasets. The graphs representing ecosystem cooling capacity as surface T deviations are in Fig. 10.

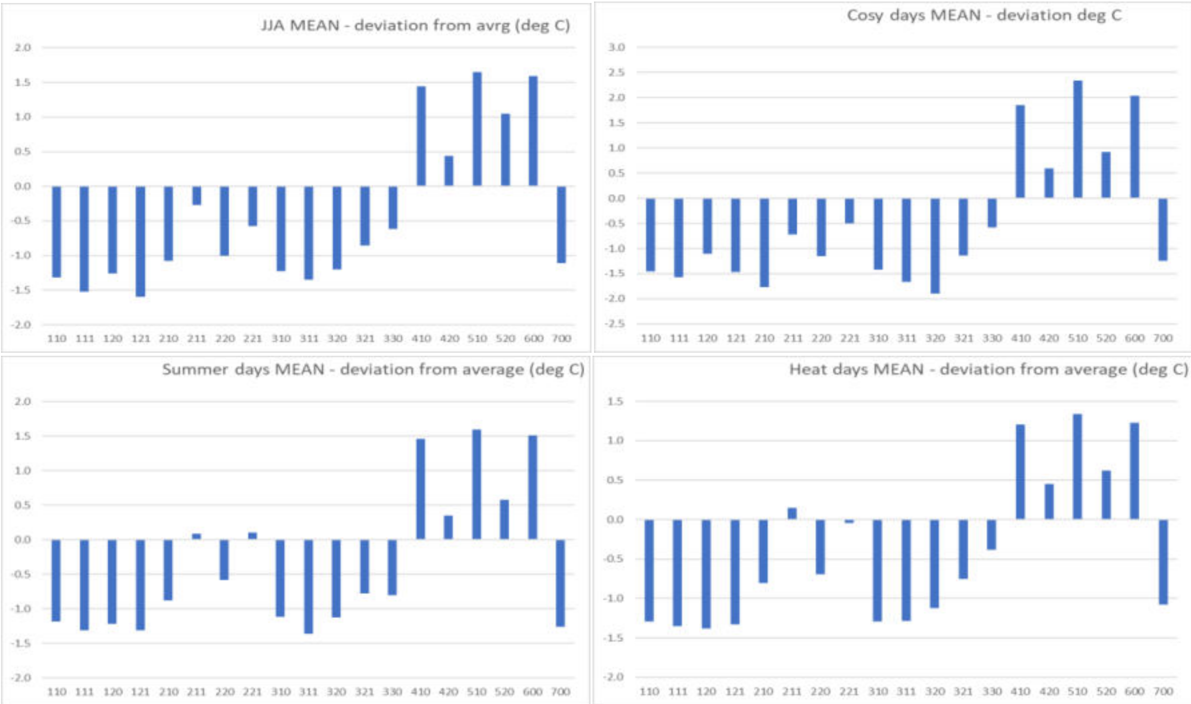



**Figure 10 Example: Desna BR. Cooling capacity of ecotope classes (axis x – see Table 6) as deviations from the mean**

The maps of the ecotope cooling capacity under each weather condition are shown in Fig. 11.

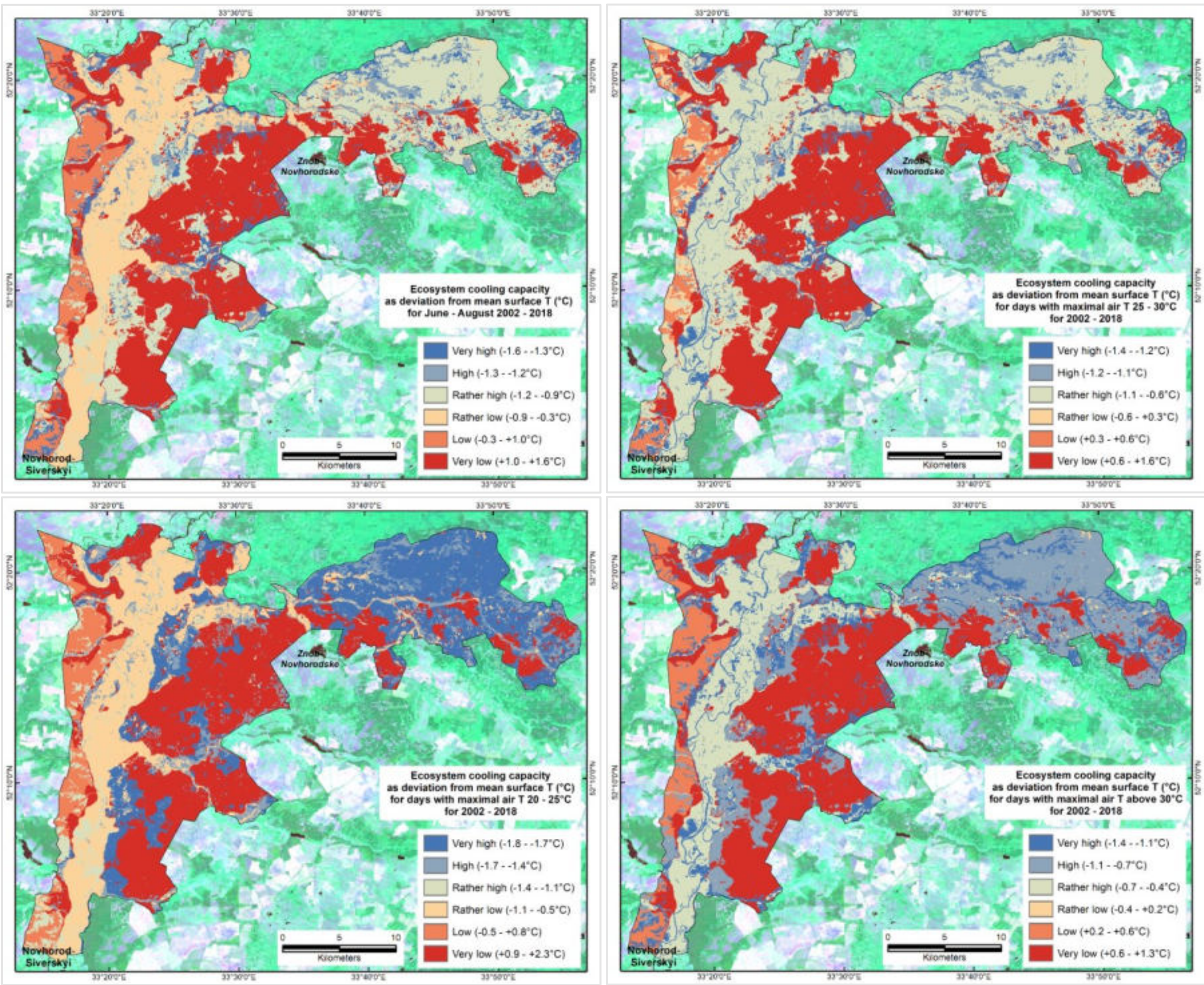



**Figure 11 Examples for Desna BR: Cooling capacity of ecotopes (in deg C) during 2002-2018 for different temperature bands**

**Thermal characterization of watersheds**

Datasets used:

PIK thermal datasets representing surface T (deg. C) for the BRs derived from the Landsat 8 thermal band for the observation period of 2002-2018 (https://www.hnee.de/ceem/ukr-thermo/index_en.html). Spatial resolution is 30*30m. Four geo datasets were used describing different weather conditions for each BR: a) Mean T for June-August; b) Mean T for cozy days (with max air T of 20 – 25 deg. C); c) Mean T for summer days (with max air T of 25 – 30 deg. C); d) Mean T for heat days (with max air T over 30 deg. C).

Watershed polygons of the BRs; 3-4 polygons per each BR (as produced in WP3).

Processing. Watershed polygons were used as zones to derive zonal statistics values of surface T represented by the four PIK surface T datasets. The zonal statistics tables contain info on 1) Watershed name, 2) Watershed area (ha), 3) Min T, 4) Max T, 5) T range, 6) Mean T, 7) T standard deviation (STD).

**Results:** These statistical data are incorporated into Excel spreadsheets describing other thermal properties of the BRs as separate sheets "Wtrshd T statistics" and shown as an example in table 10.

| **Zonal statistics for the Shatsk BR watersheds on the mean surface T in June-August 2002-2018** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Wshd Name | wshd_id | Area (Ha) | MIN T (deg C) | MAX T (deg C) | T RANGE (deg C) | MEAN T (deg C) | T STD (deg C) |
| Western Bug | 1 | 6743 | 21.2 | 34.1 | 13.0 | 24.8 | 1.7 |
| Kopauvka - Ryta | 2 | 63949 | 19.9 | 33.7 | 13.8 | 23.6 | 1.8 |
| Prypiat | 3 | 22003 | 21.0 | 33.8 | 12.8 | 24.9 | 2.0 |
| **Zonal statistics for the Shatsk BR watersheds on the mean surface T for days with max air T 20-25 deg C during 2002-2018** | | | | | | | |
| Wshd Name | wshd_id | Area (Ha) | MIN T (deg C) | MAX T (deg C) | T RANGE (deg C) | MEAN T (deg C) | T STD (deg C) |
| Western Bug | 1 | 6743 | 16.8 | 28.9 | 12.1 | 21.7 | 1.8 |
| Kopauvka - Ryta | 2 | 63949 | 12.6 | 30.9 | 18.3 | 20.7 | 2.1 |
| Prypiat | 3 | 22003 | 17.2 | 30.6 | 13.4 | 21.7 | 2.0 |
| **Zonal statistics for the Shatsk BR watersheds on the mean surface T for days with max air T 25-30 deg C during 2002-2018** | | | | | | | |
| Wshd Name | wshd_id | Area (Ha) | MIN T (deg C) | MAX T (deg C) | T RANGE (deg C) | MEAN T (deg C) | T STD (deg C) |
| Western Bug | 1 | 6743 | 21.3 | 33.4 | 12.1 | 24.8 | 1.6 |
| Kopauvka - Ryta | 2 | 63949 | 20.2 | 35.1 | 15.0 | 23.8 | 1.9 |
| Prypiat | 3 | 22003 | 21.2 | 33.9 | 12.6 | 25.3 | 2.1 |
| | | | | | | | |
| **Zonal statistics for the Shatsk BR watersheds on the mean surface T for days with max air T above 30 deg C during 2002-2018** | | | | | | | |
| Wshd Name | wshd_id | Area (Ha) | MIN T (deg C) | MAX T (deg C) | T RANGE (deg C) | MEAN T (deg C) | T STD (deg C) |
| Western Bug | 1 | 6743 | 23.0 | 35.4 | 12.4 | 26.4 | 1.6 |
| Kopauvka - Ryta | 2 | 63949 | 22.2 | 34.9 | 12.7 | 25.8 | 1.7 |
| Prypiat | 3 | 22003 | 21.6 | 35.1 | 13.5 | 26.5 | 1.9 |

**Table 9 Example: Shatsk BR - Zonal statistics summary on the surface T for the main watersheds**

## Output 2 - EbA demand analysis

**Correlations between thermal geodata and stress/integral vulnerability indicators**

Here we calculated correlations between the surface T values for the four weather conditions provided by PIK and seven ecosystem stress indicators as well as the integral vulnerability of ecosystems.

**Datasets used**: PIK raster geo datasets on the terrain surface temperature (deg. C) for the BRs derived from the Landsat 8 thermal band for the observation period of 2002-2018. Spatial resolution is 30*30m. Four geo datasets were used describing different weather conditions (https://www.hnee.de/ceem/ukr-thermo/index_en.html):

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)

The other datasets used for calculating correlations are representing:

1) Integral vulnerability of ecosystems (continuous, standardized values 0-100)

As well as ecosystem stress indicators:

2) Land-use intensity (discrete, standardized values 0-100)
3) Neighborhood effect of land-use intensity (continuous, standardized values 0-100)
4) Tree loss intensity (continuous, standardized values 0-100)
5) Road impact (continuous, standardized values 0-100)
6) Soil drought susceptibility (discrete, standardized values 0-100)
7) Artificial drainage impact (continuous, standardized values 0-100)
8) Human population presence (continuous, standardized values 0-100)

**Processing 1:** PIK thermal data were clipped out using buffered outlines of the BRs – to match the spatial extent of the geo datasets representing integral vulnerability and stress indicators of the ecosystems. Then, the thermal data were standardized on the scale of 0-100 using the formula in an ArcGIS Raster Calculator tool:

("raster" - "raster".minimum) / ("raster".maximum - "raster".minimum) * 100,

where "raster" stays for the PIK thermal datasets. After this, an ArcGIS Band Collection Statistics tool was applied on the geodata sets with an option "Compute covariance and correlation matrices". The outputs in the form of text files with correlation matrices between PIK thermal geodata and vulnerability/stress indicators were imported into Excel spreadsheets.

**Results 1** are provided in separate Excel spreadsheets (sheets "T VulnStress correlations" within Excel books on thermal profiles of each BR), here shown as an example in table 11. The highest correlations of surface T are observed for Land Use Intensity (LUI) or Neighborhood Effect of LUI geodata (0.43 – 0.73).

| | Layer | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **T jja - mean T June, July, Augus** | **1** | 1 | 0.41227 | 0.54686 | 0.49776 | -0.12432 | 0.22443 | 0.1928 | -0.05842 | 0.25423 |
| Integral vulnerability | **2** | 0.41227 | 1 | 0.71905 | 0.80512 | 0.01231 | 0.57651 | 0.71206 | 0.04263 | 0.60584 |
| Land use intensity | **3** | 0.54686 | 0.71905 | 1 | 0.79871 | -0.10594 | 0.41429 | 0.57334 | -0.14692 | 0.40294 |
| Nbhd effct of LUI | **4** | 0.49776 | 0.80512 | 0.79871 | 1 | -0.16192 | 0.52743 | 0.557 | -0.13896 | 0.50765 |
| Tree loss intensity | **5** | -0.12432 | 0.01231 | -0.10594 | -0.16192 | 1 | -0.04527 | 0.0594 | -0.00688 | -0.1402 |
| Road impact | **6** | 0.22443 | 0.57651 | 0.41429 | 0.52743 | -0.04527 | 1 | 0.37964 | -0.13864 | 0.4607 |
| Soil drought susceptibility | **7** | 0.1928 | 0.71206 | 0.57334 | 0.557 | 0.0594 | 0.37964 | 1 | -0.28489 | 0.36217 |
| Artificial drainage impact | **8** | -0.05842 | 0.04263 | -0.14692 | -0.13896 | -0.00688 | -0.13864 | -0.28489 | 1 | -0.09696 |
| Human population presence | **9** | 0.25423 | 0.60584 | 0.40294 | 0.50765 | -0.1402 | 0.4607 | 0.36217 | -0.09696 | 1 |
| | | | | | | | | | | |
| | **Layer** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **T cosy days: 20-25 deg.C** | **1** | 1 | 0.43014 | 0.57389 | 0.55748 | -0.1683 | 0.25471 | 0.16261 | -0.06527 | 0.28578 |
| Integral vulnerability | **2** | 0.43014 | 1 | 0.71905 | 0.80512 | 0.01231 | 0.57651 | 0.71206 | 0.04263 | 0.60584 |
| Land use intensity | **3** | 0.57389 | 0.71905 | 1 | 0.79871 | -0.10594 | 0.41429 | 0.57334 | -0.14692 | 0.40294 |
| Nbhd effct of LUI | **4** | 0.55748 | 0.80512 | 0.79871 | 1 | -0.16192 | 0.52743 | 0.557 | -0.13896 | 0.50765 |
| Tree loss intensity | **5** | -0.1683 | 0.01231 | -0.10594 | -0.16192 | 1 | -0.04527 | 0.0594 | -0.00688 | -0.1402 |
| Road impact | **6** | 0.25471 | 0.57651 | 0.41429 | 0.52743 | -0.04527 | 1 | 0.37964 | -0.13864 | 0.4607 |
| Soil drought susceptibility | **7** | 0.16261 | 0.71206 | 0.57334 | 0.557 | 0.0594 | 0.37964 | 1 | -0.28489 | 0.36217 |
| Artificial drainage impact | **8** | -0.06527 | 0.04263 | -0.14692 | -0.13896 | -0.00688 | -0.13864 | -0.28489 | 1 | -0.09696 |
| Human population presence | **9** | 0.28578 | 0.60584 | 0.40294 | 0.50765 | -0.1402 | 0.4607 | 0.36217 | -0.09696 | 1 |
| | | | | | | | | | | |
| | **Layer** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **T summer days: 25-30 deg.C** | **1** | 1 | 0.42182 | 0.53914 | 0.49697 | -0.08904 | 0.21658 | 0.21864 | -0.05608 | 0.24583 |
| Integral vulnerability | **2** | 0.42182 | 1 | 0.71905 | 0.80512 | 0.01231 | 0.57651 | 0.71206 | 0.04263 | 0.60584 |
| Land use intensity | **3** | 0.53914 | 0.71905 | 1 | 0.79871 | -0.10594 | 0.41429 | 0.57334 | -0.14692 | 0.40294 |
| Nbhd effct of LUI | **4** | 0.49697 | 0.80512 | 0.79871 | 1 | -0.16192 | 0.52743 | 0.557 | -0.13896 | 0.50765 |
| Tree loss intensity | **5** | -0.08904 | 0.01231 | -0.10594 | -0.16192 | 1 | -0.04527 | 0.0594 | -0.00688 | -0.1402 |
| Road impact | **6** | 0.21658 | 0.57651 | 0.41429 | 0.52743 | -0.04527 | 1 | 0.37964 | -0.13864 | 0.4607 |
| Soil drought susceptibility | **7** | 0.21864 | 0.71206 | 0.57334 | 0.557 | 0.0594 | 0.37964 | 1 | -0.28489 | 0.36217 |
| Artificial drainage impact | **8** | -0.05608 | 0.04263 | -0.14692 | -0.13896 | -0.00688 | -0.13864 | -0.28489 | 1 | -0.09696 |
| Human population presence | **9** | 0.24583 | 0.60584 | 0.40294 | 0.50765 | -0.1402 | 0.4607 | 0.36217 | -0.09696 | 1 |
| | | | | | | | | | | |
| | **Layer** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| **T hot days: >30 deg.C** | **1** | 1 | 0.31027 | 0.43763 | 0.36916 | -0.0936 | 0.17594 | 0.14907 | -0.08795 | 0.18974 |
| Integral vulnerability | **2** | 0.31027 | 1 | 0.71905 | 0.80512 | 0.01231 | 0.57651 | 0.71206 | 0.04263 | 0.60584 |
| Land use intensity | **3** | 0.43763 | 0.71905 | 1 | 0.79871 | -0.10594 | 0.41429 | 0.57334 | -0.14692 | 0.40294 |
| Nbhd effct of LUI | **4** | 0.36916 | 0.80512 | 0.79871 | 1 | -0.16192 | 0.52743 | 0.557 | -0.13896 | 0.50765 |
| Tree loss intensity | **5** | -0.0936 | 0.01231 | -0.10594 | -0.16192 | 1 | -0.04527 | 0.0594 | -0.00688 | -0.1402 |
| Road impact | **6** | 0.17594 | 0.57651 | 0.41429 | 0.52743 | -0.04527 | 1 | 0.37964 | -0.13864 | 0.4607 |
| Soil drought susceptibility | **7** | 0.14907 | 0.71206 | 0.57334 | 0.557 | 0.0594 | 0.37964 | 1 | -0.28489 | 0.36217 |
| Artificial drainage impact | **8** | -0.08795 | 0.04263 | -0.14692 | -0.13896 | -0.00688 | -0.13864 | -0.28489 | 1 | -0.09696 |
| Human population presence | **9** | 0.18974 | 0.60584 | 0.40294 | 0.50765 | -0.1402 | 0.4607 | 0.36217 | -0.09696 | 1 |

**Table 10 Example: Desna BR - Correlations between surface T and integral vulnerability / stress indicators calculated for the whole BR area**

**Processing 2** aimed at finding dependencies between the surface T and stress indicators / integral vulnerability for open (grassland and arable land) ecotopes only. The intention was to mainly explore the impact of soil properties on surface T for the areas not obscured by a tree canopy. For this purpose, the geodata sets were produced, which masked out all non-open land ecotopes (forests, settlements, and water). The thermal and stress/vulnerability datasets were clipped out using the masks before correlation analysis with the ArcGIS Band Collection Statistics tool.

**Results 2** are provided in the same Excel spreadsheets (sheets "T VulStress correlations" within Excel books on thermal profiles of each BR) here shown as an example in table 12. The correlation values are higher (if compared to all area correlations) for the soil drought susceptibility but still insignificant. For the other stress indicators, the correlation values turned out to be significantly lower (if compared to all area correlations).

| | Layer | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| **T jja - mean T June, July, August** | **1** | 1 | 0.54192 | 0.5784 | 0.52456 | 0.03317 | 0.25588 | 0.48977 | -0.09467 | 0.24012 |
| Integral vulnerability | **2** | 0.54192 | 1 | 0.9029 | 0.90093 | 0.05358 | 0.57248 | 0.89182 | 0.00217 | 0.61938 |
| Land use intensity | **3** | 0.5784 | 0.9029 | 1 | 0.85354 | 0.0362 | 0.4245 | 0.87996 | -0.16322 | 0.3707 |
| Nbhd effct of LUI | **4** | 0.52456 | 0.90093 | 0.85354 | 1 | -0.06798 | 0.51807 | 0.77594 | -0.15556 | 0.48548 |
| Tree loss intensity | **5** | 0.03317 | 0.05358 | 0.0362 | -0.06798 | 1 | -0.03406 | 0.00594 | 0.0742 | -0.10488 |
| Road impact | **6** | 0.25588 | 0.57248 | 0.4245 | 0.51807 | -0.03406 | 1 | 0.49459 | -0.16874 | 0.40733 |
| Soil drought susceptibility | **7** | 0.48977 | 0.89182 | 0.87996 | 0.77594 | 0.00594 | 0.49459 | 1 | -0.24483 | 0.47301 |
| Artificial drainage impact | **8** | -0.09467 | 0.00217 | -0.16322 | -0.15556 | 0.0742 | -0.16874 | -0.24483 | 1 | -0.12202 |
| Human population presence | **9** | 0.24012 | 0.61938 | 0.3707 | 0.48548 | -0.10488 | 0.40733 | 0.47301 | -0.12202 | 1 |
| | | | | | | | | | | |
| | **Layer** | | | | | | | | | |
| **T cosy days: 20-25 deg.C** | **1** | 1 | 0.59217 | 0.64002 | 0.61983 | -0.01574 | 0.28312 | 0.52343 | -0.1369 | 0.25332 |
| Integral vulnerability | **2** | 0.59217 | 1 | 0.9029 | 0.90093 | 0.05358 | 0.57248 | 0.89182 | 0.00217 | 0.61938 |
| Land use intensity | **3** | 0.64002 | 0.9029 | 1 | 0.85354 | 0.0362 | 0.4245 | 0.87996 | -0.16322 | 0.3707 |
| Nbhd effct of LUI | **4** | 0.61983 | 0.90093 | 0.85354 | 1 | -0.06798 | 0.51807 | 0.77594 | -0.15556 | 0.48548 |
| Tree loss intensity | **5** | -0.01574 | 0.05358 | 0.0362 | -0.06798 | 1 | -0.03406 | 0.00594 | 0.0742 | -0.10488 |
| Road impact | **6** | 0.28312 | 0.57248 | 0.4245 | 0.51807 | -0.03406 | 1 | 0.49459 | -0.16874 | 0.40733 |
| Soil drought susceptibility | **7** | 0.52343 | 0.89182 | 0.87996 | 0.77594 | 0.00594 | 0.49459 | 1 | -0.24483 | 0.47301 |
| Artificial drainage impact | **8** | -0.1369 | 0.00217 | -0.16322 | -0.15556 | 0.0742 | -0.16874 | -0.24483 | 1 | -0.12202 |
| Human population presence | **9** | 0.25332 | 0.61938 | 0.3707 | 0.48548 | -0.10488 | 0.40733 | 0.47301 | -0.12202 | 1 |
| | | | | | | | | | | |
| | **Layer** | | | | | | | | | |
| **T summer days: 25-30 deg.C** | **1** | 1 | 0.54213 | 0.58282 | 0.52304 | 0.06734 | 0.21771 | 0.48892 | -0.08524 | 0.23608 |
| Integral vulnerability | **2** | 0.54213 | 1 | 0.9029 | 0.90093 | 0.05358 | 0.57248 | 0.89182 | 0.00217 | 0.61938 |
| Land use intensity | **3** | 0.58282 | 0.9029 | 1 | 0.85354 | 0.0362 | 0.4245 | 0.87996 | -0.16322 | 0.3707 |
| Nbhd effct of LUI | **4** | 0.52304 | 0.90093 | 0.85354 | 1 | -0.06798 | 0.51807 | 0.77594 | -0.15556 | 0.48548 |
| Tree loss intensity | **5** | 0.06734 | 0.05358 | 0.0362 | -0.06798 | 1 | -0.03406 | 0.00594 | 0.0742 | -0.10488 |
| Road impact | **6** | 0.21771 | 0.57248 | 0.4245 | 0.51807 | -0.03406 | 1 | 0.49459 | -0.16874 | 0.40733 |
| Soil drought susceptibility | **7** | 0.48892 | 0.89182 | 0.87996 | 0.77594 | 0.00594 | 0.49459 | 1 | -0.24483 | 0.47301 |
| Artificial drainage impact | **8** | -0.08524 | 0.00217 | -0.16322 | -0.15556 | 0.0742 | -0.16874 | -0.24483 | 1 | -0.12202 |
| Human population presence | **9** | 0.23608 | 0.61938 | 0.3707 | 0.48548 | -0.10488 | 0.40733 | 0.47301 | -0.12202 | 1 |
| | | | | | | | | | | |
| | **Layer** | | | | | | | | | |
| **T hot days: >30 deg.C** | **1** | 1 | 0.35884 | 0.40584 | 0.33592 | 0.07062 | 0.16827 | 0.34704 | -0.12862 | 0.15419 |
| Integral vulnerability | **2** | 0.35884 | 1 | 0.9029 | 0.90093 | 0.05358 | 0.57248 | 0.89182 | 0.00217 | 0.61938 |
| Land use intensity | **3** | 0.40584 | 0.9029 | 1 | 0.85354 | 0.0362 | 0.4245 | 0.87996 | -0.16322 | 0.3707 |
| Nbhd effct of LUI | **4** | 0.33592 | 0.90093 | 0.85354 | 1 | -0.06798 | 0.51807 | 0.77594 | -0.15556 | 0.48548 |
| Tree loss intensity | **5** | 0.07062 | 0.05358 | 0.0362 | -0.06798 | 1 | -0.03406 | 0.00594 | 0.0742 | -0.10488 |
| Road impact | **6** | 0.16827 | 0.57248 | 0.4245 | 0.51807 | -0.03406 | 1 | 0.49459 | -0.16874 | 0.40733 |
| Soil drought susceptibility | **7** | 0.34704 | 0.89182 | 0.87996 | 0.77594 | 0.00594 | 0.49459 | 1 | -0.24483 | 0.47301 |
| Artificial drainage impact | **8** | -0.12862 | 0.00217 | -0.16322 | -0.15556 | 0.0742 | -0.16874 | -0.24483 | 1 | -0.12202 |
| Human population presence | **9** | 0.15419 | 0.61938 | 0.3707 | 0.48548 | -0.10488 | 0.40733 | 0.47301 | -0.12202 | 1 |

**Table 11 Example: Desna BR - Correlations between surface T and integral vulnerability/stress indicators calculated only for open land ecotopes (classes 330, 410, 420, 510, 520 – see Table 7)**

**Discussion:** The main reason for low correlations lies in the different nature of the compared datasets, particularly in the methodology of quantitative characterization of stress indicators. We have assigned discrete and non-calibrated values for most stress indicators (e.g. soil drought susceptibility dataset for Shatsk BR contains only two values – 50 and 100), while the standardized T datasets are continuous and contain the whole array of values from 0 to 100. For the Roztochya BR, which partly occupies hilly terrain, low correlation values may be additionally caused by the peculiarities of the Landsat images, which were taken at 10:30 local time and thus were sensitive to slope exposure of open ecotopes (E-SE slopes most likely were warmer than other).

## Delineation of Priority Areas for Ecosystem-based Adaptation Action

**Datasets used**:

PIK thermal datasets clipped by the buffered outlines of the BRs and standardized on the scale 0-100 – the same used for the calculation of correlations with stress / integral vulnerability indicators (see previous section "Processing 1") – four datasets per each BR.

Integral vulnerability datasets for each BR – they contain standardized values 0-100.

**Processing:** 1) The four standardized PIK datasets per each BR were added to each other using map algebra. 2) The resulting integral surface T datasets were standardized on the scale of 0-100. 3) The standardized integral surface T datasets were added to the integral vulnerability datasets. 4) The resulting datasets were standardized on the scale of 0-100 and visualized as maps of "Priority areas for ecosystem-based adaptation".

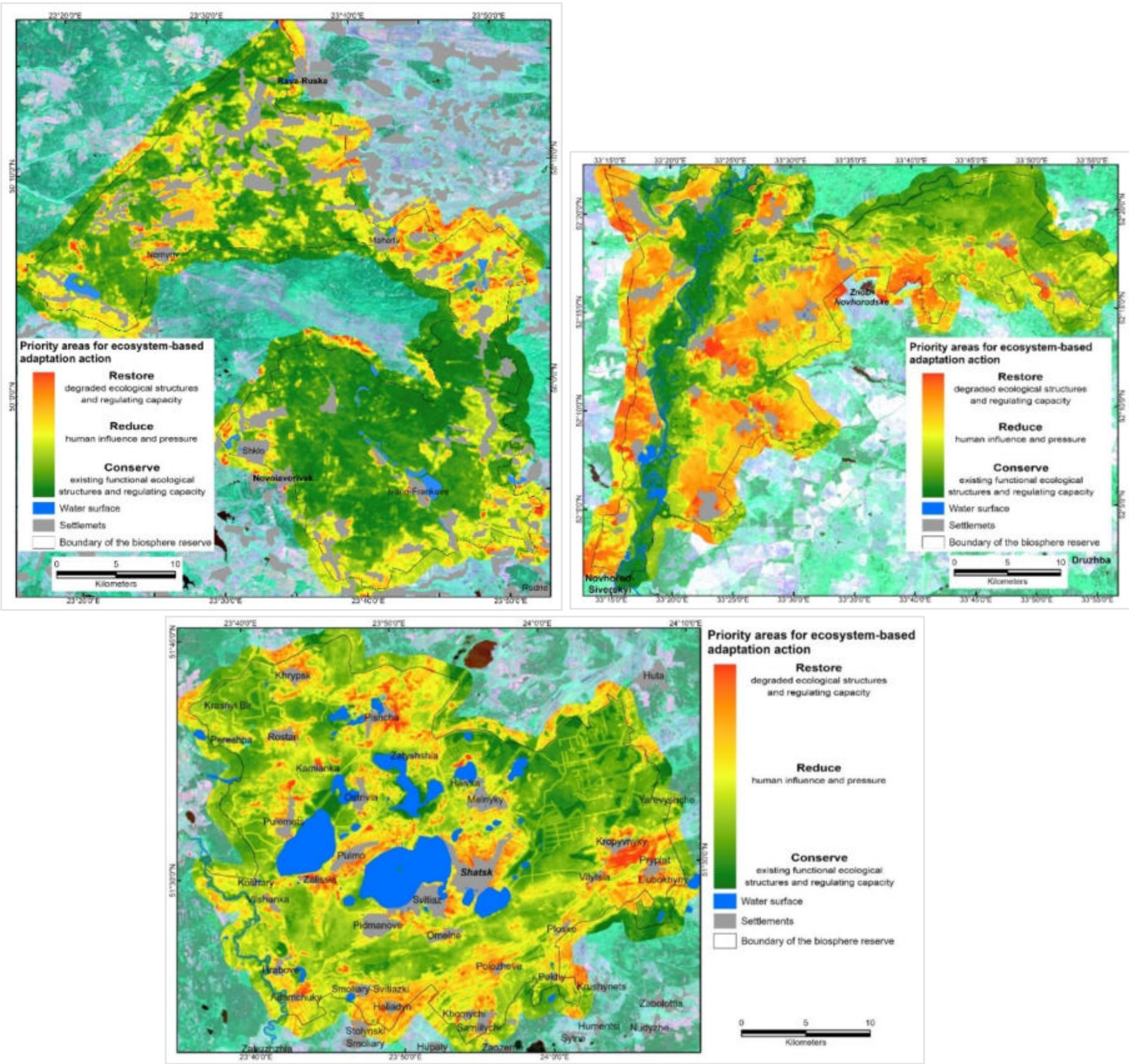



**Figure 12 Examples of the Biosphere Reserves' maps indicating "Priority areas for Ecosystem-based Adaptation Action"**

## Strategic Goals and Lines of Action

The rather concrete objectives of an Ecosystem-based Adaptation strategy are based on the situation analysis and the necessity to protect and restore (near-)natural ecosystems to safeguard ecosystem functions and services.

Due to their different characteristics, individual ecosystem types have unequal amounts of the relevant regulating ecosystem functions that can buffer climate change impacts for both the individual systems and the ecosystem network.

The strategic goals shall secure that the ecosystems

- **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**.

The overarching aim is to **reduce vulnerability to climate change**. Since vulnerability is caused at different levels, these different levels must also be addressed to reduce vulnerability holistically.

**Reducing Ecosystem Vulnerability**

Functioning ecosystems and the resulting provision of ecosystem services depend on their (self-) regulating and (self-) organizing capacity which itself grounds on the availability of certain characteristic structures, elements, properties, and processes, which:

  - must be maintained, restored, and newly established.
  - differ from ecosystem to ecosystem but have recurring patterns.

The vulnerability results not only from the functional capacity of individual ecosystems but also from their distribution and interaction. From these structural and spatial requirements of the ecosystems, strategic goals can be derived to strengthen the ecological functioning of ecosystems and corresponding Ecosystem-based Adaptation measures can be developed.

### Strategic Goals of Ecosystem-based Adaptation

***Target properties of individual ecosystems*:**

**G1. Conservation and restoration of (near-) natural hydrological conditions**

- Include various properties and processes of the small (or regional) water cycle such as groundwater level, groundwater recharge, the water table of water bodies, water quality, water flow in streams, water run-off, infiltration rate, evaporation rate, local precipitation, etc.
- The hydrological conditions depend strongly on the (geo-) location and the respective ecosystem, such that it cannot be described in general terms.
- In principle, the water balance should be as self-regulated as possible and should hardly be able to develop extremes, e.g. strong surface runoff, temporarily high flow velocities, and large amounts of water in flowing waters or drying out of wetlands.
- Even systems in use should be able to function without supplemental irrigation to the greatest extent possible.
- The structure and availability of local vegetation and the hydrological conditions (wetlands, lakes, etc.) can also have an impact on precipitation patterns.

**G2. Conservation and restoration of soil health and near-natural soil structure**

- The basis for plant growth and important storage and filter of water. Both play a supporting role in ecosystem-based adaptation to climate change. The condition of the soil influences the functioning of (semi-)terrestrial ecosystems.
- Disturbances such as compaction, deep tillage, or foreign matter inputs have an influence on ecological functions such as infiltration, water storage, or evaporation, but also on the development of soil organisms and plant growth.

**G3. Maintenance and buildup of plant biomass**

- Plant biomass and its structure play a central role in the storage and evaporation of water and thus has a cooling or temperature-regulating effect.
- Dead plant biomass also functions as a water reservoir in the form of deadwood, litter, and humus.
- Valuable nutrients are returned to the system during decomposition, which in turn flow into the buildup of biomass via vegetation growth and development

**G4. Preservation and promotion of near-natural, self-regulating species and structural diversity**

- The diverse web of organisms and nonliving structures that emerge from self-regulated processes forms the basis for ecosystem functioning.
- Diversity is a key element in a system's resilience to disturbance and change processes such as climate change.
- The risk of a system collapse is significantly reduced by a near-natural diversity of species and structures as disturbances and losses can be compensated for up to a point
- Diverse life forms and structures are of great importance for the energy and water balance of the systems.

**G5. Protection and promotion of (self-) regulated ecosystem development**

- Functioning ecosystems have, depending on the system, the ability to adapt to changing conditions.
- This requires that the processes in the system and the general dynamics of development can run in a self-regulated manner, i.e. that they are not too strongly predetermined or alienated by human influence.
- This self-regulation ensures that the ecosystem is suitably equipped concerning the site conditions.
- Examples:
    - Natural rejuvenation provides for the optimal equipment of suitable tree species in a forest and more stable individuals.
    - Succession as a process of (re)forestation produces a robust, uneven-aged, heterogenous forest adapted to the site, usually much better than can be achieved by planting.
    - In heavily used or persistently altered ecosystems, such processes can even be imitated by taking appropriate measures, e.g. single trunk, selective harvesting, or stock-oriented hunting.

**G6. Conservation, increase, and networking of vertical green structure**

- Vertical green structures such as copses, hedges, or individual trees act as connecting elements between forests and urban green spaces.
- Increase the proportion of biomass in lower-biomass systems such as agricultural land or along roads.
- Essential for the storage and evaporation of water, having a cooling function.
- They also slow down wind speed and surface runoff, filter solar radiation or provide local shading, and stop air pollution such as dust.

**G7. Conservation and creation of vegetation-, stand-, and canopy closure**

- Reduce the direct impact of solar radiation on the soil and thereby prevent local overheating and desiccation via shading. Reduces direct evaporation of water from the topsoil and increases evaporation through the larger surface area of plants (transpiration). Thus, the energy and water balance is improved.
- The impact of wind can be reduced or deflected due to the lack of surface area to attack (exposed edges).
- Slowing and buffering of heavy precipitation. Reduce the risk of soil erosion and significant surface runoff.
- Where permanent vegetation cover cannot be achieved, at least a continuous ground cover with living or dead plant biomass should be ensured (e.g. on arable land).

**G8. Conservation, creation, and enlargement of dormant or unused areas**

- Dormant areas – i.e., areas without edge effects, human interventions, and use – offer a maximum of the ecosystem properties and ecological functions that are essential for the functional efficiency of the corresponding ecosystem and thus also determine its vulnerability. They are nuclei of self-regulation and important reference areas for the adaptation of land use in general and specifically to climate change.
- The larger and more of these areas there are, the more resilient and adaptive the overall system is to (climate) change.
- The size of the resting surfaces depends on the strength and effective area of the boundary effects.

**G9. Minimization of edge effects**

- The size of the dormant areas also depends on the effective area with edge effects. Edge effects occur when the boundaries between ecosystems are abrupt and not fluid.
- These effects are particularly strong when neighboring systems differ greatly, e.g. in terms of their equipment, use, or age. Then the systems have a significant impact on each other – usually, the unfavorable, rather disturbing effects predominate over more natural ecosystems.
- The respective influenced edge areas change according to the effects, the area of the original undisturbed system decreases, and with it its functional efficiency and (self-) regulating capacity.
- Use contrasts of neighboring areas should therefore be as small as possible.
- The ratio of the edge to the base area should be as low as possible – compact and round areas have fewer edge effects than narrow, elongated base areas.

### *Objectives of the spatial design of the ecosystem network:*

**G10. Conservation and restoration of water bodies and wetlands**

- Similar to forests, water bodies and wetlands are particularly important in providing regulating ecosystem functions and services and have a local climate balancing and water retention effect. They permeate other ecosystems, and their protection should therefore be a high priority everywhere.

**G11. Conservation, networking, and enlargement of forest area**

- Due to the outstanding importance of forests in providing regulating ecosystem functions and services, but especially due to their local climate balancing and water retention effects, the highest priority must be given to the protection, promotion, and interconnection of near-natural forest ecosystems in the ecosystem network.

**G12. Conservation, restoration, and establishment of near-natural retention areas and temporary water storage**

- In addition to existing (semi-) natural water bodies and wetlands, areas should be made available to absorb water after heavy rainfall (e.g. flood plains, secondary floodplains)
- Additional near-natural small water bodies should be created, especially in more heavily used ecosystems with less climate-balancing functions such as urban areas or open land used for agriculture.

**G13. Preservation, development, and connection of cold and fresh air generation areas and corridors**

- Near-natural ecosystems in settlement areas and in their vicinity act as sources of cool, humid air, which reaches urban settlement areas, that are warming up more strongly, along unobstructed, green corridors (fresh air corridors)
- This is particularly important for areas where most building structures and only a few green structures, let alone green spaces, are present.
- The preservation or development of such nascent areas as well as the connection to climatically less favorable areas through fresh air corridors must be well prepared and accompanied by urban planning.

**G14. Conservation and enlargement of unsealed surfaces**

- Diminish and alleviate the negative consequences of surface sealing:
    - Reduces the absorption capacity and infiltration of rain and floodwater.
    - Reduces the area available for plant growth.
    - Leads to increased reflection of heat on sunny days.
- Thus, it is important to prevent further surface sealing and reconsider as many options to unseal formerly sealed surfaces.

## Strategic ecosystem functionality goals and vulnerability targets

| | How can **vulnerability be reduced** by reaching single functionality goals, i.e. by the targeted reduction of ecological stresses? How can they be prioritized? | Addressing **vulnerability and ecological stresses of Desnianskyi BR** concerning: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Energy input** | **Atmo-sphere** | **Hydro-sphere** | **Litho-sphere** | **Matter Cycles** | **Bio-mass** | **Infor-mation** | **Net-work** | **Species-specific factors** | **Energy, matter, and water efficiency** | **Resilience and resistance** |
| | **Strategic ecosystem functionality goals** | | | | | | | | | | | |
| | ***Goal characteristics of singular ecosystems*** | | | | | | | | | | | |
| **G1** | Conservation and restoration of **(near-) natural hydrological conditions** | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| **G2** | Conservation and restoration of **soil health and near-natural soil structure** | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| **G3** | **Maintenance and buildup** of plant **biomass** | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ | ✓ |
| **G4** | Conservation and promotion of **near-natural, self-regulating species- and structural diversity** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G5** | Conservation and promotion of **(self-) regulated ecosystem development** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| **G6** | Conservation, increase, and networking of **vertical green structure** | ✓ | ✓ | ✓ | | | ✓ | | ✓ | | ✓ | ✓ |
| **G7** | Conservation and creation of **vegetation-, stand-, and canopy closure** | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G8** | Conservation, creation, and enlargement of dormant and **unused areas** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G9** | Minimization of **edge effects** | ✓ | ✓ | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ |
| | ***Goals for spatial design of the ecosystem network*** | | | | | | | | | | | |
| **G10** | Conservation and restoration of **water bodies and wetlands** | | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G11** | Conservation, networking, and enlargement of **forest area** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G12** | Conservation, restoration, and creation of near-natural **retention areas and intermediate water storage** | ✓ | ✓ | ✓ | | | | ✓ | | | ✓ | ✓ |
| **G13** | Preservation, development, and connection of **cold and fresh air** generation areas and corridors | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | ✓ |
| **G14** | Conservation and enlargement of **unsealed surfaces** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | |

## Strategic ecosystem functionality goals and their ecosystem services targets

How can **ecosystem services be secured and provided** both in quantity and quality necessary to sustain human survival and well-being by reaching single functionality goals?

How can they be prioritized?

Addressing **Ecosystem Services (human benefits)** of **Desnianskyi BR**:

| | Strategic ecosystem functionality goals | Regulating | | | | | | | | Provisioning | | Cultural | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Baseline flows and extreme events** | **Lifecycle, habitat and gene pool protection** | **Pest and disease control** | **Soil quality** | **Water quality** | **Air/ Atmosphere quality & Climate regulation** | **Mediation of waste/toxins (human)** | **Mediation of nuisances (human)** | **Biomass** (Nutrition, Materials, Energy) | **Genetic materials** | **Physical and intellectual interaction** | **Spiritual & symbolic** |
| | ***Goal characteristics of singular ecosystems*** | | | | | | | | | | | | |
| **G1** | Conservation and restoration of **(near-) natural hydrological conditions** | ✓ | ✓ | | ✓ | ✓ | ✓ | | | ✓ | | ✓ | ✓ |
| **G2** | Conservation and restoration of **soil health and near-natural soil structure** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ |
| **G3** | **Maintenance and buildup** of plant **biomass** | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | tradeoff | ✓ | ✓ | ✓ |
| **G4** | Conservation and promotion of **near-natural, self-regulating species- and structural diversity** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G5** | Conservation and promotion of **(self-) regulated ecosystem development** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **G6** | Conservation, increase, and networking of **vertical green structure** | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | tradeoff | ✓ | ✓ | ✓ |
| **G7** | Conservation and creation of **vegetation-, stand-, and canopy closure** | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ | tradeoff | ✓ | ✓ | ✓ |
| **G8** | Conservation, creation, and enlargement of dormant and **unused spaces and areas** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | tradeoff | ✓ | tradeoff | tradeoff |
| **G9** | Minimization of **edge effects** | ✓ | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | | |
| | ***Goals for spatial design of the ecosystem network*** | | | | | | | | | | | | |
| **G10** | Conservation and restoration of **water bodies and wetlands** | ✓ | ✓ | | | ✓ | ✓ | ✓ | | | | ✓ | ✓ |
| **G11** | Conservation, networking, and enlargement of **forest area** | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | tradeoff | ✓ | ✓ | tradeoff |
| **G12** | Conservation, restoration, and creation of near-natural **retention areas and intermediate water storage** | ✓ | | | | | ✓ | | | | | ✓ | |
| **G13** | Preservation, development, and connection of **cold and fresh air** generation areas and corridors | ✓ | | | | | ✓ | | ✓ | | | ✓ | ✓ |
| **G14** | Conservation and enlargement of **unsealed surfaces** | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

**Strategic ecosystem functionality goals and their climate and Disaster Risk Reduction targets**

| | How can **climate and disaster risks be reduced** by addressing single functionality goals, i.e. by the targeted reduction of ecological stresses, its drivers, and underlying factors and causes? How can they be prioritized? | Addressing **climate and disaster risks in Desnianskyi BR** concerning: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Heat** | **Drought and dehydration** | **Flooding after heavy rainfall** | **Heavy storms** | **Hailstorms, heavy snow, and icing** | **Meadow, peatland, and forest fires** | **Pests, diseases, and insect calamities** | | | | |
| | **Strategic ecosystem functionality goals** | | | | | | | | | | | |
| | ***Goal characteristics of singular ecosystems*** | | | | | | | | | | | |
| **G1** | Conservation and restoration of (**near-) natural hydrological conditions** | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | |
| **G2** | Conservation and restoration of **soil health and near-natural soil structure** | | ✓ | ✓ | | | ✓ | ✓ | | | | |
| **G3** | **Maintenance and buildup** of plant **biomass** | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| **G4** | Conservation and promotion of **near-natural, self-regulating species- and structural diversity** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| **G5** | Conservation and promotion of **(self-) regulated ecosystem development** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | |
| **G6** | Conservation, increase, and networking of **vertical green structure** | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| **G7** | Conservation and creation of **vegetation-, stand-, and canopy closure** | ✓ | ✓ | | ✓ | ✓ | | ✓ | | | | |
| **G8** | Conservation, creation, and enlargement of dormant and **unused spaces and areas** | ✓ | ✓ | ✓ | | | | ✓ | | | | |
| **G9** | Minimization of **edge effects** | ✓ | ✓ | | ✓ | ✓ | | ✓ | | | | |
| | ***Goals for spatial design of the ecosystem network*** | | | | | | | | | | | |
| **G10** | Conservation and restoration of **water bodies and wetlands** | ✓ | ✓ | ✓ | | | ✓ | | | | | |
| **G11** | Conservation, networking, and enlargement of **forest area** | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | |
| **G12** | Conservation, restoration, and creation of near-natural **retention areas and intermediate water storage** | ✓ | ✓ | ✓ | | | ✓ | | | | | |
| **G13** | Preservation, development, and connection of **cold and fresh air** generation areas and corridors | ✓ | ✓ | | | | | | | | | |
| **G14** | Conservation and enlargement of **unsealed surfaces** | ✓ | ✓ | ✓ | | | | ✓ | | | | |

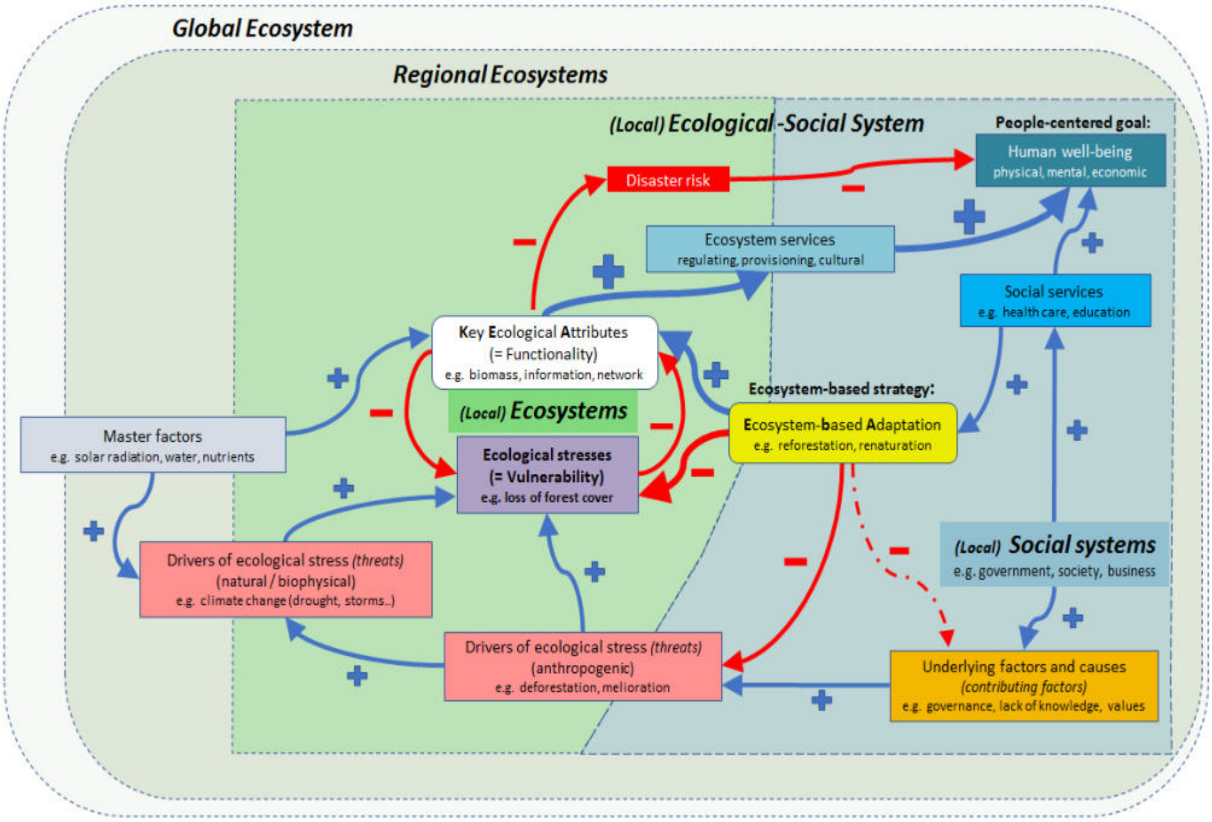



**Figure 14 Conceptual model for the MARISCO approach with Ecosystem-based Adaptation; Illustration by K.Mack**

## Lines of Action in Ecosystem-based Adaptation

At which levels this ecosystem-based approach alleviates vulnerability, is depicted in the following conceptual model, corresponding to the model presented in the first chapter.

**E**cosystem-**b**ased **A**daptation (EbA) can decrease vulnerability and risk by:

- directly **protecting, restoring, and enhancing the key ecological attributes (KEA)**, i.e. functional ecological structures and processes (e.g. biomass, information, and network);
- directly **reducing the ecological stresses.**
- **addressing and limiting the anthropogenic drivers of ecological stresses** to a minimum (land-use practices such as deforestation, drainage, monoculture cropping and forestry, etc.).
- **addressing the underlying factors and causes** leading to the drivers of ecological stress (e.g. by adapting the legal and policy framework, institutional developments, awareness-raising, educational programs, and training, etc.).

The above-described strategic goals can be pursued by implementing Ecosystem-based Adaptation measures in four lines of action.

**I. Conservation of existing functional ecological structures and (self-) regulating capacity**

The conservation of existing functional ecological structures such as trees, green structures, or water bodies is given the highest priority in the adaptation to climate change and represents the basic line of action:

- The restoration of functional structures and systems is difficult to impossible - any loss of functional surfaces reduces the ability to act, both in the present and in the future, which is why conservation is key.
- Whenever and wherever functional areas can be preserved, this should be a priority.

- At a minimum, the status should be maintained, and it should be prevented a) from intensifying existing stresses and b) from creating new stresses.
- These areas can then serve as a starting point for further developments and restoration, e.g. existing mixed, uneven-aged, near-natural deciduous forests, or functional wetlands.
- Measures within this line of action are most likely to be at the strategic planning level and start with the framework conditions, i.e. the underlying factors and causes for the current and potential disturbance of ecosystems.

**II. Reduction of human-made stresses and factors that limit and disturb (self-) regulating capacity**

This strand addresses the human activities that disrupt the functioning of ecosystems and cause stress. These must be reduced to support the preservation of the ecosystems, but also to restore or increase their functionality. This is about changing land-use practices, dismantling man-made structures, and reducing other forms of human intervention in the ecosystem and its development.

**III. Restoration and targeted support of (self-) regulating capacity**

The aim is to support specific functions of an ecosystem or a particular site. Measures of this strand can only be effective if measures of the other strands are also implemented. Conversely, measures in this strand complement and support the effectiveness of the others. The targeted development of (self-)regulating capacity is particularly relevant where ecosystems are strongly influenced by human use, where functional efficiency cannot be restored holistically, or where certain effects are to be achieved quickly (e.g. green roofs in cities, hedges in open land). Overall, this strand offers the greatest scope for action but often follows ecosystem design approaches. A clear demarcation to technical adaptation measures is not always given; mixed approaches may be more beneficial.

**IV. Development of enabling factors supporting lines of action I – III**

These enabling factors refer to legislative, regulatory, and other governmental and economic framework conditions. Furthermore, strategic planning and management approaches on a local, protected area, regional, and state-level need to be harmonized with strands I – III to support effectiveness on a holistic level. Education-, awareness- and value-based factors within local and regional society can support all strands in significant ways.

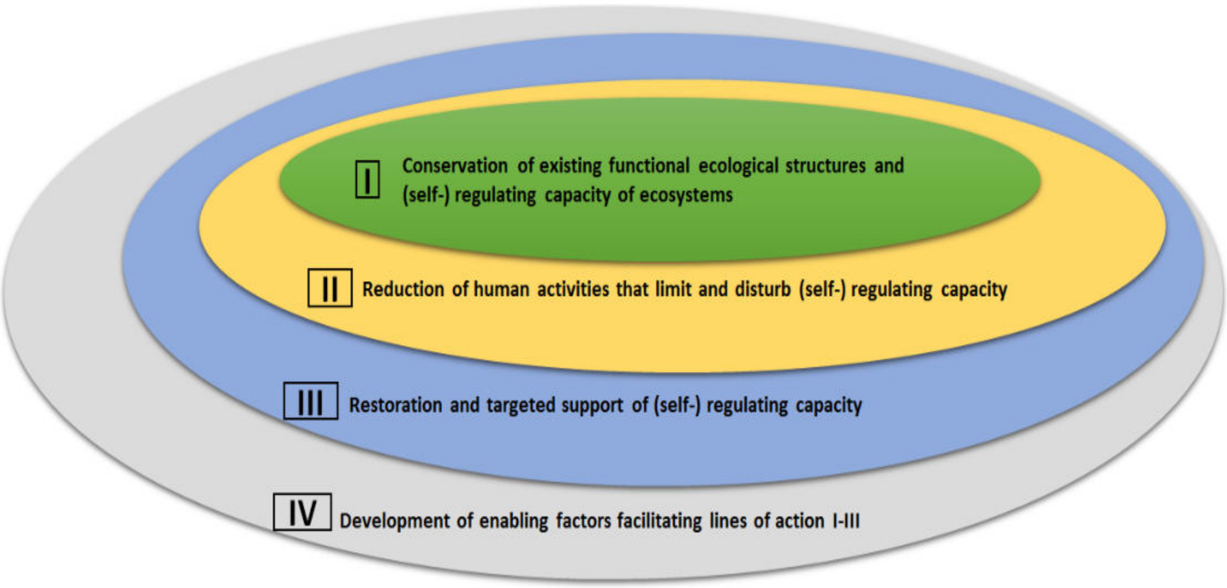



**Figure 17 EbA Lines of Action; Illustration by K. Mack**

# Catalogs - Measures and Activities of Ecosystem-based Adaptation

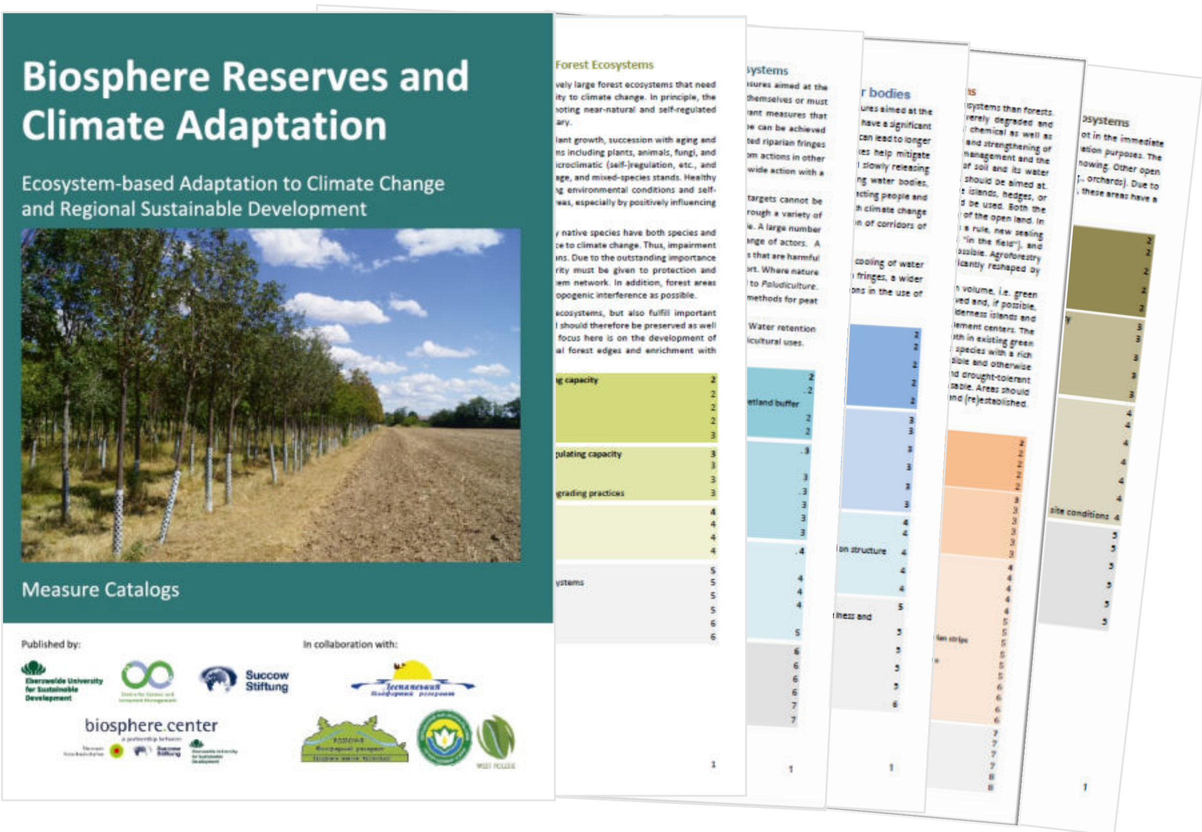
As part of this document series and toolbox, **please find attached separately printed Ecosystem-based Adaptation measure and activity catalogs** for five different ecosystems classes:

- Forests
- Wetlands
- Agricultural lands and Settlements
- Water Bodies
- Grasslands

The catalogs include non-exhaustive lists of measures which, in the best case, can be implemented and upscaled in both protected and non-protected areas. Here, land users, ecosystem managers, and decision-makers can find inspiration and hands-on examples of how conservation, stress reduction, and restoration efforts could look like when considering climate change adaptation options.

As so often, any kind of measure and activity needs to be based on proper analysis of vulnerability and risks, both for ecosystems and social systems and their interlinkage, the overall socio-ecological system. Stakeholders need to be taken into consideration and their needs and concerns seriously heard to minimize maladaptation potential and possible conflicts. By the here suggested MARISCO method, a participatory, adaptive, and holistic management approach to climate change adaptation is offered to accomplish these goals.

It is up to future projects and further action research to extend, complete, and substantiate viable and successful EbA measures and activities. Site-specific changes or more detailed elaboration of single, here proposed measures need to be based firstly on ecosystem functionality indicators, and secondly on social compatibility. Framework conditions such as legal, institutional, financial, and educational play a central role in creating acceptance, participation, and thus the sustainability of projects in the frame of Ecosystem-based Adaptation.



# CONCLUSION AND RECOMMENDATIONS

Man-made **climate change** poses a particular challenge for ecosystems and people living in them. In the worst-case scenario, sharp changes in temperature and precipitation patterns will necessitate a restructuring of the ecosystem as important flora and fauna species become extinct or are replaced. This has direct negative repercussions on human well-being, causes devastation, and social and economic costs.

The main goal of **Ecosystem-based Adaptation** efforts is to safeguard and restore ecosystem functions and thus reduce vulnerability to climate change. Like this, ecosystem services, especially the regulating services such as climate regulation (e.g. cooling) and erosion and flood control (by water retention) are maintained and enhanced. **Ecosystem services** also include provisioning and cultural benefits, vital for human well-being. These efforts are often highly synergetic with ecosystem-based mitigation (e.g. carbon sequestration) efforts in the fields of forestry, agriculture, wetland management, and other types of land use and natural resource management.

Key EbA approaches and examples include:

- **Restoring and maintaining a natural water balance** (e.g. renaturation of peatlands and wetlands), thereby enhancing water retention in the landscape (e.g. dismantling of drainage systems, increasing green infrastructure) as well as **Restoration and revitalization of riverbeds** and riverbanks of channelized small watercourses;
- **Increase above- and below-ground biomass** (e.g. expanding areas of natural and close-to-nature forests, promotion of mixed forests, diverse vertical and horizontal stand structure, natural regeneration, structurally rich agricultural and urban landscapes, organic farming);
- **Abandon harmful land-use practices**, such as forest clear-cuttings, conifer monoculture plantations, drainage of wetlands for agricultural use, deep tillage and use of heavy machinery, monoculture cropping, application of chemical pesticides and herbicides, reduction of structural diversity (field protection strips) as well as illegal land-use practices.

The attached **EbA Measure and Activity Catalogs** provide a first orientation and baseline regarding the potential measures to be considered in several ecosystem classes.

EbA is often advocated as a no-regret or "ultimate" solution in countering climate change. Yet, it is important to also highlight the context-dependency and the fact that it is not a 'one size fits all' approach. A clear, site-specific, and participatory vulnerability and risk assessment accompanied with adaptive, community-based strategy development, as suggested here with the **MARISCO method**, is necessary to maximize the effectiveness and sustainability of separate and interlinked measures and activities. Agol et al. find that "*under certain circumstances, EbA can create opportunities to enable natural systems and people to adapt effectively and respond to climate risks with the right institutional support. However, under the same circumstances, an EbA measure can generate conflicts*". Maladaptation may occur and have negative repercussions on the whole community or certain groups within the same area. While risks and disasters are reduced, it can cause trade-offs for some stakeholder groups, differing in their spatial distribution and timing.

Thus, potential negative consequences or even maladaptation need to be identified as early as possible during vulnerability and risk assessment and considered in the strategy development, project planning, and implementation to alleviate potential risks and costs where possible.[19] Thus, a holistic and systemic approach is recommended, which is both ecosystem-based and people-centered.

In this, **UNESCO Biosphere Reserves** can play a decisive role as they are 'special places for joint learning', socio-ecological systems where nature and culture shall (re-) connect. They are internationally recognized for their biodiversity and cultural values and are important "living laboratories" for the preservation of ecosystems by promoting eco-sustainable human and economic development models as well as by ensuring the continuation of research, education, and the provision of information. All of these are helpful prerequisites when experimenting and learning from Ecosystem-based Adaptation strategies and measures, for countering climate change and its increasingly harmful impacts.

Based on the above mentioned, we recommend:

- to include the **notion and principles of Ecosystem-based Adaptation to climate change in the Adaptation Strategy** as a first step to further introduce the EbA approach in practice to Ukraine. The strategy should be supplemented by the Action Plan with the list of measures, which is necessary for the implementation of the Strategy and supported by sufficient financial resources and separate institutional guidance over its implementation.

- to introduce **EbA-related research into programs and plans** within scientific research activities for biosphere reserves.

- **to support the development and implementation of EbA projects** within the biosphere reserves, to further showcase EbA measures and collect scientific information on their effectiveness in all key ecosystems.

- to **support and strengthen Ukrainian biosphere reserves** and to adjust **respective legal framework and regulations** for matching the UNESCO MAB biosphere reserve principles and requirements (such as zoning, integrated governance, etc.).

- to **introduce changes that are necessary to lay legal grounds for EbA** in respective legislation and by-laws regulating nature-protected areas management, agricultural land use, forests management, wetland and water basins management, and urban planning.

- **to start implementing existing projects and concrete activities with a clear ecosystem-based focus to start countering ongoing climate change.** The annexed **EbA Measure and Activity Catalogs** and elaborated **Strategic Documents** which are already available to the biosphere reserves help to pursue and achieve the set of strategic goals, increase ecosystem functionality, and thus safeguard vital ecosystem services for human wellbeing.

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[19] Agol D, Reid H, Crick F, Wendo H. 2021 Ecosystem-based adaptation in Lake Victoria Basin; synergies and trade-offs. R. Soc. Open Sci. 8: 201847. https://doi.org/10.1098/rsos.201847, accessed 21-12-07