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LOCAL CONSERVATION OF NATURE HERITAGE AS AN IMPORTANT COMPONENT IN THE WATER-ENERGY-FOOD NEXUS APPROACH - A CASE STUDY OF SREBARNA LAKE, BULGARIA

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Abstract

Conservation and sustainable use of natural resources are gaining more and more weight on the world political agenda and are attracting the attention of national governments at the highest level. The Water-Energy-Food (WEF) approach helps to understand the interrelationship between natural resources and human activities such as planning, managing, or consuming water, energy, or agricultural products. The world is currently facing the challenge of providing water, energy, and food for all. Scarce natural resources and the environment are increasingly being exploited, while at the same time the demand for fresh water, agricultural products, and energy increases. In this context, the protection of the quality of the available water resources becomes even more important. The preservation of the quality status of water resources is compromised by excessive exploitation, the introduction of polluting substances of different origins, hydromorphological changes in aquatic habitats, and climate changes. The main aim of this article is to clarify the Water-Energy-Food relationship and determine the current physico-chemical state of Lake Srebarna, which is a protected natural site in Bulgaria, a wetland of international importance, a biosphere reserve, and part of the list of world cultural heritage monuments and natural sights of UNESCO.

Keywords*: Sustainable development; Nexus water-energy-food; Protected areas; lake Srebarna.*

Introduction

Nowadays, society develops in the conditions of a "hyperconnected" world, in which the exploitation of natural resources and the development of society are connected in a complex system [1]. The concept of integrated management of natural resources has existed for years, but due to the diverse and multi-scale interrelationships and interdependencies between individual components in the natural-anthropogenic system, its unambiguous application and further development face certain challenges [2]. Despite intensive efforts by researchers, policymakers, and stakeholders, it is still difficult to identify the impacts throughout the system, and comparisons are significantly hampered [3]. The Water-Energy-Food Nexus approach in the context of sustainable development has been developing particularly intensively over the

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last ten years. Coherence between policies is of primary importance in clarifying the relationship. The application of the so-called "green deal" in Europe, for example, requires unprecedented coordination and coherence between policies, and the outcome is established by developing and using different models and scenarios in the study of the particular relationship. The gradual transition to a circular and low-carbon economy and the protection and efficient use of resource potential to achieve a sustainable future occupy a central place in the Nexus concept [4]. Until now, in the scientific literature, various models, scenarios, and projects dealing with the three vital resource topics in the considered water-energy-food connection have been developed and are being worked on [3, 5-7]. The interactions between the components in the water-energy-food concept can be direct or indirect. Water, for example, plays a critical role in agriculture (in the production of food and feed, for washing premises, for irrigation, etc.). Excessive fertilisation of cultivated areas leads to water pollution, while their purification requires energy. The production and consumption of energy, in turn, are related to its transformation (from one form to another), supply networks, trade, markets, prices, regulations, etc. Food in the water-energy-food system includes food production, both primary (agriculture) and secondary (industrial food processing), and food consumption. Both the production and consumption of food occur through complex service relationships [4]. The formation and change of the quantitative and qualitative characteristics of the three main components in the considered Nexus approach are determined as an integral result of the parallel and interconnected influence of natural factors and conditions and the load on the system from human activity [8]. The world is currently facing the challenge of providing water, energy, and food for all. In this context, the conservation and sustainable use of natural resources and achieving a balance between the functioning of natural systems, economic activities, and the development of local communities require the development of special strategies and the implementation of related activities and policies regarding the study, use, and conservation of natural systems. Their importance is determined by the possibilities of providing different groups of ecosystem services (food, regulatory, and cultural) and many opportunities for economic activities [9]. Today, the Nexus approach is gaining more and more weight on the world political agenda and is attracting the attention of national governments at the highest level.

The main aim of this article is to clarify the Water-Energy-Food relationship and determine the current physico-chemical state of Lake Srebarna, which is a protected natural site in Bulgaria, a wetland of international importance, a biosphere reserve, and part of the list of world cultural heritage monuments and natural sights of UNESCO.

Study Area

"Srebarna" is a maintained biosphere reserve in Bulgaria, included in the UNESCO World Cultural and Natural Heritage List. It is located on the banks of the Danube River, 18km west of Silistra. The lake is a eutrophic lake, one of the most valuable and internationally known protected natural sites in Bulgaria (Fig. 1). As early as 1942, "Srebarna" was announced as a "Breedery for Marsh Birds", and in 1948 it received the status of a reserve. The goal is to preserve the unique biological diversity for which the lake has been known among the European and Bulgarian scientific communities since the end of the 19th century. In 1975, Srebarna was included in the Ramsar Convention for the conservation of wetlands of international importance. The uniqueness of the reserve is due to the sharp rise in the water level in the lake, which leads to periodic formations of floating reed islands (kotchki), which do not flood. The reed islands are difficult to

access for terrestrial predators and are an ideal nesting site for numerous species of birds. In 1977, Srebarna was declared a biosphere reserve, and in 1983, the site was included in the UNESCO list of world natural and cultural heritage. Conservation status was changed in 1999 from strict to maintained reserve to allow wetland management activities. Currently, the territory has the category of "maintained reserve" and covers an area of 892 ha.

Fig. 1. Map of Srebarna Lake

For “Srebarna”, the colony of dalmatian pelicans (*Pelecanus crispus*), a species included in the Red List of Threatened Species, is of the greatest importance. On average, 70–80 pairs nest here annually. About two-thirds of the area of the lake is overgrown with reeds (*Phragmites australis),* papur (*Typha angustifolia*, *T. latifolia*, *T. laxmanii),* and other marsh plants. The open water area is partially covered with common frogbit (*Hydrocharis*), water lilies (*Nymphaea*), and redhead grass (*Potamogeton*). At the northern end of the lake, the reed massifs gradually transition into wet meadows. The "Srebarna" Reserve has a significant diversity of species, communities, and ecosystems. Fifteen plant species with nature conservation status have been identified, e.g., floating fern (*Salvinia natans*), water soldiers (*Stratiotes aloides*), common bladderwort (*Utricularia vulgaris*), marsh fern (*Thelypteris palustris*), and European white-water lily (*Nymphaea alba*). 37 species of fish typical of the Danube ichthyofauna have been described in the lake, and of importance for nature protection are: Danube whitefin gudgeon (*Romanogobio vladykovi*), sunbleak (*Leucaspius delineates*), European carp (*Cyprinus carpio*), Ukrainian brook lamprey (*Eudontomyzon mariae*), European mudminnow (*Umbra krameri*), etc. 12 amphibian species have been described for the area, including lake frogs (*Rana ridibunda*), European tree frogs (*Hyla arborea*), European fire-bellied toads (*Bombina bombina*), great crested newts (*Triturus cristatus*), Danube crested newts (*Triturus dobrogicus),* and 15 species of reptiles [10].

Materials and Methods

Materials

In this article, materials are processed and used in two main directions: literary sources and administrative-legal documents. The literature sources are a review of papers and scientific publications with a focus on the water-energy-food concept. This article is based on a number of conventions, directives, declarations, international agreements, acts, and other documents of an administrative-legal nature, among which are:

- Convention Concerning the Protection of the World Cultural and Natural Heritage Adopted by the General Conference at its seventeenth session in Paris on November 16, 1972. Effective for Bulgaria from December 17, 1975;
- Ramsar Convention: Convention on Wetlands of International Importance Signed on February 2, 1971. Signed by Bulgaria and in force for Bulgaria as of January 24, 1976. According to it, Srebarna is Ramsar site No. 64, declared on 9/24/1975;
- Ramsar Convention Transboundary Wetlands List. Transboundary wetland "Iezerul Calarasi (RO)-Srebarna (BG)" on the territory of Bulgaria and Romania, at the joint request of the Bulgarian Ministry of Environment and Water and the Romanian Ministry of Environment and Climate Change, from April 15, 2013, addressed to the Secretariat of the Ramsar Convention;
- List "Montreux" (Montreux record) of the Ramsar Convention for wetlands with deteriorated ecological conditions and characteristics that require the application of special conservation and management measures. Biosphere Reserve Srebarna was included in the list in 1993;
- Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals) Signed on 6/23/1979. Ratified in Bulgaria on 11/1999;
- Habitats Directive: Council Directive 92/43/EEC of May 21, 1992;
- Directive 2009/147/EC of the European Parliament and of the Council of November 30, 2009 on the conservation of wild birds;
- Water Framework Directive (WFD) 2000/60/EU, which introduces a comprehensive approach to water management in the EU;
- Water Act, effective January 28, 2000 (OG. 67, effective July 27, 1999);
- Environmental Protection Act (OG. 91 on September 25, 2002);
- Protected Areas Act (OG. 9-13 on 11/11/1998);
- Biodiversity Act (77 on 08/09/2002).

Methods

To achieve the aim set in the present article, the methods of analysis and synthesis of literary sources, geographic information systems (GIS) (through which the main spatial characteristics of the research area were visualized), and the Canadian Complex Water Quality Index (CCME, WQI) [11] have been applied (for determining the water quality of Srebarna Lake). According to the applied model above, differentiation of the water quality status could be as follows: excellent (WQI = 95–100); good (WQI = 80–94); fair (WQI = 65–79); marginal (WQI = 45–64); poor (WQI = 0–44). The complex and differentiated evaluation of the physico-chemical status of the studied water body model was based on Ordinance No. N-4/14.09.2012 (concerning the characterization of surface waters) [12] in accordance with Directive 2000/60/EC (Water Framework Directive). The present study was based on the analysis of the values of the indicators: pH, electrical conductivity (EC), dissolved oxygen (DO), ammonium

nitrogen ($N\text{-}NH_4$), nitrate nitrogen ($N\text{-}NO_3$), nitrite nitrogen ($N\text{-}NO_2$), total nitrogen (N-Total), total phosphorus (P-Total), orthophosphates ($P\text{-}PO_4$), and biochemical oxygen demand (BOD_5). The study used verified data from the National Monitoring Network for the only monitoring point, Lake Srebarna, with the code of the water body and the monitoring point as follows: BG1DU000L1003 and BG1DU00992MS011 [10]. The period of the study was 2017–2021. For clarifying the Nexus Water-Energy-Food, a number of regulations were also used, for example, the Tourism Act (2013), the Environment Protection Act 2002, the Biodiversity Act 2002, the Protected Areas Act 1998, etc. The obtained results have been referred to as the Water-Energy-Food Nexus.

Results and discussion

Brief overview over the Nexus approach

The Water-Energy-Food Nexus approach links three interdependent, scarce, and valuable resources for human development. The complex connections in the system, both quantitative and qualitative, are diverse in scale and degree of impact. For example, the production of food requires the use of large amounts of water; moreover, many foods contain water as their main ingredient; the delivery and distribution of food products use energy; and water and food are both sources of energy (hydropower, bioenergy, etc.). According to UN global predictions, the world population is expected to grow by 30% (reaching 9.5 billion people) by 2050. In this perspective, the demand and consumption of natural resources are expected to grow exponentially, and this in turn will inevitably lead to increasing competition for resources and the emergence of more conflicts than synergies in ensuring food, water, and energy security for the population. The OECD's Environmental Outlook Report predicts that global primary energy demand will increase by 40% by 2030 and a further 30% by 2050, and global water demand will increase by 55%. Under these conditions of intense demographic pressure and increasing competition between natural resources, the Nexus approach can be crucial in overcoming the challenges facing humanity. The water-energy-food connection is a current topic of research, reflecting the importance of the three sectors for society. From a practical perspective, the approach represents a conceptual macro-framework for better understanding and systematic analysis of the interactions between the natural environment and human activities. This contributes to the identification and management of existing trade-offs and to building synergies for integrated and cost-effective planning, decision-making, implementation, monitoring, and evaluation. Although the presentation of the tripartite interaction in the Water-Energy-Food Nexus approach appeared in 2008, and the promotion of developing and analysing a range of approaches in different contexts continues, the concept is still insufficiently implemented in practice [13]. The main message from the 2011 Bonn conference is the need for a new approach focused on providing water, energy, and food for humanity and addressing unsustainable growth patterns. The questions raised at the conference are practically the first official published recognition of the tripartite interplay between water, energy, and food [13, 14]. Water, which is considered the key to food security, takes a leading place at the forum. The connection between water and food is elementary and is expressed in the need for water for the development of agricultural crops and animals. On the other hand, agriculture and energy are closely related. From producing fertilisers to processing and transporting food to market, fossil fuels are necessary to sustain industrialised agriculture and business. In addition, global biofuel production has increased, and traditional food crops are being diverted primarily to energy production. Climate change, increasing demand for

resources, and water scarcity can threaten the long-term viability of energy projects and hinder societal development. In this regard, the challenges in the production and transmission of energy, which require the use of large amounts of water resources, especially for hydroelectric, nuclear, and various sources of thermal energy, are also increasing [7, 13]. The main goal of the proposed conceptual cross-sectoral framework in the water-energy-food approach is to present as starting points the three dimensions of sustainable development, etc., in the green economy: social, economic, and ecological. Water, energy, and food are the basic prerequisites for our existence; without them, there is no life. However, there is still no generally accepted definition of the relationship, as a result of which quite a few organisations and authors interpret the essence of the relationship quite differently. The actual number of nexus sectors also differs [13], focusing sometimes on only two sectors or extending the connection to additional sectors, for example, climate change, ecosystems [15], and livelihoods. Sometimes food is replaced by land, and so on. The connection context also varies greatly from cities to transboundary water bodies, etc. [13, 16].

Values of water-related heritage and challenges for well-being

The United Nations Educational, Scientific, and Cultural Organisation (UNESCO) promotes the identification, conservation, and promotion of the world's cultural and natural heritage that is of outstanding value to humanity. The desire to protect the world's heritage is expressed in the Convention for the Protection of the World Cultural and Natural Heritage, adopted by UNESCO in 1972. The most significant feature of the Convention is that it combines in one document the concepts of preserving nature and protecting cultural values. The Convention appreciates the interaction between man and nature and the fundamental need to maintain a balance between them. Bulgaria became a member of the Convention in 1974 and was one of the first 20 countries to sign it. Cultural heritage includes monuments, groups of buildings, and objects with historical, aesthetic, archaeological, scientific, ethnological, or anthropological value. Natural heritage refers to exceptional physical, biological, and geological formations, habitats of endangered species of animals or plants, and localities of scientific, nature conservation, or aesthetic value. The objects of cultural and natural heritage under the Convention are entered on the World Heritage List. Heritage is what is bequeathed to us from the past, what we live with today, and what we pass on to future generations. On the basis of its qualities, the World Heritage List is inscribed with the best examples of cultural and natural heritage in the world. World Heritage Sites belong to all of humanity, regardless of where they are located. The inscription of a site on the World Heritage List gives it special status and protection and is a source of national pride. At the same time, the inclusion of objects in the UNESCO list carries a great deal of responsibility for the respective countries. The exceptional global value of natural and cultural sites provides a higher level of public awareness, thus increasing their interest and tourist appeal. When the management of a site is carried out in accordance with the principles of sustainable development, significant financial resources can be attracted to the site itself and to the local economy. For the identification, protection, and promotion of the World Heritage sites, the States Parties to the Convention may also receive financial support from the World Heritage Fund.

The role of heritage (natural and cultural) typically demonstrates a community's emotional well-being, identity, and contribution to the place. This, in the most general sense, is the result of both the interaction of people in the social system and with the environment in which they live [14]. In their existence and development, natural and cultural sites are gradually becoming destinations with a focus on so-called heritage tourism [17, 18].

Qualitative and quantitative analysis in the water-energy-food Nexus approach helps to understand in more detail the interrelationships among the existing critical dependencies and helps to reduce trade-offs. In this sense, the prepared and implemented policies have a significant place because, very often, the insufficient or absence of intersectoral cooperation is the result, apart from the lack of appropriate mechanisms and approaches, but it is also closely related to the striving for influence between different sectors and participants [19, 20].

Local conservation of nature heritage, ecosystem opportunities and some transboundery aspects

The purpose, management goals, mode of protection, and use of the resources of the maintained reserves in our country are determined by the Protected Areas Act [21]. For each specific protected area, depending on its characteristics, the requirements of the law are specified and further developed through its respective management plan. It defines the natural and socio-economic significance (world, European, and national) of the territory. The Srebarna Maintained Reserve Management Plan outlines the long-term goals and risks for the reserve. The objective choice in the management approach is related to the protection of the biodiversity of the complex wetland, with emphasis on the preservation of rare and protected habitats, plant species, and birds. Their value is determined by their status according to the IUCN lists, the EU Habitats Directive, the EU Birds Directive, the Ramsar Convention, the Bern Convention, the UNESCO List of World Cultural and Natural Heritage Sites, the Biodiversity Act, the Red Lists at the national level, and the Red Book of the Republic of Bulgaria [10]. The management plan also contains a description of the programmes, measures, and projects whose implementation will lead to the achievement of management goals. The document takes into account the necessary conditions for prospective nature-friendly management, educational value, local socio-economic and cultural conditions, access to the tourist routes of the reserve, etc.

The maintained reserve "Srebarna" covers Lake Srebarna, the adjacent section of the Danube River, and Devnya Island. This is the first Bulgarian Ramsar site, No. 64, announced on September 24, 1975. Recently, due to a highly disturbed water balance, "Srebarna" has been included in the "Montreux Record" list of the Ramsar Convention on Wetlands as a wetland with deteriorated ecological conditions and characteristics, which necessitates the application of special conservation and management measures. In connection with this and as a result of the joint efforts of stakeholders and institutions coordinated by the MOEW, it has now been successfully excluded from the list [10]. Today, the purpose of the maintained reserve "Srebarna" is to protect the conservationally important species and natural habitats of the complex wetland. Wetlands are one of the most dynamic and sensitive natural systems. Different wetlands provide a range of goods and support constant human activities. Research on wetland systems provides good opportunities to study natural processes and anthropogenic impacts over a short period of time. Wetland system transformation is linked to the level of ecosystem services. The concept of ecosystem services develops the possibility of assessing conditions in space and time in a changing world. The Biosphere Reserve "Srebarna" is one of the most famous and rich in landscape and biological diversity protected areas on the Bulgarian section of the Danube River. The study of the spatial characteristics and dynamics of ecosystem services is a current issue related to the transformation in the wetland system and ecosystem service parameters as a result of natural evolution and continuous human impact [22, 23]. In this sense, the landscape diversity and the state of the Biosphere Reserve are formed under the influence of various anthropogenic forms of pressure and impacts. The maintained reserve "Srebarna" and the settlements in its adjacent territories have opportunities for the development of agriculture and tourism. The main activities of the population in the villages of Srebarna,

Vetren, and Aydemir are the cultivation of wheat, corn, sunflower, rapeseed, and vegetable production. In the village of Vetren, there are massifs of permanent plantations—vineyards, apricots, walnuts, and hazelnuts—and the old part of the village has been restored with the characteristic Vetren houses. The development of livestock breeding is limited to private holdings, where mainly sheep, goats, and cows are raised. Fishing along the Danube River is developed, as is wild goose hunting in winter. In all three settlements, there are traditions of making products from reeds (*Phragmites australis*) and papur (*Typha)*. The offer of various tourist products and the possibilities for their combination are a good opportunity for the development of the reserve and its adjacent territory. For example, the traditional summer welcome of the rowing regatta on the Danube is a prerequisite for welcoming guests from different, mainly European, countries. At that time, the festival of the Danube takes place. In the village of Srebarna, there is a natural museum with an exhibition of stuffed inhabitants of the reserve. There is also an eco-trail with gazebos for rest and observation decks. Srebarna Biosphere Reserve has the capacity to develop rural tourism combined with culinary, wine, and other types of tourism. The protected area "Pelikanites" and the surroundings of the maintained reserve "Srebarna" are exceptional places for recreational and ecological tourism. Sustainable development, conservation of species, and opportunities to optimise tourism activities are based on the balanced management and use of the natural and cultural heritage in the area. For this purpose, it is necessary to conduct coordinated and consistent policies for the protection, restoration, monitoring, and control of the ecosystem [24]. The conservation of the landscape requires not allowing changes that will disturb its natural characteristics. The main feature of the biosphere reserve is that it is a complex wetland consisting of a river, a flooded island, and a lake with its adjacent low coastal areas. The Danube River marks the northern border of the study area and has an important landscape-forming role, especially in the riverside and island sections. The ecological condition of this section of the Danube River is formed under the influence of various forms of pressure and impacts outside the boundaries of the maintained reserve and even outside the boundaries of the Bulgarian Danube sector. The proximity of the site to our northern border is a good prerequisite for cross-border cooperation, as expressed in the development of an integral plan for managing the cross-border system of protected areas in Bulgaria and Romania. Placing the focus of the current discussion on the water-energy-food nexus in the specific context of transboundary water bodies means that the emphasis should be directed towards integrated and sustainable water management.

The nexus approach to management aims to reduce trade-offs, enhance synergies between individual components, and encourage participants to cross their sectoral and disciplinary boundaries, which act as boundary concepts. In the specific case, for the realisation of profitable solutions and efficiency of use of resources, the nexus approach between Bulgaria and Romania makes it desirable to integrate intersectoral relations at the value, normative, pragmatic, and empirical levels [25]. The value level corresponds to disciplines concerned with values and ethics; the normative level focuses on laws, policy, and planning; the pragmatic ones reflect management and technological disciplines; and the empirical level provides a better understanding of the biophysical and social world [13].

As a result of the analysis performed of the local conservation of natural heritage in Bulgaria (Srebarna Lake), the following conclusions can be drawn:

The policies implemented for sustainable management of natural resources may reinforce or counteract each other. When synergy is emphasised in relationships, efficiency and effectiveness increase, and negative trade-offs are prevented, mitigated, or compensated for. The gradual transition to a circular and low-carbon economy and the conservation and efficient

use of resource potential to achieve a sustainable future are central to the Nexus concept. Wetlands are: ecosystems in which water is the primary factor on which ecological conditions and associated animals and plants depend; have an important role in the water cycle by restoring water reserves and feeding groundwater; protect against flooding; take a special place in people's lives as a water source, fishing place, herb gathering place, animal husbandry, etc. The fertile soils around them are suitable for agricultural activities. In addition, wetlands offer good conditions for recreation and tourism.

Current physico-chemical state of Srebarna Lake

Changes in water quality and quantity have a direct impact on the local environment and population. Water is in many ways a local resource, but at the same time it is also a global one. Nowadays, the sustainable management and protection of water resources occupies a central place in environmental policies at the local, national, and supranational levels. The ecological condition of water ecosystems, including wetlands, depends on the physicochemical characteristics of the water, which determine its quality, which is necessary for various purposes.

The analysis and assessment of the quality state of the lake waters in the "Srebarna" Biosphere Reserve are based on data provided by the Executive Environment Agency (ExEA) to the Ministry of Environment and Water (MOEW) for the period 2017–2021. The analysis shows that in the period 2017–2021 (with the exception of 2020, for which there is no data), the water body falls into two quality categories: good and fair. Figure 2 shows the distribution of the values of the applied complex index by year.

According to the obtained results, the quality of the lake waters fully fulfils the criteria for a good physico-chemical state, as the established values of the index are, respectively, for 2017 and 2018: WQI=93.9, for 2019 - WQI=83 and for 2021 - WQI=70.9. The differentiated assessment shows that the most common indicators, whose values exceed the regulated values up to 10 times, are dissolved oxygen, total N, total P, and BOD_5. The values of the other indicators remain within the norms.

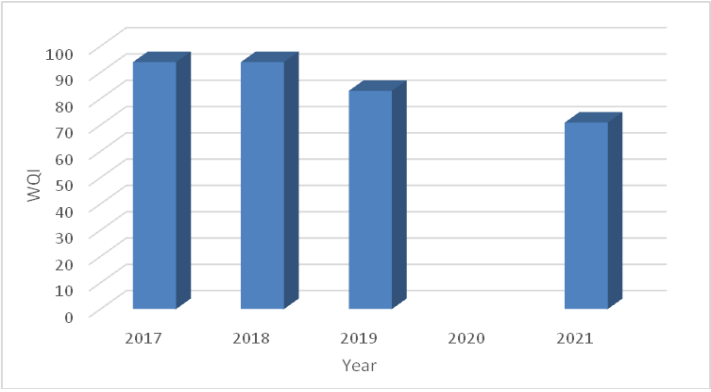

Fig. 2. Changes in the values of the water quality index of the Srebarna lake for the period 2017-2021

Lake Srebarna is a wetland whose water quality characteristics are determined by a complex of factors, among which are the deposition of different sedimentary materials, eutrophication, the lake's water regime, climate change, etc. [26]. Water, energy, food, and, in particular, ecosystems form a relationship that is of particular importance in providing resources and services that meet the needs of the population (food, social, cultural, etc.). Overcoming

modern challenges requires cooperation, often cross-border, through a multidisciplinary and cross-sectoral approach in the interest of the economic and environmental needs of society.

Conclusions

Interactions between components in the Water-Energy-Food concept can be direct or indirect. The formation and change of the quantitative and qualitative characteristics of the three main components in the considered Nexus approach are determined as an integral result of the parallel and interconnected influence of natural factors and conditions and the load on the system from human activity. Given the special state of Lake Srebarna Biosphere Reserve and the vital role of water in all aspects of our lives, the adoption of a more balanced and integrated approach within the framework of intersectoral policies corresponding to the Nexus approach of Water-Energy-Food will help preserve the planet's water wealth and the heritage associated with it. This necessitates the development of innovative solutions to address the challenges in the water sector and the implementation of a policy to support the development of innovative technologies and business models to improve water quality characteristics.

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