NEPAT-DIGITAL TOOL FOR HOLISTIC MANAGEMENT OF WEFE SECTORS. STUDY CASE: JIU-DANUBE HYDROGRAPHICAL AREA

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Abstract. The digitalization process of various fields of activity is a challenge and an ambitious target for governments in various EU member states, but especially for Romania. The need to develop digital tools that can be successfully used in various fields of activity has become more important than ever. The purpose of these tools is to make management decisions at an intersectoral level targeting vital sectors of the economy at a regional level in Romania and beyond. The Nexogenesis project was promoted and implemented in this context and focused on the cross-sectoral management of 4 areas essential to the socio-economic development of a river basin - water, energy, agriculture as a source of food and ecosystems (WEFE for short). As case studies for this project, 5 pilot river basins were selected, transboundary river basins for which the 4 WEFE domains represent the essence of economic and social development in the regions to which they belong. One of the results of the Nexogenesis project is the NEPAT instrument, an interactive platform designed to analyze the interconnections between water, energy, agriculture and ecosystems (WEFE) under various climate and socio-economic scenarios. The paper aims to present the concept around which the Nexogenesis project was developed, to introduce the Nepat digital tool, to present its functionality and to highlight its importance in cross-sectoral decision-making in the fields of water-energy-agriculture-ecosystems.

Keywords: nexus, Nexogenesis, NEPAT, cross-sectoral management, WEFE.

Rezumat. NEPAT-instrument digital pentru managementul holistic al sectoarelor WEFE. Studiu de caz: Spațiul hidrografic Jiu-Dunăre. Digitalizarea diferitelor domenii de activitate reprezintă o provocare și o țintă ambițioasă pentru guvernele din diferite state membre ale UE, dar mai ales pentru România. Necesitatea dezvoltării unor instrumente digitale care să fie utilizate cu succes în diferite domenii de activitate a devenit necesară mai mult decât oricând. Scopul acestor instrumente este de luare a unor decizii de management la nivel intersectorial ce vizează domenii vitale ale economiei la nivel regional în România și nu numai. Proiectul Nexogenesis a fost promovat și implementat în acest context și s-a concentrat pe managementul transectorial a 4 domenii esențiale dezvoltării socio-economice a unui bazin hidrografic - apă, energie, agricultură ca sursă de hrană și ecositeme (pe scurt WEFE). Ca studii de caz pentru acest proiect au fost selectate 5 bazine hidrografice pilot, bazine hidrografice transfrontaliere pentru care cele 4 domenii WEFE reprezintă esența dezvoltării economice și sociale în regiunile cărora le aparțin. Unul din rezultatele proiectului Nexogenesis este instrumentul NEPAT, o platformă interactivă concepută pentru a analiza interconexiunile dintre apă, energie, agricultură și ecosisteme (WEFE) în diverse scenarii climatice și socio-economice. Lucrarea își propune să prezinte conceptul în jurul căruia a fost dezvoltat proiectul Nexogenesis, să introducă instrumental digital NEPAT, sa-i prezinte funcționalitatea și să evidențieze importanța acestuia în luarea deciziilor intersectoriale din domeniile apă-energie-agricultură-ecosisteme.

Cuvinte cheie: nexus, Nexogenesis, NEPAT, management trans-sectorial, WEFE.

INTRODUCTION

Water, energy, food, and ecosystems create an interconnected nexus: the WEFE nexus. For example, water supply demands energy, and water is used to generate hydropower, which alters river flows and ecosystem functioning. Water and Energy are intimately connected in cities. Irrigated agriculture for food consumes 70% of global water withdrawals. Fertilizers damage ecosystems and require energy to produce. Land conversion impacts ecosystems, and expansion in agriculture leads to water pollution, reducing the quality of ecosystem services. About one-third of global food production is lost or wasted. Food demand targets can be met with limited land expansion (BREZEANU et al., 2011; DUDĂU et al., 2011).

Fossil fuel energy resources must be substituted for cleaner sources more rapidly. The potential for solar and wind energy is substantial. The production of energy crops conflicts with food production targets. The combustion of fossil fuels impacts the climate, hydrological cycles and ecosystems. Water demand may rise by 40% (90% in cities), energy by 50% and food by 35% by 2050. Water, energy, food, and ecosystems (the WEFE nexus) are interconnected and are influenced by climatic and socio-economic drivers. Resource constraints and the general lack of consideration by policies of various interconnections could hamper economic development and resource security itself, as well as affect actor behavior and policy formulation initiatives (https://circabc.europa.eu-hymo_technical_report, 2006).

MATERIALS AND METHODS

The materials used in this research are the official documents existing in the Jiu Water Basin Administration, the management plans at the national level and at the hydrographic basin (HB) level, the plans for flood risk management at the level of the Jiu-Danube River Basin, the summaries of the quality of water bodies in HB Jiu, the national and European legislation for all WEFE sectors, software, specialized literature, online resources, including scientific articles (DUDĂU, 2010; www.abajiu.ro).

The methods are focused on the use of participatory observation, statistical analysis and comparative analysis of data, analysis of existing textbooks, guides and support resources. To evaluate the usefulness of the NEPAT tool, semi-structured interviews were conducted with users from the WEFE fields or experts from the digital field for a clearer perspective on the importance of using this tool. The comparison of different digital tools was also considered in order to evaluate their efficiency and functionality in the practical activity (https://circabc.europa.eu-hymo_technical_report, 2006).

RESULTS AND DISCUSSION

1. Overview of the Nexogenesis project. NEXOGENESIS is a 4-year European collaborative project financed by the European Commission under the Horizon 2020 programme. It gathers 20 partners from Europe and South Africa focusing on facilitating the next generation of effective and intelligent water-related policies using artificial intelligence and machine learning to assess policy impacts on the WEFE nexus to suggest new ways to design better, more harmonious policy. For an in-depth research of the WEFE domains and for results that have a practical utility in these fields, the Nexogenesis project considered 5 case studies, namely 5 transboundary river basins, of which 4 are located in Europe (Nestos, Lielupe, Jiu, and Adige) and one is located in South Africa (Inkomati-Usuthu).

NEXOGENESIS project will develop and validate 3 solutions: a cross-sectoral policy-making framework developed for and validated by stakeholders; a Self-Learning Nexus Assessment Engine taking different aspects into account and exploring the consequences of possible policy options; a WEFE Nexus Footprint to track impacts of policy objectives and communicate results in a more digestible way (Fig. 1).

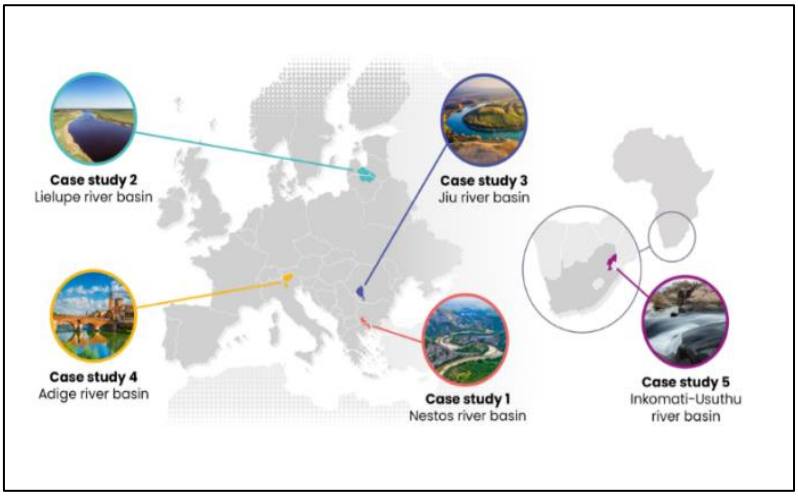

Figure 1. Geographical position of the 5 pilot river basins within the NEXOGENESIS project (original).

The Nestos River Basin - covers 5,479 km2 and crosses the Bulgarian-Greek border in the southeastern part of Europe. The Lielupe River Basin has a catchment area of 17,788 km2, divided between Latvia and Lithuania, and the Jiu River Basin is an important part of the lower Danube River basin representing a border area of Romania with Bulgaria and Serbia. The Adige River is the second longest river in Italy, with a length of 409 km and a catchment area of 12,100 km^2.

2. The nexus concept. Changes in the WEFE nexus are driven by changes in biophysical (climate, precipitation, land cover) and human (economic development, agriculture, urban growth) conditions. Continuing current consumption rates imply deepening resource and ecological deficit – when resources are extracted at a faster rate than they are replaced. To effectively manage resources and avoid conflicts between users, many relevant policies must be intelligently designed to address nexus interconnectedness across spatial scales.

The European Commission (EC) has developed an initiative for a resource-efficient Europe. However, EU-wide policies (Water Framework Directive (WFD), Renewable Energy Directive (RED), Common Agricultural Policy (CAP)), have been developed 'sectorally' and the EU Green Deal are developed without fully considering trade-offs between objectives, leading to conflict and fragmentation with little consideration of impacts on other sectors and stakeholder relationships, with inefficient and sub-optimal markets and trade in resources as result. Recently, research has shown that billions of euros have been misspent, sometimes at the cost of environmental protection. An integrated approach is urgently needed. At the same time, it is recognized that managing the WEFE nexus effectively is extremely challenging due to the complexity and interconnectedness of the system. Current fragmentation in policy formulation, along with advances in research, offer an opportunity to improve policy design and the policy design process based on the latest science and research across disciplines (https: lege 5.ro, 2022).

A better understanding of the impact of policies on the WEFE nexus by exploiting artificial intelligence tools to assist policy makers in guiding integrated policy design is required if sectoral synergy is to be achieved. Such improved

understanding will facilitate coherent water-related policy design to achieve resource use efficiency, leverage synergies, and promote sectoral cooperation. The problem can be stated as a combination of: (a) a complex, poorly understood water-energy-food system; (b) the lack of ecosystem integration into the WEF system; (c) sectoral policy development; (d) a lack of understanding on how policies impact the WEFE nexus. Understanding the mutual response of biophysical and human system components to policy implementation is in its infancy, a gap that NEXOGENESIS seeks to fill so that nexus policy formulation and integration can be optimized for effective streamlining while addressing resource (i.e. trade), transboundary (e.g. diplomacy), and stakeholder concerns.

GENERAL PRESENTATION OF JIU-DANUBE HYDROGRAFICAL AREA

Romania is divided into 11 districts or river basin administrations (Fig. 2). These ensure the water management for the most important rivers and their tributaries, the catchment area of a stream being the area from which the flow of that stream is collected (CIOBOIU & BREZEANU, 2012; 2014).

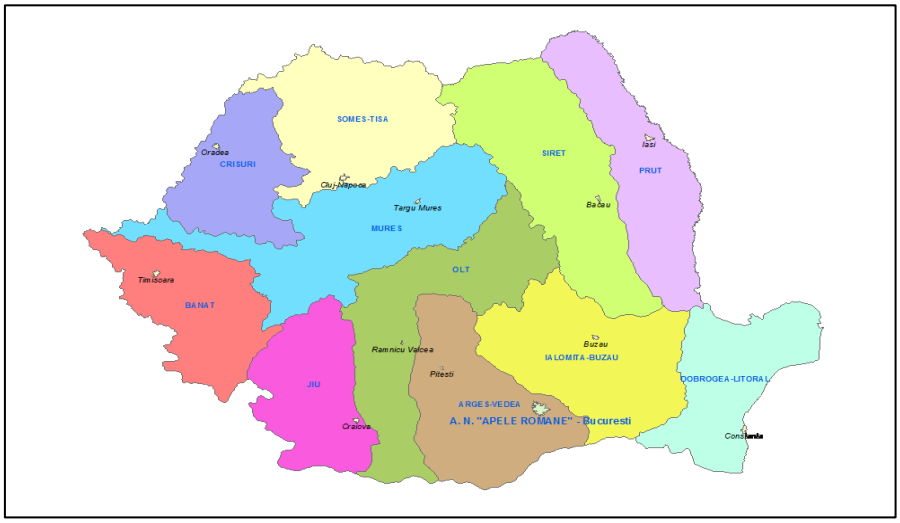

Figure 2. The main river basins in Romania (according to the Rivers Basin Management Plans, N.A. Apele Române, 2009).

Two types of watersheds can generally be distinguished: the open, surface watershed and the closed, underground watershed. The line that delimits the watershed is called the watershed, an area characterized by the runoff transmitted to a receiver. The Jiu River Basin is one of the 11 designated river districts in Romania, and table 1 presents the main river basin administrations in the country, the area drained by the major rivers and their tributaries, as well as the percentage of the country's territory drained by them (CIOBOIU & CISMAȘIU, 2016).

Table 1. The main river basins in Romania (according to the Rivers Basin Management Plans, N.A. Apele Române, 2019).

Nr. crt.	The administrations of the main river basins in Romania	Surface of the river basin administration (km²)	Percentage (%) of Romania's area
1.	Someș – Tisa	22.380	9,42
2.	Crișuri	14.860	6,30
3.	Mureș	28.022	11,80
4.	Banat	18.320	7,84
5.	Jiu	16.734	7,05
6.	Olt	24.050	10,13
7.	Argeș – Vedea	20.911	9,28
8.	Ialomița – Buzău	22.289	9,40
9.	Siret	28.678	12,08
10.	Prut	20.328	8,56
11.	Dobrogea Littoral including Danube Delta with 4318 km²	16.610	5,31

The Ministry of Environment and Forests coordinates the water management activity through the National Romanian Waters Administration, under its subordination, which is a regional water management authority at the level of each hydrographic basin, represented by the water basin administration (ADLER et al., 2013). The latter may have three or more county water management systems (SGA) subordinated to it, as well as one or more independent hydro technical systems (SHI). The institution that ensures the water management for the Jiu River basin is Jiu Water Basin Administration, which manages the Jiu-Danube hydro-geographic space (16,734 km²) of which 10,080 km² belong exclusively to the Jiu River and its tributaries (Fig. 3).

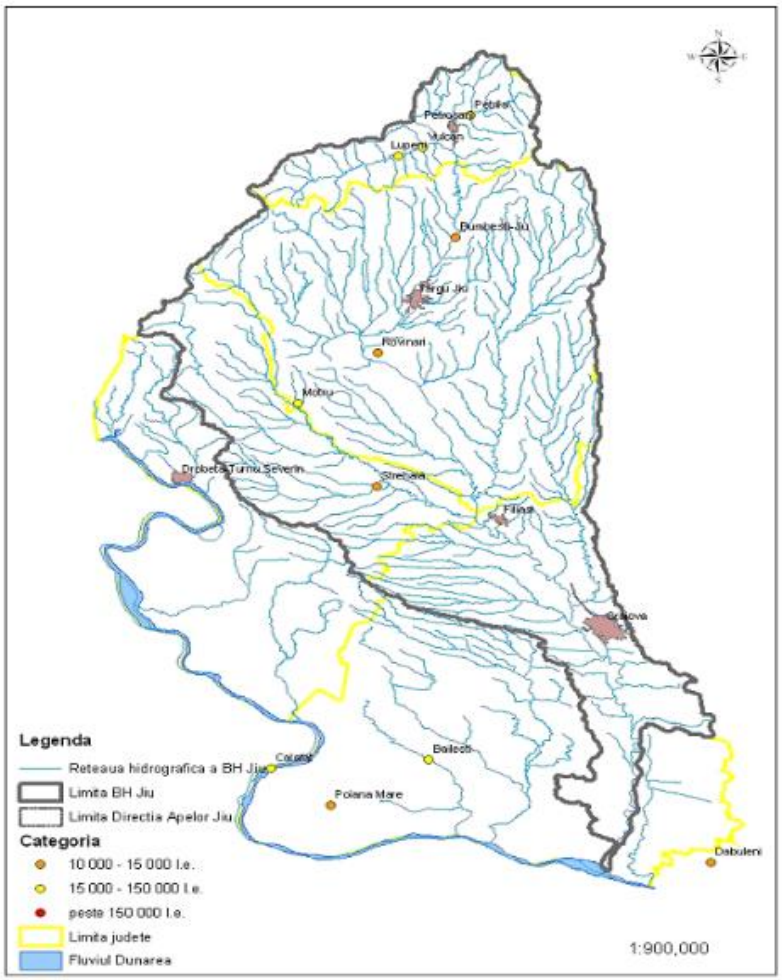

Figure 3. Administrative map of the Jiu River Basin (according to the Jiu Basin Management Plan, Report 2009).

3. The water resources users in the Jiu River Basin. The total surface water resources in the Jiu River Basin amount to approx. 677.448 million m3/year (Table 2), of which approximately 2109.5 million m3/year are usable (according to the Jiu River Basin Management Plan).

Table 2. Distribution of water volume by source in the Jiu River Basin (www.abajiu.ro).

Name of the River Basin	The water sources	Volume (Millions cubic meters)
JIU	Surface water bodies	**624,63682**
	Ground water bodies	**52,81119**
	TOTAL	**677,44800**

Unlike other rivers, the Jiu River does not have important tributaries, its stock being almost uniform along its entire course, a fact that is more clearly expressed by the variation of the multiannual average flow along its course (Sadu 21.6 m^3/s, Filiaşi 63.9 m^3/s, Rovinari 45.6 m^3/s and 87.7 m^3/s at the confluence with the Danube, but also areas poor in resources such as the Amaradia basin (2.6 m^3/s). In the following table (Table 2; Fig. 4) we have centralized data regarding the balance of surface water and groundwater in the main counties of the Jiu River Basin, which overlap with the researched water body, values expressed in million m^3 per year (according to the Jiu WBA) (DUDĂU, 2013).

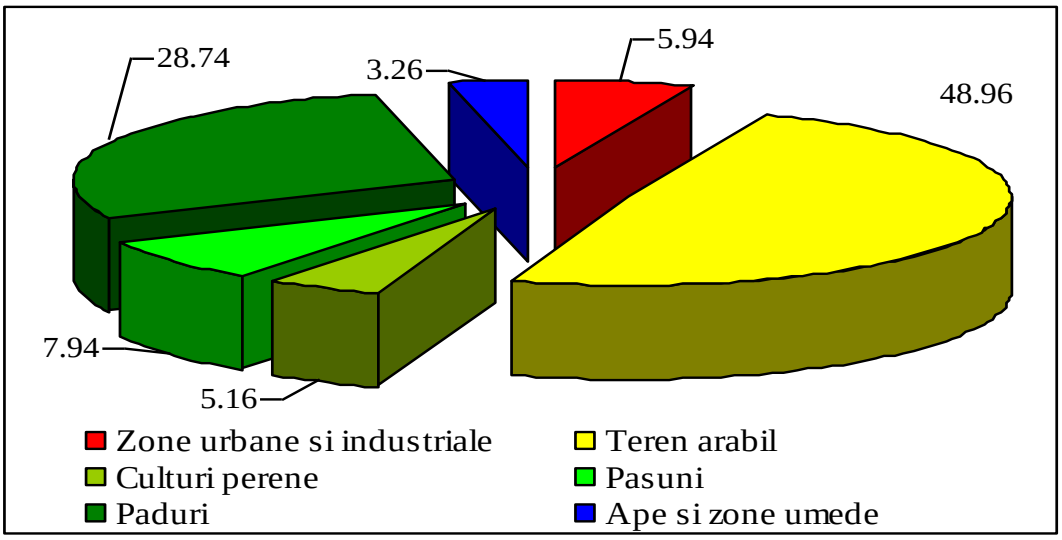

Figure 4. The land use in Jiu River Basin (according to the Jiu River Basin Management Plan Report).

4. The energy production in Jiu River Basin and in Romania. As can be seen in figures 5 and 6, the main source of energy in Oltenia is the coal. A major influence on the environment is the thermal power plants from Rovinari, Turceni, Işalniţa and Craiova, which use coal extracted from different areas of the Oltenia coal basin for energy purposes (ADLER et al., 2013).

Figure 5. Jiu Catchment area position in Lower Danube Area (https://nexogenesis.eu/case-study-3-jiu-river-basin-lower/).

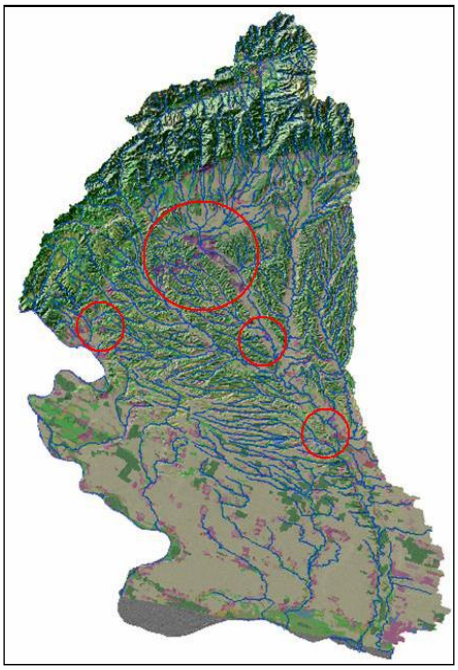

Figure 6. Main areas affected by energy activities in the Jiu River Basin (according to the ISSWaP Report).

Romania is in the midst of a transition process towards ensuring energy security through the production of electricity from renewable sources. The European Green Deal, with ambitious targets for the coming period at the level of all member states regarding the reduction of carbon emissions, the recent turbulence on the energy markets in Europe or the effects of the conflict in Ukraine will influence the medium and long-term strategy for Romania (Fig. 7).

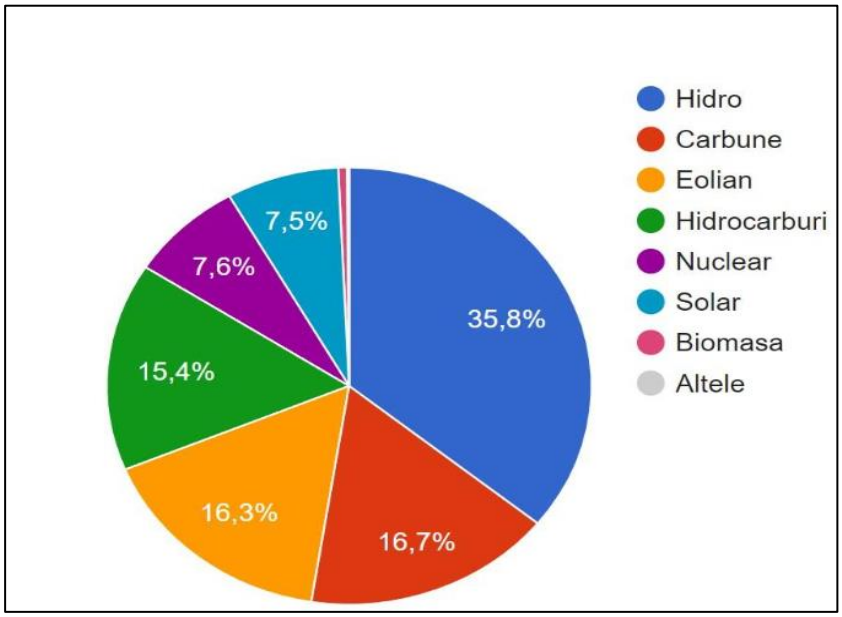

Figure 7. The main sources of electricity production in Romania (CEZ source, 2021).

In 2021, Romania's electricity production came from 16,3% wind power, 7,5% solar photovoltaic and 35,8% hydropower. In total, green energy production (wind, photovoltaic and biomass) represented 16% of the total. In terms of energy consumption, according to Eurostat data, in 2019, just over 24% of energy consumption came from energy sources, placing Romania in 10th place in the EU and above the Union average. Agriculture, as a source of food and a major consumer of water, is in continuous dynamics in the SW region of Romania, the dominant crops in this area being represented by rapeseed, wheat, sunflower, oats, corn. The supply of drinking water to the population has an upward trend as a result of projects to expand drinking water supply and sewage networks. This makes the availability of water in the near future a major problem in the context of climate change (https://apanova.ro/blog/).

Following the application of the requirements formulated in European and national legislation, 228 protected areas of European interest and 21 areas of national interest have been designated for the territory administered by ABA Jiu; there are 19 surface water catchments for drinking purposes (approx. 3,868 km of river), 135 groundwater catchments (with a protection area of 1,459 km2), 41 river sectors or small rivers with economically important species (especially *Salmo trutta fario* - brown trout, on a length of approximately 665 km of river and an area of 0.82 km2 of lake).

5. NEPAT- an important result of the NEXOGENESIS project. The "Food-Water-Energy Nexus" highlights the critical interdependence between the three fundamental resources for life and the economy. It has been found that the management of one resource directly affects the accessibility and sustainability of the other two. The main objectives of the concept are: increasing efficiency in resource use to meet increased demand, reducing environmental impact, including greenhouse gas emissions and water consumption, ensuring resource security to prevent conflicts and social instability. Key principles of the nexus concept are: sustainability - resources must be used without compromising future regeneration capacity and efficiency-losses of food, water and energy must be minimized. NEXOGENESIS develops tools aimed at facilitating cross-sectoral policy-makers dialogue for integrated WEFE resource planning, management and security.

The tools benefits include: NEPAT tool, that allow optimization of natural resource management, contributing to the creation of water smart societies in a more resilient world and increase acceptance across all sectors through multi-sectoral and multi-stakeholder dialogues and better identification of policy packages. NEPAT is an interactive platform designed to analyze the interconnections between water, energy, agriculture and ecosystems (WEFE) under various climate and socio-economic scenarios.

Developed as part of the Nexogenesis case studies, it offers the following key functionalities: policy impact assessment: analyzes the effects of policies on WEFE sectors under future scenarios that integrate climate projections (RCPs) and social projections (SSPs). Nepat tests an AI tool for public policy applications, which provides personalized suggestions to effectively achieve nexus objectives, facilitates collaboration and encourages informed dialogue through shared decision-making on WEFE challenges.

The main nexus issues generate by the Jiu-Danube hydrographical area are: challenges results from competing interests regarding water availability, in terms of quantity, quality and associated risks management. Hydropower production requires a precise amount of water to maintain electricity production even during dry periods, which directly competes with the irrigation water demand in the agricultural sector and also with the population water supply assurance. Agricultural activity in the basin further affects the groundwater availability, thus jeopardizing the main water supply for the 1.5 million inhabitants of the region.

The energy production both in the northern upstream (to include transition towards alternative energy sources) and in southern downstream regions (hydropower) impact the water resources and surrounding environment. Floodplain restoration projects are already initiated in the region demonstrating nature-based approach to climate change adaptation and socio-economic co-benefits. Further steps are currently designed by the river management plans aimed at promoting ecological connectivity for enhanced biodiversity and ecosystem services.

The Nepat tool can be successfully used in management decision-making for WEFE sectors because it is designed to consider different scenarios that take into account policies, statistically analysed social trends, possible economic and technological changes, different scenarios of climate change and resource use, especially water consumption. The Nepat tool considers global CO2 emissions that are severely reduced by strong mitigation efforts to maintain radiative forcing at 2.6 W/m2 and to keep the temperature increase below 2 °C by the end of the century, in line with the objectives of the Paris Agreement.

It also considers a scenario in which the world follows a path in which social, economic and technological trends do not deviate significantly from historical patterns. Development and income growth are uneven, with some countries making relatively good progress while others are failing to meet expectations. Global and national institutions are working to achieve the Sustainable Development Goals, but progress is slow. Environmental systems are suffering degradation, although there are some improvements, and overall resource and energy intensity is declining. Global population growth is moderate and stabilizing in the second half of the century. Income inequality persists or improves only slowly, and challenges to reduce vulnerability to societal and environmental change remain.

CONCLUSIONS

The activities in the case study of the NEXOGENESIS project aim to actively involve stakeholders and facilitate their engagement in co-creation and validation of a tailored NEXUS WEFE approach and use of the National Lignite Exploitation Society (SNLE) for improved policy-making. The project results will be promoted as trustful and solid reference at national level for substantiating actions and measures towards sustainable water resources management, supporting the strategic objective of updating the assessment of water use requirements at the level of river basins and improved evaluation of the vulnerabilities of current water systems. Furthermore, the case study targets dissemination cross border Serbia and Bulgaria to support maximizing project impact within the Lower Danube region.

The water cycle in nature is part of the circular economy that we have referred to in this paper, but the links established in the WATER-ENERGY-FOOD-ECOSYSTEM circle are extremely fragile due to climate change in recent decades. The Jiu River is the base of this circuit in the S-W part of Romania, but the 11% reduction in its multiannual average flow makes it an extremely vulnerable river given that the aridisation and desertification process in the Oltenia Plain is in continuous expansion, difficult to control.

The research results of this dissertation work led to a series of conclusions, which support the restoration of wetlands in the Jiu floodplain, the advantages of this type of project being presented below. The wetlands restoration in the Jiu River basin has several advantages, because such a project aims to create additional channels for water storage and pollutant removal, the new channels will be parallel to the Jiu River. Additionally, to increase water reserves, the excavation of transverse channels perpendicular to the river is also being considered. In this case, wetlands take on a buffer role and must be placed upstream of the treated wastewater discharges, upstream of their actual discharge into the emissary (Jiu River) in order to purify them and eliminate pollutants through sustainable biological processes. It is known that Romania is a country with a large deficit in river restoration, which is why it is considered that this type of project could be beneficial for the field of water management. Wetlands have a special ecological importance, both from a landscape point of view and in terms of improving water quality. These function as true natural filters, which retain excess nutrients, suspensions, heavy metals, and create spawning areas for many cyprinid species from the Getic Piedmont area, these habitats being favourable for the reproduction of waterfowl species (DUDĂU, 2010).

In addition, the development of aquatic vegetation, corresponding to biological purification in the Jiu riverbank area, can favor the stability of slopes and increase the protection of banks against erosion, additionally determining a purification similar to the tertiary stage (using aquatic macrophytes). This type of project can be developed separately in the future research and can be connected to industrial wastewater treatment, being perfectly integrated into the concept of a circular water economy, both in Romania and in other EU Member States. Taking into account the fact that the work was developed in collaboration with specialists from the Jiu Water Basin Administration (ABA Jiu), the document has a high degree of pragmatism, realism and originality, and the results obtained in the research and documentation stages were consistent with the proposed objectives.

The list of measures developed and presented in this paper can be added to the basin management plans, which can be completed with an additional chapter on Circular Water Economy in the River Basin, which can be developed not only at the level of BH Jiu, but also in other river basins in Romania, given that these aspects have not been addressed in the basin management plans. This can be the topic of a separate project, which can be developed and implemented in the future in collaboration with water management institutions.

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