ANALYSIS OF THE SUSTAINABLE DEVELOPMENT INDICATORS IMPLEMENTATION IN ROMANIA

Doctoral Thesis – Summary

For obtaining the scientific title of Doctor at Politehnica University of Timişoara

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The doctoral thesis was developed during the research period conducted within the Department of Hydrotechnics, Faculty of Civil Engineering, Politehnica University of Timișoara.

The content of the thesis is structured into 7 chapters spanning 147 pages, including 67 figures and 17 tables that present synthesized information and original research results, as well as a bibliography with 151 bibliographic entries and 23 web sources. The references highlights recent and significant sources, providing a comprehensive and up-to-date view on the addressed issues.

The research theme concerning Sustainable Development Goals (SDG) 6 – clean water and sanitation – and SDG 13 – climate action – is particularly relevant both at the European level and in the Romanian context due to the common and interconnected challenges related to the sustainable management of natural resources and mitigating the effects of climate change. In Europe, the increasing frequency of extreme weather events such as droughts, floods, and heatwaves highlights the importance of efficient water resource management, essential for achieving SDG 6 and SDG13. In Romania, access to sanitation infrastructure in rural areas, combined with growing risks associated with climate change – such as the reduction of freshwater resources and degradation of ecosystems – highlights the necesity of adopting effective measures for both SDG 6 and SDG 13. This can primarily be achieved through proper monitoring. Additionally, Romania is involved in transitioning to a green economy, committed to follow the European Green Deal and implement national adaptation strategies to climate change and carbon emission reduction, making these objectives current priorities for environmental and sustainable development policies.

The main research objectives addressed in the PhD research are:

- Analysis of the methodology and data sources used for monitoring SDG indicatorsrelated to SDG6, in particular 6.4.1 and 6.4.2.; as well as SDG13.
- Analysis of how SDG 6.4.1 and SDG 6.4.2 indicators are reported in Romania, identifying the relevance and challenges associated with the reported values, and indicating necessary adaptation methods for monitoring to achieve targets 6.4.1 and 6.4.2 by 2030.
- Investigating the possibilities to use Earth Observation (EO) data, particularly the FAO WaPOR database, to monitor the progress of SDG 6.4.1 through similar physical indicators.
- Analysis of the spatial distribution of monitoring data and their role in evaluating indicators corresponding to SDG 6.4.1 in Romania.
- Analysis of Earth Observation (EO) data, especially satellite images from the European Copernicus monitoring program, for monitoring water-related SDGs in general and determining the feasibility of using them for monitoring SDGs.
- Investigation of possibilities for using numerical models describing hydrological and hydraulic processes at a catchment level to monitor the progress of SDG 13.
- Evaluation of the current status of the studied SDGs in Romania, and determining the need or lack thereof for steps to accelerate the fulfillment of

indicators, or identifying what is missing from reports, especially when the actual indicators are at a higher level than reported.

The proposed research program was carried out according to a well-defined methodology, based on a series of sequential research steps. These steps were designed to gradually build knowledge and bring relevant contributions at each stage, ensuring continuous and coherent development of information and conclusions leading to robust and well-founded results. The work stages were as follows:

- Documentation and presentation of the current state of research regarding sustainable development goals globally;
- Analysis of the reporting of water-related SDGs and Romania's status at the European and global levels;
- Determination of calculation methodologies and data collection for determining SDG 6 indicators and description of SDG13;
- Critical analysis of the advantages and limitations of the current monitoring methods;
- Analysis of potential monitoring methods for SDG 6 and proposal of their usage methods;
- Understanding how water resources are calculated for SDG13;
- Case studies in Romania, both for SDG 6 and for SDG 13;
- Modeling the effect of climate change both in cases of droughts and floods in Romania to meet SDG13 monitoring requirements;
- Interpretation of results from hydrological and hydraulic analyses and modeling.

The content of the thesis is detailed as detailed below.

In Chapter 1, ***The Importance of the Research topic***, the context and motivation for this research are presented. The scientific questions addressed in the thesis are also included in this chapter.

Principles of sustainable development were initiated in the early 1970s, becoming an important subject on the international scene. An important moment in defining these was the United Nations Conference on the Human Environment in Stockholm in 1972, which brought the severe issue of environmental degradation caused by unsustainable human activities to global attention. Initially, the concept of sustainable development was conceived as a solution to the ecological crisis, aiming to conserve environmental quality for future generations. Over time, the concept expanded to include essential economic and social aspects.

In 2015, the United Nations (UN) and 193 countries adopted the "2030 Agenda", consisting of 17 Sustainable Development Goals (SDG). These goals are defined by 169 targets and 232 indicators, replacing the eight Millennium Development Goals (MDG) defined in 2000. The SDGs include specific objectives related to water, recognizing its impact on poverty, education, gender equality, the economy, and health.

Monitoring and reporting the progress of the SDGs are crucial to verify if the 2030 targets will be achieved. Measurable indicators enable the communication of complex issues among various stakeholders, including scientists, decision-makers, politicians, and the general public. Each SDG indicator is monitored by a custodial data agency at the UN level, which collects, verifies, and validates data from various member states' sources.

Romania is committed to establishing a national framework to support the 2030 Agenda, aiming to reduce poverty, social injustice, eliminate inequalities, and protect the environment by 2030. The National Strategy for Romania's Sustainable Development (SNDD) was developed in two stages, with the last published in 2018, under the coordination of the Sustainable Development Department. This strategy involves a wide range of stakeholders and defines the SDGs descriptively, linking them to the European Union's development strategy.

In conclusion, sustainable development presents a complex global challenge requiring coordinated efforts at international, national, and local levels. Implementing and monitoring the SDGs is essential to ensuring a sustainable future, with a particular focus on managing vital resources such as water.

Chapter 2, ***Specific Water Resources SDG Indicators*** describes all sustainable development indicators, focusing specifically on water-related ones. It specifies why SDGs 6 and 13 were chosen for analysis. The chapter provides an in-depth analysis of Romania's current situation regarding sustainable development goals in the water sector and their related indicators.

Globally, Sustainable Development Goals (SDG) are prioritized differently based on the specifics of each country or region. To facilitate the implementation of these objectives, countries have been classified into three distinct levels. The first level includes countries with significant social, economic, and structural issues. The second level consists of developing countries at various stages of progress, including Romania. The third level represents developed countries, members of the Organization for Economic Cooperation and Development (OECD).

This classification offers numerous advantages in the SDG implementation process. Firstly, it allows for a more precise identification and dimensioning of the efforts required for implementing these goals in each country. It also facilitates strategic allocation of financial and human resources, considering the specific capacities and needs of each state. Lastly, classification allows for the adaptation of strategies based on each country's economic capacity and political vision. However, it is important to note that this classification does not limit countries' involvement in achieving all SDGs. On the contrary, each country is encouraged to contribute to each goal, adapting their strategies and actions according to their needs and capacities. This flexibility in implementation is essential for the global success of the initiative.

This differentiated approach in implementing SDGs allows each country to maximize its impact and efficiency in achieving objectives, tailoring efforts to the local context. At the same time, by each country's contribution to all goals, coordinated global progress in sustainable development is ensured. This flexible and adaptable strategy represents a promising path for achieving the ambitious objectives set by the international community for a more sustainable and equitable future.

Finally, the chapter provides a detailed analysis of the temporal evolution of specific water resource indicators for Romania. The chapter takes the example of reporting (Figure 1).

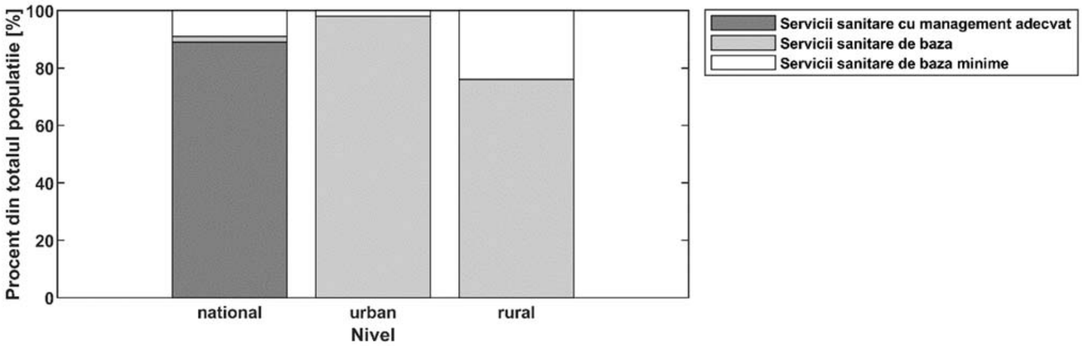

Figure 1. Temporal Progress of Indicator 6.2.1 by area type (according to available data from WHO and UNICEF, downloaded on June 20, 2024)

In the reporting of the sanitation situation in Romania (Figure 1), a discrepancy is noted between national and urban data. Although adequate wastewater management services are not reported at the urban and rural levels, they are reported at 90% nationally. In Romania, water and sewerage companies efficiently manage these services, making it surprising that basic sanitation services are only reported at the city level. Therefore, it is necessary to correct these reports not only for the year 2024 but also as errata for previous years.

Regarding wastewater treatment, under indicator 6.3.1, Romania reported a relatively low level (30%) globally and within Europe, compared to countries like Germany, the USA, and the Netherlands, which have wastewater treatment rates of 98%, 90%, and 100%, respectively. However, there are countries far behind Romania, like Malta, where only 5% of wastewater is treated.

The chapter concludes an important fact that forms the basis of the research conducted: the comparison of available reported data shows that although Romania is well-positioned on various indices, data are presented very differently and can create inaccuracies in decision-making for improving SDG6. It is necessary to have available methods of verifying how primary data are processed by various custodial agencies.

Chapter 3 of the thesis focuses on ***Evaluating the Current Methodology for Monitoring Water-related SDGs***, critically analyzing how these indicators are defined, calculated, and reported.

The chapter begins by presenting how SDG indicators are calculated, highlighting the role of custodial agencies in data collection and validation. It is emphasized that the methodology of calculating indicators is complex, involving a series of crucial steps, including:

- Defining the indicator
- Data collection
- Data processing
- Data analysis

- Data reporting

The work highlights the challenges in accessing methodologies for calculating indicators and obtaining complete and clear information about the monitoring of water-related SDGs.

The presentation of analysed indicators starts with SDG Indicator 6.4.1 - *Change in Water Use Efficiency over Time* (WUE), which measures the contribution of water resource use to the economic growth of a country.

A series of challenges related to indicator 6.4.1 are emphasized, such as:

- Lack of historical data for comparison.
- Complexity of the calculation methodology, which considers both hydrological and economic aspects.
- Lack of precision in how the concept of "water use efficiency" is defined, which varies depending on research discipline.

The study highlights the need for a clearer and more precise definition of indicator 6.4.1 to ensure the correct interpretation of data. It is also emphasized the importance of including aspects such as:

- Water reuse
- Climate change
- Population numbers
- Water quality

Next follows the analysis of SDG 6.4.2 - *Level of Water Stress (WS)*, which measures the level of stress on freshwater resources by comparing used water with available water, continues. The work highlights a series of limitations in calculating indicator 6.4.2:

- The current definition of the indicator does not include water capture, which can lead to an underestimation of water stress.
- Lack of precision in calculating the environmental flow requirement (EFR), affecting the accuracy of the analysis.
- Lack of monthly-level data, limiting the capacity to monitor seasonal changes in water stress.

The last analysed SDG is no 13 - *Climate Action*, which aims, as the name says at combating climate change. The impact of climate change on water resources is presented, including:

- Increase in frequency and intensity of droughts and floods.
- Decrease in river flow.
- Sea level rise.

The work emphasizes the importance of adapting to climate change, including risk mitigation and strengthening community resilience to natural disasters.

Chapter 3 concludes that the current methodology for monitoring water-related SDGs presents a series of limitations and challenges affecting analytical accuracy. The need for standardizing indicator calculation methodologies and improving data collection is highlighted to ensure more accurate monitoring of progress in implementing water-related SDGs.

Chapter 4 of the thesis, ***Proposal of Support Calculation Tools for SDG6 and SDG13***, addresses the importance of finding appropriate tools to evaluate progress towards achieving the SDG 6 and SDG 13.

This task requires the use of innovative methods, as SDGs refer to complex aspects, such as clean water and sanitation (SDG 6) and climate action (SDG 13), which require precise monitoring and impact evaluation.

The chapter begins by presenting a promising solution: WaPOR, a portal developed by FAO, offering free access to remote sensing data (satellite images) obtained from Earth observation programs. WaPOR is a robust tool for monitoring agricultural water productivity and land, offering a wide range of data, including evapotranspiration, precipitation, net primary production, and vegetation quality. These data are available at various spatial and temporal resolutions, making them useful for a variety of applications.

However, WaPOR data can be incomplete, and their spatial resolution is not always sufficient to cover all relevant aspects. The chapter highlights the need to complement these data with information from other sources, such as Earth Observation (EO) or satellite observations. EO provides an even broader range of data, including water quality, evapotranspiration, and land use, which can be integrated with WaPOR data to create a more complete picture. Copernicus services, a large-scale European initiative, are then presented, offering satellite data for a variety of applications, including monitoring water, climate, and the environment. Copernicus services include the Atmosphere Service, Marine Data Service, Land Monitoring Service, Climate Change Service, and Emergency/Hazard Management Service, which provide data relevant for assessing SDGs 6 and 13.

An important aspect of Chapter 4 is the analysis of the links between EO data and specific SDGs. It discusses how EO data can be used to directly calculate SDG indicators or contribute to them, either directly or indirectly. For example, EO data on water surfaces can be used to monitor changes in water quantity in lakes and reservoirs, contributing to the assessment of SDG 6 indicators. The chapter also explores the use of mathematical models for hydrological processes, such as the HEC-HMS model, to simulate the hydrological cycle, predict floods, and assess water availability. These models, combined with EO data, can provide a more detailed picture of the complex interactions between water, climate, and human activities.

Finally, Chapter 4 explores the use of data from intergovernmental initiatives, such as the Group on Earth Observations (GEO), which aims at optimizing the use of satellite observations to address global challenges, including sustainable development. These initiatives emphasize the importance of international collaboration to collect and analyze EO data, making them more accessible and useful for assessing progress on SDGs. By presenting a diverse range of tools, including WaPOR, EO, Copernicus services, and mathematical models, Chapter 4 offers a clear perspective on how we can monitor and evaluate progress towards SDGs 6 and 13. These tools are essential for identifying gaps and finding solutions to achieve sustainable development goals, thus contributing to building a better future for all.

In Chapter 5, ***Determining SDGs for Romania: Case Study Examples***, two case studies are analysed in order to see how SDG13 can be analysed. The two identifyed case studies are from two different regions of Romania, a basin constantly prone to droughts and one prone to floods. Their description is given in detail in the chaper and summarised here below. The Chapter also analyzes the water deficit at the national level, but calculation at the basin level is suggested for a clearer identification of affected areas.

Case Study 1: Jieț Basin, is a river basin in Romania exposed to drought for which the characteristics are:

- The Jieț Basin is located in Dolj County, covers an area of 633 km², and is characterized by an average slope of 1%.
- The Jieț River was once part of the Jiu River, but due to climate change and regulation works, it became a direct tributary to the Danube.
- Hydrological data are scarce, with only one monthly measurement available between 2006 and 2019.
- The multi-annual average flow is 0.436 m3/s, with a maximum value of 0.658 m3/s in December 2009 and a minimum value of 0.265 m3/s in March 2018.
- The Jieț Basin is affected by aridization, with increasingly difficult agricultural activities and heightened socio-economic and ecological vulnerability.
- There is a shortage of water, with underground sources contaminated by pollution from agricultural activities, a deficient irrigation system, and dependence on water from the Danube for irrigation.
- Protected areas (Natura 2000) in the region are also exposed to drought and aridization.

Case Study 2: Timiș-Bega Basin - A river basin in Romania exposed to floods.

- The Bega and Timiș Rivers are the two main rivers in the region.
- The area has a population concentrated in cities and villages, with Timișoara as the largest urban aggregation in western Romania.
- The Timiș-Bega Basin is located in southwest Romania, covers an area of 18,320 km², and includes a river network with a total length of 6,311 km.
- Due to the low slopes of the terrain and the sudden transition from highlands to lowlands, watercourses in the area are unstable.
- The current flood forecast is based on empirical and hydrological models, which have limitations in terms of the spatial and temporal variability of floods.
- The 2005 floods inundated a vast area and highlighted the need to improve forecasting models, with a deeper analysis of the flood impact and adaptation to climate change.

For both case studies the data used for the analysis was obtained from ANAR, or downloaded from Copernicus services.

After describing the two case studies, the calculation method for SDG 6.4.1 – Romania is presented, respectively:

- Analysis of the FAO methodology for calculating indicator 6.4.1, which requires data on land cover (cultures) and soil.

- Presentation of available data sources, including the AQUASTAT database, which contains information on the volume of water extracted for agriculture, gross value added from agriculture, and the proportion of irrigated land.
- Discussion of the limitations of AQUASTAT data and the proposal of a more automated and explicit calculation methodology.
- Analysis of the need to improve water efficiency in agriculture in Romania, although water stress at the country level is not present, but in certain areas (especially those exposed to drought) more efficient management of water is required.
- Emphasize the importance of monitoring evaluation indicators at the European level, where WUE and WS indicators are not considered.

The drought and floods are further analyzed from the perspective of SDG 13, as follows:

SDG 13- Drought in the Jieț Basin

- Analysis of flow data as an indicator of hydrological drought, but highlighting the need for meteorological data for a more detailed drought analysis.
- Meteorological data used come from global data sources (satellite images) and reanalysis data, with a detailed analysis of each data set.
- Presentation of the standardized precipitation index (SPI) calculation methodology for drought analysis, with a detailed explanation of definitions and results interpretation.
- Analysis of three drought scenarios: past (1990-2020), present (2020-2050), and future (2070-2100), with a comparison of results with historical events and an analysis of drought trends.

SDG13 - Floods in the Timiș-Bega Basin

- Presentation of data sources used for flood analysis in the Timiș-Bega Basin, including flow data, precipitation, cross-sections, and land elevations.
- Analysis of the flood calculation methodology, based on the integration of three numerical models: HEC-HMS, HEC-RAS, and SOBEK.

The chapter concludes with an analysis of the impact of climate change on droughts and floods in Romania, emphasizing the need for mitigation and adaptation measures to climate change.

In Chapter 6, ***SDGs and Stakeholders – The Situation in Romania***, the implications of the SDGs in water management in Romania are analyzed, emphasizing the collaboration and role of stakeholders in implementing Sustainable Development Goals (SDG) in Romania, considering the interdependence between the economy, climate change, governance, and civil society. The necessity of collaboration between various institutions within a legislative framework to achieve sustainable goals is also highlighted.

The main institutions involved in water resource management in Romania include: the Ministry of Environment, Waters and Forests, the National Administration "Romanian Waters", the National Institute of Hydrology and Water Management, and the Basin Water Administrations, among others. Each institution has specific roles, such as legislation development, water quality monitoring, flood management, and international collaboration.

The chapter details the responsibilities of each institution, such as water resource management and environmental policy development and emphasizes the importance of European funds in supporting sustainable development. Political objectives for sustainable natural resource management, with an emphasis on water and climate change management, are also highlighted, with suggestions for future strategic priorities and actions.

In Chapter 7 ***"Conclusions and Personal Contributions"*** of the doctoral thesis, the general conclusions and the author's personal contributions regarding the implementation of sustainable development objectives in Romania are presented, with a focus on water resource management and adaptation to climate change. The research has emphasized the importance of monitoring and reporting on sustainable development indicators to facilitate understanding of progress and identify necessary measures for achieving the objectives by 2030. Challenges related to gaps in determining certain indicators and the need for common and long-term approaches to tackle climate change and ensure effective climate policy have been highlighted.

Personal contributions highlight an analytical synthesis of the indicators and identification of gaps in determining water stress, evaluation of satellite methods for data collection, as well as exemplifying case studies on the applied plan regarding components of water use efficiency and future scenarios of droughts and floods.

Finally, future research directions are suggested, including the expansion and automation of flood management models. This work offers an integrated perspective on SDG indicators and proposes innovative solutions for water resource management and climate change adaptation.

The overall conclusion of Chapter 7 is that the research carried out has contributed to a deeper understanding of the complexity of implementing SDGs in Romania, highlighting the need for an integrated, multidisciplinary, and long-term approach, with effective collaboration among various stakeholders.

The final part of the doctoral thesis, the bibliography is presented, comprising 151 bibliographic titles from both domestic and foreign sources, including 25 significant reference titles:

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