MODIFIED METHODOLOGICAL FRAMEWORK FOR SUSTAINABILITY EVALUATION OF EXISTING HYDRAULIC STRUCTURES IN ROMANIA: THE CASE STUDY OF CINCIS DAM, HUNEDOARA

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Abstract. Present paper presents the development of a framework to evaluate the sustainability of existing dams and dikes infrastructures, after several years of being in operation. The proposed framework starts from the coherent and internationally recognized sustainability method of International Hydropower Association (IHA), which is defined for structures in design phase, and adapts it for existing in-operation infrastructures. As such, it highlights the opportunities for improvement and the development of a sustainability evaluation framework that is easy to understand. The framework can be used mainly by Romanian water boards, which are certifying in-operation structures, and can be equally used to check the sustainability of the infrastructures by its owners and stakeholders.

As an example the proposed adapted framework is applied on the Cincis dam of Hunedoara County. The dam is checked for certification in accordance to Romanian standards and sustainability results based on the adapted protocol, showing that the dam performs well from sustainable point of view. The proposed protocol is valuable because it gives Romanian Waters more insights, than just the certification from structural point of view.

Moreover, this proposed modified framework holds the potential to actively facilitate the fulfilment of the United Nations Agenda 2030 Sustainable Development Goals (SDGs) committed to by Romania under the ambit of the 2030 Agenda for Sustainable Development.

Key words: hydraulic structures, IHA protocol, Cincis dam, SDGs

1. INTRODUCTION

In 2018, the Romanian government presented its Sustainable Development Strategy for the year 2030, with a notable emphasis on Goal 17 – Partnerships for the Goals. The overarching objective is to align Romania's Sustainable Development Goals (SDGs) attainment with those of the European Union, reflecting a commitment to harmonize national sustainable development initiatives with broader regional and international benchmarks (Firoiu *et al.*, 2019).

The comprehensive strategy delineates objectives in two distinct timelines: a short-term horizon and a longer-term perspective aiming at 2030 (Xu *et al.*, 2020).

Central to the short-term horizon is the evaluation of the challenges in implementing the (SDGs) in Romania, based on the outlined critical analysis, identifying specific areas that demand additional efforts and resources.

The country's overall performance in monitoring SDGs ranks 39 out of 165 countries in 2021, and 35 in 2023, based on the UN SDG index rankings (UN, 2023; World Bank, 2020).

Figure 1 provides a comprehensive view of the country status, showing both the overall performance and individual SDG achievements changes over the period 2021 to 2023, at global and European level. While the country's overall position is good on a global scale, it is positioned on a lower scale at the European level. This shows the need for continuous monitoring efforts, and defined methodologies that will facilitate the evaluation of indicators of various SDGs, allowing for identification of where efforts for improvement should be done.

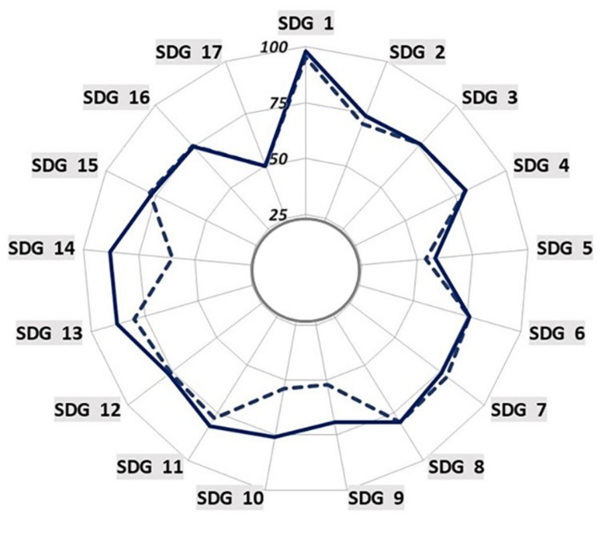
All indicators of the SDGs are evaluated based on several proposed methodologies put forward by several authors (Teau *et al.*, 2022), drawing from statistical data available at European Comission (EC,2018) and from data published by National Institute of Statistics in Romania. Benedek *et al.* (2021) introduce an Earth Observation-based method that provides a comprehensive visualization of country's SDG status in 2019. However, this approach is a singular effort of Benedek *et al.* (2019), and it is not offered as a database, such that different stakeholders will access it, or enrich his data. In contrast, Firoiu *et al.* (2019) data presents a clear numeric analysis over the 2007–2017 decade, reporting in detail the obtained values, but lacking insights into the computation methodology for composite indicators. It is important to emphasize that Firoiu *et al.* (2019) and Benedek *et al.* (2021) are mainly focused on aspects such as poverty, education, and health, with way less attention directed towards SDGs related to water. In this article the focus is on the aspect of clean energy evaluation, the one obtained from hydropower. By addressing the clean and affordable energies, the paper aims to contribute to the implementation of robust tools to support the monitoring efforts to ensure the successful realization of SDG goals by the targeted year 2030 (Leroy Poff and Olden, 2017).

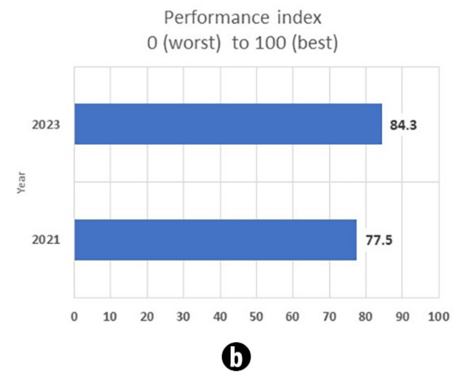
As part of the long-term horizon one of the key strategies outlined for 2030 is to mitigate climate change and mitigate its impacts, which entails a concerted effort to transition towards a „green" economy, characterized by significantly reduced carbon dioxide emissions. A key element of this shift is the promotion and use of sustainable renewable energy sources.

Romania has a series of approaches for renewable energy, such as hydropower and wind. Recognized as a viable means to address environmental concerns, the sustainable harnessing of hydropower is integral to achieving the defined national climate goals (Cortes-Borda *et al.*, 2022). The Romanian status of the SDG 7 for affordable and clean energy is at 71.4%, improving and with moderate challenges. It has an impact on SDG 13, climate action, which is just at 50%, stagnant and with significant challenges.

Given that for Romania is important to optimize its hydropower potential, emphasizing the need for enhancing the efficiency of existing hydrotechnical constructions, particularly dams, and this study looks into methodologies for evaluation of sustainability of existing hydropower infrastructures (i.e. dams and dikes around reservoirs).

At international level, several national institutions and international organizations joined their efforts and are committed to sustainable development while operating hydropower. All together these institutions forms the International Hydropower Association (IHA), which is a non-profit membership association, with the aim to support and provide a robust platform for the delivery of sustainable hydropower.





Country overall ranking on world scale (out of 165 countries) and EU scale (out of 34 countries)

Year	World	EU
2021	39	29
2023	35	(not available yet)

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Fig. 1. Romania's SDG overall performance comparison 2021 and 2023 (based on data from dashboards.sdgindex.org).

At the forefront of the IHA's initiatives is the Hydropower Sustainability Assessment Protocol (HSAP), a tool meticulously developed and put forward by the association. This protocol serves as a comprehensive instrument for evaluating projects in the design phase across a spectrum of criteria encompassing social, environmental, technical, and economic aspects. Grounded in objective evidence, HSAP is able to provide standardized results, facilitating a clear understanding of the performance of preconstruction existing facilities and the quality of development in new projects (HSPA, 2022). The Assessment Protocol covers all stages of a project's lifecycle: planning, preparation, implementation, and operation.

Despite hydropower constituting the largest share (35.8%) of the energy mix in Romania, as reported by the National Energy Regulatory Authority (ANRE), it is noteworthy that the HSAP remains relatively unfamiliar within the country. At present, the authors of this article could not find official documentation for the adoption and implementation of the HSAP in Romania, and there is a no data attesting to its utilization. This underscores the urgency for increased awareness and integration of the HSAP within the national energy framework, ensuring that sustainable hydropower practices play a central role in Romania's transition towards a more environmentally responsible and resilient future.

The official Hydropower Sustainability website (www.hs-alliance.org) provides information on hydropower projects that have achieved certification in compliance with energy sustainability standards, using the HSAP evaluation tool. Each certified project is accompanied by publicly accessible information, including the evaluation report, resulting sustainability profile, and supplementary discussions.

Building upon these studies and recognizing that hydrotechnical projects inherently involve key components such as hydrotechnical constructions (*e.g.*, dams), we propose adapting the protocol to encompass existing operational infrastructures. This adaptation involves retaining relevant indicators identified in each study and constructing a sustainability profile through the assessment of performance against these indicators. Each evaluation will be customized for the specific case study under consideration. The scoring of these indicators will be based on available data concerning the structure's objectives and publicly or institutions available information on its current performance.

The proposed modified framework for constructing sustainability profiles for diverse structures aims to enhance communication channels among various stakeholders, thereby fostering advancements and facilitating the fulfilment of the countries' sustainability development goal (SDG) indicators for water related goals, including clean energy.

After this introductory section, the paper presents the general HSAP methodology and the proposed modifications for evaluation of structures in-operation, followed by a study case with exemplification of applying the new method to it. Results on the evaluation of the dam are based on the Romanian national standards. The article ends with the conclusion section, where the potential benefits of applying such a method are emphasized.

2. RESEARCH METHODOLOGY

Figure 2 shows the step by step approach followed during research. The methodology employed a comprehensive three-step approach.

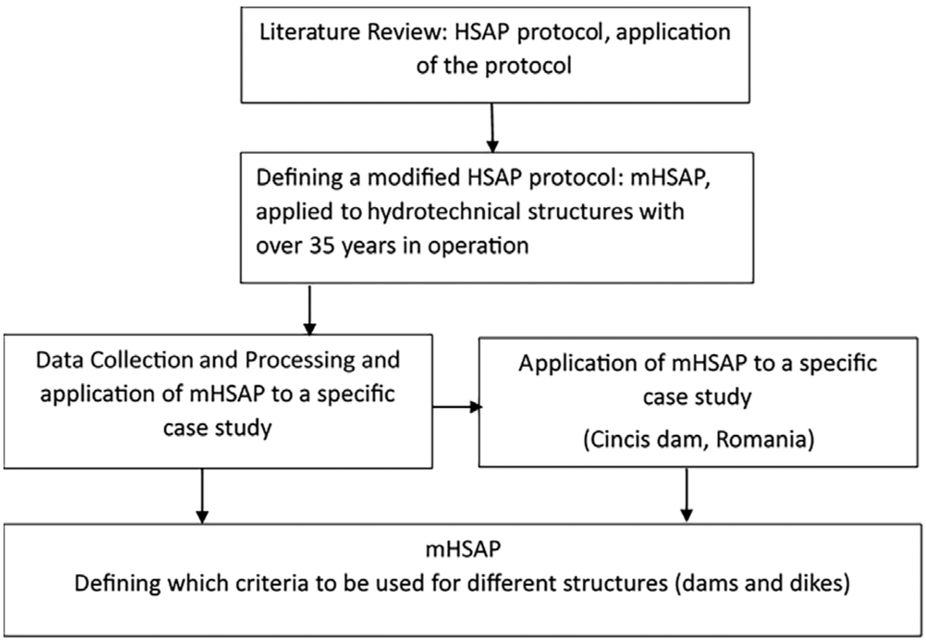

Fig. 2. Research approach.

Initially, the study involved a thorough analysis of the existing Hydropower Sustainability Assessment Protocol (HSAP) currently utilized across all four stages of hydropower projects, spanning from design to in-operation. Building on the insights derived from the previously mentioned analysis, the research introduces a refined protocol, termed mHSAP. This modified protocol included an examination of structures built 50-60 years ago to gain insights into historical practices; and takes into account the current operational status of structures. It also tries to anticipate their future performance, especially in the context of climate change conditions. The primary focus is on evaluating hydropower projects for sustainability.

In section 2.1 the HSAP protocol is detailed and steps of its application are analysed. Section 2.2 of the methodology provides an in-depth exploration of the HSAP methodology alongside the newly introduced mHSAP framework. To illustrate the practical application of the proposed methodology, a case study in Romania is presented in the article in Results and discussion.

2.1. Overview of the HSAP protocol methodology

In 2010, IHA releases the final Hydropower Sustainability Assessment Protocol (HSAP) for the evaluation of the sustainability of dams during the critical design phase of infrastructure projects (https://www.hydrosustainability.org/assessment-protocol). The protocol, developed over a two year period from 2008 to 2010, emerged in response to a recommendation from the World Commission on Dams. The formulation involved a comprehensive approach that considered policies and performance standards. Building on the IHA's previous sustainability tools, the development process engaged in close dialogue and consultation with a stakeholder forum. This forum had representatives from diverse sectors, including environmental organisations (such as the World Wide Fund), social development banks, governments (*e.g.*, Iceland, Norway), and the hydropower sector, played a pivotal role in defining the parameters of what constitutes a sustainable project. Significantly, the HSAP made an update in 2018 to address climate change resilience and mitigation, ensuring its continued relevance and applicability in the face of current environmental challenges.

The evaluation encompasses over 20 criteria directly related to the sustainability of the project under study. These criteria are categorized into key topics covering environmental, technical, economic, and social aspects (with a particular focus on human rights and gender-related issues). Notably, HSAP comprehensively addresses all stages of project design, including early stages, preparation, implementation, and operation. Each stage entails its own set of criteria for evaluation. Corresponding to each project phase, the performance criteria are assessed and depicted on a rosette featuring five ranking levels. These levels range from one for low performance to five for the highest performance. Specifically, level three is designated as the initial viable level for sustainability. To be deemed sustainable, an infrastructure must achieve at least level 3 or above across all criteria. Conceptually these are represented in Figure 3.

An overview of the performance criteria, as per their project phases, is presented in Table 1.

Assessments are based on objective evidence and presented in a standardized format, facilitating a clear understanding of the performance of hydropower infrastructures and the quality of ongoing project development. The evaluations rely on verifiable existing data, aiding in the determination of scores for each criterion specific to the evaluation phase. These scores are graphically represented in standardized rosettes, ensuring ease of interpretation. Furthermore, the results obtained serve as a foundation for identifying areas of focus for future improvement, particularly for decision-makers, and are valuable for sharing with potential stakeholders. When shared with stakeholders, including public entities, private companies, NGOs, and directly affected individuals, the protocol should serve as the basis for collaboration, co-design, and the exchange of ideas.

It is essential to note that in order to be used properly the protocol must be adopted as a guideline by organizations owning the infrastructures, and does not substitute national rules and regulations. A positive evaluation does not confer official certification of the sustainability of the project under study in any country where this is apply. Certification must comply with national laws, rules and regulations.

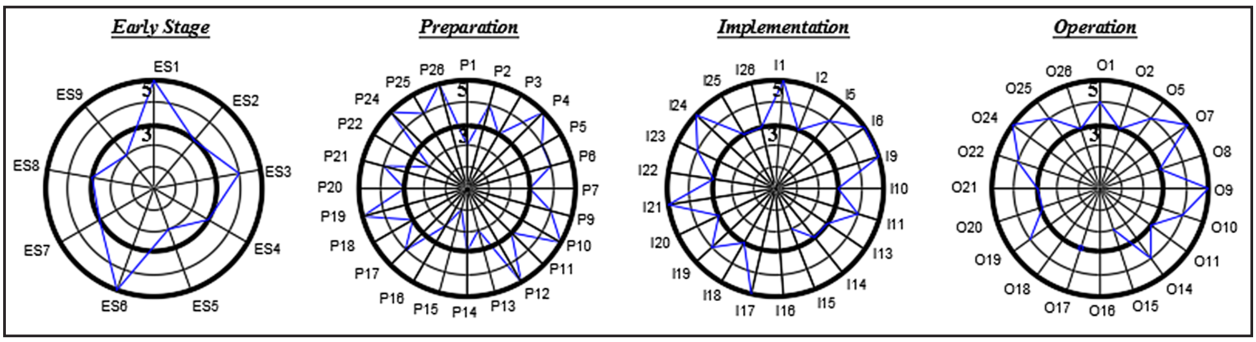

Fig. 3. HSAP key topics and corresponding criteria example rosettes.

Table 1. HSAP criteria and stages of project where they are used for HSAP assessment.

Topic /Criteria	Project phase			
	Early Stage	Preparation	Implementation	Operation
Demonstrated Need	ES1			
Options Assessment	ES2			
Policies and Plans	ES3			
Political Risks	ES4			
Institutional Capacity	ES5			
Technical Issues and Risks	ES6			
Social Issues and Risks	ES7			
Environmental Issues and Risks	ES8			
Economic and Financial Issues and Risks	ES9			
Communications and Consultations		P1	I1	O1
Governance		P2	I2	O2
Demonstrated Need and Strategic Fit		P3		
Siting and Design		P4		
Environmental and Social Impact Assessment and Mgmt/ Issues Mgmt		P5	I5	O5
Integrated Project Management		P6	I6	
Hydrological Resource		P7		O7
Asset reliability and Efficiency				O8
Infrastructure Safety		P9	I9	O9
Financial Viability		P10	I10	O10
Project Benefits		P11	I11	O11
Economic Viability		P12		
Procurement		P13	I13	
Project Affected Communities and Livelihoods		P14	I14	O14
Resettlement		P15	I15	O15
Indigenous Peoples		P16	I16	O16
Labour and Working Conditions		P17	I17	O17
Cultural Heritage		P18	I18	O18
Public Health		P19	I19	O19
Biodiversity and Invasive Species		P20	I20	O20
Erosion and Sedimentation		P21	I21	O21
Water Quality		P22	I22	O22
Waste, Noise and Air Quality			I23	
Reservoir Planning/Preparation and Filling/Management		P24	I24	O24
Downstream Flow Regimes		P25	I25	O25
Climate Change Mitigation and Resilience		P26	I26	O26

However, it significantly contributes to enhancing the understanding of the project's sustainability and guides the adoption of optimal solutions in this context.

2.2. The proposed modified protocol: mHSAP

The current research adapts the protocol to specifically assess existing dams and dikes. The objective is to retain relevant indicators applicable to hydropower infrastructures that have been operational for an extended period, more than 35 years. This approach aims to construct a comprehensive sustainability profile, adding extra information to the regular structural feasibility studies done periodically. The sustainability evaluation is valid generally for any in operation infrastructure, however each case study comes with its own particularities that will be reflected ultimately in the final evaluation report. The scoring of indicators is based on available data related to the structure's objectives and the gathered information about its current performance. The protocol is named mHSAP (modified HSAP).

Though mHSAP specifically looks at criteria for Romanian structures on operation, it can be used for any structure in any country. The proposed mHSAP adapts some of the early stage criteria to revaluation for the next 5 years in operation of a structure, starting the moment of the mHSAP evaluation finalisation. The ones retained in the evaluation are presented in table 2, in total 17 criteria.

The proposed mHSAP uses the same consistent scoring principles across levels 1 to 5. In this scale, 1 represents the lowest score, while 5 signifies the highest, evaluating best practices related to a specific sustainability concern. The breakdown of scoring levels is as follows:

- Level 1 – Significantly lacking good basic practices.
- Level 2 – The most relevant aspects of basic good practices have been implemented, but there is a notable deficiency.
- Level 3 – Delineates that fundamental good practices concerning a specific sustainability theme are present.
- Level 4 – All elements of fundamental good practice have been executed, and in some instances, surpassed, but there is a marked shortfall in meeting the criteria for established best practice.
- Level 5 – Characterizes proven best practices on a particular sustainability issue.

All results obtained should be disclosed to the public through the owner of the infrastructure, except for official documents, which could only be accessed based on consent of the authorities who issued them.

Table 2. mHSAP criteria and their relation to sustainability aspects

Topic /Criteria	Project phase		Sustainability aspect	Criteria acronym
	HSAP coding	mHSAP		
Policies and Plans	ES3	5Y1	Integrated	C1
Institutional Capacity	ES5	5Y2	Economic and financial	C2
Risks (technical, social, environmental)	ES6, ES7, ES8	5Y3	Technical, social and environmental	C3
Communications and Consulting	P1, I1, 01	OP1	Social	C4
Governance	P2, I2, 02	OP2	Integrated	C5
Environmental and Social impact assessment	P5, I5, 05	OP3	Environmental and social	C6
Integrated Project Management	P6, I6	OP4	Integrated	C7
Hydrological Resource	P7, 07	OP5	Technical	C8
Infrastructure Safety	P9, I9, 09	OP6	Technical	C9
Project Benefits and financial viability	P10, P11, I10, I11, 010, 011	OP7	Economic and financial	C10
Labour and Working Conditions	P17, I17, 017	OP8	Social	C11
Public Health	P19, I19, 019	OP9	Social	C12
Biodiversity and Invasive Species	P20, I20, 020	OP10	Environmental	C13
Erosion and Sedimentation	P21, I21, 021	OP11	Environmental	C14
Water Quality	P22, I22, 022	OP12	Environmental	C15
Downstream Flow Regimes	P25, I25, 025	OP13	Environmental	C16
Climate Change Mitigation and Resilience	P26, I26, 026	OP14	Integrated	C17

3. APPLICATION OF THE MODIFIED PROTOCOL

3.1. Case study description

To illustrate the concept of mHSAP, the chosen case study is the Cincis dam located in Romania, at the confluence of the Cerna and Teliucu Superior rivers within the Mures basin. Constructed in the early sixties (1961-1964), the dam was designed to establish a reservoir that could supply water to the downstream industrialized city of Hunedoara and the former metallurgical factory. Additionally, it serves as a flood protection measure by storing water. The reservoir behind the dam functions as a permanent storage, managed by the Mures Water Basin Administration. The associated catchment area contributing to the reservoir's storage is 305 km^2 (Figure 4).

The Cincis dam is 48 meters high, with a corresponding reservoir covering 867 hectares. The lake is deep, with sandy shores on almost 50% of its perimeter (Gaftoi *et al.*, 2021).

Evaluating the functionality of this structure is crucial, given its evolved role; it no longer serves as the primary water supply for the city, and industrial activity has considerably diminished. This shift results in increased storage availability throughout the year. In 2011, one stakeholder established a small hydropower plant utilizing a portion of the water under specific conditions.

While the dam undergoes certification every five years according to Romanian safety standards, these norms do not encompass economic and environmental considerations. The proposed mHSAP complements certification processes by providing information to decision-makers and stakeholders involved in the area. It enhances understanding of all aspects of the dam and reservoir functionalities, facilitating effective communication among involved parties.

3.2. Evaluation using the mHSAP framework

The mHSAP applied to the Cincis Dam, as outlined in this section, relies on accessible data obtained through various sources. These include visual data gathered during on-site visits, documentation available at Mures Water Administration, and verbal information acquired through discussions held both on-site and at the Mures Water Administration. The on-site visits were conducted from February 13 to 17, 2023.

We started the evaluation and application of the proposed mHSAP from the principles that the protocol should be implemented collaboratively to ensure optimal access to information and perspectives concerning the criteria under study. This required that we carried out transparent discussions with project administrators; the personnel directly engaged in the exploitation process; as well as with the staff in charge of finance and human resources. Additionally, communication with project beneficiaries and individuals affected by the existence of the structure and by its operation is essential for a comprehensive understanding of all viewpoints.

Below, each evaluated criterion is presented as it was assessed in connection with established basic good practices, along with a justified score. It is important to note that scoring is conducted relying on interviews conducted at the dam site, at ABA Mures and assessments of the scores are based on our knowledge and expertise in the field, and no automated algorithms are employed. Moreover, for certain criteria we could not find any documentation, hence the score is not evaluated. The Cincis dam evaluation is done for its operational stage, and considering its age as well as the absence of initial documentation on specific subjects, 14 evaluation topics were employed to align with the current circumstances. Because of the dam's age, certain criteria depend on the same documents, leading to repeated scores for them, where applicable.

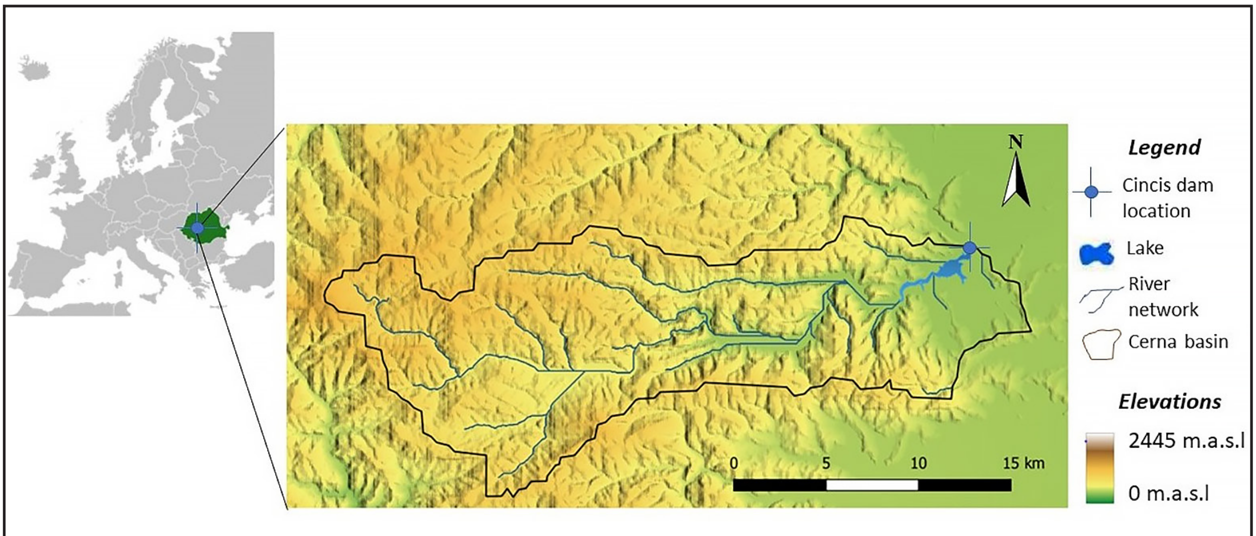

Fig. 4. Cincis dam location and corresponding contributing catchment.

The evaluation focuses on various topics starting with governance. If the documentation for the five-year horizon criteria remains consistent over several criteria, then it is referred and analysed only once.

Governance (C5) is evaluated at level 3. Successful management of reservoirs requires effective overview of both corporate governance, the internal rules and processes governing the operations of the reservoir; as well as external governance, which involves institutional, legal, and regulatory framework within which the infrastructure operates.

The reservoir operates based on guidelines valid until mid-2024, last updated in 2019. These rules are typically renewed and revised every five years, with an expected renewal this year. Initial operation regulations date back to 2010, later revised in 2012 due to new flow rate monitoring requirements. The Romanian government, represented by the Ministry of Environment and Sustainable Development, oversees the dam and water storage through the Mures National Water Administration (in Romanian, Administratia bazinala de apa Mures-ABA Mures). Three primary users of the reservoir water include energy producers and steel industries, with an intermittent fourth user being the Hunedoara water supply company. All fees for these use of water are revenues to ABA Mures. Although policies and guidelines are in place, sustainability issues are not addressed within the policies; only guidelines for water use are provided, hence the level is assessed to be 3. There is room for improvement in terms of making rules accessible and specifying how revenue is allocated for environmental sustainability both upstream and downstream.

Policies and plans (C1) is strongly related to the corporate governance, hence receives the same score as C5, level 3.

Institutional capacity (C2) is evaluated at level 2. Though there are many rules and regulations in place, all documentation available during the evaluation did not explicitly mentioned what are the needs in terms of staff to operate and maintain the dam, more meetings with stakeholders are held on a regular basis, as results from criteria 4. Communication and consulting below.

Communications and Consulting (C4) is evaluated at level 2. This aspect addresses ongoing engagement with project stakeholders, both within the company and between the company and external stakeholders (*e.g.* affected communities, governments, key institutions, partners, contractors, watershed residents, etc.).

ABA Mures has identified the main stakeholders of the dam as:

- the administrator of the dam itself,
- steel industry that needs a minimum extra discharge of 1.44 m^3/s, not available continuously through the natural river flow
- a small hydropower plant producer, located downstream of the dam
- Hunedoara city population
- Hunedoara city's industrial platform, who are protected by floods through the dam, or are receiving extra water from the dam in case of droughts.
- Population downstream of the dam, that are continuously receiving water at arate of 75 liter/sec
- All commercial places on the shore of the lake

Communication is done in various ways depending on the stakeholders and their position with respect to the dam. Though there are a series of communication policies and procedures, they are mainly restricted to announcements in case of hazards to the dam. All the other exchanges with stakeholders are not on a regular basis, nor transparent. All complaints are responded in 30 days after their initiations with ABA Mures. All paper work is available at ABA Mures. A series of press releases are also done by ABA Mures, but little is done for involvement of stakeholders and understanding their needs, adapting the operation rules for optimum water use. All decisions are taken by ABA Mures based on studies and without any consultation or communication with stakeholders.

Environmental and Social impact assessment (C6) is evaluated at level 4. This topic addresses the management processes for the environmental and social issues. The intention is that the negative environmental and social impacts associated with the dam are managed; such that minimization, mitigation, compensation and improvement measures are implemented; and environmental and social commitments are met.

All these measures are part of the Integrated Management System in place at the administrator of the dam. Details about these are in C7, hence the same evaluation of C6, as for C7.

Integrated project management (C7) is evaluated at level 4. This topic addresses the ability of the infrastructure's owner to ensure operational sustainability and to effectively coordinate and manage all the aspects related to construction safety, environmental concerns, communications, acquisitions, as well as to secure financial resources for ongoing operation.

The National Administration „Romanian Waters" (ANAR), as the main owner and administrator of the Cinsis hydrotechnical infrastructure has implemented and maintains an Integrated Management System (IMS), in accordance with Romanian standards (such as ISO 9001:2015; ISO 14001:2015; ISO 45001:2018). The implementation of the IMS entails a policy that aims to satisfy water demands of all stakeholders as long as the negative impact on the environment are reduced and safety and health of their employees is ensured. The dam operating rules are authorized based on a "Technical Expertise Report for the assessment of the operational safety of the Cincis dam and the reservoir".

Moreover, ANAR has implemented the SR ISO 37001 certification regarding the Anti-Bribery Management System, which refers to access to European funds.

During the research phase, while in a discussion with ABAM, the Hunedoara office it was clear that there is no debt related to the hydrotechnical infrastructure and the operating costs are part of the annual revenue and expenses budget, which is approved in ANAR.

Based on the above findings a level 4 of this criteria is achieved, as there are good practices in place. However, improvements can be done, particularly concerning the lack of detailed income data which impedes conducting long-term financial benefit analyses. Although all the elements of good practices have been undertaken and in some cases they have been surpassed, improvements in the management system can be done by developing scenarios related to the future aspects of interest, such as the resilience of the structure and dam operation in view of climate changes, social changes, and diverse economic scenarios.

Hydrological Resource (C8) is assessed on level 3. This topic addresses the level of understanding of the availability and reliability of hydrological resources in the short and long term, taking into account the needs, requirements as well as the trends in the likely future. Currently this is done by the Hydrological service at Mures Water administration. Time series of discharge data inflows into the lake are available, monitored by hydrological stations and water levels in the lake are available on a daily basis. However, there are no hydrological modelling tools available for monitoring daily operations or optimizing water allocation needs, based on forecasted inflows. Rainfall events are recorded by meteorological institute and not available at the administration. Hence, any forecast for flood or droughts is received from another institution.

Infrastructure safety (C9) is assessed at level 4. This criteria addresses the safety of dams and other infrastructures with the aim of protecting life, property and the community from the consequences of construction failure. Cincis dam was evaluated as per Romanian norms and received certification for safety in operation. According to these rules, the dam spillway are designed for a 1,000 years return period of the flood, which is calculated at 315 m^3/s. However, the overtopping flow rate with no damage on the dam is not estimated, nor the consequence of climate change.

The certification of the dam took place on 2017, also looking at stability and monitoring of the dam. The safety certification report does not record any failure of materials used in the dam construction, no seepage and the monitoring is done as per required standards, for a period of 7 years. The dambreak analysis was updated in 2023, without taking into account potential climate change conditions.

Continuous monitoring of the dam safety is done as per Romanian rules and regulation through the UCC monitoring programme, where UCC is the acronym for monitoring construction behaviour. The 2023 UCC notices small horizontal cracks, which are taken care of by ABA Mures. The UCC programme takes place once a year, except for pendulum of the structure's verticality which is monitored twice a week; and deformation markers that are checked once every ten days. At the time of the checking it was noticed that the deformation markers were not monitored for 2015 because of faults in functioning.

There is a need to carry out further studies on the safety of the structure, and until these are carried out, though best practices are in place, the level of the criteria is maintained at 4.

Work and working conditions (C11) gets the level 3. This subject covers aspects of work environments, encompassing employee opportunities, equity, diversity, and health and safety. The aim is to ensure that workers are treated fairly and provided with adequate protection.

The Cincis dam is part of Mures Water administration, however the evaluation is done only for the administrators and workers of the dam itself. As per Romanian laws there are clear safety working conditions for everyone. The career growth is missing due to the nature of the employment. However there are no specific trainings on how to administrate the dams. These can be added for improving the working conditions.

Public health (C12) topic is evaluated at level 5. This topic addresses the public health issues associated with the operation of hydrotechnical construction. Since the dam, serving both recreational and functional purposes, does not pose any health issues, it is concluded that the criteria for public health conditions are satisfied. This criteria is strongly related to criteria C15 on water quality. The reservoir serves as water supply source for the city of Hunedoara, and needs to fulfil all standards for starting the process of treating water to drinking purposes. In this context water quality is carefully monitored and it is not affected by the other uses of the water. Water quality criteria gets a level 5 evaluation.

Biodiversity and invasive species (C13) is at level 4. The topic looks into ecosystem values, habitats, and specific issues, from the perspective of potential impacts of the dam and its reservoir on these aspects. The goal is to ensure a functional, and sustainable ecosystem as a whole.

In accordance with the European Union regulations and Romanian laws, a monitoring plan for the water in the reservoir is existing and executed by ABA Mures. Monitoring is done both chemically and biologically, and sampling is done simultaneously, for a more accurate interpretation of the results. At the moment of the interviews and evaluation carried out for the mHSAP, these sampling collection were defined to be carried out 4 times a year, from two collection points, one located upstream of the dam, and one in the middle of the lake. The aim is not only to preserve the water quality within the established parameters, but also to preserve biodiversity and reduce the risks of the appearance of invasive species.

In the framework of the chemical analyses, the Ph of the water, the suspensions, the residues, the chemical and biological consumption of oxygen, the nutrients, elements that directly influence the biodiversity in the lake are studied. If a negative evolution is found, of any kind, strategies are developed, measures are taken or the source of pollution is concretely eliminated if possible.

Along with these chemical analyses the constant monitoring of the evolution/changes over time of the phytoplankton, which can provides a complex picture of the biodiversity of the reservoir. Thus, possible negative impacts can be avoided/prevented or reduced to a minimum, and when avoidance or reduction is not possible, mitigation and compensation measures will be taken.

The level for the criteria is evaluated at 4, because more often sampling could be collected and in more points in the lake.

Water quality (C15) is evaluated at same level with C13, as they are strongly related and all campaigns regarding water quality are done in the same time as the ones for C13. Moreover, there is no constant water supply for drinking, from Cincis reservoir.

Erosion and sedimentation level (C14) is at level 2. This subject addresses the responsible management of erosion and sedimentation problems associated with the exploitation of hydrotechnical facilities. In case such problems exist, they need to be addressed through particular measures that will alleviate the problem.

Several morphological aspects in the river downstream and upstream of the reservoir started to be measured, as of 2010. The length of the monitored sector is 100m, which is rather short. The overall solid flow is of 0.47ks/s

Measurements of the solid flow are done only for the suspended flow, not the dragged flow, due to the lack of appropriate programs and technology. The measurements are made at a station upstream of the reservoir (Toplita) and at the dam outlet where the water is calm, which favours the deposition of the solid flow and makes it difficult to measure. The solid flow at the exit is not measured. During the mHSAP evaluation the hydrology department of the ABA Mures state that approximately 90% of the flow entering the lake, does not go out and is deposited in the reservoir.

The level of the criteria is 2 because as far as sedimentation is concerned, it is monitored so that any problems that arise can be properly managed. The fact that these do not to represent problems in the operation of the reservoir or in relation to other social, economic and environmental objectives makes it not fully monitored. There is space for improvement.

Downstream flow regimes (C16) is at level 4. This topic addresses the flow regimes downstream of the dam, such that national defined environmental, social and economic objectives are met. With every certification of a dam, the downstream regime is evaluated and a minimum environmental flow is required to be ensured for certification. As Cincis dam is certified, the minimum required flow in the downstream riverbed is ensured. However though these measurements are taken are regular intervals, not all of them are transferred immediately to ABA Mures, and some are recorded very often on special notes.

Table 3. Monitored parameters for downstream flow regime

Measured Parameter	Determined by	Frequency of measuring (no/day)		Recording data	Transmitting frequency
		Operation rules during normal operation	Operation rules during Special events		
Incoming discharge (m^3/s)	Flowmeter	2	4	Catalogue (manual)	Twice a day to local dispatch
Hydropower supply discharge (m^3/s)	Flowmeter	2	4	Catalogue (manual)	Twice a day to local dispatch
Spilled discharge	Rating curve	2	4	Catalogue (manual)	Twice a day to local dispatch
Bottom outlet discharge	Rating curve	2	4	Catalogue (manual)	Twice a day to local dispatch
Reservoir water level (m.a.s.l)	Water level gauge	2	4	Catalogue (manual) and record in a database	Twice a day to local dispatch and once a month to ABA Mures

An overview of the frequency of the monitoring of the downstream flow regime is represented in Table 3.

While the monitoring is very good, the data transmission and recording could be done in real time, this is why it was evaluated at 4, instead of 5.

Climate change mitigation and resilience (C17) is on level 1. This topic addresses the management of greenhouse gas (GHG) emissions due to the dam, as well as the analysis and management of climate change risks for the project and the role of the project in adapting to climate change. At the present moment there are no clear climate change estimations for the area of Cincis dam, which ABA Mures addresses and uses during planning. Moreover there are no measurements of the gas emissions. A series of improvements are needed.

Following the evaluations for each criterion, a sustainability profile for the Cincis dam was obtained, as presented in Figure 5.

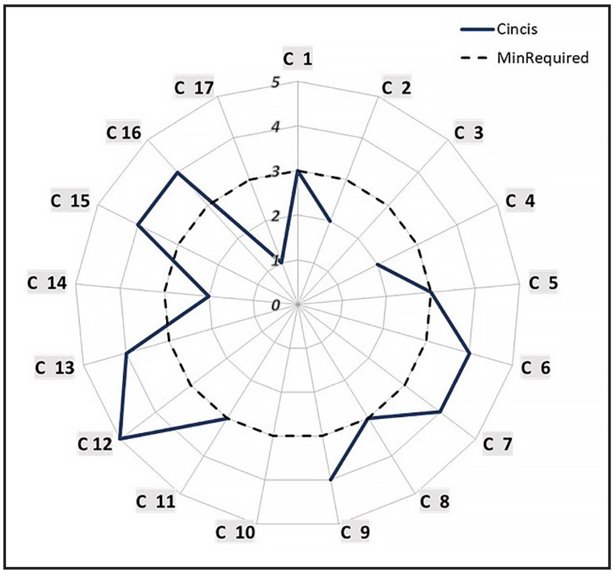

Fig. 5. mHSAP evaluation of Cincis dam and its reservoir.

From the obtained sustainability profile Cincis dam is well for the majority of criteria. For criteria 2 and 4, minimum required level is not yet attained and for C3 and C10 we did not find data such that the level can be determined. With such an overview ABA Mures can see where there is a need to take actions for improvements and where everything goes well.

The presented proposed method for evaluation of the dam sustainability, though is not quantitative it can provide a good overview about the characteristics of the dam and where improvements can be done. Moreover the fact that it can be carried out periodically, provides an additional overview for the dam owner, such that they know when more complex investigations are needed.

4. CONCLUSIONS

The majority of medium and large dams in Romania were constructed between 1950 and 1980 (Gaftoi *et al.*, 2021). Despite many of them being designed for multiple functions, approximately 39% are dedicated to a singular purpose; i.e. hydropower or flood management. Due to the era of their construction, aspects related to the sustainability of these projects – such as cultural heritage, impacts on communities and livelihoods, and the effective management of associated issues – cannot be thoroughly examined. This limitation arises from the lack of conclusive historical information about project design and approval, as well as the absence of well-documented commitments to the affected communities during that period.

In Romania, each dam undergoes periodic renewal processes for approvals and authorizations, adhering to the country's legislative requirements. However, these approvals primarily focus on the safety aspects of the dam, including operational authorizations, technical expertise reports assessing the safety status during operation, water usage and/or management authorizations, and action plans for dam accidents. While these safety-focused approvals are crucial, they may not comprehensively address the various sustainability aspects that Romania aims to enhance. Therefore, the method proposed in this study could be adopted to identify areas requiring improvement. This tool would not only benefit decision-makers but also serve as a valuable resource for stakeholders in the region if made publicly available.

It is important to mention that the study do not suggest that such results should be a legal requirement, and no obligation for the structure's managers or decision-makers, based on the achieved sustainability score, to implement improvement measures. Nevertheless, the obtained results serve as a crucial information source for future decisions related to optimizing dam operations, prioritizing projects, and fostering open and constructive dialogue among all parties impacted by the hydrotechnical structure in question.

Moreover, in case that a study obtains the best possible score, should not be used to obtain official certifications regarding the sustainability of the hydrotechnical structure, but to inform and offers a real, clear idea of the existing situation in the field and what can be improved in the future.

Assessing existing constructions from a sustainable perspective and trying to operate them in the most sustainable manner has become not only a necessity but also a challenge. Relying solely on technical and economic criteria when examining hydrotechnical constructions must not be the only method. Additionally, the awareness of climate change necessitates timely planning to prevent and mitigate the adverse effects of such existing structures, enhancing Romania's capacity to adapt to climate-related risks.

Conducting comprehensive studies, based on the proposed method, on numerous hydrotechnical works can yield a thorough and intricate national-level report. This approach considers various viewpoints, ranging from the administrators of the structures to the political environment. By doing so, it has the potential to bring substantial improvements in the overall management of hydrotechnical structures and create a platform for constructive discussions leading to positive changes in the legislative framework related to water management.

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REFERENCES

Benedek, J., Ivan, K., Török, I., Temerdek, A., Holobâcă, I.H. (2021). Indicator-based assessment of local and regional progress toward the Sustainable Development Goals (SDGs): An integrated approach from Romania. *Sustainable Development* **29**(*5*): 860-875

Cortes-Borda, D., Andres Polanco, J., Escobar-Sierra, M. (2022). Social perception assessment of hydropower sustainability: A stepwise logistic regression modelling. *Journal of Environmental Science and Policy*, **134**(*8*): 108-118.

European Commission. Standard Eurobarometer (2018). Public Opinion in the European Union — First Results. Available online: http://ec.europa.eu/commfrontoffice/publicopinion/ (last accessed on 10 December 2023).

Firoiu, D., Ionescu, G.H., Băndoi, A., Florea, N.M., Jianu, E. (2019). Achieving Sustainable Development Goals (SDG): Implementation of the 2030 Agenda in Romania. *Sustainability,* **11**: Article No. 2156.

Gaftoi, D., Abdulamit, A., Aldea, A., Sarghiuta, R., Popescu, C. (2021). Assessing Structural Safety of an Arch Dam Using in Situ Vibration Tests. *IOP Conference Series: Materials Science and Engineering*, **1203**(*1*): Article No 022122.

HSAP (2022). Hydropower Sustainability Assessment Protocol available from https://www.hydrosustainability.org/ (last accessed December 2023)

LeRoy Poff, N., Olden, J. (2017). Can dams be designed for sustainability? *Science*, **358** (*6368*): 1252-1253.

Teau C., Popescu I., Florescu C., Constantin A., Ciocan C.M., Vlaicu V. (2023). Implementation of water related Sustainable Development Goals in Romania: overview of current and future challenges. *IOP Conference Series: Earth and Environmental Science*, **1136**(*1*): Article No. 012013.

United Nations (2023). Transforming our world: the 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda (last accessed January 2024).

Xu, Z., Chau, S.N., Chen, X., Zhang, J., Li, Y., Dietz, T., Wang, J., Winkler, J.A., Fan, F., Huang, B., Li, S., Wu, S., Herzberger, A., Tang, Y., Hong, D., Li, Y., Liu, Y. (2020). Assessing progress towards sustainable development over space and time. *Nature,* **577**: 74-78.

World Bank (2018). Romania Water Diagnostic Report: Moving toward EU Compliance, Inclusion, and Water Security, from https://openknowledge.worldbank.org/handle/10986/29928 (last accessed June 2023).