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Navigating Data Management Challenges and Seizing Opportunities in the Sahel Region: Selecting Weighting Factors within a Sustainability Framework

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ABSTRACT

Successfully steering the intricate transition to a sustainable energy system entails the inclusion of diverse stakeholders and the evaluation of numerous criteria in a multifaceted decision-making framework. This frequently presents challenges in the realm of data management. This work lays out conceptual considerations for identifying suitable weighting approaches in the context of Multi-Criteria Decision Analysis applied in sustainable energy transitions in the Sahel region.

Keywords: energy planning, decision-making, weighting methods, data management plan, Sahel region, MCDA

NONMENCLATURE

Abbreviations	
DMP	Data Management Plan
DOI	Digital Object Identifier
FAIR	Findable, Accessible, Interoperable, Reusable
MCDA	Multi-Criteria Decision Analysis
RES	Renewable Energy Sources
SDGs	Sustainable Development Goals

1. INTRODUCTION

The Sahel region spans over 10 countries, including Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan, and Eritrea [1]. It is characterized by a wealth of opportunities and vast potential thanks to its natural, demographic, and cultural strengths [1]. The region possesses notable capacity for harnessing renewable energy sources, particularly solar and wind energy [1]. The extent of its solar energy potential amounts to approximately 13.9 billion kWh annually [1]. This potential output is greater than the global electricity consumption of 20 million kWh in the year 2016 [1]. However, merely 31 percent of the population residing in the Sahel region had access to electricity as of 2014 [1]. In this connection, the UN seeks to mobilize public resources and stimulate private investments across the ten countries in synergy with the ongoing initiatives undertaken by governments, international and regional entities, and other involved partners [1]. For this, an understanding of the local conditions is indispensable.

In a similar manner, the European Unions (EU) updated Sahel strategy highlights the importance of a more comprehensive and context-sensitive approach to tackling regional instability [2, 3]. This strategy recognizes governance and fostering sustainable development as vital aspects [2, 3]. Furthermore, it seeks to encourage customized solutions at the regional, national, and local levels to consider unique requirements and circumstances [3]. This includes the necessity of engaging a broader range of stakeholders, including local and decentralized authorities, as well as national civil society participants [3]. The specific methods to implement these actions have not been publicly disclosed at this time [3].

In this connection, Multi-Criteria Decision Analysis (MCDA) has become an established and valuable approach to addressing complex questions within the realm of sustainable development [4]. This methodology offers a structured framework that allows decision-makers to consider multiple factors and trade-offs when making choices. The integration of social considerations in the context of utilizing renewable energy sources (RES) is considered vital [5, 6]. Frequently, stakeholder data is

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collected to weigh criteria and assign importance. There are various methods within MCDA requiring various levels of stakeholder involvement. Balancing the interests and perspectives of diverse stakeholders is frequently considered essential, as it ensures more comprehensive and inclusive solutions. Thus, MCDA approaches can illustrate a viable tool for utilization in respective decision frameworks in striving to achieve progress towards the Sustainable Development Goals (SDGs).

Given the existing challenges faced in the region, such as environmental degradation, resource scarcity, and social inequalities, it is crucial to address potential obstacles that may hinder the effective application of MCDA. This relates in particular to the involvement of stakeholders via weighting factors. These obstacles could range from limited data availability to conflicting stakeholder interests. Therefore, questions of data management and acquiring weighting play a central role when conducting research in the region. By proactively identifying and addressing these obstacles, we can enhance the efficacy of MCDA and pave the way for more sustainable development outcomes that benefit both the region and its inhabitants.

In this context, this paper proceeds as follows: First, given the importance of data handling within the region, key characteristics of a Data Management Plan (DMP) will be illustrated and the FAIR principles will be introduced. Subsequently, existing challenges and opportunities for conducting socio-economic research in the region and related implications for DMPs are analyzed. Next, methodological implications for the selection of weighting methods are derived. Finally, considerations for the utilization of MCDA within a sustainability context in the Sahel region are discussed.

2. BACKGROUND

2.1 Data management plans

Formulating DMPs stands as a pivotal aspect of successful data handling, particularly within research ventures. They serve to trace the process of data collection, organization, storage, sharing, and preservation across the project's duration. Still, the development and implementation of DMPs often come with hurdles and the potential DMPs offer is not fully realized yet [7].

A primary challenge involves ensuring the security and confidentiality of sensitive data, especially when it comes to personal data in a tense security environment. Unauthorized access or data breaches can potentially result in repercussions. Thus, striking a balance between the necessity of data sharing and collaboration and confidentiality constraints proves intricate [8]. Therefore, this is a crucial aspect of research projects in the Sahel region that must be considered when designing DMPs.

Addressing data format and standardization is necessary to facilitate sharing and interoperability across diverse systems and researchers. This is especially crucial since evolving technology prompts adopting data management strategies to align with emerging tools and platforms.

Awareness of best data management practices requires training and awareness efforts for DMP compliance. However, allocating adequate resources within the project's budget for data management activities, like curation, storage, and sharing, can prove challenging [9].

In interdisciplinary research endeavors, harmonizing data management practices across divergent fields with unique data requirements can result in further complexity. Effectively implementing the DMP throughout the project's course and ensuring ongoing compliance necessitate commitment and attention [9]. Thus, upholding data integrity and quality, encompassing aspects like accuracy, completeness, and consistency, remains paramount.

Addressing these challenges mandates collaboration among researchers, data managers, and other stakeholders to construct comprehensive, adaptable, and pragmatic data management plans. Regular review and updates of the DMP to accommodate changing data management demands are vital for sustained effectiveness, particularly when handling sensitive data in a dynamic region.

2.2 FAIR Guiding Principles

The FAIR Guiding Principles encompass a series of recommendations crafted to enhance the handling and usability of scientific data [10]. The acronym FAIR represents Findable, Accessible, Interoperable, and Reusable. These principles were formulated with the intent of guaranteeing the seamless sharing and application of data across diverse fields and platforms [10]. Their objective is to amplify the significance and influence of research data by augmenting its detectability, availability, and potential for use by both individuals and automated systems [10]. The following are the core four tenets of the FAIR principles as laid out by Wilkinson et al. [10].

Data must be findable (F) and possess high discoverability, accessible to both humans and automated systems. This necessitates the provision of an unambiguous and enduring identifier, such as a Digital Object Identifier (DOI), in conjunction with

comprehensive metadata delineating the data's substance, backdrop, and origin. Using standardized metadata and effective indexing plays a pivotal role in augmenting data's findability.

Moreover, data ought to be accessible (A) to both users and systems. This entails the data being retrievable in a practical format via clearly defined access protocols. The permissions granted to users regarding data usage, as well as any applicable limitations, should be transparent. Any mechanisms for access control need to be explicitly conveyed.

Further, it is important that data is interoperable (I). Thus, data must be organized and delineated in a manner that simplifies its fusion with alternative datasets and tools. This process entails the adoption of universally recognized data standards, formats, and terminologies. Data that is interoperable enables researchers to amalgamate and scrutinize datasets originating from diverse origins, culminating in more comprehensive and profound insights.

Finally, data must be reusable (R) and possess thorough documentation and appropriate licensing to foster and promote its repeated use. This encompasses furnishing precise details regarding proper data citation, applicable usage rights, and any potential constraints on reuse. Meticulous documentation guarantees that data can be comprehended and harnessed proficiently by others. This also applies for respective software that ideally should be open source [11].

The FAIR principles advocate for the advancement of open science and the adoption of data sharing methodologies, empowering researchers to optimize the influence of their endeavors and easing cross-disciplinary collaborations [10]. Embracing these principles enables researchers to play a role in fostering a scientific environment that is characterized by transparency, efficacy, and cooperation.

While the FAIR principles prove immensely useful in enhancing the overall quality of research, their successful implementation can be challenging, contingent upon the specific use case. The following section will delve into the related opportunities that embracing FAIR principles offers, as well as the potential challenges that researchers might encounter during their application in the Sahel region.

3. IMPLICATIONS FOR DATA MANAGEMENT

Conducting socio-economic research in the Sahel region presents a range of opportunities that can contribute to a deeper understanding of the region's dynamics and challenges. The Sahel, characterized by its semi-arid climate and complex socio-political landscape, offers a unique context for studying various aspects of development, resilience, and community dynamics [1].

3.1 Opportunities

Food security is of vital importance in the Sahel due to its heavy reliance on rain-fed agriculture [1]. This makes the region an ideal location for investigating aspects such as food security, sustainable agricultural methods, diversification of crops, and the ramifications of climate change on agricultural output [1]. Research has the potential to delve into how communities within the Sahel region broaden their livelihood strategies to manage environmental and economic difficulties. This encompasses the examination of alternative income avenues beyond agriculture, such as trade, craftsmanship, and service sectors.

Considering the Sahel's susceptibility to desertification and land degradation, there is a pronounced importance in investigating sustainable approaches to managing natural resources. Related approaches in research can contribute valuable insights for shaping policies concerning land utilization, water governance, and environmental preservation. Additionally, the interplay between cultural norms and social frameworks holds notable value. It can contribute towards a deeper understanding of how these factors influence economic undertakings, decision-making processes, and equitable access to resources.

Gaining insight into how communities in the Sahel region fortify their resilience against environmental upheavals and socio-economic strains holds the potential to shape impactful energy transitions and developmental strategies [1]. Additionally, comprehending how innovation, technology, and digital platforms are harnessed for economic advancement and community empowerment unveils novel avenues for addressing challenges. In this context, there is potential to extract lessons on enhancing access to high-quality education.

Conducting socio-economic research in the Sahel requires collaboration with local communities, understanding cultural contexts, and engaging with relevant stakeholders. Such research can contribute to evidence-based policies and interventions that address the region's challenges and promote sustainable development.

3.2 Challenges

Engaging in research within the Sahel region entails distinct obstacles that can notably influence the formulation and execution of DMPs.

Research endeavors might occur in distant and hard-to-reach locations, introducing data gathering and

transmission complexities. This situation demands meticulous strategizing for data storage and transportation. Frequently, the Sahel region faces a deficiency in sufficient research infrastructure, encompassing dependable internet connectivity and storage capabilities, which can impede endeavors related to data sharing and the preservation of data.

The region has encountered political and security obstacles [3], which possess the potential to disrupt research initiatives and impede respective endeavors, requiring constant evaluation of existing DMPs.

The Sahel region exhibits linguistic and cultural diversity [1-3]. Effectively communicating data management practices across varying languages and cultures can further contribute to existing challenges. In this connection, countries in the area adhere to distinct data privacy regulations and ethical concerns. This underscores the need for meticulous compliance with local laws and sensitivity to community norms. When conducting research involving indigenous communities in the Sahel, it is crucial to give special consideration to the preservation and respectful treatment of their traditional knowledge and data ownership.

Access to training and resources for data management might be restricted in parts of the region, potentially resulting in knowledge gaps concerning the adoption and execution of best practices.

Research conducted within the Sahel region could encounter financial constraints that influence the distribution of resources for tasks related to data management.

Thus, research approaches and respective DMPs must accommodate the region's distinct requirements and constraints. They should interact with local stakeholders and communities and encourage regional partnerships to support the efficacy of data management. Hence, a willingness to be flexible, adaptable, and adhere to ethical and culturally attuned data practices is indispensable for prosperous research and effective data management.

4. CONCEPTUAL APPROACH & METHODOLOGY

The majority of multi criteria group decision methods were intended for utilization within a business setting [12]. However, the usefulness of a multi-criteria study hinges greatly on how the mathematical model is integrated into the broader social, political, and technical context. This is precisely why in the realm of MCDA, the emphasis is placed on the importance of the decision process itself rather than solely on the solution [13, 14].

Decisions in a social and environmental context differ from those in business or in a pure technical setting. In finite world with limited resources, not every aspect in the natural environment can be substituted. Acknowledging these limitations influences how sustainability is perceived and has implications for related policies.

Weights within a MCDA framework linked to sustainability decisions are not trade-offs but should be understood as importance coefficients since they represent divergent ethical considerations that result in varied perspectives on the significance of criteria [14]. That strengthens reasoning towards the utilization of non-compensatory approaches since lesser-weighted criteria, potentially illustrating perspectives of minorities or less influential stakeholder groups, can maintain considerable impact on the obtained results [14].

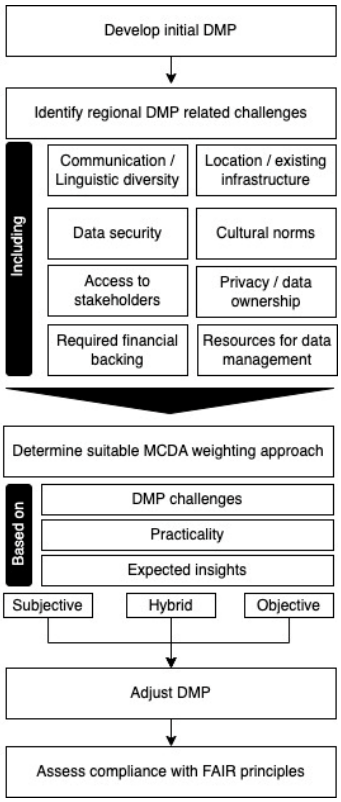

Fig. 1. Workflow for DMP and weighting approach

While not all MCDA methods demand the allocation of weights, those potentially relevant for the present analysis require a different weighting of the various criteria and underlying goals. Setting weights for indicators within MCDA approaches allows for integrating different priorities and assign relative importance of criteria. Thus, choosing an appropriate weighting method and respective weights can be considered a key step within the decision making process. While various approaches exist, they differ notably with respect to the fundamental assumptions, required input, in case stakeholders are involved during the process, and have a substantial influence concerning the result obtained by an analysis based on MCDA.

With respect to decision-making in sustainable energy research, two main categories have been widely applied, namely equal-weights and rank-order weights [15, 16]. As the name suggests, equal-weights distributes the weights equally among the respective number of criteria. Using this approach, no external input is required. While this approach has been widely applied and its utilization is simple, it has repeatedly been criticized since it ignores the relative importance of criteria [15]. It is expressed as:

$$w_i = \frac{1}{n}, i = 1,2, \dots, n, \quad (1)$$

In contrast, rank-order weights allow to address these differences of relative importance among criteria. Generally, rank-order weighting methods for MCDA can be distinguished into *objective* and *subjective* methods, as well as *integrated* (sometimes referred to as *hybrid*) approaches. The following part illustrates these subcategories and depicts their main differences.

4. 1 Objective weighting methods

Objective approaches do not require the decision maker to actively assign weights to the different criteria. Instead, weights are assigned based on the information provided by the criteria themselves. Depending on the specific method, the information is obtained through computational procedures based on the initial data or the decision-matrix [17]. Thereby, the amount of information within a criterion illustrates the relative importance. However, applying an objective weighting method still entails subjective considerations since results gathered might differ notably depending on which of these methods is applied. Commonly used methods in this regard are Criteria Importance Through Inter-criteria Correlation, Entropy method, mean weight, variance and standard deviation [17-19]

Beneficial aspects of objective weighting methods include that they require little to none stakeholder input. Hence, they can be considered as specifically useful in situations where stakeholders either have no knowledge of the particularities concerning the intended analysis or obtaining that knowledge is not feasible. Examples of situations where obtaining stakeholder input is not feasible can manifest if stakeholders can expect negative repercussion should they express their views openly or the effort to accumulate this knowledge exceeds the hoped-for benefits. In addition, time and budget constraints can further limit possibilities to incorporate stakeholder input appropriately.

4.2 Subjective weighting methods

Subjective weighting methods rely on input provided by the involved stakeholders. Depending on the respective method, the degree of stakeholder involvement as well as the complexity in executing the method vary notably. Thus, deciding which method is considered the most useful is strongly determined by decision problem. Beyond that, in practice, budget and time constraints need to be addressed. Various methods were developed to systematically include stakeholders within the weighting procedure. Commonly used methods in this regard are direct weighting, point allocation, and the analytic hierarchy process [15, 17, 19-21]

In addition, several hybrid methods have been developed, which utilize and combine aspects of methods of both categories.

5. DISCUSSION & CONCLUSIONS

This paper analyzes approaches for addressing data management complexities and challenges within the context of sustainable energy transitions in the Sahel region. Furthermore, the work delves into the intricate task of employing MCDA methods in the region, offering valuable conceptual insights for identifying appropriate weighting approaches. It provides novel perspectives particularly relevant in addressing this region's unique challenges of sustainable energy transitions.

The different weighting approaches have advantages and disadvantages. Thus, there is no optimal procedure to obtain weights within MCDA. Therefore, the respective method needs to be selected according to the decision problem and is highly context-dependent. Given the notable influence of weights for the overall outcome of the analysis, the weighting approach is considered as a crucial step.

Conducting research and collecting data in the Sahel region can be a demanding task, often riddled with complexities. The unique challenges posed by multifaceted decision-making processes and diverse stakeholder involvement require a keen understanding of specific data needs. To effectively address these challenges, researchers must develop tailored approaches that align with the intricate nature of the subject matter. Such approaches should not only account for the diverse perspectives and criteria involved but also ensure that data collection methods are well-suited to capture the nuances of the decision-making landscape.

Developing and implementing a comprehensive DMP while considering the FAIR principles in the Sahel region can contribute to an increased understanding. Yet, it needs to be assessed whether the additional effort of using subjective weighting methods delivers substantially more understanding of respective energy transitions and decision-making compared to the utilization of objective methods. This paper provides conceptual considerations for developing suitable

applications that can be built upon. Case studies in the region could provide valuable insights in this regard.

DECLARATION OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. All authors read and approved the final manuscript.

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