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# Assessing the Challenges to Leverage Carbon Markets for Renewable Energy in Developing Countries: A Multi-Criteria Decision-Making Approach

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**ABSTRACT**

Harnessing carbon markets for renewable energy involves evaluating various factors carefully. To address this, a multi-criteria approach is employed for its flexibility and supplementary tools. This study assesses five challenges of leveraging carbon markets for renewable energy in Africa. The stepwise weight assessment ratio analysis (SWARA) method is applied in an interval-valued spherical fuzzy environment (IVSF) to facilitate group decision-making. The study emphasizes institutional capacity shortfalls and regulatory framework gaps as the most significant obstacles to harnessing carbon markets for renewable energy. The research findings guide policymakers in formulating effective strategies to address these challenges.

## 1. Introduction

Africa, with its low greenhouse gas emissions, is at a pivotal time to reach net-zero goals by 2030 [1]. Achieving this goal requires new ways of funding climate, with carbon markets playing a crucial role [2]. However, maximizing their potential in Africa is challenging. In the face of challenges, the Africa Carbon Market Initiative (ACMI) aims to generate 300 million credits annually by 2030 [3]. This ambitious plan seeks to create significant income. The growing off-grid solar sector in Africa is key to unlocking the carbon market's potential. Cold storage solutions, solar power systems, and water pumps could contribute up to billions of dollars by 2030 [4, 5]. The convergence of durable energy and carbon markets offers a distinctive occasion for Africa's energy transition.

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Despite their potential, carbon markets face significant challenges, especially in developing countries [6]. Many carbon-offset projects fail to meet emission reduction targets, and industries may misuse carbon credits to delay embracing greener technologies [7]. Additionally, the lack of standardized evidence and a consolidated registry increases the risk of carbon credit duplication, frightening market cohesion.

Many studies have explored the challenges of utilizing carbon markets globally. For instance, Lo [6] discussed the main economic and political obstacles to developing carbon markets in China. Zhou and Li [8] conducted a structured review of the advancements and issues in China's carbon finance and carbon market. Sun et al. [9] reviewed the progress of carbon trading to date and analyzed the main challenges facing its future development in China. Cheffo [10] assessed carbon trading in Africa, noting opportunities, challenges, and solutions. Feindt et al. [11] analyzed the effects of a European carbon price on households across 23 EU countries. Shi et al. [12] detailed carbon markets in major Asian economies, with a specific focus on China.

However, there is a lack of studies assessing the severity-ordered challenges of carbon markets for renewable energies in developing countries, especially in Africa. Addressing this requires a managerial perspective to identify and evaluate these challenges [13-16], ideally using multi-criteria decision-making (MCDM) techniques [17-20].

### *1.1 Objectives*

Our study aims to: (1) Evaluate the obstacles in leveraging carbon markets for renewable energy (RE) in Africa, and (2) Prioritize these challenges based on their severity.

### *1.2 Contributions*

This research makes two key contributions: (a) It assesses the challenges of leveraging carbon markets for RE in Africa using an MCDM perspective based on IVSFs, a first in the literature, and (b) it provides practical implications for addressing the most critical challenges identified through this ranking.

### *1.3 Motivations*

Fuzzy sets (FSs) have gained significant attention in science, with SFSs and IVFSs offering enhanced ways to tackle ambiguity [21]. IVSFSs combine these advantages, allowing decision-makers to express uncertainty more effectively compared to traditional FSs [22]. IVSFSs are particularly useful for modeling uncertainty comprehensively and integrating diverse ways of evaluation. Keršuliene et al. [23] developed the SWARA technique to find out the weights of criteria, noted for its clarity and applicability in the IVSF context. The rest of the paper is structured in four sections.

## **2. Literature Review**

### *2.1 Approaches Related to Carbon Markets Studies*

Numerous studies have investigated carbon markets in different contexts. Zhang et al. [24] analyzed risk spillover between carbon and stock markets in China. Song et al. [25] applied an innovative carbon-electricity linkage model to study how carbon emission quota (CEQ) prices affect efficiency and PV power revenue. He and Song [26] assessed carbon discharge ability and investigated the policy's impact using the difference-in-difference method. Lin and Huang [27] examined the persistence of carbon emission reductions in an immature market and studied their overall effectiveness. Li et al. [28] analyzed carbon trading operations and spillover impacts in the EU and

China, offering guidance for Chinese policymakers on market establishment and regulation. Wang et al. [29] studied the world's largest carbon trading market. Hou et al. [30] analyzed the decade-long effect of the carbon discharge trading policy. He et al. [31] created a new stress measurement system for carbon markets.

### *2.2 MCDM-related Studies on the Carbon Markets*

MCDM methods are efficient strategies that have been applied in many areas of life [32-34]. Zhang et al. [35] proposed criteria and a rough TOPSIS for carbon market evaluation. Wu and Niu [36] created a comprehensive system comprising TOPSIS and VIKOR approaches to evaluate carbon finance development in China. Nguyen [37] identified factors affecting low-carbon shipping (LCS) decisions and proposed an MCDM framework to help companies select appropriate LCS measures for ships in various conditions. Mishra et al. [38] devised an IF-CODAS approach for low-carbon prioritization. Li et al., [39] used a Delphi and FAHP technique to formulate green finance practices in China aimed at reducing carbon emissions. Dinçer et al. [40] pinpointed key factors for reducing carbon emissions using decision-making techniques and data mining. Krishankumar et al. [41] created a hybrid framework for zero-carbon action ranking. No study has explored the challenges of utilizing carbon markets for RE in Africa. Additionally, the SWARA method has not been used to assess these challenges in Africa within the IVSF environment.

## 3. Methodology

The methodology consists of two stages: At first, data was collected via experts' opinions and literature review. Then, five challenges to leverage carbon markets for renewable energy in Africa were assessed via the application of the SWARA approach under the IVSF environment. The flowchart of our study approach is shown in Figure 1.

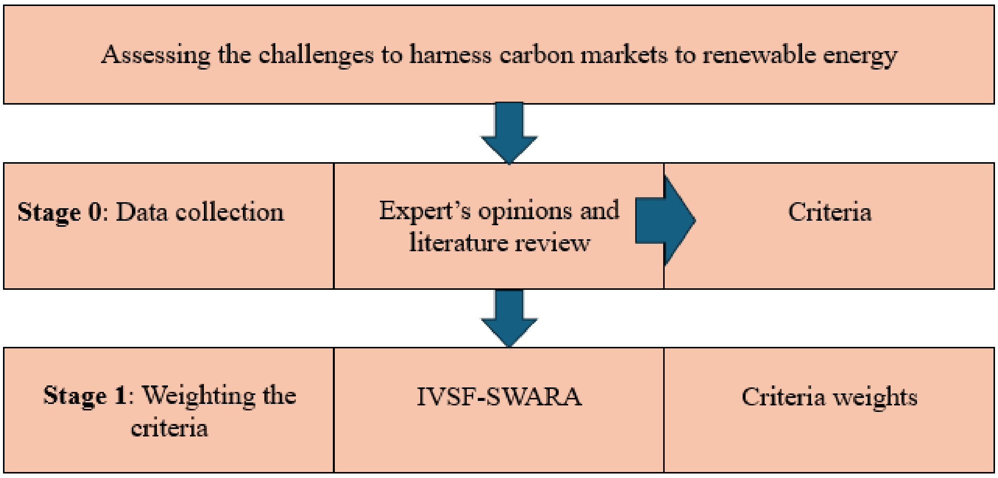


**Fig. 1.** Flowchart of our study approach.

Step 1. Problem evaluation via criteria.

Step 2. Experts classify criteria in descending order using an IVSF set linguistic scale (see Table A1 in the Appendix), offering flexibility in handling uncertain practical problems.

The creation of the weight matrix is shown in Eq. (1):

$$\widetilde{W} = \begin{bmatrix} \tilde{\mu}_{11} & \tilde{\mu}_{12} & \cdots & \tilde{\mu}_{1t} \\ \tilde{\mu}_{21} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ \tilde{\mu}_{n1} & \cdots & \cdots & \tilde{\mu}_{nt} \end{bmatrix} \tag{1}$$

where $n$ –criteria numbers, $t$-experts (p=1, 2……, t).

Step 3. Following the determination of corresponding significant scores by experts, these scores are aggregated using the arithmetic mean. The weights of experts are then calculated using IVSWAM.

Step 4. Positive score values in the aggregated matrix $\tilde{A}$ are computed using the score function for IVSF weights from Eq. (2).

$$s_j = \text{Score}\left(\tilde{\beta}_j\right) + 1 \tag{2}$$

Step 5. Criteria are classified using their practical score.

Step 6. The corresponding significance of each criterion $(c_j)$ is established by evaluating these scores $s_j$ .

Step 7. Computation of $k_j$

$$k_j = \begin{cases} 1 & j = 1 \\ c_j + 1 & j > 1 \end{cases} \tag{3}$$

Step 8. Determination of unscaled weights $q_j$.

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{x_{j-1}}{k_j} & j > 1 \end{cases} \tag{4}$$

Step 9. Determination of corresponding weights through the normalization of criteria weights.

$$w_j = \frac{q_j}{\sum_{j=1}^{n} q_k} \tag{5}$$

## 4. Application

A study using the IVSF-SWARA approach evaluated and prioritized challenges in harnessing carbon markets for RE in Africa. An expert panel of four experienced individuals (Table 1) provided assessments on the severity of these challenges. Five key challenges, identified through literature review and expert opinions, are detailed in Table 2.

**Table 1**
Experts' characteristics

| Experts (Es) | Gender | Occupation | Degree | Experience |
|---|---|---|---|---|
| $E_1$ | Female | Academia | Ph.D. | 10 |
| $E_2$ | Male | Industry | M.Sc. | 17 |
| $E_3$ | Male | Industry | B.Sc. | 20 |
| $E_4$ | Male | Academia | M.Sc. | 12 |

**Table 2**
Challenges to harness carbon markets for RE

| Criteria | References |
|---|---|
| Regulatory framework gaps (C1)<br>Institutional capacity shortfalls (C2) | [4, 6, 42] |

| |
|---|
| Complex approval processes (C3) |
| Monitoring infrastructure deficiencies (C4) |
| Limited information access (C5) |

Data were gathered from experts using Table A1, based on the challenges identified in Table 2 through expert interviews and detailed literature research.

### *4.1 Prioritizing the Challenges*

Step 1. Assessment of five challenges in harnessing carbon markets.

Step 2. Determination of criteria weights by four experts based on evaluation of challenges from Table 3.

**Table 3**
Challenges assessment

| Criteria | E-1 | E-2 | E-3 | E-4 |
|---|---|---|---|---|
| Regulatory framework gaps (C1) | VHI | HI | HI | HI |
| Institutional capacity shortfalls (C2) | VHI | AMI | AMI | VHI |
| Complex approval processes (C3) | HI | LI | SMI | SMI |
| Monitoring infrastructure deficiencies (C4) | HI | HI | SMI | HI |
| Limited information access (C5) | LI | LI | VLI | LI |

Note: E: Expert.

Step 3. Initially, mathematical expressions are employed to convert the linguistic variables (LV) as shown in Table A1. Next, experts' ideas are compiled in Table 4, assuming equal weights for all experts.

**Table 4**
Aggregated evaluations of criteria

| Criteria | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| Regulatory framework gaps (C1) | 0.6791 | 0.7807 | 0.1861 | 0.2364 | 0.0349 | 0.0559 |
| Institutional capacity shortfalls (C2) | 0.8072 | 0.9141 | 0.1225 | 0.1732 | 0.0106 | 0.0310 |
| Complex approval processes (C3) | 0.5285 | 0.6260 | 0.3002 | 0.3604 | 0.0524 | 0.0797 |
| Monitoring infrastructure deficiencies (C4) | 0.6282 | 0.7287 | 0.2115 | 0.2617 | 0.0450 | 0.0685 |
| Limited information access (C5) | 0.1888 | 0.2386 | 0.6737 | 0.7738 | 0.0357 | 0.0570 |

Step 4. Provision of the computation of results for criteria in Table 5.

**Table 5**
Positive scores of criteria

| | C1 | C2 | C3 | C4 | C5 |
|---|---|---|---|---|---|
| $s_j$ | 1.4896 | 1.7209 | 1.2244 | 1.4054 | 0.5194 |

Step 5. The rank of the criteria is $C2 > C1 > C4 > C3 > C5$.

Step 6. Calculation of comparative importance of criteria in Table 6.

**Table 6**
Comparative significances of criteria

| | C2 | C1 | C4 | C3 | C5 |
|---|---|---|---|---|---|
| $c_j$ | - | 0.231 | 0.084 | 0.181 | 0.705 |

Step 7. Provision of coefficients calculation in Table 7.

**Table 7**
Coefficients for criteria

| | C2 | C1 | C4 | C3 | C5 |
|---|---|---|---|---|---|
| $k_j$ | 1 | 1.231 | 1.084 | 1.181 | 1.705 |

Step 8. Presentation of disorganized criteria weights in Table 8.

**Table 8**
Disorganized criteria weights

| | C2 | C1 | C4 | C3 | C5 |
|---|---|---|---|---|---|
| $q_j$ | 1 | 0.812 | 0.749 | 0.634 | 0.372 |

Step 9. Figure 2 indicates the final weights of the criteria.

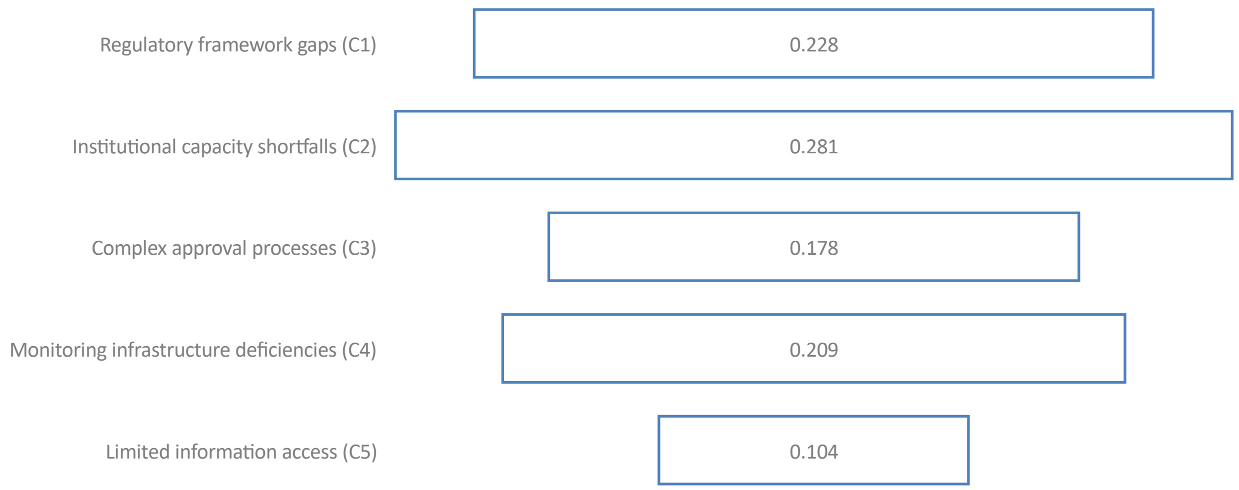


**Fig. 2**. Final criteria weights

Institutional capacity shortfalls are a very critical issue (0.2810) and following regulatory frameworks gaps (0.2280), monitoring infrastructure deficiencies (0.2090), complex approval processes (0.178), and limited information access (0.104) hold the fifth position from Figure 2. This rank of institutional capacity aligns with the findings of Mo and Lu [42] who indicated that insufficient transparency and governance, and a lack of technical expertise impede the development and enforcement of carbon market policies. Poor coordination among stakeholders and limited human resources further restrict the effectiveness of carbon market initiatives. Additionally, difficulties in translating policies into actionable plans hinder progress.

Regulatory framework gaps are the second most critical issue, which is consistent with the study of Waziri [43], who claimed that the absence of clear and comprehensive regulations makes it difficult for stakeholders to understand the requirements and processes involved. Regulatory gaps hinder the integration of Africa’s carbon markets with global systems, limiting access to broader market opportunities and funding.

### *4.2 Managerial Implications*

The conclusions of this study offer valuable insights for policymakers looking to harness carbon markets for renewable energy. The research highlights two major challenges: institutional capacity shortfalls and gaps in regulatory frameworks. These challenges are particularly relevant for policymakers in Africa. Our study stresses the need for robust institutions to develop and enforce effective regulations, ensure transparency, and streamline administrative processes. In regions where governance and infrastructure issues are prevalent, enhancing institutional capacity is crucial for building trust, attracting investment, and effectively developing carbon markets. Moreover, strong regulations are necessary to incentivize RE projects and ensure they can compete with traditional energy sources within the carbon market framework. Robust regulatory frameworks are essential for the successful operation and growth of carbon markets, promoting investments in RE and facilitating Africa's transition to a low-carbon economy.

## 5 Conclusions and Recommendations

This study utilizes the IVSF-SWARA approach to analyze challenges in utilizing carbon markets for renewable energy, providing insights crucial for policymakers. It assesses these challenges through expert opinions and a literature review, focusing on a case study in Africa to identify key issues. The study highlights institutional capacity shortfalls and regulatory gaps as major concerns. However, it has limitations. Firstly, it examines Africa at a continental level, overlooking the diversity among countries and regions. Secondly, a few experts have been considered for data collection. Lastly, while the proposed methodology offers benefits, managing large expert groups without a consensus-reaching process remains a challenge.

Future studies should consider all these limitations by examining these challenges at either the regional or the national level. More experts should take part during the data collection and a consensus-reaching process should be adopted.

## Appendix

**Table A1**
Linguistic terms

| Linguistic terms | IVSF number | Score index |
|---|---|---|
| Absolutely more important (AMI) | ([0.85, 0.95], [0.10, 0.15], [0.05, 0.15]) | 9.00 |
| Very high important (VHI) | ([0.75, 0.85], [0.15, 0.20], [0.15, 0.20]) | 7.00 |
| High important (HI) | ([0.65, 0.75], [0.20, 0.25], [0.20, 0.25]) | 5.00 |
| Slightly more important (SMI) | ([0.55, 0.65], [0.25, 0.30], [0.25, 0.30]) | 3.00 |
| Equally important (EI) | ([0.50, 0.55], [0.45, 0.55], [0.30, 0.40]) | 1.00 |
| Slightly low important (SLI) | ([0.25, 0.30], [0.55, 0.65], [0.25, 0.30]) | 0.33 |
| Low important (LI) | ([0.20, 0.25], [0.65, 0.75], [0.20, 0.25]) | 0.20 |
| Very low important (VLI) | ([0.15, 0.20], [0.75, 0.85], [0.15, 0.20]) | 0.14 |
| Absolutely low important (ALI) | ([0.10, 0.15], [0.85, 0.95], [0.05, 0.15]) | 0.11 |

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**Conflicts of Interest**
The author declares no conflicts of interest.

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