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# Addressing the Crucial Factors Affecting the Implementation of Carbon Credit Concept Using a Comprehensive Decision-Making Analysis: A Case Study

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**Abstract:** As global focus on climate change intensifies, carbon credits have become an important tool for reducing greenhouse gas emissions. Africa, with its abundant natural resources and potential for sustainable development, is well-positioned to capitalize on this growing market. This article explores how Africa can enhance its participation in the carbon credit market, transforming environmental initiatives into economic opportunities by addressing key implementation challenges. By utilizing the Stepwise Weight Assessment Ratio Analysis (SWARA) method within an interval-valued spherical fuzzy (IVSF) framework, the study supports collective decision-making. It identifies three crucial factors: access to financing issue, the absence of clear policies and legal frameworks, and the lack of capacity and expertise within governments, businesses, and communities. The research provides practical recommendations for governments aiming to effectively implement the carbon credit concept.

**Keywords:** Carbon credit concept; IVSF; SWARA; Decision-making analysis; Africa

## 1 Introduction

Carbon credits (CC) are vital tools in reducing greenhouse gas (GHG) emissions on both national and global levels. They offer a way for organizations, companies, and individuals to compensate for their emissions by supporting projects that remove or decrease an equivalent amount of GHGs from the atmosphere. Each carbon credit corresponds to the right to emit one ton of carbon dioxide or its equivalent in other GHGs. These credits are typically generated through activities such as reforestation or renewable energy projects, which reduce or eliminate emissions. The international trade of carbon credits requires the host country's approval, creating a marketplace where emitters can buy credits from entities that have successfully cut their emissions [1, 2].

The CC are essential for driving and financing sustainable development projects (SDPs) that reduce GHG emissions and support global climate action. By participating in carbon credit initiatives, communities, businesses, and countries can address environmental challenges and make strides toward their sustainability objectives. Dechezleprêtre et al. [3] described that CC for sustainable development involve quantifying and checking emissions reductions, managing projects, tracking progress, approving results, providing credits, and trading them.

Various studies have been focused on the carbon credit market in Africa. For instance, Winkelman and Moore [4] highlighted that several critical factors can influence the successful implementation of carbon credits in Africa. Bryan et al. [5] examined global carbon markets, focusing on agricultural trading opportunities in sub-Saharan Africa (SSA), outlined major barriers to SSA's participation, and proposed strategies for regional integration. Marenya et al. [6] evaluated the advantages of carbon payment plans versus subsidies for lowering the costs of land management practices that enhance productivity and support carbon sequestration. Yemi and Iván [7] stressed the need for climate funding in Africa and proposed voluntary carbon credits as a remedy for broken promises from the Global North. Arunda [8] explored how Africa can increase its participation in carbon-credit trading to turn environmental actions into economic benefits. However, these studies have not focused on the factors that affect the implementation of carbon credit concept at continental level. Sustainable carbon markets in Africa require a comprehensive approach using multi-criteria decision making (MCDM) techniques for better decisions [9–14].

### 1.1 Objectives, Contributions, and Motivations

Our study aims to (1) Identify key factors impacting the implementation of carbon credits concept in Africa and (2) Rank these factors by their level of critical severity.

This research offers two main contributions: (a) It ranks the critical factors influencing carbon credit concept implementation in Africa from an MCDM perspective using IVSFs, which is a novel approach in the literature, and (b) it provides practical insights for addressing these factors.

Fuzzy sets (FSs) have become prominent in research, with SFSs and IVFSs providing better ways to address ambiguity [15, 16]. IVSFSs, by combining these benefits, enable decision-makers to handle uncertainty more effectively than traditional FSs [17]. They are particularly valuable for comprehensive uncertainty modeling and integrating various evaluation methods. Keršuliene et al. [18] introduced the SWARA technique to determine criterion weights, noted for its clarity and effectiveness within the IVSF framework. The remainder of the paper is organized into five sections.

## 2 Literature Review

Many studies have investigated the global carbon credit markets. For instance, Battocletti et al. [19] investigated the functioning of the voluntary carbon market for generating and trading carbon offsets and assessed the need for its regulation. Xu et al. [20] examined the risks associated with funding carbon credit projects and explored strategies to mitigate these risks. Michaelowa et al. [21] examined the fragmented management of carbon removals in compliance and voluntary markets. Chanda et al. [22] investigated the potential carbon credits India could achieve by eliminating emissions from crop residue burning. Anjos et al. [23] studied how a global carbon-credit market affects renewable standards, emissions, and the energy mix. Song [24] examined price fluctuations in the carbon trading market and the evolution of global carbon credits.

MCDM techniques have proven to be successful in various areas [15, 16, 25–28]. In the carbon credits related studies, for instance, Wei et al. [29] developed a framework for assessing obstacles to Chinese forest carbon sink projects. Chen et al. [30] analyzed Taiwanese carbon offset projects to assess domestic development. Wu and Niu [31] ranked pilot cities for carbon finance in China. Florindo et al. [32] evaluated and ranked measures to reduce the carbon footprint of Brazilian beef exports based on their impact profiles. Table 1 shows the use of MCDM approaches in studies related to carbon credit markets.

**Table 1.** MCDM application on studies related to carbon credit markets

| Source | Location | Focus | GDM | Methodology |
|---|---|---|---|---|
| Wei et al. [29] | China | Barrier assessment of forest carbon sink project implementation | Yes | BWM, IT2F, PROMETHEE II |
| Chen et al. [30] | Taiwan | Carbon offset mechanism implementation challenge assessment | Yes | AHP, SWOT, TOPSIS |
| Wu and Niu [31] | China | Carbon finance development | Yes | TOPSIS, VIKOR |
| Florindo et al. [32] | Brazil | Carbon footprint reduction actions assessment | Yes | F-TOPSIS |
| Our study | Africa | Addressing the crucial factors affecting the implementation of carbon credit idea | Yes | IVSF-SWARA |

Note: **AHP**- Analytic Hierarchy Process; **BWM**- Best Worst Method; **GDM**-Group Decision Making; **IT2F**- Interval Type-2 Fuzzy; **PROMETHEE**- Preference Ranking Organization Method for Enrichment Evaluation; **SWOT**- Strengths, Weaknesses, Opportunities, and Threats; **TOPSIS**- Technique for Order Preference by Similarity to Ideal Solution; **VIKOR**- Vlsekriterijumska Optimizacija I KOmpromisno Resenje.

As indicated in Table 1, the application of the SWARA approach within an IVSF framework to address key factors impacting carbon credit implementation in Africa is a novel contribution to the literature.

## 3 Methodology

The methodology involves two steps: collecting data from experts and previous studies, followed by evaluating six factors affecting carbon credit implementation in Africa using the SWARA method within an IVSF framework. Figure 1 shows the study's flowchart.

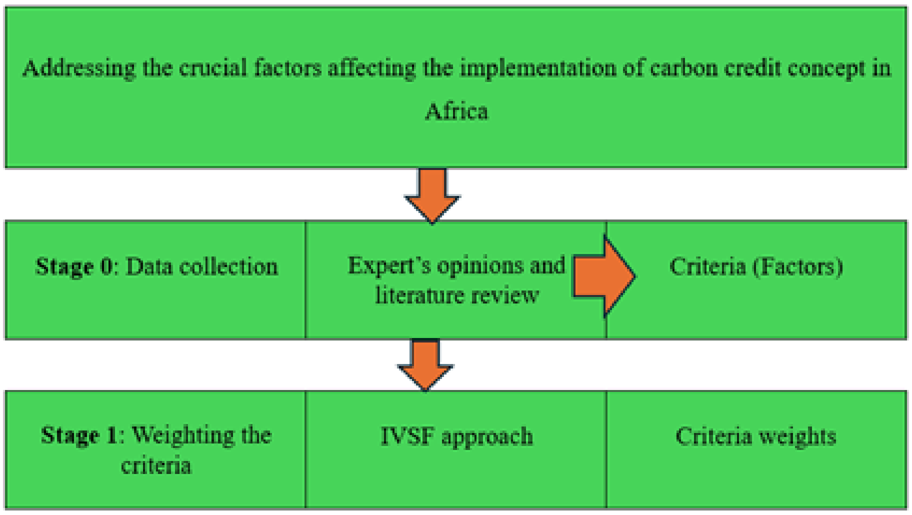


**Figure 1.** Flowchart of our study approach

Nine steps have characterized the IVSF-SWARA approach.

**Step 1.** Problem evaluation via various factors.
**Step 2.** Using the IVSF linguistic scale (refer to Table A1 in the appendix), experts prioritize criteria in descending order, enabling adaptable solutions to uncertain challenges.
Eq. (1) indicates the weight matrix establishment.

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

where, n –criteria numbers, t-experts (p=1, 2. . . ..., t).
**Step 3.** Once experts assign significance scores, the scores are averaged using the arithmetic mean, and the experts' weights are then determined using IVSWAM.
**Step 4.** The score function from Eq. (2) is used to calculate positive score values in the aggregated matrix $\tilde{A}$ for IVSF weights.

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

**Step 5.** Criteria are organized according to their practical scores.
**Step 6.** The importance of each criterion ($c_j$) is determined by analyzing the scores $s_j$.
**Step 7.** Computation of $k_j$.

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

**Step 8.** Determination of unscaled weights $q_j$.

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{\mathrm{x}_{j-1}}{\mathrm{k}_j} & j > 1 \end{cases} \tag{4}$$

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

$$\mathrm{w}_j = \frac{q_j}{\sum_{j=1}^{n} q_k} \tag{5}$$

## 4 Application

Using the IVSF-SWARA method, the study assessed and ranked key factors with input from a panel of four experts (Table A2). Details on the six factors, identified through literature and expert opinions, are provided in Table A3. Experts provided data based on Table A1, which was used to evaluate the factors outlined in Table A3.

### 4.1 Prioritizing the Factors

**Step 1.** Assessment of six factors affecting the implementation of the carbon credit concept.
**Step 2.** Determination of criteria weights by four experts based on evaluation of factors from Table 2.

**Table 2.** Factors evaluation

| Criteria | E-1 | E-2 | E-3 | E-4 |
|---|---|---|---|---|
| C1 | VHI | VHI | VHI | HI |
| C2 | HI | VHI | HI | VHI |
| C3 | AMI | AMI | VHI | VHI |
| C4 | SMI | SMI | HI | SMI |
| C5 | HI | HI | HI | SMI |
| C6 | SMI | EI | SLI | SLI |

Note: E: Expert.

**Step 3.** Mathematical formulas are initially used to convert linguistic variables from Table A1, and then experts' opinions are compiled in Table 3 with equal weighting.

**Table 3.** Aggregated evaluations of criteria

| Criteria | a | b | c | d | e | f |
|---|---|---|---|---|---|---|
| C1 | 0.7287 | 0.8301 | 0.1612 | 0.2115 | 0.0262 | 0.0447 |
| C2 | 0.7052 | 0.8072 | 0.1732 | 0.2236 | 0.0304 | 0.0500 |
| C3 | 0.8072 | 0.9141 | 0.1225 | 0.1732 | 0.0106 | 0.0310 |
| C4 | 0.5785 | 0.6791 | 0.2364 | 0.2866 | 0.0563 | 0.0822 |
| C5 | 0.6282 | 0.7287 | 0.2115 | 0.2617 | 0.0450 | 0.0685 |
| C6 | 0.1769 | 0.2265 | 0.6982 | 0.7984 | 0.0314 | 0.0515 |

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

**Table 4.** Positive scores of criteria

| | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| $s_j$ | 1.5744 | 1.5340 | 1.7209 | 1.3277 | 1.4054 | 0.4783 |

**Step 5.** The rank of criteria is C3>C1>C2>C5>C4>C6.
**Step 6.** Calculation of comparative importance of criteria in Table 5.

**Table 5.** Comparative significances of criteria

| | C3 | C1 | C2 | C5 | C4 | C6 |
|---|---|---|---|---|---|---|
| $c_j$ | - | 0.147 | 0.040 | 0.129 | 0.078 | 0.849 |

**Step 7.** Provision of coefficients calculation in Table 6.

**Table 6.** Coefficients for criteria

| | C3 | C1 | C2 | C5 | C4 | C6 |
|---|---|---|---|---|---|---|
| $k_j$ | 1 | 1.147 | 1.040 | 1.129 | 1.078 | 1.849 |

**Step 8.** Presentation of disorganized criteria weights in Table 7.

**Table 7.** Disorganized criteria weights

| | C3 | C1 | C2 | C5 | C4 | C6 |
|---|---|---|---|---|---|---|
| $q_j$ | 1 | 0.872 | 0.838 | 0.743 | 0.689 | 0.373 |

**Step 9.** Figure 2 indicated the final weights of criteria.

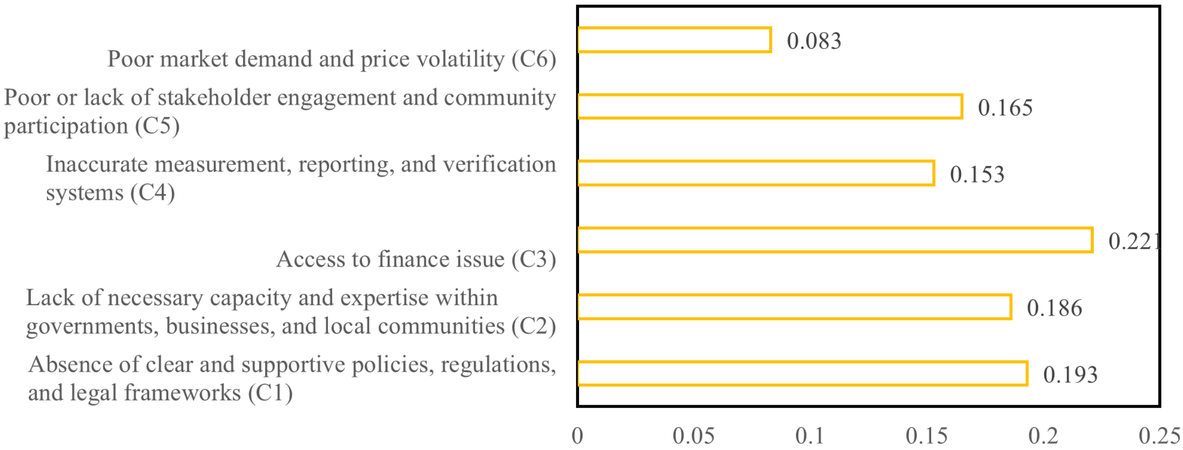


**Figure 2.** Final criteria weights

### 4.2 Findings and Discussion

Our research, using the IVSF-SWARA method, highlights that access to financing is the most crucial factor in implementing the carbon credit concept in Africa. This aligns with Otundo Richard [33] findings, emphasizing that financing challenges directly affect project initiation and scaling, especially in renewable energy, reforestation, and sustainable agriculture. In Africa, the lack of financial resources, high interest rates, and strict lending criteria hinder project development. Moreover, risks like political instability and weak regulatory frameworks worsen the situation. To overcome these challenges, strategies such as strengthening local financial institutions, offering government-backed incentives, enhancing financial literacy, and promoting international collaboration with climate funds are necessary. Additionally, using risk mitigation tools like insurance can make these projects more appealing to investors.

The absence of clear and supportive policies and legal frameworks is the second most critical factor. Gujba et al. [34] noted that this uncertainty discourages investment, as developers and investors lack confidence in the recognition and protection of their efforts. Vague regulations can lead to delays, legal issues, and difficulties in trading carbon credits, deterring both local and international investors. Establishing clear policies is essential for building a credible carbon market and ensuring projects are properly validated and benefits are fairly distributed.

The third key issue is the lack of capacity and expertise within governments, businesses, and local communities, as noted by Cheffo [35]. This deficiency hinders the effective development and management of carbon credit projects. Without the necessary skills, stakeholders struggle to design projects, navigate carbon markets, and accurately measure emissions reductions. It also limits engagement with international partners and adherence to global standards, weakening the success of these initiatives. To address this, targeted training, education, and collaborations with international organizations are crucial for building local expertise and improving participation in the carbon credit market.

## 5 Managerial Implications

This study offers actionable insights for African governments to address key challenges in implementing the carbon credit concept. It identifies three critical factors: access to financing, the absence of clear policies and legal frameworks, and a lack of capacity and expertise in governments, businesses, and communities. To overcome these issues, governments should strengthen local financial institutions, provide government-backed incentives, improve financial literacy, and encourage international collaboration with climate funds. Risk mitigation tools like insurance can also attract investors. Establishing clear policies is vital for creating a credible carbon market, ensuring proper project validation, and fair distribution of benefits. Additionally, targeted training, education, and partnerships with international organizations are essential for building local expertise and enhancing participation in the carbon credit market.

## 6 Conclusions and Future Recommendations

This study utilizes the IVIF-SWARA technique to address critical factors that influence the implementation of the carbon credit concept in Africa, offering key insights for African governments. By drawing on expert opinions, it evaluates these factors and lays the groundwork for informed decision-making. Through a case study in Africa, the research demonstrates the effectiveness of this technique in identifying significant issues. The study points to three main factors: access to financing issue, the lack of clear policies and legal frameworks, and the shortage of capacity and expertise within governments, businesses, and communities. Although the study has made some contributions, there are some limitations. Being conducted at a continental level, it does not fully capture the diverse contexts of individual African countries and regions. Future research should focus on regional or country-specific studies for a more nuanced understanding. Additionally, the study relied on feedback from a small group of experts. Expanding this pool in future research and developing a consensus-based model with a consensus coefficient would enhance the robustness of the findings.

## Author Contributions

Conceptualization, M.B.B.; methodology, S.Q., M.B.B and Y.Q.; software, S.Q. and M.B.B.; validation, M.B.B.; formal analysis, B.I.P.Z and M.B.B.; investigation, B.I.P.Z and I.B.; resources, B.I.P.Z and I.B.; data curation, S.Q., M.B.B and Y.Q.; writing—original draft preparation, X.X.; writing—review and editing, M.B.B and I.B.; visualization, S.Q., Y.Q and I.B.; supervision, S.Q., Y.Q and I.B.; project administration, S.Q., Y.Q and N.K.M.; funding acquisition, S.Q. and Y.Q. All authors have read and agreed to the published version of the manuscript." The relevant terms are explained at the CRediT taxonomy.

## Data Availability

The data supporting our research results are included within the article or supplementary material.

## Conflicts of Interest

The authors declare no conflict of interest.

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**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 |

**Table A2.** Expert 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 A3.** Factors affecting the implementation of the carbon credit concept

| Criteria | References |
|---|---|
| Absence of clear and supportive policies, regulations, and legal frameworks (C1) | [33, 36–38] |
| Lack of necessary capacity and expertise within governments, businesses, and local communities (C2) | |
| Access to finance issue (C3) | |
| Inaccurate measurement, reporting, and verification systems (C4) | |
| Poor or lack of stakeholder engagement and community participation (C5) | |
| Market demand and price volatility (C6) | |