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Expert preferences for carbon farming contract design: an extended VIKOR-based decision-making

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The complicated nature of carbon-based payments and their dependence on voluntary carbon market prices call for efficient carbon farming contracts that can ensure sustainable projects. This study treats contract design as a decision-making problem and applies a multi-criteria decision-making tool, VIKOR, to identify optimal solutions through expert opinions. The findings indicate that experts highly prioritize ‘hybrid payments’ and ‘training, advisory, and capacity building’ as key contract attributes. The preferences also vary significantly based on experts’ on-ground experience and professional characteristics, particularly for different incentive mechanisms. Combining the ranking results with literature-based causal relationships, we developed a decision-support framework that links contractual attributes to project performance. In conclusion, the results suggest that effective contracts are best designed with hybrid incentive mechanisms that provide support to the farmers and have robust certification systems, rather than single-mechanism approaches. Such contracts can translate the EU’s climate goals into scalable and credible carbon removal schemes.

Keywords: carbon farming; multi-criteria decision-making; voluntary carbon markets; contract design; decision-support framework; expert preferences

1. Introduction

The European Commission’s communication on sustainable carbon cycles (European Commission 2021) laid down plans to use and upscale carbon farming to provide financial incentives to farmers using both private and public funds to help increase carbon removals through changed agricultural practices. However, such a ‘green business model’ can only be profitable and sustainable if the benefits outweigh the costs borne by both farmers and society (McDonald *et al.* 2021). However, economic incentives in an agri-environmental scheme (AES) are not the only motivators for farmers’ and landowners’ participation (Raina *et al.* 2021); other contract characteristics, such as transaction costs, monitoring, sanctions, and other non-monetary incentives like training and advisory, and stakeholders’ cooperation contribute significantly to farmers’ enrollment in a scheme (Lienhoop and Brouwer 2015). Similar to an AES, carbon farming scheme incentives and other characteristics can motivate landowners and

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farmers to adopt carbon removal strategies for sustainable agriculture. However, despite a growing global interest, a comprehensive understanding of how to effectively design and implement carbon farming projects, as well as their impact on various agricultural carbon markets, remains elusive. Numerous studies highlight the success of agri-environmental contracts, such as those within the EU's Common Agricultural Policy (CAP) or under the USA's Farm Bill (Snilsveit *et al.* 2019), to the program's institutional setup and, consequently, to the specific features of the contract design (Engel 2016; Mettepenningen *et al.* 2013). For instance, studies suggest that stakeholder involvement is a key determinant for the effective co-design and implementation of these programs (Ajzen 1991; Schulze and Matzdorf 2023; Sok *et al.* 2021). The same holds for voluntary carbon farming schemes. Under these schemes, farmers voluntarily enter contracts with intermediaries to generate 'agricultural carbon credits' by modifying their existing practices, like no-till, cover cropping, etc., which intermediaries then sell in the voluntary carbon markets (VCM). The VCM operates with diverse pricing models and contractual strategies tailored to the business interests of private actors (Plastina, Jo, and Wongpiyabovorn 2024). 'Carbon credits' or 'carbon certificates' are a complex type of traded goods that do not have a materialistic form; rather, their label depends on a certificate of assurance, so it is important to have a robustly designed contract between a buyer and a seller when trading such goods. The complicated nature of carbon-based payments and their dependence on VCM prices raises farmers' transaction costs, increases their risks, and, ultimately, impacts participation (Fortmann *et al.* 2016). Paul *et al.* (2023) also noted that comprehensive assessments regarding certification schemes are lacking due to the complexities of soil carbon dynamics and uncertainties in the governance of these schemes. Fortmann *et al.* (2016) suggested that carbon contracts could become more attractive to farmers by tailoring key aspects of contract design, such as their duration, contract providers involved, payment type, payment schedules, flexibility, etc.

To further analyze what contract features should collectively make up a better-performing scheme, we need to examine contract design through the lens of 'project performance,' similar to the approach by Vlachos (2021). Project performance analyzes how the project did ex-post compared to its objectives ex-ante (Yuristanti, Wiguna, and Budianto 2020). A successful project is achieved when all stakeholders' objectives and needs are met. In the context of carbon farming, project performance extends beyond contractual success or economic returns; it is fundamentally rooted in the ecological and economic outcomes these projects aim to achieve. Performance assessment must therefore rely on well-defined indicators that can serve as measurable proxies to ensure that carbon removal and emission reductions are 'real, measurable, and additional' (Bose *et al.* 2021). Also, the financial accessibility to farmers is a critical aspect of performance, for instance, covering the costs of soil carbon testing and verification, reducing the financial burden of farmers, and ensuring the availability of a carbon market that farmers can access (Raina, Zavalloni, and Viaggi 2024).

Since carbon farming schemes are in their infancy, and primary data are owned by businesses, not publicly available. So, relying on stakeholder opinions provides a practical top-down approach for identifying gaps and improving project performance (Finn *et al.* 2009). Studies have assessed the effectiveness of programs, projects, and policies by quantifying utility based on relevant criteria through multi-criteria decision-making (MCDM) tools (Bartolini and Viaggi 2010). The MCDM tools can assist stakeholders and decision-makers in prioritizing the best options and

generating preferences from alternatives that maximize performance (Taherdoost and Madanchian 2023), which is the goal of this study. Contract design presents a multi-dimensional decision-making challenge, as contract clauses often encompass various quantifiable elements (Liu and Çetinkaya 2009). Unlike other quantitative methods (e.g. surveys) or qualitative approaches (e.g. focus groups), MCDM techniques offer a structured decision-making tool where preference relations are established across multiple criteria and involving multiple stakeholders, thus contributing to group decision-making.

Thus, this study aims to understand how to design high-performing contracts for carbon farming by treating the contract design as a decision-making problem. We employ MCDM tools to elicit expert preferences that will rank contractual elements based on their contribution to project performance, measured using 'performance indicators' that serve as measurable proxies for ecological integrity and economic viability within these projects. In addition, by integrating these rankings with literature-based causal relationships, the study develops a decision-support framework that links contract design attributes to performance outcomes. We also aim to compare the rankings among experts with different experiences and expertise to find synergies in collaborations and alignment in preferences for successful project implementation.

2. Methodology

2.1. Expert selection, data collection, and research design

The experts were systematically identified from global carbon farming case studies based on our recent systematic mapping review (Raina, Zavalloni, and Viaggi 2024) which identified and analyzed 52 peer-reviewed studies and 40 carbon farming case studies across the globe (Africa, EU, USA, Asia, Australia, UK, and South America). From this evidence base, we used purposive sampling to identify potential experts who had demonstrated involvement in developing and implementing carbon farming cases during the months of September 2023 to August 2024. The sample was expanded using snowball sampling. The final sample selected comprised individuals who could represent the carbon farming value chain, including public authorities, policy experts, researchers, intermediaries (e.g. project developers, carbon brokers, certifiers), and financiers. We invited 50 experts for an online interview, to which 32 experts agreed. Our sample represented significant sectoral and geographical diversity across the global landscape, which is further detailed in the Results section. Also, to explore heterogeneity in expert preferences, respondents were further categorized based on (i) their professional experience (on-ground involvement in designing and implementing carbon farming projects vs. research or policy-oriented engagement), and (ii) their stakeholder role within the carbon farming value chain (e.g. as government agencies, policy experts, research institutes, intermediaries, financiers, etc.). These classifications helped compare preference patterns across different expert groups (Results Sections 3.5 and 3.6).

Interviews were conducted using a structured questionnaire designed in Qualtrics¹. Experts were asked to evaluate the perceived impact of each contract attribute on performance indicators using an 11-point bounded scoring scale (0–10), where higher values indicate stronger perceived influence (Table 1). While such a scoring scale allows fine-grained differentiation, they may introduce heterogeneity in individual scale interpretation (e.g. differences in extreme or central response tendencies). To mitigate

Table 1. Decision matrix (Average scores).

	Farmer participation	Additionality	Permanence of carbon sequestered	Carbon leakage avoidance	Carbon market access	Net carbon sequestration	Risk management	Contract compliance
Long contract duration	1.8750	3.4375	8.0938	3.5000	5.2500	5.5313	5.1875	2.6875
High flexibility to change or exit contractual agreements	8.0938	0.9375	0.2813	2.2500	2.0313	1.9063	6.4375	4.5313
Low transaction costs	8.1875	1.9375	1.6563	1.7500	5.4688	3.6250	5.1250	2.9063
Land ownership	5.7813	3.2188	5.5000	2.9375	3.8125	4.4063	4.8750	5.2500
Public incentives	6.8750	5.2188	4.1563	3.0000	3.7188	4.7188	6.0625	5.2188
Private incentives: market-based	6.3125	5.8438	5.1250	3.1563	7.9688	5.5938	4.5625	5.6875
Private incentives: supply chain-based	7.2500	5.0625	5.1250	3.5938	4.0313	5.3125	5.5313	6.5313
Hybrid payments	7.5625	6.0938	5.6563	4.5938	6.0313	6.8125	6.2813	6.7500
Action-based payments	7.8125	5.2813	3.8125	3.1875	3.3750	4.7500	7.5313	6.7813
Result-based payments	3.8125	6.3125	6.0313	4.0625	6.4063	7.1250	2.2500	4.4063
Training, advisory, and capacity building	8.0938	5.3438	6.5625	5.0938	6.1875	6.3125	6.8125	6.6250
Stakeholder engagement	6.9688	4.7813	5.8750	4.4063	6.2500	4.8125	5.6875	6.1875
Farmer cooperation among each other	7.5000	4.0625	5.1875	4.6250	6.2500	6.0313	6.5313	6.5313
Stringent MRV mechanism	0.7188	7.9375	7.5938	6.1250	6.3125	6.1250	2.9063	5.5625
Certification of carbon sequestered	5.1875	6.6563	5.8750	5.3125	8.6250	5.9063	4.2500	6.1875
Availability of baseline data	5.5313	7.2813	4.3438	4.1875	5.9375	5.5625	4.6250	4.0625
Liability mechanism(s) in case of reversal	3.5938	4.5938	5.8125	2.9688	5.1875	4.9688	4.4063	4.4688
Valuation of co-benefits	6.2500	3.0000	4.8750	3.3750	5.3125	4.1250	4.4375	4.0313

Table 2. Normalized weights.

Farmer participation	Additionality	Permanence of carbon sequestered	Carbon leakage avoidance	Carbon market access	Net carbon sequestration	Risk management	Contract compliance
0.1534	0.1339	0.1344	0.1026	0.1083	0.1206	0.1195	0.1272

Table 3. Average weights.

Farmer participation	Additionality	Permanence of carbon sequestered	Carbon leakage avoidance	Carbon market access	Net carbon sequestration	Risk management	Contract compliance
9.34375	8.15625	8.1875	6.25	6.59375	7.34375	7.28125	7.75

potential scale-use bias, scores were aggregated and criteria weights were normalized prior to VIKOR computation (Table 2). In addition, robustness checks using sensitivity analysis and alternative methodologies were conducted to ensure that rankings were not driven by scale artifacts. We also asked the experts to assign weights to different performance indicators on a scale of 0 to 10 (averages in Table 3).

Analysis was done using an MCDM tool called VIKOR. The key steps of any MCDM or multi-criteria decision analysis (MCDA) approach are identifying the options and determining the criteria used for assessing the options, which in our study are the contract design attributes and performance indicators, respectively. Using the weighted scores, the options are ranked from highest to lowest preference/importance, and the results are validated through sensitivity analyses. Analyses are done using the extended version of VIKOR (abb. VIseKriterijumska Optimizacija I Kompromisno Resenje) explained in sub-sections below, adapted from (Opricovic and Tzeng 2007).

Mathematically, an MCDA problem can be represented by a decision matrix with m rows and n columns or $m \times n$ elements. Each element, like f_{ij} represents the performance of alternative i on criterion j . The decision matrix (D) is expressed as Equation 1:

$$D = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} f_{11} & f_{12} & \dots & f_{1n} \\ f_{21} & f_{22} & \dots & f_{2n} \\ \vdots & \vdots & f_{ij} & \vdots \\ f_{m1} & f_{m2} & \dots & f_{mn} \end{bmatrix} \end{matrix} \quad (1)$$

where the various alternatives are denoted as $A_1, A_2, \dots, A_i, \dots, A_m$; and the various criteria are denoted by $C_1, C_2, \dots, C_j, \dots, C_n$.

Data were stored in Excel and analyzed using MATLAB ver. R2023b. The methodological workflow of the study, from expert elicitation to VIKOR-based analysis, validation, and expert-group comparisons, is illustrated in Figure 1.

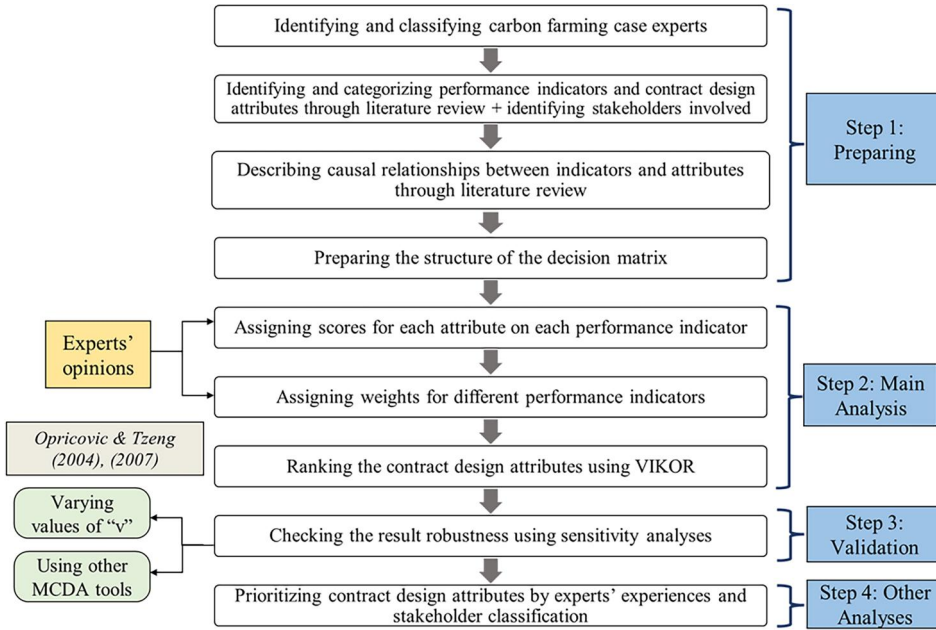


Figure 1. Methodological workflow of the study. Adapted from Darmian, Afrasiabi, and Yazdani (2023).

2.2. Study variables

We start the study by adapting the conceptual framework in the EU-H2020 project CONSOLE (Viaggi *et al.* 2022) which defines innovative contractual solutions for AES and the indicators of their performance, like effectiveness, acceptance, profitability, feasibility, etc. (Figure 2), to illustrate efficient carbon farming contracts. We also employed a narrative literature review process using qualitative content analysis to extract the contractual and performance elements, categorize them, and find causal linkages between the elements.

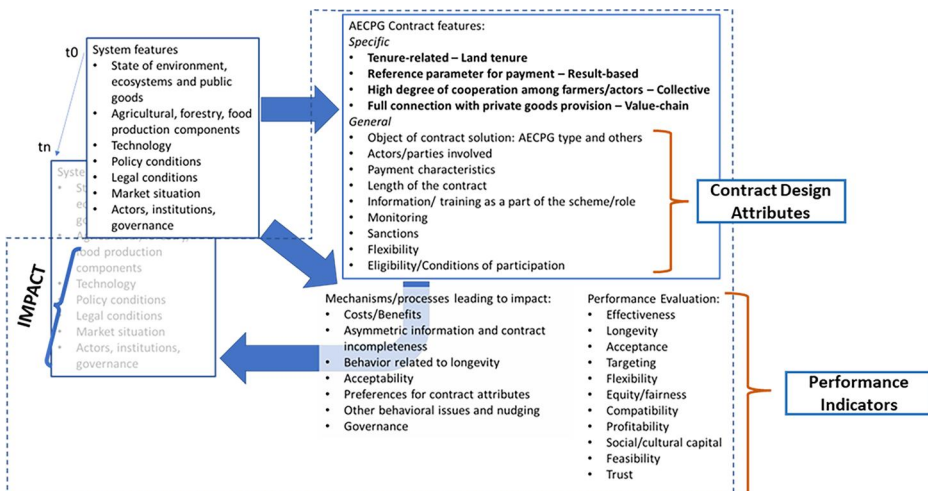


Figure 2. Deriving contract design attributes and performance indicators from CONSOLE Framework. Adapted from Viaggi *et al.* (2022).

2.2.1. Extraction and categorization of performance and contractual elements

Contractual elements or design attributes refer to structural and procedural features of carbon farming contracts that encourage adoption like, financial incentives (Evans 2018), flexibility (Macintosh and Waugh 2012; Schirmer and Bull 2014; Van Oosterzee, Blignaut, and Bradshaw 2012), contract length (Kragt *et al.* 2016; Macintosh and Waugh 2012; Schirmer and Bull 2014; Torabi *et al.* 2016), transaction costs, land tenure, co-benefits (Kragt *et al.* 2016; Torabi *et al.* 2016), etc. Using the CONSOLE framework and other literature (provided in [Supplementary Material 1](#)), contract design attributes specific to carbon farming schemes were extracted and categorized as follows:

- a. **Fundamental factors** are basic to any agri-environmental contract and include attributes such as ‘contract flexibility,’ ‘land ownership,’ ‘flexibility,’ ‘transaction cost,’ and ‘valuation of co-benefits.’ These attributes define the basic functioning of a contract.
- b. **Incentive factors**, which include mode and source of the incentives, i.e., the attributes ‘public incentives,’ ‘private incentives: market-based,’ and ‘private incentives: supply-chain based,’ define the source of funding of the payments and the attributes ‘payments based on changing agricultural practices’ (or action-based payments, here forward), ‘payments based on result’ (or result-based payments, here forward), and ‘mixed mode of incentives’ (or hybrid payments here forward) define the mode of the payments which characterizes the incentives.
- c. **Compliance mechanisms** include the ‘stringent monitoring, reporting, and verification (MRV) mechanism,’ ‘certification of carbon sequestered,’ ‘availability of baseline data,’ and ‘liability mechanisms,’ which define what factors contribute to farmer compliance with the carbon farming contracts, and finally,
- d. **Support structures** are factors that can also be understood as non-monetary incentives to the farmers, which can help reduce information asymmetries between the farmers and the project developers. These include ‘training, advisory, and capacity building,’ ‘stakeholder engagement,’ and ‘farmer cooperation.’

Generally, alternative prescriptions or regulations are compared in policy or program evaluations to identify the best strategy or a set of dominating alternatives to adopt (Bartolini and Viaggi 2010). Thus, instead of identifying one best option, we divided the attributes into four topologies as shown in [Figure 3](#), so as to highlight the preference set through this research.

In carbon farming, project performance extends beyond just achieving carbon removals and emission reductions through the project objectives, but rather it is about ensuring farmer enrollment and profitability, delivering co-benefits to society, and creating sustainable and ecological business models that can be scaled efficiently (Wongpiyabovorn, Plastina, and Crespi 2021). Barclay and Osei-Bryson (2010) define ‘project performance’ as an achievement of ‘product success.’ High-quality carbon certificates, which represent the product achieved from carbon farming projects, (generated through offsetting or insetting) are characterized as additional, permanent, not overestimated, and not posing any social or environmental harms (like carbon leakage) (Broekhoff *et al.* 2019). These criteria align with the international frameworks such as the Kyoto Protocol’s Clean Development Mechanism (UNFCCC 1998) and the voluntary carbon credit standards (Verra 2024), both of which stress environmental integrity

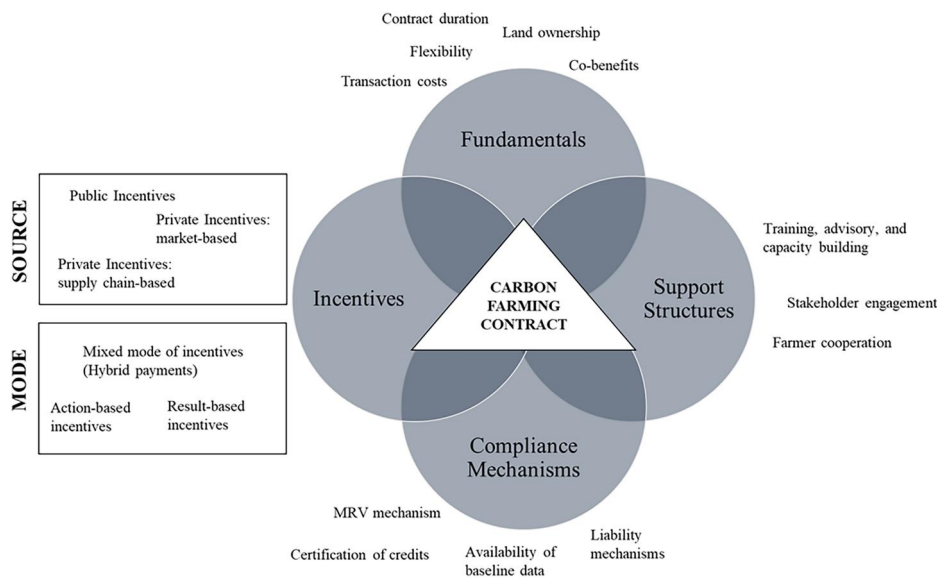


Figure 3. Categorization of carbon farming contractual elements. Source: Authors’ own elaboration.

and socio-economic viability. So, we define *project performance* through high quality product delivery, by using indicators that measure farmers’ involvement in these projects, the economic welfare of the farmers due to the product as well as environmental integrity of the product. So, based on the CONSOLE framework and the supporting literature (in [Supplementary Material 1](#)), we extracted the following project performance elements, that include, ‘farmer participation,’ ‘carbon market access,’ ‘risk management,’ and ‘contract compliance,’ which capture the economic success of the project, and ‘additionality,’ ‘permanence,’ ‘carbon leakage avoidance,’ and ‘net carbon sequestration,’ which highlight the environmental integrity of carbon farming outcomes. A detailed glossary of all the variables is provided in [Supplementary Material 1](#).

2.2.2. Causal relationships

To explore how contract attributes influence performance, each literature source was examined to systematically map the relationships between contract design attributes and performance indicators to identify consistent patterns between the two. The resulting relationship matrix makes all the contractual and performance variables used in this study directly traceable to the literature, while also providing a transparent basis for how they are linked, as presented in [Table 4](#). The wide range of case-based studies were derived from a structured narrative literature review, explained in [Supplementary Material 1](#), collectively highlight how different contract attributes, such as incentives, monitoring mechanisms, contract duration, support structures, etc., affect project outcomes and performance, like additionality, permanence, farmers’ willingness, risk, sanctions, etc., across diverse carbon farming cases. These causal relationships were operationalized as directional linkages (positive/negative), rather than as weighted causal strengths (detailed in [Table 4](#)). Importantly, these interlinkages are not incorporated into the ranking of different contract design attributes or the weighting of the

Table 4. Causal relationship between indicators and attributes derived through literature review +/- indicate the direction of the relationship between the indicator and the attributes as supported in the literature.

Performance indicator	Indicator category	Relevant contract design attributes	Attribute category	Supporting literature
Additionality	Environmental	- Baseline availability (+) - Certification mechanisms (+) - Stringent MRV (+) - Result-based payment (+) - Contract duration (+) - Liability mechanisms (+) - Stringent MRV (+) - Certifications (+) - Hybrid payments (+)	Compliance, Incentive	(Lötjönen <i>et al.</i> 2024; Paul <i>et al.</i> 2023; Raina, Zavalloni, and Viaggi 2024; Stella 2022), etc.)
Permanence of carbon sequestered		- Contract duration (+) - Liability mechanisms (+) - Stringent MRV (+) - Certifications (+) - Hybrid payments (+)	Fundamental, Compliance, Incentive	(Geier, Bahr, and Sponagel 2023; Gratz, Cornish, and Goeringer 2023; Mooney <i>et al.</i> 2004; Raina, Zavalloni, and Viaggi 2024), etc.)
Carbon leakage avoidance		- Credit Buffers (liability mechanisms) (+) - Land tenure (+)	Fundamental, Compliance	(Mooney <i>et al.</i> 2004; Paul <i>et al.</i> 2023)
Net carbon sequestration		- Result-based payments (+) - Training and advisory (+) - Low transaction costs (+) - Liability mechanisms (+) - Stringent MRV (+) - Flexibility (-)	Fundamental, Compliance, Incentive, Support Structures	(Badgery <i>et al.</i> 2021; Paul <i>et al.</i> 2023)
Farmer participation	Economic	- Action-based payments (+) - Hybrid payments (+) - Result-based payments (-) - Flexibility of contracts (+) - Reducing ex-ante transaction costs (+) by reducing fixed costs through training and advisory (+) and farmer cooperation (+) - Long contract duration (-) - Land ownership (+)	Fundamental, Compliance, Incentive, Support Structures	(Evans 2018; Gratz, Cornish, and Goeringer 2023; Lee 2017; Lötjönen <i>et al.</i> 2024; Stella 2022), etc.)

(Continued)

Table 4. (Continued).

Performance indicator	Indicator category	Relevant contract design attributes	Attribute category	Supporting literature
Carbon market access		• Co-benefits (+)	Fundamental, Compliance, Incentive, Support Structures	(Cacho, Lipper, and Moss 2013; Lee 2017; Raina, Zavalloni, and Viaggi 2024; Wang <i>et al.</i> 2023)
		• Stringent MRV (-)		
		• Certification (+)		
		• Public incentives (+)		
		• Co-benefits (+)		
		• Certification (+)		
		• Result-based payments (+)		
		• Market-based incentives (+)		
		• Stringent MRV (+)		
		• Training and advisory (+)		
		• Liability Mechanisms (+)		
		• Stakeholder engagement (+) and farmer cooperation (+)		
		• Baseline information (+)		
		• Flexibility (-)		
		• Stringent MRV (+)		
Risk management		• Flexibility (-)	Fundamental, Compliance, Support Structures	(Badgery <i>et al.</i> 2021; Stella 2022; Wang <i>et al.</i> 2023)
		• Co-benefits (+)		
		• Training and advisory (+)		
Contract compliance		• Liability mechanisms like buffer pools (+)	Compliance, Incentive	(Cacho, Lipper, and Moss 2013; Gratz, Cornish, and Goeringer 2023; Lee 2017)
		• Incentives (+)		
		• Complex MRV (+)		

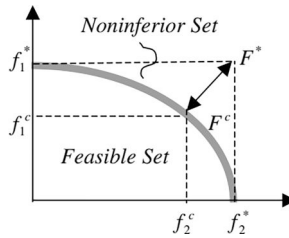


Figure 4. Ideal and compromise solution. Source: Opricovic and Tzeng (2004).

performance indicators. Instead, they serve as a conceptual and structural basis for interpreting the MCDM results, which were then illustrated as a decision-support framework presented in Figure 6 in the Discussions section.

2.3. Multi-criteria decision analysis using VIKOR

The VIKOR method was developed for multicriteria optimization of complex systems by Serafim Opricovic in 1979. VIKOR ranks alternatives and determines the solution closest to the ideal solution, which is called the ‘compromise’ solution (Opricovic and Tzeng 2004) (Figure 4). The VIKOR steps, including those of traditional and extended VIKOR, with validation conditions, are illustrated in Figure 5, which are further explained in detail in Supplementary Material 1.

2.4. Sensitivity analysis of results

2.4.1. Control parameter ‘ ν ’

The relative importance of the group utility ‘ S_i ’ and the individual regret ‘ R_i ’ of the assessment results is managed by ‘ ν ’ to generate the VIKOR ranking index (Q_i). In our study, we took the value of ν as 0.5625 as explained in the methodology. However, the value of ν can be changed to determine its influence level and conduct a sensitivity analysis. The value of ν typically ranges from 0 to 1 and is used to balance the emphasis between the majority’s satisfaction and the smallest group’s dissatisfaction. Taking $\nu = 0.1, 0.3, 0.5, 0.7$, and 0.9 , the new VIKOR index can be measured to check if rankings change, or if the VIKOR index is sensitive to changes in ν .

2.4.2. Using multi-method MCDA approaches

To further ensure the robustness of our results, it is important to consider comparing VIKOR with other MCDA methods to cross-validate the results. If multiple methods yield similar rankings, the results can be considered more robust. Discrepancies between methods might indicate the need for further analysis or adjustments. We use the simple additive weighting (SAW) and Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) tools to compare the rankings. SAW is the best-known and simplest MCDA tool for complex problems (Thakkar 2021) and TOPSIS aggregates alternatives to find the best one by measuring how close each is to the best possible solution (positive-ideal) and how far it is from the worst (negative-ideal) (Thakkar 2021). While all the methods are outranking methods, some crucial

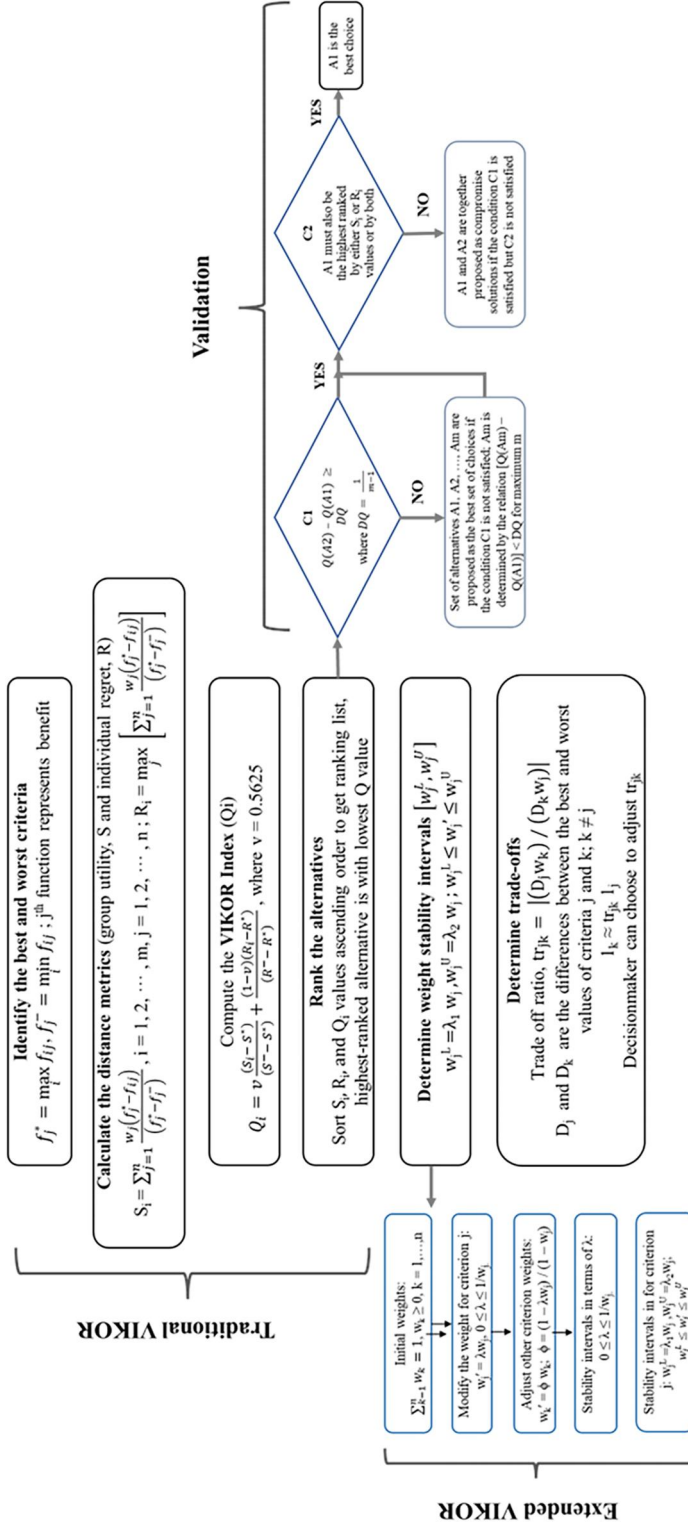


Figure 5. VIKOR steps, including the traditional VIKOR, extended VIKOR, and validation of ranking. Source: Author's own elaboration.

differences in the VIKOR ranking make it better in terms of results. As VIKOR can provide a compromise solution with conflicting criteria, it can give solutions closer to ideal values than TOPSIS (Opricovic and Tzeng 2007). Also, SAW aggregates the performance of each alternative on each criterion, which may not accurately capture the interactions between criteria.

3. Results

3.1. Characteristics of the expert sample

The expert sample reflects a diverse representation across stakeholder groups involved in carbon farming projects (Table 5). The majority of the experts interviewed belonged to research institutes (RI) ($n = 12$), followed by policy experts (PE), intermediaries (IN), financing institutions (FI), and government agencies (GA). The sample was globally spread, with the majority of experts from the European Union, particularly in Belgium, Italy, and the Netherlands, followed by Australia and the United States. The European sample was relatively more represented because of the policy relevance of the EU context and the timing of data collection, which coincided with the development of the Carbon Removals and Carbon Farming Certification (CRCF) framework proposal (The European Parliament and The Council of the European Union 2024). During this period (2023–2024), a growing number of stakeholders in the EU were actively engaged in carbon farming initiatives, making them accessible and relevant for capturing emerging design practices and policy-oriented perspectives.

In terms of professional experiences, 20 experts had direct involvement in designing and implementing carbon farming projects (on-the-ground experience), whereas 12 experts were primarily engaged in research or policy analysis without direct project implementation roles.

Table 5. Different expert groups.

Characteristic	Category	Number of experts	Country
Stakeholder Group	Government Agency (GA)	3	EU (Belgium), USA, Australia
	Research Institute (RI)	12	EU (Belgium, France, Netherlands, Denmark, Austria, Finland), USA, Australia
	Policy Expert (PE)	6	EU (Italy, France, Belgium, Germany)
	Intermediary (IN)	6	EU (Germany, Italy, Sweden, Netherlands), Uganda
Professional Experience	Financer (FI)	5	EU (Ireland, Belgium, Germany)
	On-ground experience (design/implementation in 1 or more cases)	20	EU (Germany, France, Belgium, Finland, Italy, Sweden, Netherlands, Ireland), Australia, Uganda,
	No on-ground experience	12	EU (Italy, Belgium, Denmark, Austria, Germany, Netherlands, France), Australia, USA

3.2. General preferences of experts

The calculated rankings (Table 6) indicate that experts highly prefer the attributes ‘training, advisory, and capacity building’ and ‘hybrid payments’ that are the compromise set of best-ranked solutions that contribute to the maximal environmental and economic performance of a carbon farming project (after validation given below). ‘Certification of carbon sequestered’ is also ranked highly, indicating the importance of certifying farmer efforts and verifying environmental benefits as an important attribute for carbon farming contracts, which is in contrast to how experts weigh the performance indicator ‘carbon market access’ (Table 2). ‘Certification’ also ranked higher than ‘stringent MRV mechanism.’ Support mechanisms like ‘farmer cooperation’ and ‘stakeholder engagement’ are also highly preferred. ‘Low transaction costs’ and ‘high flexibility to change’ were ranked the lowest on average, indicating a low preference for these attributes.

The causal relationships (Table 4) derived from the literature served as the methodological backbone for our MCDA. Using our ranking and merging them with the causal relationships between attributes and indicators, we illustrate a decision-support framework for an efficient contract design in Figure 6. The node sizes are proportional to the relative importance of indicators, derived from expert weights (Table 2) and the VIKOR-derived ranking of attributes, which can be modified by decision makers, and thus it provides a scalable tool for future decision-making.

3.2.1. Validation of results

3.2.1.1. Condition C1 is not satisfied.

$$Q[A2] - Q[A1] \geq DQ$$

However, $Q[A2] - Q[A1] < DQ$

The value attained suggests that the top-ranked attribute is not significantly better than the second-ranked attribute. In such a case, it is not safe to declare just one attribute as the best. Considering our Q values in Table 6, A1: ‘training, advisory, and capacity building’ ($Q = 0.0258$) and A2: ‘hybrid payments’ ($Q = 0.0278$) are compromise solutions since no more attributes would satisfy the condition for inclusion in the compromise set beyond A2.

3.2.1.2. Condition C2 is satisfied. The attribute ‘hybrid payments’ is best ranked by R and Q values.

Since condition C1 is not met, the set of compromise solutions proposed is alternatives A1 and A2, which are the attributes ‘training, advisory, and capacity building’ and ‘hybrid payments’ that are collectively ranked first.

3.3. Extended VIKOR

3.3.1. Weight stability intervals

With our given set of criteria with weights w_j , we calculated the weight stability interval by $[w_j^L, w_j^U] = [0, \lambda_{\max}]$, where $\lambda_{\max}$ is the maximum λ value (number of alternatives) before any change in the ranking occurs, i.e. the upper bound of the weight stability interval. We varied λ in small increments of 1000 iterations between 0 and 1/ w_j values for each criterion and recorded at which $\lambda_{\max}$ there are changes in the Q_i values for each alternative (Table 7).

Table 6. Ranking by ascending values of S, R, and Q indices.

Attributes	S_i	Rank	Attributes	R_i	Rank	Attributes	Q_i	Rank
Training, advisory, and capacity building	0.1820	1	Hybrid payments	0.0426	1	Training, advisory, and capacity building	0.0258	1
Hybrid payments	0.2050	2	Training, advisory, and capacity building	0.0496	2	Hybrid payments	0.0278	1
Certification of carbon-sequestered	0.2643	3	Stakeholder engagement	0.0604	3	Stakeholder engagement	0.2171	3
Farmer cooperation among each other	0.2681	4	Certification of carbon-sequestered	0.0696	4	Certification of carbon-sequestered	0.2208	4
Stakeholder engagement	0.3165	5	Farmer cooperation among each other	0.0741	5	Farmer cooperation among each other	0.2209	5
Stringent MRV mechanism	0.3422	6	Private incentives: market-based	0.0743	6	Private incentives: market-based	0.2910	6
Action-based payments	0.3466	7	Public incentives	0.0754	7	Private incentives: supply chain-based	0.3233	7
Private incentives: market-based	0.3551	8	Private incentives: supply chain-based	0.0806	8	Action-based payments	0.3514	8
Private incentives: supply chain-based	0.3657	9	Availability of baseline data	0.0845	9	Availability of baseline data	0.4179	9
Availability of baseline data	0.4076	10	Action-based payments	0.0862	10	Public incentives	0.4363	10
Public incentives	0.4346	11	Land ownership	0.0903	11	Land ownership	0.5538	11
Result-based payments	0.4380	12	Liability mechanism(s) in case of reversal	0.0944	12	Result-based payments	0.5831	12
Land ownership	0.5086	13	Valuation of co-benefits	0.0945	13	Valuation of co-benefits	0.5865	13
Long Contract duration	0.5205	14	Result-based payments	0.1195	14	Liability mechanism(s) in case of reversal	0.5979	14
Valuation of co-benefits	0.5333	15	Low Transaction costs	0.1204	15	Stringent MRV mechanism	0.6430	15
Liability mechanism(s) in case of reversal	0.5499	16	Long Contract duration	0.1297	16	Long Contract duration	0.7554	16
Low Transaction costs	0.6358	17	High flexibility to change or exit contractual agreements	0.1344	17	Low Transaction costs	0.8151	17
High flexibility to change or exit contractual agreements	0.6847	18	Stringent MRV mechanism	0.1534	18	High flexibility to change or exit contractual agreements	0.9251	18

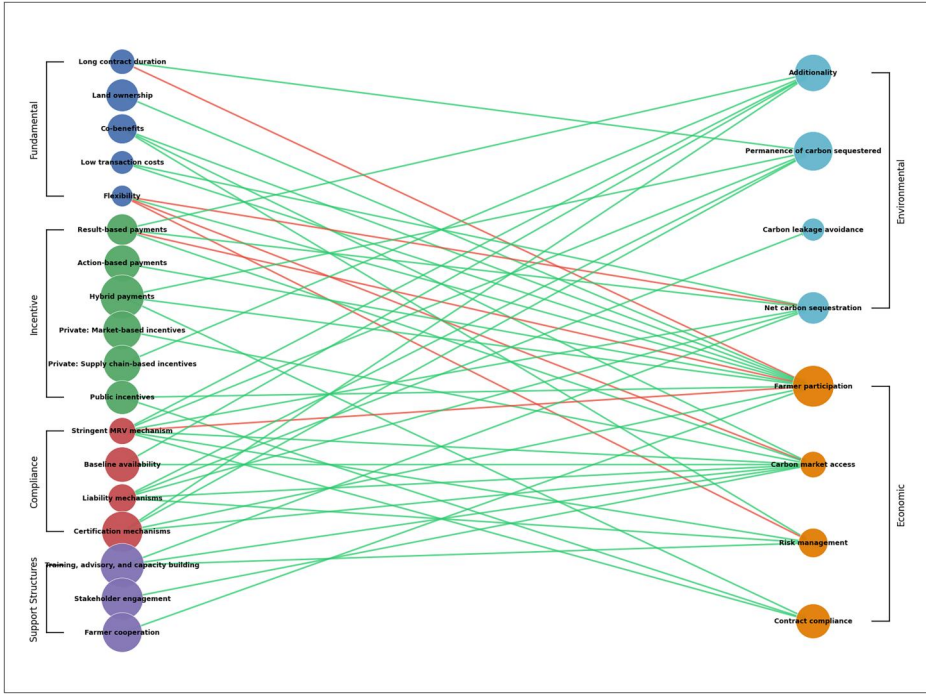


Figure 6. Decision-support Framework; Green edge (—): positive influence; Red edge (—): negative influence; Attribute node size $\propto$ VIKOR ranking; Indicator node size $\propto$ experts' weights. Source: Authors' own elaboration.

The results indicate that the stability of the ranking is more sensitive to changes in the weights for some criteria than others. Specifically, the stability for criterion 1, 'farmer participation,' is $[0,0]$, indicating that as soon as any weight is assigned to this criterion, it immediately affects the overall ranking of the alternatives, thus highlighting its extreme sensitivity. Criterion 2, 'additionality,' criterion 3, 'permanence,' criterion 4, 'carbon leakage avoidance,' and criterion 8, 'contract compliance,' have the broadest stability intervals, indicating that changes to their weights are not sensitive. This indicates that these criteria are not critical to decision-making since their relative importance can be adjusted without greatly affecting the overall ranking. This is also reflected in how many attributes under these intervals sustain their rankings, which is high for the abovementioned criteria, for example, 16 alternatives can maintain their ranking for changes to the weight of criterion 'contract compliance.'

3.3.2. Determining the trade-offs

The trade-off ratios (tr_{jk}) are presented in Table 8, where each cell (tr_{jk}) indicates the ratio between criterion j in the row and criterion k in the column. For instance, the trade-off ratio between criterion 5 (carbon market access) and criterion 8 (contract compliance) (tr_{58}) is 1.89, indicating that almost 1.89 units of weight of 'carbon market access' are needed to compensate for a 1-unit change in the weight of 'contract compliance.' This suggests that 'contract compliance' is relatively more influential in

Table 7. Attributes that maintain their ranking under different ‘weight stability intervals’ for each criterion.

Criterion	Criterion names (performance indicators)	Weight stability intervals $[w_j^L, w_j^U]$	Max unchanged count, $\lambda_{\max}$ (no. of attributes that maintain their ranking)
1	Farmer participation	0–0	1
2	Additionality	0 – 1.0016	10
3	Permanence of carbon sequestered	0 – 0.9978	11
4	Carbon leakage avoidance	0 – 1.0047	14
5	Carbon market access	0 – 0.9986	3
6	Net carbon sequestration	0 – 0.9962	11
7	Risk management	0 – 0.9964	6
8	Contract Compliance	0 – 0.9991	16

the decision-making process compared to ‘carbon market access.’ Ratios closer to 1, like between ‘risk management’ and ‘net carbon sequestration’ ($tr_{76} = 1.02$), and between ‘net carbon sequestration’ and ‘carbon leakage avoidance’ ($tr_{64} = 1.015$) dictate a more balanced relationship where changes in one criterion are almost equally compensated by changes in another. These results highlight the critical trade-offs in the decision-making process regarding what constitutes project performance.

3.4. Sensitivity analysis

3.4.1. Control parameter ‘ ν ’

The box plot (Figure 7) shows the sensitivity of the rankings to changes in ‘ ν ’ values. Narrow boxes indicate that the rankings of an alternative are relatively stable across different ν values, meaning that an attribute’s ranking is not sensitive to changes in ν ; whereas wider boxes indicate greater variability. Overall, the Q -values of most attributes do not show high variability to changing ν values. However, only the attribute ‘stringent MRV mechanism’ shows the largest interquartile range, indicating that its Q -value and, thus, its ranking is more sensitive to changes in ν .

3.4.2. Using multi-method MCDA approaches

The comparative rankings of SAW, TOPSIS, and VIKOR are compared in Figure 8. Since the top-ranked attributes (‘training, advisory, and capacity building’ and ‘hybrid payments’) and lowest-ranked attributes (‘low transaction costs’ and ‘high flexibility to change or exit contractual agreements’) remain the same across all methods, this indicates that our ranking results are stable and not highly sensitive to the choice of method. However, there are some variations observed, especially in the middle ranks, that could indicate that some attributes might be more sensitive to the choice of method, particularly for the attributes ‘public incentives,’ ‘liability mechanisms,’ and ‘stringent MRV mechanism.’ The highest divergence can be seen for the attribute ‘stringent MRV mechanism,’ which shows different rankings for all three methods (15th by VIKOR, 10th by TOPSIS, and 7th by SAW). One reason for this divergence could be the nature of VIKOR, which, as a compromise solution, focuses on balancing utility and regret instead of finding idealized solutions (as in TOPSIS) or only

Table 8. Trade-off ratios between criteria (tr_{jk}).

Performance indicators	Farmer participation	Additionality	Permanence of carbon sequestered	Carbon leakage avoidance	Carbon market access	Net carbon sequestration	Risk management	Contract compliance
Farmer participation	0.0000	0.9314	0.8377	1.1419	0.7993	1.1248	1.1020	1.5132
Additionality	1.0737	0.0000	0.8994	1.2261	0.8582	1.2077	1.1833	1.6248
Permanence of carbon sequestered	1.1937	1.1118	0.0000	1.3631	0.9542	1.3427	1.3156	1.8064
Carbon leakage avoidance	0.8757	0.8156	0.7336	0.0000	0.7000	0.9850	0.9651	1.3252
Carbon market access	1.2510	1.1652	1.0480	1.4286	0.0000	1.4072	1.3787	1.8931
Net carbon sequestration	0.8890	0.8280	0.7447	1.0152	0.7106	0.0000	0.9798	1.3453
Risk management	0.9074	0.8451	0.7601	1.0362	0.7253	1.0207	0.0000	1.3731
Contract Compliance	0.6608	0.6155	0.5536	0.7546	0.5282	0.7433	0.7283	0.0000

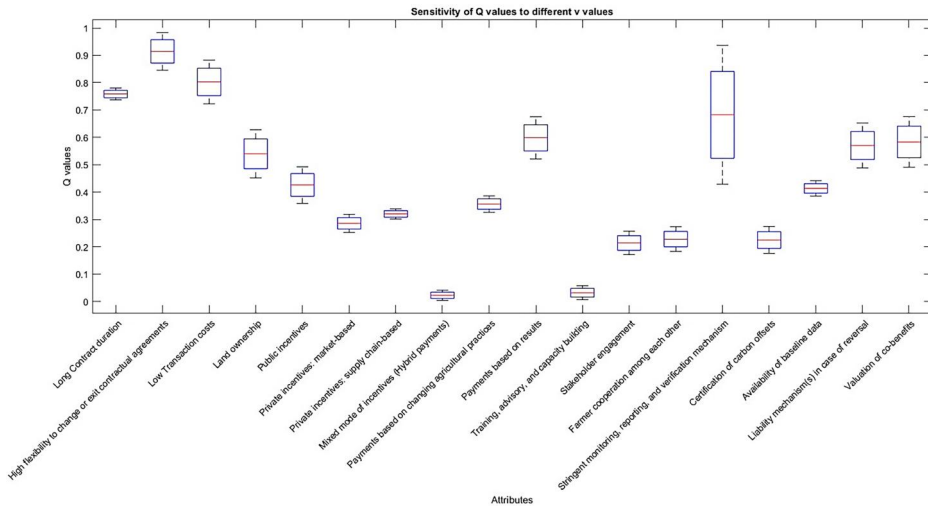


Figure 7. Sensitivity of the Q-values to changes in v-values.

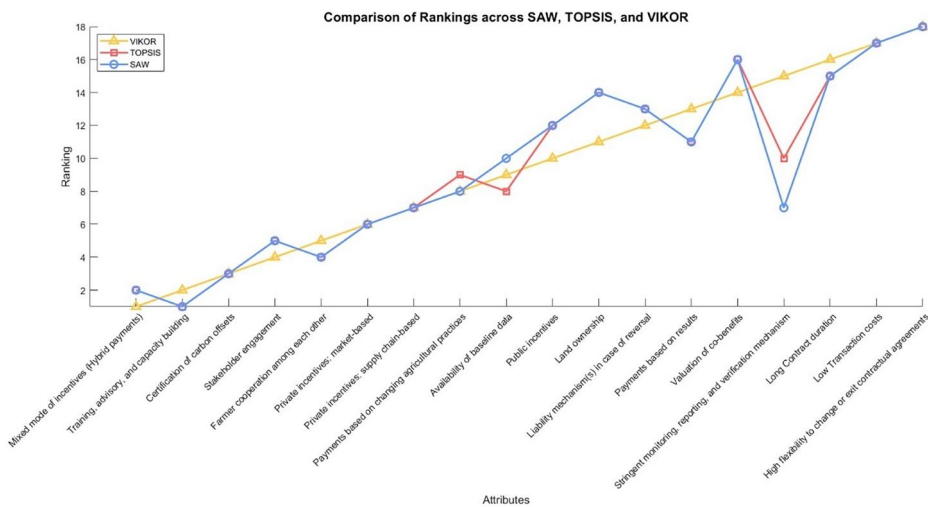


Figure 8. Ranking comparisons of SAW, TOPSIS, and VIKOR.

considering total utility (as in SAW). The sensitivity analyses, even though it verified the robustness of our results, some of the middle-ranked attributes can be sensitive to the method of choice (Muñoz, Romana, and Ordóñez 2016).

3.5. Ranking by experts' experiences

Comparing the preferences of experts who worked on a case vs. those of experts who didn't, the higher-ranked attributes and lower-ranked attributes are similar. However, there are higher divergences in the preferences than similarities (Figure 9). It highlights how the expert preferences have been shaped by their experiences of working on a carbon farming case. The preferences diverge highly specifically about incentive modes and sources, wherein experts who have been involved in designing and implementing

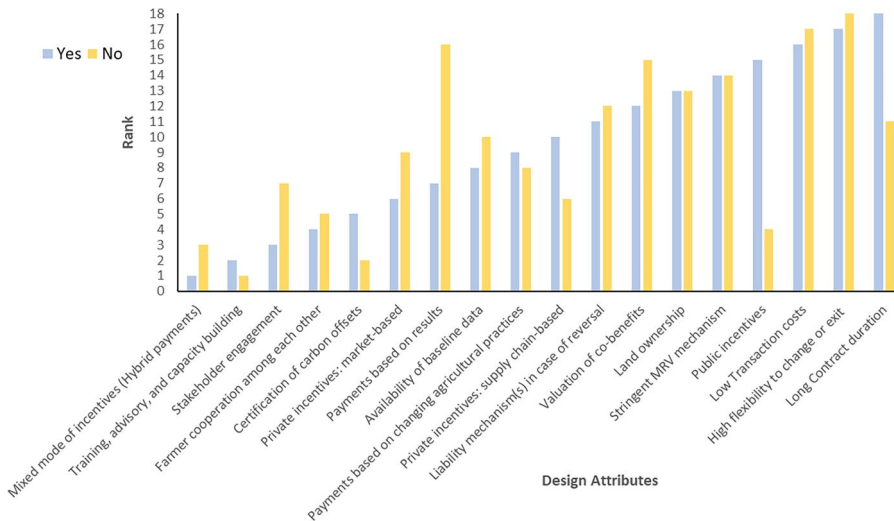


Figure 9. Ranking by different expert experiences.

carbon farming case(s) put more emphasis on private incentives that are market-based and result-based modes of incentives, while ranking public incentives very low among all attributes. In contrast, experts who do not have experience working within a carbon farming project rank public incentives very highly, prefer action-based payments, and rank result-based payments very low. Other attributes that show high divergences in rankings are ‘stakeholder engagement,’ ‘long contract duration,’ ‘certification,’ and ‘valuation of co-benefits.’

3.6. Ranking by expert groups

The ranking results by expert group classifications are illustrated *via* a spider plot in Figure 10. Each axis represents an attribute, and the rankings for each expert group are plotted with lower values representing higher rankings. The general results show that there is a high consensus among different groups on the highest-ranking attributes. Interestingly, incentive-oriented attributes show divergent results, like preferences for ‘public incentives’ show a clear group divide. Government agencies (GA) and policy experts (PE) seem to prioritize public incentives significantly, recognizing their role in shaping and implementing large-scale environmental policies and public sector initiatives. In contrast, financiers (FI) and researchers (RI) place much less emphasis on public incentives, likely due to their preference for market-driven approaches and direct financial mechanisms that are more closely tied to measurable outcomes and research. Similarly, intermediaries (IN) tend to highly prefer market-based incentives, i.e. offsetting models of the VCM, and on the contrary, GA and PE exhibit a stronger preference for ‘supply chain-based incentives’, reflecting a broader interest in the inseting model of carbon farming contracts. Analyzing the mode of payments, the attribute ‘result-based payments’ is generally favored by FI, whereas ‘action-based payments’ is preferred highly by PE, ranking them second among all attributes.

Apart from incentives, there is considerable divergence in preferences for other attributes such as ‘stringent MRV mechanism.’ IN rank it relatively low, indicating

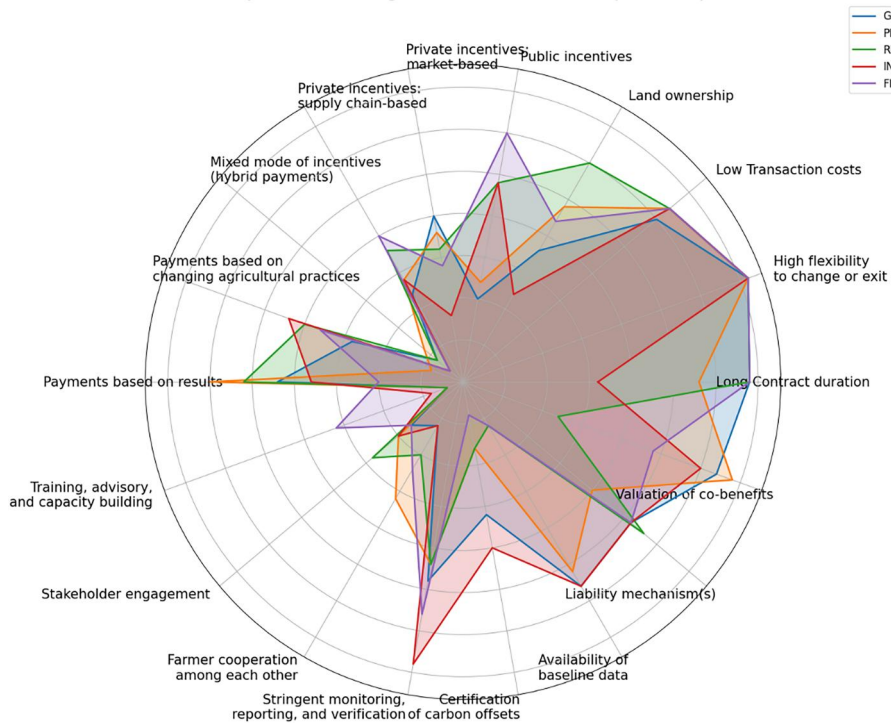


Figure 10. Comparative ranking of different expert groups for different attributes.

less concern about MRV, whereas other expert groups rank it somewhere in the middle compared to all attributes, reflecting their stronger emphasis on ensuring mechanisms are in place to monitor the outputs. Another such attribute is the ‘valuation of co-benefits,’ with RI placing a high importance on it, while other experts believe it to be less critical for the project. Also, RI and FI have a high preference for the attribute ‘availability of baseline data,’ whereas GA, IN, and PE rank it very low.

Overall, GA and RI appear to have more aligned rankings across many attributes, and similarly, IN and FI also show strong alignment in rankings. GA and PE share some alignment but diverge on attributes like ‘result-based payments’ and ‘public incentives.’ These differences and similarities reflect the unique perspectives and priorities of each stakeholder group, highlighting the need to integrate these varying priorities to design effective carbon farming schemes. This also highlights how each group collaborates with other groups when designing a carbon farming project, which can be further utilized to increase their alignment with each other.

4. Discussion

4.1. Interpretation of key findings

This study started with a literature review that helped to extract contractual and performance elements of a carbon farming project and set up causal relationships between them that served as the backbone for our decision-support matrix. Applying the

extended VIKOR tool, we realized that the farmer's profitability and comprehension of the contracts are highly preferred by the experts since they prioritize 'hybrid mode of payments' and 'training and advisory' rather than flexibility in agreements or immediate financial benefits in terms of low transaction costs. Many studies (Dumbrell, Kragt, and Gibson 2016; Paulsen *et al.* 2022), etc.) parallel our results that farmers' willingness to adopt these schemes is hindered by their lack of knowledge about carbon farming. Experts also reported a high preference for all support structures in general, including 'stakeholder engagement' and 'farmer cooperation,' which corresponds to social norm theories that argue that cooperation is the key to designing an incentive mechanism for providing public goods (Ostrom 2000). Also, the preference of 'certification' over 'stringent MRV mechanisms' indicates that experts prioritize credible yet implementable verification approaches. Additionally, the relatively lower importance assigned to 'carbon market access' indicates that experts view the connection to the market as something facilitated by the intermediaries rather than promised by the contract (Schilling *et al.* 2023). Among incentives, 'private incentives' funded by the market is preferred by the experts more than 'public incentives,' which is in contrast with their preferring 'action-based payments' over 'result-based payments.'

While long-term commitments are often associated with permanence (McDonald *et al.* 2021), our results highlight that overly extended contracts may deter farmer participation, especially under market uncertainty, which parallels other AES reviews (such as Raina *et al.* 2021). Interestingly, the relatively low ranking of 'low transaction cost' and 'contractual flexibility' is counterintuitive given their prominence in the AES literature. However, experts might perceive these attributes as secondary or indirect drivers of project performance. The low ranking of 'low transaction costs' indicates that experts view transaction costs as a context-dependent outcome of broader institutional arrangements, such as the role of intermediaries, project developers, and validation and verification bodies, rather than a primary contractual factor directly managed by project designers (Cacho, Lipper, and Moss 2013; Lee 2017; Mettepenningen, Beckmann, and Eggers 2011). Similarly, while flexibility is often seen as a positive adaptive feature in AES (Cacho, Lipper, and Moss 2013), experts associated high levels of flexibility with weakened long-term commitment, increased uncertainty for project stakeholders, and potential risks to permanence and MRV credibility. Recent literature shows that temporary contract structures can conflict with the permanence requirement for soil carbon sequestration, while weak long-term monitoring is a major concern in certifications (Lötjönen *et al.* 2024; Paul *et al.* 2023). These findings highlight that the experts understand the complexities of carbon farming schemes rather than assuming that they are similar to other agri-environmental or conservation schemes.

4.2. Implications for contract design

Translating these expert preferences into actionable design guidance, we identify how attributes should be structured within the four typologies of contract factors we illustrated in Figure 3. Considering the fundamental factors, 'land ownership' and 'valuation of co-benefits' are highly preferred, indicating that the experts treat these attributes as important design factors rather than optional add-ons, as is also highlighted by other studies (Bithas and Latinopoulos 2021; Dumbrell, Kragt, and Gibson

2016; Kragt *et al.* 2016; Torabi *et al.* 2016). Regarding incentive mechanisms, private ‘market-based’ payments are preferred by experts over public payments. However, Lee *et al.* (2016) concluded that voluntary markets alone cannot achieve the upscaling of carbon farming projects; public funding is needed for the adaptive capacity of farmers enrolled in these schemes. Observing the compliance mechanisms, ‘stringent MRV mechanisms’ was ranked very low, compared to the highly ranked attribute ‘certification,’ which resonates with findings by Cacho, Lipper, and Moss (2013), who suggested that stringent MRV is a key challenge for carbon farming projects unless it is accompanied by an incentive element that ‘certification’ provides. All support structures were consistently ranked highly among other attributes. Analyzing the weights given by the experts to the different performance indicators also gives an insight into the relative objectives of a carbon farming project. The experts put most emphasis on boosting ‘farmer participation,’ followed by ensuring the ‘permanence’ and ‘additionality’ of the carbon removals. In contrast, ‘carbon market access’ is not seen as an important indicator of a project’s success, since the connection to the market is usually ensured by the intermediaries rather than promised by the contract (Schilling *et al.* 2023).

Considering the preferences among stakeholder groups, studies have shown that intermediaries can help in reducing projects’ total transaction costs, reducing risks to farmers, and scaling up the projects (Cacho, Lipper, and Moss 2013; Lee *et al.* 2016; Schilling *et al.* 2023; Tamba *et al.* 2021). Oldfield *et al.* (2022) also highlighted the role of buyers (general businesses or agri-food companies) in encouraging private financing that can lead to verifiable, additional, and long-term climate benefits (Paul *et al.* 2023). Government agencies, however, can push for guaranteed action-based public incentives to ensure farmer participation (Block, Hermann, and Mußhoff 2024; Evans 2018). Since researchers and intermediaries both work closely with farmers (Oldfield *et al.* 2022) their alignments should be evaluated for project design. Our study noted that both research institutions and intermediaries rank both the attributes, ‘public incentives’ and ‘liability mechanisms’ low, but this is in contrast with studies that push for public funding (like, Nyssens 2021; COWI, Ecologic Institute, and IEEP 2021, etc.). Also, experts’ experiences with real-world projects hugely affect their perception of how a contract should be designed. These results show that effective contracts require combining preferred incentive mechanisms, rather than adopting purely one approach.

4.3. Decision-support framework

The decision-support framework illustrated in Figure 6 provides an example of the potential use of our study results in the decision process of designing an effective contract (which meets both economic and environmental objectives). The causal relationships derived from the literature (Table 1), when combined with the VIKOR ranking results (Table 6) and weighted indicators (Table 5), provide this framework with multi-dimensional relationships between contractual attributes and performance indicators and can be used as a structured ex-ante design tool by policymakers and project developers. In practical terms, a policymaker or project developer could use the decision-support framework as follows: first, they identify the primary performance objectives for their carbon farming project (e.g. maximizing farmer participation vs. ensuring environmental integrity). Then, using Table 5 (normalized weights), they

assess the relative importance of these performance indicators in their specific context. Third, they reference [Figure 6](#) to identify which contract attributes most directly influence their prioritized performance indicators. The framework shows, for instance, that ‘training, advisory, and capacity building’ directly influences ‘farmer participation’ and ‘contract compliance,’ the two key indicators for project success. Finally, project designers can adjust the framework based on local constraints (e.g. budget limitations, regulatory requirements) to prioritize contract attributes accordingly. Using a hypothetical example to better illustrate the applicability of the framework, consider a European project developer designing a carbon farming contract for a region with low farmer literacy about carbon farming. Using the framework, the developer aims to maximize farmer participation in a carbon farming scheme. Drawing on the expert-derived weights ([Table 5](#)), this would imply placing relatively higher importance on the performance indicator ‘farmer participation.’ Using the relationships illustrated in [Figure 6](#), the developer can identify contractual attributes that positively influence this indicator, particularly ‘training, advisory, and capacity building,’ ‘hybrid payments,’ ‘stakeholder engagement,’ ‘valuation of co-benefits,’ ‘action-based payments,’ etc., and ensure they are present in the contractual agreements. Accordingly, the project developer may also choose to avoid overly long-term contracts, adopt simpler MRV mechanisms, and not rely solely on result-based payments in order to maximize farmer participation. Of course, this does not substitute for the detailed design of the mechanisms (e.g., payment levels), incentive compatibility, and legal feasibility, which can be implemented as the next step. The effectiveness of such a configuration can then be assessed ex-post through indicators related to farmer participation, such as enrollment and retention rates, thereby linking the ex-ante design choices with measurable project outcomes.

4.4. Policy implications for the EU

In the context of current EU policy frameworks, our results suggest that effective, farmer-preferred carbon farming contracts are unlikely to emerge from a single incentive mechanism or governance model. Rather, they should include a hybrid-blend payment structure that combines practice-based public incentives for participation and transaction costs with private, offset or inset-based payments for outcomes. These results align with the current EU policy landscape, where the Sustainable Carbon Cycles Communication (European Commission [2021](#)) conceptualized carbon farming as a business model supported by public and private finance, with the CAP providing instruments such as eco-schemes and rural development interventions that can support practice adoption, cooperation, and advisory services. As planned in the approved proposal (The European Parliament and The Council of the European Union [2024](#)) the CRCF will establish the certification architecture needed to ensure credibility, additionality, and permanence. In this sense, our results also anticipate that the future schemes in the EU might not be purely outcome-based, but rather integrated designs that meet the interests of all stakeholders across the value chain and enable upscaling of such schemes. These findings point toward a shift toward hybrid-blend incentive models that are support-intensive for farmers and have strong certification regulations, complemented by simple MRV mechanisms, rather than stringent market-based contracts or purely publicly funded schemes that are currently observed globally.

4.5. Limitations and further scope

However, our study has some limitations, such as the sample size of our experts may not fully capture the diversity of perspectives across all stakeholder groups involved in a carbon farming value chain. But the sample size aims to represent the global perception, and since these schemes are still developing, gathering this sample size to represent at least every stakeholder group from different countries was arduous. Also, the study primarily focuses on experts with direct experience in carbon farming project design, potentially overlooking insights from other related fields such as environmental policy, economics, and rural development, and lacks insights from farmers. However, this focus was intentional since the most significant influence on carbon farming schemes comes from the project designers themselves, so we wanted to capture direct insights from those deeply involved in the design and implementation process. We did, however, capture insights from soil scientists, policy experts, and farmer organizations, who did not have direct experience in designing the projects but had ample research experience and worked closely with the farmers. A significant limitation comes from our choice of method for testing contract design attributes. i.e. MCDM, which may not comprehensively capture all nuances of agri-environmental contract designing since these schemes have concurrent vertical and horizontal stakeholder interactions with economic, social, and political influences. MCDM also does not account for the full spectrum of qualitative factors, such as stakeholder sentiments and market and policy situations that affect scheme success. However, MCDM can elicit what is important for performance in a direct way, signifying experts' preferences, which can then be tested further through empirical real-world models. Discussing our chosen MCDM tool, the traditional VIKOR, which is more suitable for deterministic values (Ying-Yu and De-Jian 2011). However, real-world expert evaluations are often uncertain and subjective. Thus, extended VIKOR allows our experts to express uncertainties when scoring alternatives and assigning weights since this methodology accounts for validity and robustness checks.

Our results do not guarantee that any specific contractual configuration will be highly effective in all carbon farming projects. Rather, the study identifies the individual design attributes most likely to support project performance based on the selected indicators and expert preferences. However, in practice, the success of a carbon farming project is more complex than defining it through the lens of just eight performance indicators. While the indicators selected provide a balanced representation of environmental vs. economic performance, existing literature highlights a broader list of other relevant indicators, such as 'cost-effectiveness' (Tang *et al.* 2016), 'inclusiveness' (Schilling 2026), 'trust and transparency' (Mallappa, Gadde, and Cariappa 2025; Sasaki 2025), 'institutional feasibility' (Paul *et al.* 2023), and 'social and ecological co-benefits' (Thorsøe *et al.* 2025). But our study aims to provide a structured starting point for predicting contract performance, rather than a complete representation of project success. Important dimensions such as additionality, permanence, leakage, net sequestration, etc., often unfold over long time periods and remain difficult to assess ex-ante, especially for soil carbon projects (Lötjönen *et al.* 2024; Paul *et al.* 2023). Therefore, our proposed framework should be seen as a structured ex ante decision-support tool, rather than as a definitive predictor of effectiveness.

5. Conclusion

This study makes two major contributions; first, it provides empirical evidence to help bridge the gap between theory and praxis of contract design by analyzing which factors

can lead to high performance. Analysis shows that factors that influence incentives and support mechanisms in a contract are more relevant than other factors for successful carbon farming projects. Second, the extended VIKOR reveals how much margin for uncertainty and decision-making is available to the decision-makers and project developers, thus providing them with a model to test their choices for the different performance indicators. Our evaluation also highlights sets of solutions that provide a decision-making toolkit that predicts how the contractual elements interact with the project performance through a decision-support framework. Our results do not indicate that any single attribute can guarantee the successful implementation of these projects. Rather, they identify the contractual prescriptions that can most likely support effective project performance.

Our decision-support framework is particularly relevant in the context of the EU's CRCF Regulation, which establishes the quality criteria (The European Parliament and The Council of the European Union 2024) for carbon farming projects, but provides limited guidance on contract design for farmer adoption and economic viability. Especially, combining public support structures (e.g. baseline data, training systems, certifications) with private incentives. Such combinations can help create favorable conditions for scaling carbon farming schemes as a policy tool as well as a business model. While certification standards (like Verra, Gold Standard, and eventually CRCF) assess the quality of outcomes ex-post, this study supports ex-ante decision-making by providing a starting point for designing contractual objectives, agreements, and incentive structures for carbon farming projects, especially in multi-stakeholder contexts.

The relevance of our hybrid incentives may increase further as the EU develops complementary instruments, such as the Roadmap towards Nature Credits (European Commission 2025), which aim to mobilize private investment alongside public support for land-based environmental outcomes beyond carbon. However, continued research and empirical validation remain essential to adapt our findings across different projects ex-ante, national contexts, changing market conditions, and the broader policy goals of climate mitigation at the EU level. In conclusion, this study offers a decision-making toolkit for translating the EU's high climate ambitions into on-the-ground implementation by paving the way for more scalable and credible carbon removal efforts.

Note

1. <https://www.qualtrics.com/>.

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Ethics statement

According to the policies of the University of Bologna, where this research took place, ethical approval was not required for non-interventional survey studies. Participation in the survey was voluntary, and informed consent was obtained from all respondents.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Supplemental data

Supplemental data for this article can be accessed [here](#).

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Data availability statement

The datasets generated for this study consist of expert scores collected *via* structured questionnaires. Aggregated and anonymized data supporting the findings of this study are available in [Supplementary Material 2](#). Due to confidentiality agreements with the participants and to protect expert intellectual contributions, the raw individual-level data can be made available by the corresponding author upon reasonable request.

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