AN INTEGRATED MCDM MODEL FOR CLIMATE-SMART AGRICULTURE

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ABSTRACT

Due to climate change, sustainable agriculture is under threat. Climate Smart Agriculture practices are recommended for policymakers and farmers to improve agricultural productivity sustainability. In this study, a multi-criteria decision model was proposed to evaluate Climate Smart Agriculture practices and recommend the most appropriate ones for farmers. For this purpose, the integration of the Analytic Hierarchy Process approach and the Technique for Order of Preference by Similarity to the Ideal Solution method was utilized to prioritize the evaluation criteria and reveal the preferences of Climate Smart Agriculture practices. A case study was conducted in the region of Navarra in northern Spain.

Keywords: Climate Smart Agriculture, MCDM, TOPSIS, AHP.

1. Introduction

Climate change is one of the main troubles faced by nations. It affects several sectors, including agriculture. On the other hand, sustainable agriculture is one of the targets to be achieved to end hunger, supply food security, improve nutrition, and ensure healthy lives. Therefore, new agriculture policies, such as Climate Smart Agriculture practices, are necessitated. Climate Smart Agriculture (CSA) is designed to address the problems posed by climate change's effects on agriculture. CSA recommends that policymakers and farmers take several actions to improve agricultural productivity sustainably, provide support against the influence of climate change, and cut down greenhouse gas emissions (Pagliacci et al., 2020; Khatri-Chhetri et al., 2017). In this study, to analyze and prioritize the CSA practices that can be adapted by the farmers, an integrated MCDM model utilizing AHP and TOPSIS was proposed.

2. Literature Review

Pagliacci et al. (2020) emphasized the impact of financially supported voluntary policies and relevant information about the regulations on the adaption of CSA. Khatri-Chhetri et al. (2017) indicated that embracing CSA technologies leads to higher crop yields and increases inputs' efficiency. Ndamani & Watanabe (2017) constructed an MCDM model to evaluate drought adaptation practices with respect to climate conditions. Grusson et al. (2021) analyzed necessary irrigation investments that should be done to compensate for future rain shortages and the suitability of crop types.

3. Objectives

CSA practices that the farmers can adapt were prioritized with respect to evaluation factors (criteria). As a case study, the region of Navarra in northern Spain was considered.

4. Research Design/Methodology

Through a deliberate literature review and interaction with three experts in the farming industry, we came up with the CSA practices (alternatives) and the factors (criteria) that can be used to evaluate those practices. The proposed decision model is given in Appendix 1. Then, we utilized AHP method to prioritize evaluation criteria and sub-criteria. The pairwise comparison questionnaire survey participants were the big-scale farmers growing cereal crops in Navarra. Through Gruopo AN, an association of cooperatives operating in the agri-food sector, we reached 27 farmers to conduct the survey. Out of 27, 10 farmers replied. As one of the respondent's judgments was found inconsistent, we computed the geometric average of the remaining nine farmers. We utilized Super Decisions software to reveal the importance of the criteria and sub-criteria. As a further step, the farmers also rated each CSA practice with respect to sub-criteria on a 5-point scale questionnaire. Finally, we utilized the TOPSIS method to reveal the global scores of CSA practices and find the most appropriate one that would be recommended to the farmers.

5. Model Analysis

Feasibility was by far the most important criterion. The most important sub-criteria were Resilience, Cost of implementation, Timeliness, and Robustness. Appendices 2 and 3 exhibit the importance of all criteria and sub-criteria. Based on TOPSIS results, CSA practices are ranked according to their similarities to positive-ideal solution in descending order (Appendix 4). According to the analysis results, Mulch and cover cropping was the most preferred alternative, followed by No-till farming and Improving irrigation efficiency.

6. Limitations

The number of participants can be increased. The survey can be conducted in other regions of Spain and other Mediterranean countries to generalize the results.

7. Conclusions

The results obtained by this model can guide farmers in their strategic farm planning to reduce the adverse outcomes of climate change in this region.
We also conducted sensitivity analyses to examine the effects of changes in the importance of sub-criteria on the TOPSIS results.

8. Key References

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9. Appendices

Appendix 1. The Decision Hierarchy

GOAL
Evaluation of CSA Practices

CRITERIA AND SUB-CRITERIA
C1 Compatibility with natural resources
- C11 Compatibility with the available land
- C12 Compatibility with the available soil
- C13 Compatibility with the available water

C2 Adaptability to farm's conditions
- C21 Culture and tradition
- C22 Competence
- C23 Knowledge and skills of farmers

C3 Feasibility
- C31 Cost of implementation
- C32 Timeliness
- C33 Robustness
- C34 Resilience

C4 Impacts on society
- C41 Impact on current society
- C42 Impact on future generations

C5 Effects
- C51 Short-term effects
- C52 Medium-term effects
- C53 Long-term effects
- C54 Frequency and criticality of side effects

ALTERNATIVES
A1 Rainwater harvesting
A2 Breeding for resistance to droughts and floods
A3 Enhancing soil moisture retention capacity
A4 Changing cropping pattern and diversification
A5 No-till farming
A6 Mulch and cover cropping
A7 Improving irrigation efficiency
A8 Water recycling
A9 Monitoring, modelling and forecasting systems for pesticides usage
A10 Supplemental irrigation

Appendix 2. Importance of Criteria

Criteria	Priorities
C3 Feasibility	76.83%
C2 Adaptability to farm's conditions	7.60%
C1 Compatibility with natural resources	7.29%
C5 Effects	4.96%
C4 Impacts on society	3.31%

Appendix 3. Importance of Sub-Criteria

Subcriteria	Priorities
C34 Resilience	20.95%
C31 Cost of implementation	20.53%
C32 Timeliness	18.96%
C33 Robustness	16.39%
C13 Compatibility with the available water	3.97%
C22 Competence	3.65%
C23 Knowledge and skills of farmers	3.16%
C42 Impact on future generations	2.00%
C12 Compatibility with the available soil	1.86%
C52Medium-term effects	1.51%
C11 Compatibility with the available land	1.47%
C54 Frequency and criticality of side effects	1.42%
C53 Long-term effects	1.41%
C41 Impact on current society	1.32%
C21 Culture and tradition	0.78%
C51 Short-term effects	0.62%

Appendix 4. Ranking of CSA Practices

CSA Practices	**C***
Mulch and cover cropping	0.9311
No-till farming	0.8513
Improving irrigation efficiency	0.7728
Changing cropping pattern and diversification	0.6896
Enhancing soil moisture retention capacity	0.5180
Breeding for resistance to droughts and floods	0.3615
Water recycling	0.3305
Rainwater harvesting	0.3128
Supplementing irrigation	0.2281
Monitoring, modelling and forecasting systems for pesticides usage	0.1878