Flood risk assessment; A MCDM approach

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ABSTRACT

Uncertainty and risk are caused by million variables and either they will happen due to complex nature of the universe. This short communication investigates on effects of food risk variables (drives) on the agricultural section. Those drivers consider climate change, urban issues, socio-economic factors, and other measures. As the evaluation of agricultural production system based on multi variables is tough and usually confronts with conflicts, therefore, this article provides a framework to propose a structure with aid of multiple criteria decision making (MCDM) and expert attitudes. By an empirical example, eight decision factors and six alternatives compose a decision matrix and multi-objective optimization method (MOORA) delivers the optimal solution. The findings of this paper can be a route for experts in this area to explore the further questions and strategies.

Keywords: multi objective optimization based on ratio analysis, flood risk drivers, multiple criteria decision making, decision support model, RUC-APS

INTRODUCTION

Decision Support Systems (DSS) is a well-known approach introduced to offer the users the possibility of comparing options and computerize management decisions making activities through using information system technology. This concept has been integrated into many decision making applications involving multiple criteria decision-making (MCDM) to enhance capability and reliability of decision modeling [1] [2].

Risk and uncertainty are inevitable substances in agriculture and are appeared in terms of climate changes, soil erosion, water contamination, flood risk etc. These variables have the most significant impact on the ecosystem which should be addressed in agriculture decision making. The farmers and agriculture systems must realize and assess the risks and react to those risks through providing efficient strategies [3-5]. Recently a research project has been loaded called Risk and Uncertain Conditions for Agriculture Production Systems (RUC-APS) which mainly concentrates on finding the optimal solution for agricultural production systems through decision making and information technology assistance [6]. The project is supported by a scientific section of European Commission and guarantees to model decision support systems in order to deal with a sustainable agriculture supply chain once risk and uncertainty exist. This is a call of H2020-MSCA-RISE-2015 with the proposal number of 691249 in economic sciences panel. The project headed to improve agricultural conditions through modeling well-structured decision process. Therefore, based on the RUC-APS objectives (**Figure 1**), to deal with a sustainable agriculture production system and to overcome those risks, establishing policy in land use management can be a challenge. In a sustainable agriculture, land use management and flood risk evaluation have essential affection. In this paper, we try to address a multi-criteria decision-making problem to build an initiative perspective in the evaluation of risk of disasters like the flood in agriculture production system.

Application of MCDM in agriculture decision making is growing quickly [7]. Adoption of integrated decision tools in terms of a decision support model to analyze decision problem, measure and formulate solutions can benefit users and decision experts to reach a robust land use strategy [8-10]. In this paper, it is possible to ask decision makers to present their comparison about risk factors importance and among decision alternatives in front of factors according to a predefined scale (see the **Table 1**). It will be reliable to count on Entropy technique, expert approach or other weighting process. Once decision makers report their opinions, then MOORA is able to produce desired results. Normally TOPSIS and VIKOR [11] tools are developed to find the optimal solution, however, in this study; we are going to experience a different taste of MCDM with the application of MOORA. In more recent works MOORA is going to be constituted by other well-known MCDM tools due to its simplicity and fast computation [12].

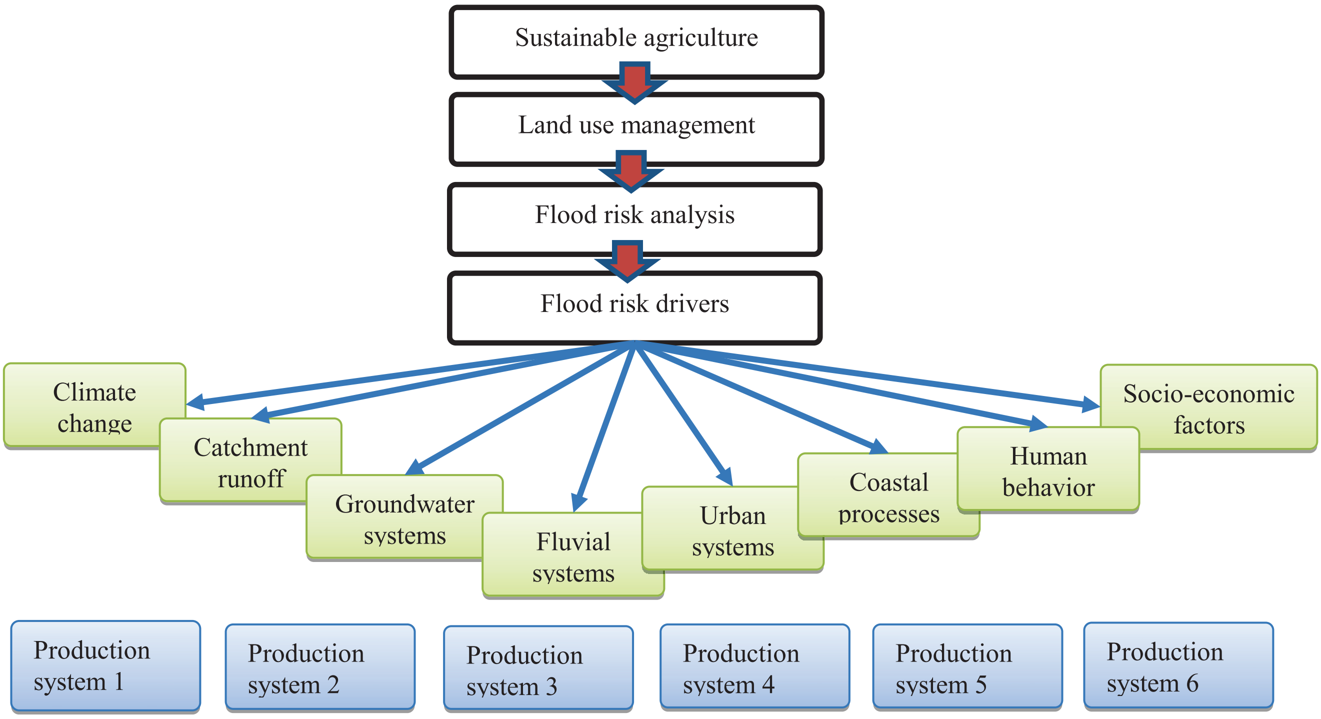

Figure 1: Analytical model for production system assessment

Proposed risk assessment model

This section undergoes to implement an evaluation frame by MOORA [13] method. To build decision making matrix firstly alternatives and criteria are detected, thereafter weights of the criteria and also rating of alternatives with respect to each decision criterion must be interpreted. For this paper, experts provide a rating scale to rate production systems performance confronting flood risk drivers, and MOORA will compare and rank production systems. To evaluate flood risk affection, drivers (decision criteria) are defined as climate change (C_1), catchment runoff (C_2), groundwater systems (C_3), fluvial systems (C_4), urban systems (C_5), coastal processes (C_6), human behavior (C_7) and socio-economic factors (C_8) [5], six main agricultural production systems should be considered (alternatives) as it is observed in **Figure 1**. Among decision factors, C_1 is a cost factor because it is stated lower climate change lower risk for agricultural system and production. The decision making problem is this paper is solved by MOORA method. It has been claimed that considering interrelation between objectives and alternatives simultaneously, a cardinal approach and non-subjective dimensionless measures are the main characteristics of the MOORA. MOORA insists on two parts as; reference point approach and ratio system and is able to measure both non-benefit and benefit criteria in a process of selecting from a set of alternatives. Its process starts with identification of alternatives, detecting the most relevant criteria and determining the importance weights of criteria. The algorithm for MOORA is interpreted in this section [13]:

Step 0. Consider the following matrix is used to start the solution procedure: $X = x_{kj}$ (1)

It defines a decision matrix with k alternatives and j decision criteria

Step 1. Normalizing the decision matrix by: $r_{kj} = \dfrac{x_{kj}}{\sum_{k=1}^{t} x_{kj}^2}$ $k = 1,2,...t$ (2)

Step 2. Determining the weighted normalized matrix: $v_{kj} = r_{kj} \cdot w_j$ (3)

Step 3. Computing the overall rating of benefit and cost criteria for each alternative. The overall ratings of the k-th alternative considering the beneficial and non-beneficial criteria are calculated implementing;

$$S_k^+ = \sum_{j \in J^{Max}} v_{kj}\ ,\ S_k^- = \sum_{j \in J^{Min}} v_{kj} \quad (4), (5)$$

where J^{Max} is the index set of the set of beneficial criteria and J^{Min} is the index set of the set of non-beneficial criteria

Step 4. Evaluating the overall performance of each alternative; $S_k = S_k^+ - S_k^-$ (6)

Step 5. Ranking the alternatives. The S_k values form a cardinal scale that can be used to rank the alternatives: the higher the value of S_k, the more preferred is the k-th alternative.

Results

An empirical study was considered to evaluate the risk of floods on production systems. The experts of the project are asked to present their judgments by relevant factors to evaluate alternative production system using **Table 1** predefined scale. In each driver, some sub-drivers are realized. For *climate change*: precipitation, temperature, relative sea-level rise, waves, surges; for *Catchment runoff*: urbanization and rural land management; Groundwater flooding; for *Fluvial systems*: environmental regulation, river morphology and sediment supply, river vegetation and conveyance, urbanization and Intra-urban Runoff; for *urban system*: sewer conveyance, blockage and sedimentation, Impact of external flooding on intra-urban drainage systems; for *coastal process*: coastal morphology and sediment supply; for *human preference* stakeholder behavior have been considered. Additionally regarding the *socio-economic* factors these items were possible: buildings and contents, urban impacts, infrastructure impacts, agricultural impacts, social impacts, and science and technology [2],[4-5]. All of these issues are regarded and measured in the evaluation process.

The preference and overall judgments of decision makers should be provided using numerical scale in **Table 1** (how each system is influenced by a criterion). **Table 2** indicates the preference rating of decision makers (initial evaluation). The weights of the criteria can be obtained utilizing Entropy method. The information about Shannon Entropy method and its algorithm can be found in [14]. The generated weights by pairwise comparison are as; W_1 =0.084, W_2 =0.147, W_3 =0.056, W_4 =0.276, W_5 =0.177, W_6 =0.054, W_7 =0.128, W_8 =0.078. As observed the importance of fluvial system is much higher than others and this shows treatment with this system can affect risk of floods. The weights are utilized as importance level of risk drivers for MOORA process in order to determine the final solution.

Table 1: Relevant verbal reference to rate alternatives

Scale to rate production systems	
1	Very low
3	low
5	moderate
7	high
9	very high
For decision makers who decide values between each category 2,4,6 and 8 can be considered	

Table 2: Initial decision matric

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	3	4	5	2	6	3	7	5
A_2	5	2	5	2	1	4	4	5
A_3	7	6	6	4	3	3	4	4
A_4	6	3	7	6	3	5	3	3
A_5	3	3	7	6	5	6	3	3
A_6	4	7	3	1	4	5	2	2

Table 3: Weighted normalized matric and ranking of alternatives

	Weighted normalized matrix								S^+	S^-	S_k	Rank
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8				
A_1	0.021	0.0529	0.0203	0.0561	0.1081	0.0149	0.0884	0.0414	0.38204	0.021002	0.362	2
A_2	0.035	0.0264	0.0203	0.0561	0.018	0.0199	0.0505	0.0414	0.23262	0.035003	0.1977	6
A_3	0.049	0.0793	0.0244	0.1122	0.0541	0.0149	0.0505	0.0331	0.36842	0.049004	0.3195	4
A_4	0.042	0.0396	0.0284	0.1683	0.0541	0.0249	0.0379	0.0248	0.37798	0.042004	0.336	3
A_5	0.021	0.0396	0.0284	0.1683	0.0901	0.0298	0.0379	0.0248	0.41899	0.021002	0.398	1
A_6	0.028	0.0925	0.0122	0.028	0.0721	0.0249	0.0253	0.0165	0.27146	0.028003	0.24346	5

In this step, we can solve MOORA decision problem by algorithm presented in previous section and formulas 5-10. Firstly normalized matrix is delivered; thereafter weights of decision factors must influence decision process. In the further action overall rating for benefit and cost criteria are measured and validated based on weighted normalized matric values (**Table 3**). Ultimately, ranking of production systems can be derived based on higher values of S_k which are depicted here (see the **Table 3**);

$A_5 > A_1 > A_4 > A_3 > A_6 > A_2$

The ranking order of the alternatives shows the optimal option for agricultural objectives based on risk drivers of flood. The benefit of the results is that users in this project can figure out a better view on different variables, their relationship and affection on main objective of the research. For example from the climate change issue, it is a deal to support decision and assessment process because it has impacts on soil structure, biogeochemical cycles, and hydrological processes.

CONCLUSIONS

MCDM aims to develop models and structures to offer a better understanding of the decision system, feasible solutions, interrelationship of factors and windows for further improvements. This is core contribution of the MCDM modeling. This paper originates by an assessment approach based on multiple criteria decision making methods. It is investigated to develop a sustainable agriculture management, considering flood risk and its management is a significant topic. Therefore, it will demand an evaluation system to study the influence of the flood risk drivers with respect to several alternative production systems. We tried to improve better perspective of drivers such as climate change and its impacts on the production system based on experts judgment. To head that goal, a decision making problem regarding multiple factors has been structured. The relative importance of risk drivers has been obtained by experts' interaction and preferences. Then a decision table was built to deal with the affection of those factors with agriculture production system. Finally, by a newborn multi objective decision making tool, the ranking list of alternative projects has been announced. The contribution of this work will be implemented in RUC-APS project to analyze alternatives projects and warn the stakeholders and partners about possible corrective reactions. We have shown how conflicting factors can come together to the judgments of decision makers and through an MCDM framework. This is an initial but potential study for realization the interaction and influence of different factors related to risk and danger of floods and another kind of disasters. The users and partners in RUC-APS projects can take advantage of this model, and then is easy to implement, extend or combine it with other research projects. Integrated multi attribute modeling [15-16] with aid of the engineering tool can enhance the reliability of the work and decrease complexity.

The configuration of a decision support system allows the managers and policy makers to make effective decisions. Moreover, a strong decision support system requires a comprehensive and understandable decision framework. In this paper we have provided a decision model which is able to give this chance to the experts and managers to confront with the risk of flood and natural disasters. The managers can consider the proposed MCDM algorithm as a primal perspective for further improvement and possible extensions.

REFERENCES

1. Ngai, E. W., & Wat, F. K. T. (2005). Fuzzy decision support system for risk analysis in e-commerce development. *Decision support systems*, *40*(2), 235-255
2. Levy, J. K. (2005). Multiple criteria decision making and decision support systems for flood risk management. *Stochastic Environmental Research and Risk Assessment*, *19*(6), 438-447.
3. Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. Environmental management, 43(5), 804-816.
4. Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. Progress in planning, 62(1), 3-65.
5. Wheater, H., & Evans, E. (2009). Land use, water management and future flood risk. Land Use Policy, 26, S251-S264.
6. RUC-APS, 2016; http://cordis.europa.eu/project/rcn/204775_en.html
7. Jozi, S. A., & Ebadzadeh, F. (2014). Application of multi-criteria decision-making in land evaluation of agricultural land use. Journal of the Indian Society of Remote Sensing, 42(2), 363-371.
8. Chung, E. S., & Lee, K. S. (2009). Prioritization of water management for sustainability using hydrologic simulation model and multi criteria decision making techniques. Journal of Environmental Management, 90(3), 1502-1511.
9. Collins, M. G., Steiner, F. R., & Rushman, M. J. (2001). Land-use suitability analysis in the United States: historical development and promising technological achievements. Environmental management, 28(5), 611-621.
10. Uricchio, V. F., Giordano, R., & Lopez, N. (2004). A fuzzy knowledge-based decision support system for groundwater pollution risk evaluation. Journal of environmental management, 73(3), 189-197.
11. Yazdani, M., & Payam, A. F. (2015). A comparative study on material selection of microelectromechanical systems electrostatic actuators using Ashby, VIKOR and TOPSIS. Materials & Design (1980-2015), 65, 328-334.
12. Brauers, W. K. M., & Zavadskas, E. K. (2008). MULTI-OBJECTIVE OPTIMIZATION IN LOCATION THEORY WITH A SIMULATION FOR A DEPARTMENT STORE. Transformation in Business & Economics, 7(3).
13. Brauers, W. K. M., & Zavadskas, E. K. (2006). The MOORA method and its application to privatization in a transition economy. Control and Cybernetics, 35(2), 445.
14. Shemshadi, A., Shirazi, H., Toreihi, M., & Tarokh, M. J. (2011). A fuzzy VIKOR method for supplier selection based on entropy measure for objective weighting. Expert Systems with Applications, 38(10), 12160-12167.
15. Ignatius, J., Rahman, A., Yazdani, M., Šaparauskas, J., & Haron, S. H. (2016). An integrated fuzzy ANP–QFD approach for green building assessment. Journal of Civil Engineering and Management, 22(4), 551-563.
16. Yazdani, M., Chatterjee, P., Zavadskas, E. K., & Zolfani, S. H. (2017). Integrated QFD-

MCDM framework for green supplier selection. Journal of Cleaner Production, 142, 3728-3740.