



Research Article

A Study on Fuzzy Logic-Based Evaluation of Pesticide Effects on Agricultural Ecosystems

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Abstract

In this paper, the impact of pesticides on human health is analysed using a fuzzy decision-making system. Pesticide use in agricultural fields is indispensable, as they help to protect crops, fruits, vegetables, grains and other agricultural products from insects, pests and other organisms, which destructs crops growth. As pesticides have toxic ingredients, they can create adverse health problems for human beings, and they will degrade the environment gradually. When the composition of the pesticides exceeds its limit, it will create health problems for the farmers. Thus, there exists uncertainty in diagnosing the impact level of human health hazards. Hence, a fuzzy logic-based decision-making model is designed to diagnose the human health hazards.

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KEYWORDS: Triangular Fuzzy Number, Pesticides, Health issues, Linguistic variable, Normalisation.

1. INTRODUCTION

In agriculture, the use of pesticides is unavoidable when crops are lost. According to Damalas and Eleftherohorinos (2011), the primary goals of using pesticides in agricultural fields are to reduce weeds, prevent illnesses, manage pests, control other plant diseases, and boost agricultural output. The purpose of pesticides is to eradicate pests in the field. However, pesticides can have an impact on non-targeted species (Aktar et al. 2009), including birds, animals, the environment, and earthworms, which are thought to be farmers' friends. Through ingestion of fruits, vegetables, cereals, and other foods, as well as inhalation, pesticides can reach the human body. Initial indications of pesticide use by farmers include eye discomfort, skin allergies, breathing difficulties, unconsciousness, and convulsions. Chronic non-epidemic diseases like cancer, Parkinson's disease, Alzheimer's disease, reproductive disorders, respiratory disorders, genetic damage, etc., may result from excessive pesticide exposure, according to new studies (Sabarwal et al. 2018). Therefore, it is challenging to link pesticide exposure to the harmful consequences it has on human health. Gupta et al. (2000) modified a fuzzy multi-criterion decision-making system for agricultural land and water management. Finizio and Villa (2002) employed a fuzzy decision-making system to evaluate the environmental risk associated with the field application of pesticides. Ferraro et al. (2003) created a set of indicators to measure the environmental impact of pesticide use and evaluated them using fuzzy logic. Biswas and Pal (2005) used a fuzzy goal programming model to handle the problem of agricultural land use planning for optimal production. Prato (2005) suggested a different approach that uses fuzzy logic to assess an ecological system's sustainability. Kouloumpis et al. (2008) employed Sustainability Assessment by Fuzzy Evaluation (SAFE) to rank the countries based on their overall sustainability and assess the two main components of sustainability: ecological sustainability and human sustainability. In order to evaluate environmental consequences using a decision support system, Liu et al. (2009) used fuzzy logic. If necessary, they developed rules to determine the significance of environmental impacts. Using the IPEST index, Arregui et al. (2010) employed a fuzzy expert system to assess the environmental risk of pesticide use on various crop types. Papa Georgiou et al. (2011) used fuzzy cognitive maps to study the high-yield cotton crop production method and concluded that it was practical for producing high-yield cotton. Fuzzy analysis was used to determine the most vulnerable area for reclamation activity because the most vulnerable area was unclear due to contamination from unmanaged landfills (Caniani et al. 2011). Based on the current pest indicator, Lindahl and Bockstaller (2012) created a new sub-indicator for

groundwater and assessed its development using mechanistic model simulations. Uricchio et al. (2004) used a fuzzy decision support system to assess the danger of groundwater pollution. Fuzzy logic was used by Sattler et al. (2012) to assess single farming methods in relation to the risks of biodiversity indicators of single species. This method can be used to identify farming practices that support biodiversity conservation. Ashraf et al. (2014) created a fuzzy GIS model to categorise fertiliser applications for wheat crops. In order to evaluate the danger of using pesticides over herbicides, Le Bellec et al. (2015) created a decision support system for farmers on the effects of pesticides. They then evaluated this approach under specific environmental conditions and applied it to I-Phy (a pest indicator).

In order to assist farmers in making decisions on the application of fungicides in vineyards, a fuzzy control system was created to determine the necessity of fungicide applications in a vineyard using a decision support system (Gonzalez-Dominguez et al. 2016). The input factors for decision-making analysis are linguistic variables. The majority of researchers have recently focused on decision-making models in order to make significant decisions in real-world scenarios. A novel fuzzy linear programming method was created by Li and Wan (2013) to solve multiple attribute decision-making situations in which the attribute weights are not fully known. This method used intervals, real numbers, and triangular fuzzy numbers to characterise the various kinds of decision information. The distance between the options and the fuzzy ideal solution was later used to calculate the ranking. Li and Wan (2014) have developed a hybrid method consisting of the fuzzy TOPSIS method and a linear programming technique for multidimensional analysis of preference in order to solve inhomogeneous multi-attribute group decision-making problems with incomplete weight information. This is because the fuzzy TOPSIS method is insufficient for multi-attribute group decision-making problems because it is only valid when attribute weights are fully known. It is evident from the aforementioned literature that the fuzzy decision method is helpful for making decisions in real-world situations when uncertainty occurs. Thus, the goal of this project is to develop a fuzzy decision-making system for assessing the health effects of pesticides used in agricultural areas.

2. MATERIALS AND METHODS

Step 1: Identify the input variables and output variables.

Step 2: Construct suitable fuzzy membership function values for input variables.

Step 3: Derive initial linguistic matrix.

Step 4: Convert the linguistic matrix into a triangular fuzzy matrix.

Table 1. Fuzzy linguistic scale

Linguistic Variables	Triangular fuzzy numbers
Very Low (VL)	(0, 0, 0)
Low (L)	(0, 0, 0.3)
Medium (M)	(0, 0.3, 0.6)
Dangerous (D)	(0.3, 0.6, 0.9)
Very Dangerous (VD)	(0.6, 1, 1)

Step 5: Converting fuzzy value into crisp value.

Step 6: Defuzzification

Table 2. Defuzzified Value

Linguistic variables	Fuzzy numbers	Defuzzification
VL	(0, 0, 0.25)	0.063
L	(0, 0.25, 0.5)	0.25
M	(0.25, 0.5, 0.75)	0.5
D	(0.5, 0.75, 1)	0.75
VD	(0.75, 1, 1)	0.94

3. RESULTS AND DISCUSSION:

The input variables are $P_1, P_2, P_3, P_4, P_5, P_6, P_7$ and the output variables are D_1, D_2, D_3, D_4, D_5 . The input variables are pesticides, and the output variables are health issues.

Table 3. Linguistic value matrix

Health issues Pesticides	D_1	D_2	D_3	D_4	D_5
P_1	M	M	VD	L	M
P_2	M	D	VD	L	L
P_3	L	L	M	VD	L
P_4	D	D	M	D	D
P_5	VD	L	M	VD	L
P_6	VD	L	VD	VD	L
P_7	VD	L	VD	D	L

As per step 4, convert the linguistic value into a triangular fuzzy number.

Table 4. Linguistic value matrix to triangular fuzzy number matrix.

Health issues Pesticides	D_1	D_2	D_3	D_4	D_5
P_1	(0, 0.3, 0.6)	(0, 0.3, 0.6)	(0.6, 1, 1)	(0, 0, 0.3)	(0, 0.3, 0.6)
P_2	(0, 0.3, 0.6)	(0.3, 0.6, 0.9)	(0.6, 1, 1)	(0, 0, 0.3)	(0, 0, 0.3)
P_3	(0, 0, 0.3)	(0, 0, 0.3)	(0, 0.3, 0.6)	(0.6, 1, 1)	(0, 0, 0.3)
P_4	(0.3, 0.6, 0.9)	(0.3, 0.6, 0.9)	(0, 0.3, 0.6)	(0.3, 0.6, 0.9)	(0.3, 0.6, 0.9)
P_5	(0.6, 1, 1)	(0, 0, 0.3)	(0, 0.3, 0.6)	(0.6, 1, 1)	(0, 0, 0.3)
P_6	(0.6, 1, 1)	(0, 0, 0.3)	(0.6, 1, 1)	(0.6, 1, 1)	(0, 0, 0.3)
P_7	(0.6, 1, 1)	(0, 0, 0.3)	(0.6, 1, 1)	(0.3, 0.6, 0.9)	(0, 0, 0.3)

As per step 5, convert the triangular fuzzy number into a crisp value.

Table 5. Triangular fuzzy number matrix to crisp value matrix.

Health issues Pesticides	D_1	D_2	D_3	D_4	D_5
P_1	0.437	0.437	0.936	0.043	0.437
P_2	0.437	0.585	0.936	0.043	0.043
P_3	0.043	0.043	0.437	0.936	0.043
P_4	0.585	0.585	0.437	0.585	0.585
P_5	0.936	0.043	0.437	0.936	0.043
P_6	0.936	0.043	0.936	0.936	0.043
P_7	0.936	0.043	0.936	0.585	0.043

Similarity Analysis: In similarity analysis, we compare the results of the proposed method with the results of the fuzzy TOPSIS method.

Table 6. Weights for input variables.

Pesticides	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Weights	0.65	0.6	0.4	0.45	0.6	0.8	0.15

Table 7. Normalized variables

Pesticides	P_1	P_2	P_3	P_4	P_5	P_6	P_7
D_1	0.2841	0.2622	0.0172	0.26325	0.5616	0.7488	0.1404
D_2	0.2841	0.3546	0.0172	0.26325	0.0258	0.0344	0.00645
D_3	0.6084	0.5616	0.1748	0.14175	0.2622	0.7488	0.1404
D_4	0.02795	0.0258	0.3744	0.26325	0.5616	0.7488	0.08865
D_5	0.28405	0.0258	0.0172	0.26325	0.0258	0.0344	0.00645

The following tables show positive and negative ideal solutions.

Table 8. Ideal solutions

Positive	0.6084	0.5616	0.3744	0.26325	0.5616	0.7488	0.1404
Negative	0.02795	0.0258	0.0172	0.14175	0.0258	0.0344	0.00645

Decision Analysis: After comparing the proposed results with the TOPSIS results, we decide using the ranking method as follows.

Table 9. Results and its ranking

Health issues	Proposed method	TOPSIS method	Rank
D_1	0.75	0.670723	2
D_2	0.5	0.237119	4
D_3	0.936	0.791716	1
D_4	0.591	0.607935	3
D_5	0.437	0.12675	5

4. CONCLUSION

The fuzzy decision-making method regarding the effects of pesticides on human health is framed in this work. Additionally, the fuzzy TOPSIS approach is used to validate this system. Additionally, this study demonstrates that the fuzzy decision-making system can replicate expert knowledge to address any real-world problem in a fuzzy setting.

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