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Integration Satellite Imagery with Fuzzy Logic for Potential Change Detection in Land Use/Land Cover

Dr. Intehaa Abdullah Mohammad AL-Juboury, Safa Ahmed Jabbar Al-Rubaye

College of Education for Pure Science, University of Babylon, Iraq.

drphysics990@gmail.com

Abstract. Considered survey systems for monitoring the earth's surface of the techniques basic and developed for all countries because of their great importance in collecting and providing data and information required as engineering science and research applications can be an important database for many of the establishments. Remote sensing and fuzzy logic are employed to design systems for the survey, monitoring, and changes detect that have occurred in the study area in 2020. The studied area is in Baghdad and its extensions, with an area equivalent to approximately 2776.7628 km². This paper consists of two parts; the first part when the remote sensing classified the study area in unsupervised methods to detect the ratios of components the land use and land cover via divide it into four parameters (vegetation, urban, empty area, and water). As for the second part of the study, the change's detection results are the inputs of the fuzzy logic system. The four inputs were processed using hypothetical probabilities of the FL system. The results were reasonable and could be considered useful for predicting the future of the four parameters (vegetation, urban, empty area, and water) of the study area in the coming years.

Keywords. Remote Sensing, Fuzzy Logic, Satellite Image, Change Detection, Monitoring, Land Use, Land Cover.

1. Introduction

Change detection is the process of identifying the differences or phenomena of a given region at a particular time [1]. The detection of subtle changes in the characteristics of the Earth's surface provides a basis for better understanding of the relationships and interactions between natural and human phenomena for better resource management and use [2]. The important advantages of acquiring repetitive data, [3] its synoptic view, and digital format suitable for computer processing, have made space data sources of key data for various applications of detection of change over the past decades [4]. In general, change detection involves the application of sets of data to analyse the temporal effects of the phenomenon of interest [5]. Change detection research should provide the following information: the spatial distribution of changed types, change trajectories of land- cover types, accuracy assessment of change detection results and area change and rate of change [6]. The use of fuzzy logic gives these types of projects support to confirm the validity of the results that may occur soon [7]. The combination of fuzzy logic and satellite engineering has effectively served many institutions to set up major projects in change detecting [8].

2. Data sources and methods



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2.1. Study area

The studied area is in middle Iraq (Baghdad area and its extensions) between Longitudes $44^{\circ}8' 24.04''$ E to $44^{\circ} 42' 32.21''$ E and Latitudes $33^{\circ} 3' 41.32''$ N to $33^{\circ} 32' 3.38''$ N, within area approximately equal 2776.7628 km^2 as shown in (Figure 1). Identified in UTM coordinates (Universal Transverse Mercator), Zone 38 North, and georeferenced in the WGS84 system, were used. The studied area is located on either side of the Tigris River.

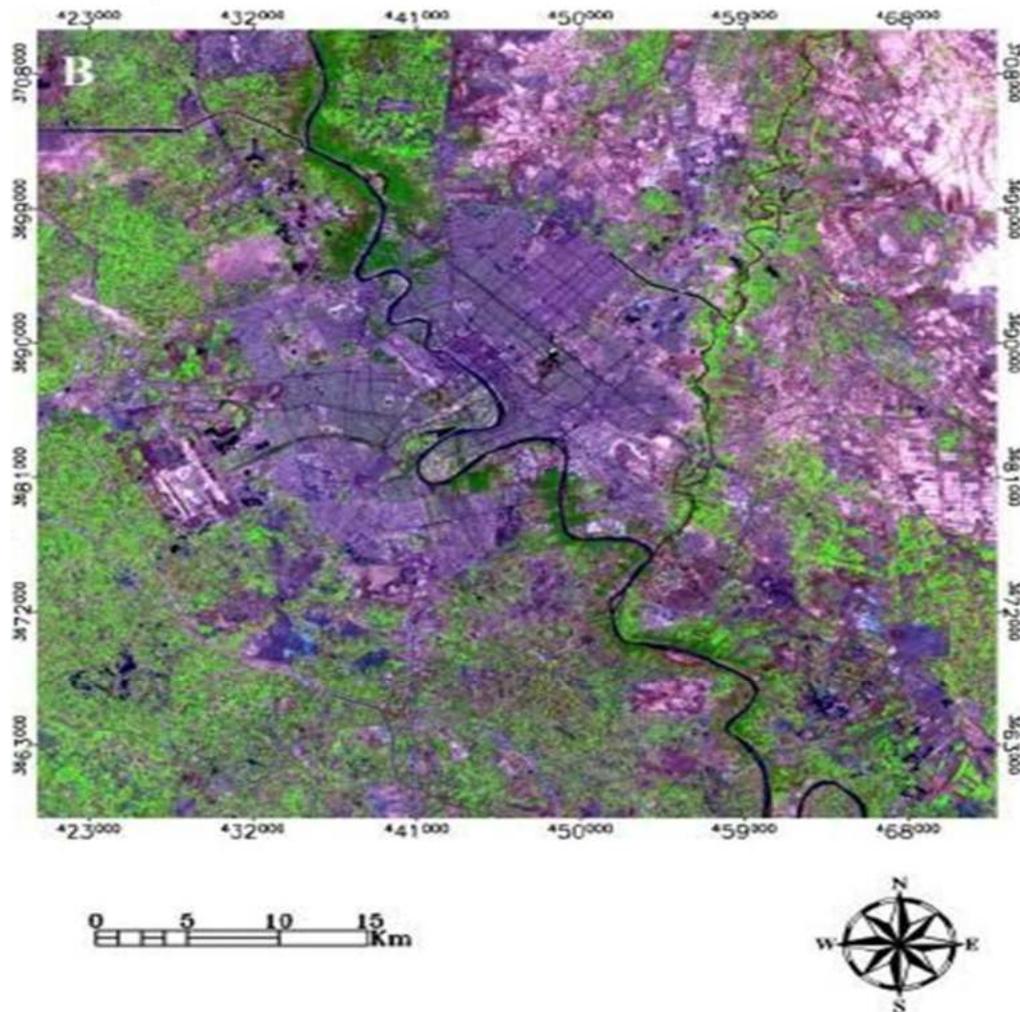


Figure 1. Satellite image of the study area.

2.2. Analysis of Change detection remote sensing technology

Change detection was applied to study the changes resulting from the construction of residential areas and urban growth, [9] and the effects of natural disasters such as floods, forest fires, pastures and the effects of insect outbreaks upon forest cover [10]. Specially designed algorithms have been applied to detect meaningful changes, after analyzing space scene and its classification obtained the following results as in (Figures 2).

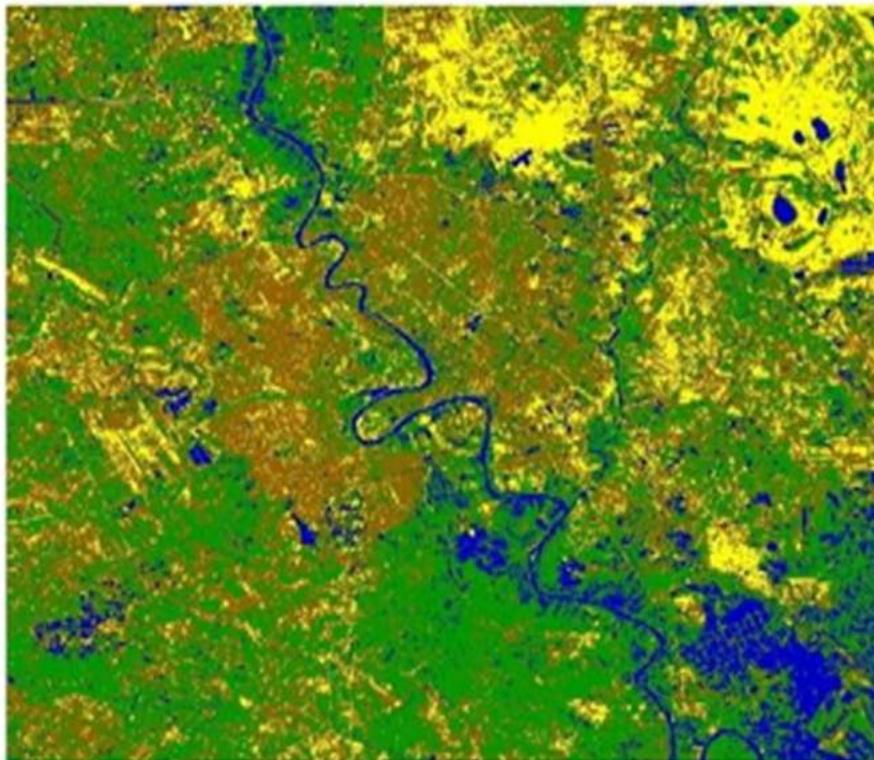
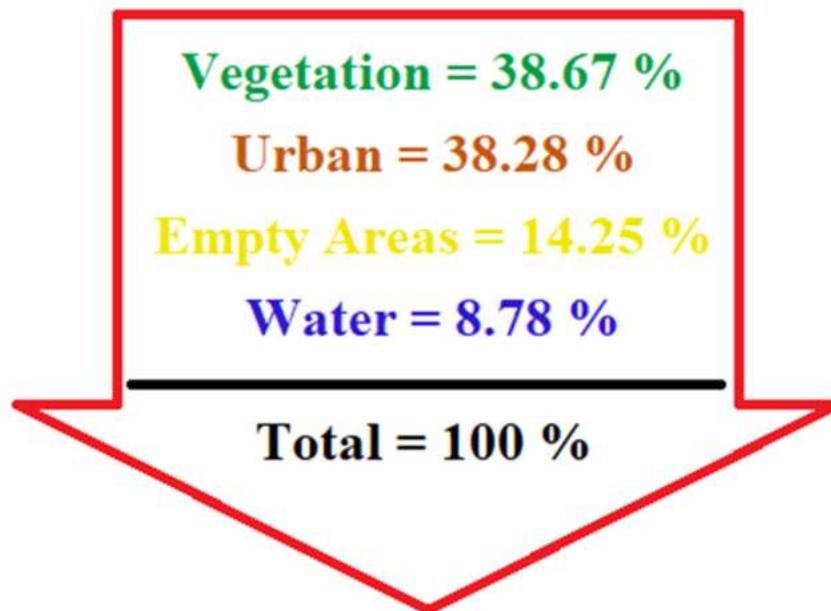


Figure 2. GIS Percentages extracted for the four parameters.

The inputs (crisp) were vegetation, empty areas, urban and water, depending on the percentage of space obtained from the change detection. Where the proportion of vegetation is 38.67 %, the proportion of urban is 38.28%, the proportion of empty areas is 14.25%, and the proportion of water is 8.78%. The outputs (crisp) of the fuzzy logic system was the total area of change of Km² in the study area for each of the four parameters.

3. Design of fuzzy logic (FL) structure

3.1. Fuzzification

Process of changing a crisp (real scalar) value into its corresponding fuzzy value. After introducing values of crisp value and depending on membership, functions will get fuzzy values.

3.2. Rule base

The rule base is designed according to the four approved parameters; the ratios were classified according to the table below:

Table 1. Classification of the suggested ratios of the four parameters in FL system.

0-10 %	11-20 %	21-30 %	31-40 %
%			
Low	Medium	High	Very High

It has also been used Mamdani-Fuzzy Inference System (FIS) which expects the output membership functions to be fuzzy sets.

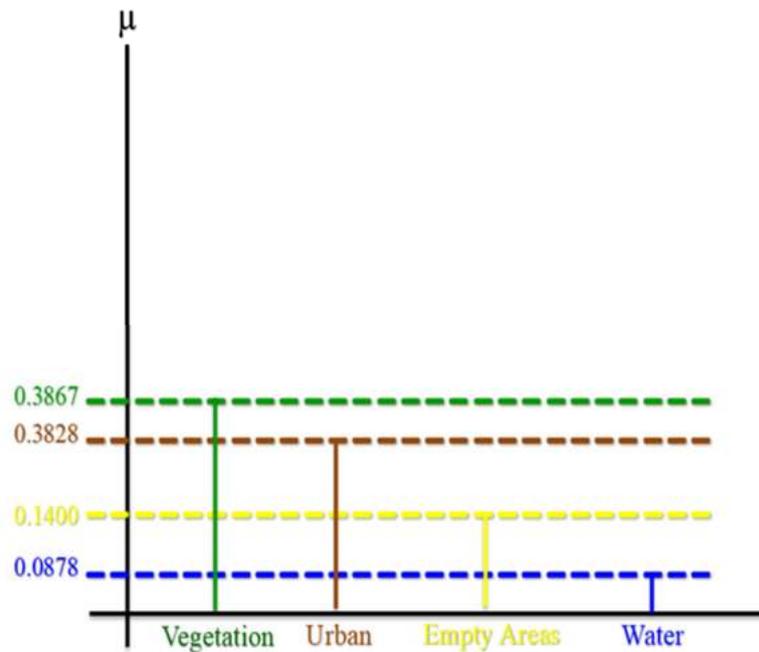


Figure 3. Fuzzy classification for the considered land cover classes of vegetation, urban, empty area and water.

3.3. Defuzzification

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set), and the output is a single crisp number. The centroid defuzzification method was adopted in the design of the FL system. The FL structure consists of the parts shown in the (Figure 4) below:

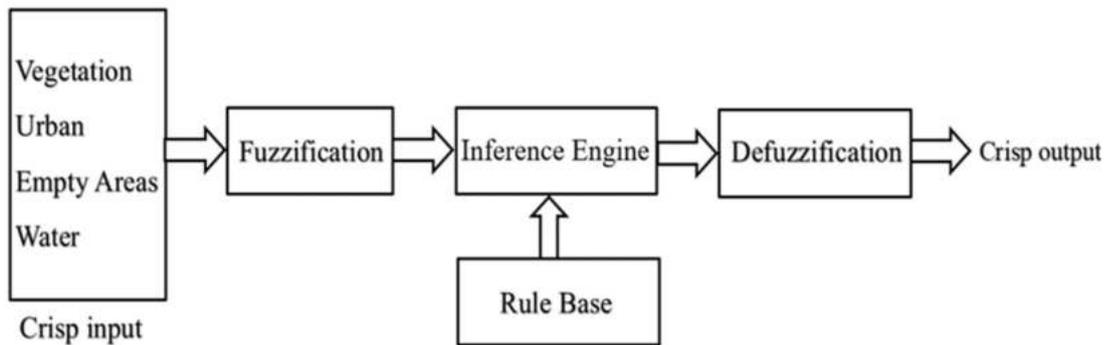


Figure 4. Block diagram of FL system structure.

4. Performance of FL system

The FL structure is designed and add input four parameter (vegetation, empty areas, urban and water) and select centroid from defuzzification. Add membership function for each input (FIS variables) and select type triangle and the select number of FMs equal 4, select range from 0 to 40 and naming the four triangles (Low, medium, High, Very High) (Figure 5), thus for the empty area, urban and water in sequence. Consider the direct default division of the triangle rule to be adopted. Membership function has the following [11]:

$$(1) \quad A(t) = \begin{cases} 1 - \frac{a-t}{\alpha} & \text{if } a - \alpha \leq t \leq a \\ 1 - \frac{t-a}{\beta} & \text{if } a \leq t \leq a + \beta \\ 0 & \text{otherwise} \end{cases}$$

Add membership function for output variable (Area Km²) and select type trapezoidal and the select number of FMs equal 4, select range from 0 to 100 and naming the four trapezoidal (Low, medium, High, Very High). The upper trapezoidal base was considered half its bottom base, as in (Figure 6). And the membership function has the following form:

$$A(t) = \begin{cases} 1 - \frac{a-t}{\alpha} & \text{if } a - \alpha \leq t \leq a \\ 1 & \text{if } a \leq t \leq b \\ 1 - \frac{t-b}{\beta} & \text{if } a \leq t \leq b + \beta \\ 0 & \text{otherwise} \end{cases}$$

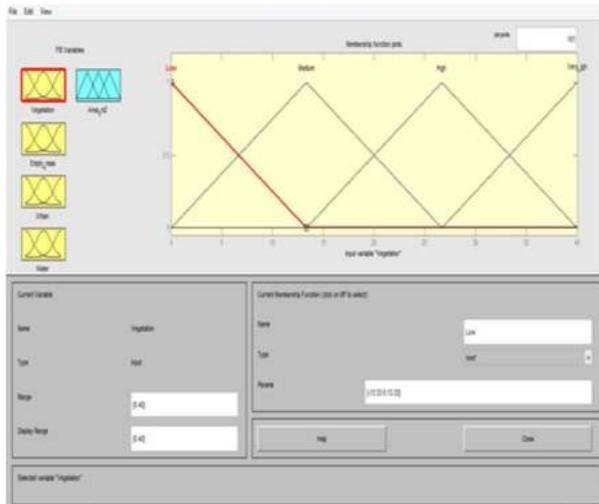


Figure 5. Membership function editor for input. **Figure 6.** Membership function editor for output.

5. Results and discussion on the performance of FL system

The performance of the FL system depends on system design, system input, processing during system operation and system output. The system inputs were four values (vegetation, empty areas, urban and water) and the FL system was designed regularly used Mamdani-Fuzzy Inference System (FIS). The centroid defuzzification method was adopted in the design of the FL system. The percentages for 2020 are real percentages obtained through the project, but the real proportions of the coming years cannot be predicted to compare with the 2020 percentages. Therefore, the concept of fuzzy logic has been used. Certain probability assumptions have been imposed for hypothetical percentages as water is the most variable element annually in most countries of the world, including the study area because of rainfall and floods, so changing the percentage of water area will play a major role in changing the percentages of the areas for the other three elements as in below see (Table 2).

Table 2. Results of the rules in four cases.

Vegetation %	Empty %	Urban %	Water %	Area Km ²
Low	High	High	Low	Medium
Medium	Medium	Medium	Medium	Medium
High	Medium	Medium	High	High
Very High	Low	Low	Very High	Very High

- 1- If (Vegetation is Low) and (Empty_Area is High) and (Urban is High) and (Water is Low) then (Area_Km² is Medium).

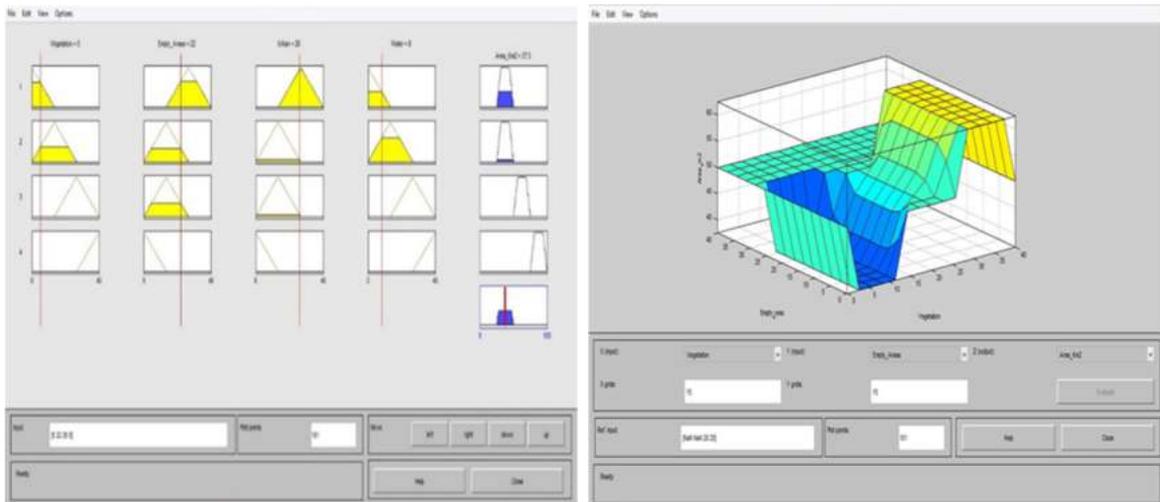


Figure 7. Rule viewer and surface viewer FL system (Area is Medium).

- 2- If (Vegetation is Medium) and (Empty_Area is Medium) and (Urban is Medium) and (Water is Medium) then (Area_Km² is Medium)

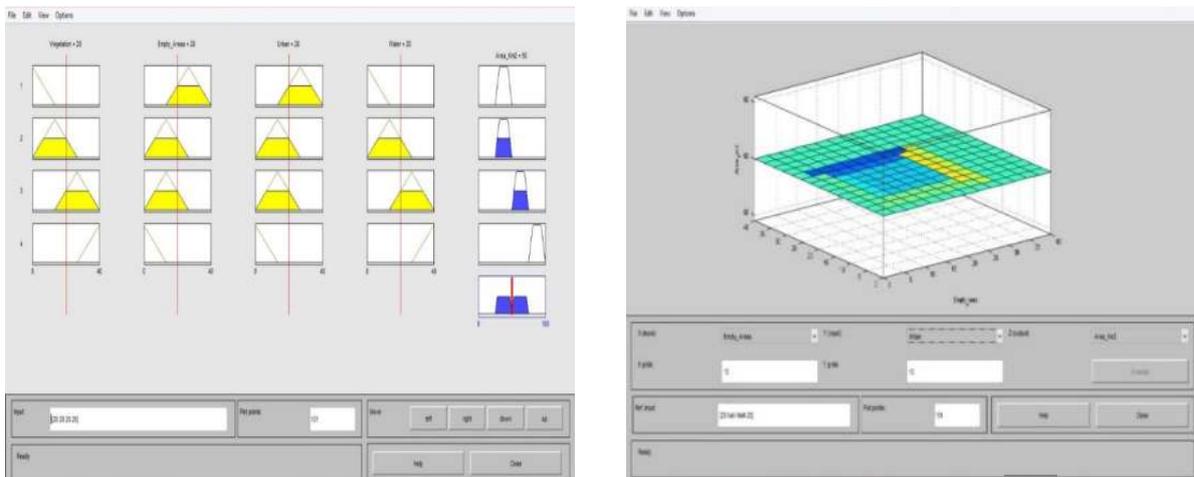


Figure 8. Rule viewer and surface viewer FL system (Area is Medium).

- 3- If (Vegetation is High) and (Empty_Area is Medium) and (Urban is Medium) and (Water is High) then (Area_Km² is High).

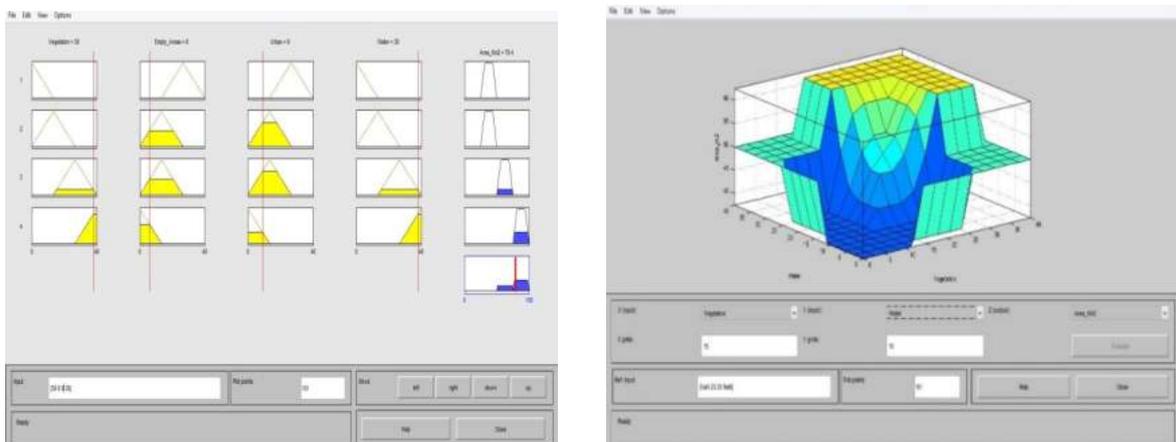


Figure 9. Rule viewer and surface viewer FL system (Area is High).

- 4- If (Vegetation is Very High) and (Empty_Area is Low) and (Urban is Low) and (Water is Very High) then (Area_Km² is Very High).

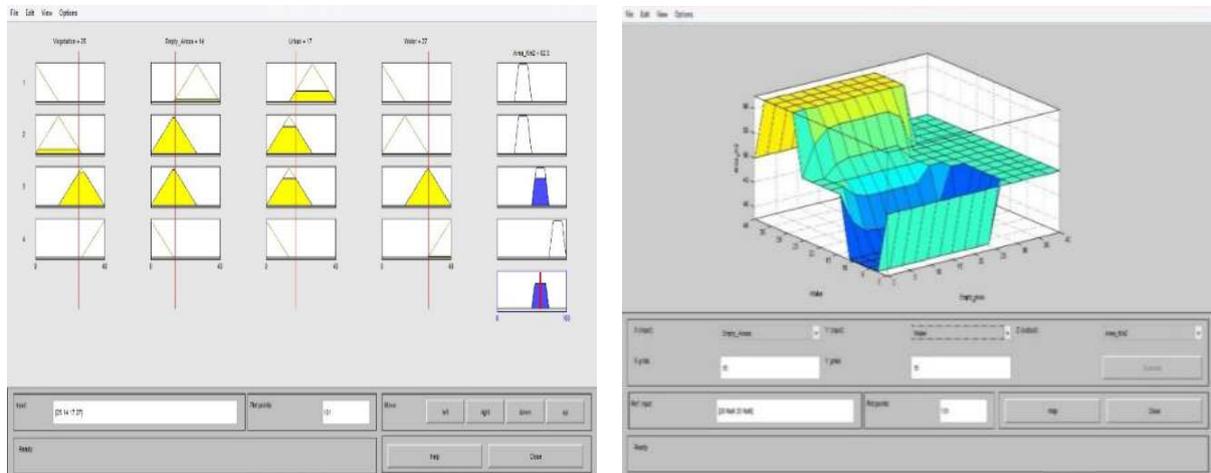


Figure 10. Rule viewer and surface viewer FL system (Area is Very High).

6. Discussion on comparison with other FL structure

When compared with other FL structure, let it be the method used in the source article, we find the main object from the search is flooded mapping for study area by using fuzzy logic, when classed Image directly, for results concerning three elements are backscatter value, clutter size, and local slope values. Where proposed an SBA algorithm to perform a robust tile selection process, the final rating is then improved by merging the pixel backscatter value cluster size and local slope into a fuzzy logic-based post-grouping structure. While this paper was based on the detection of changes that occurred in 2020 in the study area via satellite images, based on four elements are vegetation, empty areas, urban and water. Using special algorithms (image differencing technique), the final results were obtained. These results were then exported to the fuzzy logic, where these four ratios represent inputs to the FL system, consider that values (low, medium, high and very high) are the ones that control the output values of the FL system, the results of the fuzzy logic is detailed in the context of the paper.

7. Conclusions

1. The change detection using image differencing is an efficient method to detect changes in ground cover and to determine the total area of these changes during different times.
2. The ability to monitor very large areas without complying.
3. The use of fuzzy logic in the project analyzed all possible possibilities, so the results were very close to reality.
4. Getting very accurate information.
5. Select and identify any study freely and fully area.
6. Get results by much less effort than the classical methods.
7. Low cost compared to other means.
8. The integration of the use of fuzzy logic with the spatial images of the study area gave a broader view of the results.

Acknowledgments

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