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Extended Abstract

Estimating Precipitation Data using a Fuzzy-based Technique

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Introduction

For years, it was believed that with the scientific progresses and the increase of human knowledge, uncertainties may diminish. But uncertainties are an unavoidable part of natural systems. Conventional methods based on statistics and probability theories are successful in facing uncertainties in many simple cases. However, when it comes to more complex systems these theories need many theoretical assumptions that, practically, make them awkward and cumbersome.

Compelling emphasis on more detailed models, has made modeling too complex and, therefore, in some cases impractical [Bardossy and Duckstein, 1995]. In this regard the fuzzy logic offers alternate solutions towards uncertainties. The fuzzy logic has been reviewed as an acceptable measure in the realistic science world that can be applied to many disciplines [Zimmermann, 1985].

Objectives

Fuzzy logic as an adaptable tool that suites many systems can also be employed to express the influence of one or more climatic and environmental variables on other climatic and environmental phenomena. In this research a fuzzy model has been developed and presented for precipitation data estimation and restoration.

Methodology

With some inspiration from the architecture of the real world system and based on the physical factors affecting the precipitation in each climate, the fuzzy-based model for precipitation data estimation and restoration was established as shown in figure 1.

To evaluate the model performance results were compared to the results of two conventional models, namely: the distance-inverse method and the mean of nearby points method. The Mean Bias Error (MBE) and the Mean Absolute Error (MAE) were employed as performance indicators.

Khorasan province, with an area of 313000 sq. km and an average annual precipitation of 219 mm, was selected as the research area. The area has a vast variety in climate and precipitation patterns due to its wide range of geographical latitudes as well as considerable differences in its altitudes.

Results and Discussion

Fuzzy memberships for distance function were made from four fuzzy sets: Near, Near_m (near to medium), Far_m (far to medium), and Far. In the same manner fuzzy memberships for the elevation deviation function were made from four fuzzy sets: Low (almost with the same elevation), Low_m (low to medium deviation), High_m (high to medium deviation), and high (high deviation) triangular and trapezoidal shapes were given to these fuzzy sets.

Then, the fuzzy model output was determined with the Mamdani fuzzy inference, the minimum and product implication, and the maximum and product aggregation [Coa, and Kandel, 1989; Kerre, 1992; Lee, 1990]

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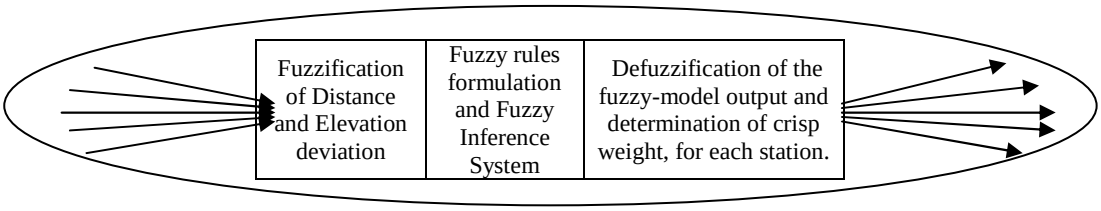

Figure 1- The overall architecture of the fuzzy-model for precipitation data estimation and restoration

Next the fuzzy-model output was de-fuzzified with the "center of area" method to deliver a crisp weight for each station in the data restoration process.

The fuzzy rule-base is composed of 16 rules. For each station the fuzzy engine fires two to four rules based on the values of distance and elevation deviation.

After finding weights for all contributing stations, missing data were estimated from the following weighted average formula:

$$Data_m = \frac{\sum_{i=1}^{n} Coef_i * Data_i}{\sum_{i=1}^{n} Coef_i} \quad (1)$$

In which: $Coef_i$ is the ith station weight; $Data_i$ is the observed precipitation of the ith station; and $Data_m$, is the estimated value for the missing data.

Conclusions

Review of the results showed that

1- the performance indicators differ less than 1%; hence, no preference may be concluded.

2- the fuzzy-model results were affected by the number of contributing stations. The best results were found with four contributors and the least with two.

3- the fuzzy-model, in comparison with the other two conventional models performs better. The MAE and MBE for the fuzzy-model were equal to 7.4 mm and -0.64 mm, respectively; These values were respectively equal to 14.53 mm and -3.89 mm for the inverse distance method; and 12.74 mm and 4.67 mm for the mean of the nearby points method. Specifically, results of the fuzzy-model, compared to the other two methods, were superior in regions with higher elevation deviations.

Keywords: Fuzzy model, Fuzzy rules, precipitation data, Average method, Inversed-distance method, Khorasan.

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