KUFA JOURNAL
OF ENGINEERING
ISSN 2071-5528
PRINTED IN IRAQ

Volume 4, Number 1 pp.69- 80, 2012

PREDICTION OF LAND SOIL EROSION USING FUZZY INFERENCE SYSTEM MODEL (FIS)

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(Received:15/4/2011 ;Accepted :22/2/2012)

ABSTRACT:

Fuzzy Inference System appears a promising approach to address many important aspects of networks, particularly in allied fields of civil engineering. In this paper a Fuzzy Inference System for land soil erosion assessment was investigated.

The land soil erosion is controlled by multifarious parameters, such as slope, soil physical properties (texture, structure, permeability, etc.), rainfall, runoff, and crop cover.

The rainfall coefficient(R), slope coefficient (LS), soil erodibility factor (K), cropping system(C), and supporting practices (P) parameters are treated as antecedents and the land soil erosion (A) is the consequent. Developing the basis model using generalized Mamdani method based on data collected from available literature and assessment of the validity of the basic model depending on experimental data. The obtained results with Fuzzy Inference System are compared with experimental values and found remarkably close to each other values and found remarkably close to each other.

Keyword: Soil Erosion, Fuzzy Inference System.

التنبؤ بتآكل التربة السطحية باستخدام نظام الاستدلال الضبابي

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الخلاصة:

نظام الاستدلال الضبابي اظهر طريقة مقبولة للعديد من مجالات العمل المهمة وخاصة في حقول الهندسة المدنية. في البداية سيتم تحري تقييم نظام الاستدلال الضبابي لتأكل التربة السطحية.
يعتمد التآكل من التربة السطحية على عدد من العوامل المتنوعة مثل الميل والمطر والسيح والغطاء النباتي والخواص الفيزياوية للتربة(كالنفاذية والتركيب والبناء وغيرها).
لقد تم معاملة كل من معامل المطر ومعامل الميل ومعامل التربة ومعامل الغطاء النباتي ومعامل نظام إسناد التربة كأسبقيات أما مقدار التآكل من التربة السطحية فاعتبر كتابع. طور النموذج اعتمادا على معلومات تم تجميعها من Mamdani الأساسي باستخدام طريقة مجموعة من البحوث المتاحة وتقييم صلاحية النموذج بالاعتماد على النتائج العملية ثم قورنت النتائج المستحصلة من نظام الاستدلال الضبابي مع النتائج العملية ووجد هناك تقارب كبير بينهما.

الكلمة الدلالية: تآكل التربة، ونظام الاستدلال الضبابي.

INTRODUCTION:

Land soil erosion removes organic matter from the soil and contributes to the breakdown of soil structure that will in turn affect soil fertility and the crop yields. According to Merritt et. al. (2003), soil erosion is a three – stage process: detachment, transport, and deposition. Detachment occurs when the erosive force of rainfall drop impact or when flowing water exceeds the soil's resistance to erosion. Detached particles are transported by the splash and flow of raindrop (Foster 1982). Detachment of soil particles is a function of the erosive forces of raindrop impact and flowing water, the susceptibility of the soil to detachment, the presence of material that reduces the magnitude of the eroding forces, and the management of the soil that makes it less susceptible to erosion. Transport is basically a function of transport forces of the transportability of the detached particles, and the presence of material that reduces the transport forces.

Understanding the soil erosion mechanism is very important to develop the soil erosion control techniques. The factors that influence the rate of soil erosion include rainfall, runoff, slope, land cover and the presence or absence of conservation strategies. However, it is impossible to develop precise simplest mathematical model that can predict the values of land soil erosion due to the behavior of controlled parameters.

In this paper a powerful tool known as Fuzzy Inference System (FIS) is used to precise analysis of the land soil erosion. Term “Fuzzy” was used by prof. Lotfi Zadeh, for the first time in 1962(Zadeh). In 1965 he published his pioneer, today still classic paper entitled “Fuzzy sets” the Fuzzy sets have since spread practically too all aspects of scientific disciplines (Zadeh 1965).

Fuzzy models have supplanted more conventional technologies in many scientific applications and engineering systems, especially in control systems and pattern recognition (Bezdek 1994). The property that makes Fuzzy set theory particularly interesting is its ability to handle the imprecision inherently present in a system. For the most complex systems where a few numerical data exist and where only ambiguous and imprecise information may be available, Fuzzy provides a way to understand system behavior by allowing the interpolation between observed input and output situations. The imprecision in Fuzzy models is generally quite high (Ross 1997).

This paper presents an (FIS) based model to predict land soil erosion by making use of available experimental data. These data are divided into training data and testing data. Training data are used in developing the (FIS) based model. In validating the (FIS) based model testing data are used. Five antecedents and one consequent is considered. The rainfall coefficient(R), slope coefficient (LS), soil erodibility factor (K), cropping system(C), and supporting practices (P) are treated as antecedent and the land soil erosion (A) as consequent.

FUZZY INFERENCE SYSTEM

Fuzzy Inference System is the process of formulating the mapping from a given input to an output using Fuzzy logic. Fuzzy Inference System has been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision.

Fuzzy Inference System, which is also called Fuzzy rule based system, is composed of (4) blocks as shown in figure (1).

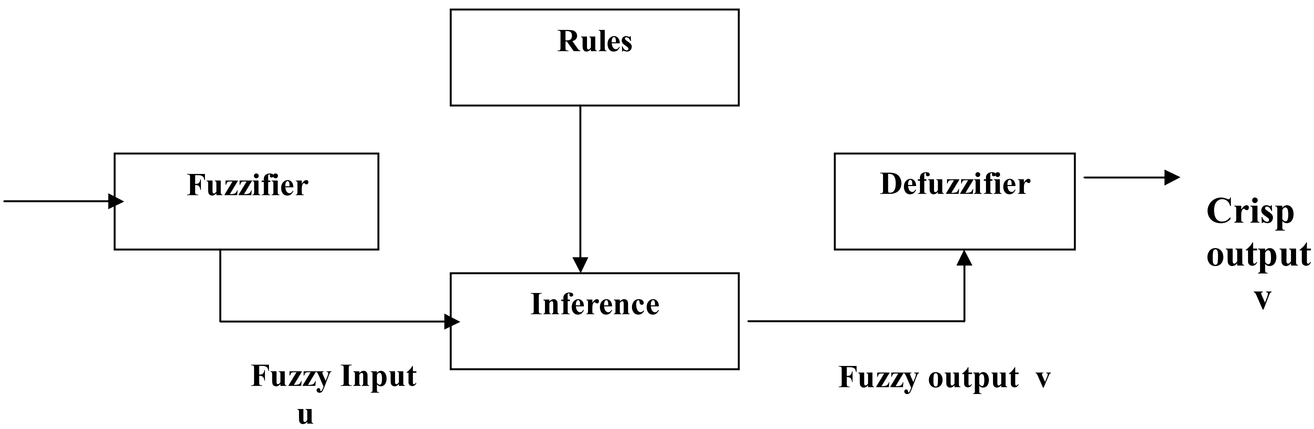

Fig. (1) A Fuzzy Inference System (FIS)

1- Fuzzifier: Transforms the crisp inputs into fuzzy inputs by member- ship functions (MF) that represent Fuzzy sets of input vectors; in this work, singleton fuzzifieer is assumed; ie., $\mu A(x) = 1$ for $x = x^o$ and $\mu A(x) = 0$ for all $x \ni u$ with $x \neq x^o$.
2- Rules : Consists of fuzzy IF-THEN rules;
3- Inference : Inference engine for fuzzy rules;
4- Defuzzifier: Transforms the fuzzy output into crisp output. Defuzzification process requires the most computational complexity in FIS, and center of gravity or height defuzzification method is common (Chul Min 2003). The center of gravity method consists of selecting the value corresponding to the center of gravity for the solution set. Bisector is another method

which produces a value that will split the area of the solution set in half. Three other defuzzification methods focus on the maximum member ship value attained by the solution set. Frequently the maximum value of the solution set is arranged of values rather than a point value. “smallest of maxima” selects the lowest value at which the highest membership value is attained similarly, “ middle of maximal” and “ largest of maxima” respectively select the middle value and the largest value at which the largest membership value occurs the objective of the model will influence the selection of defuzzification methods.

The major component in an FIS is “Rules”, and rules are expressed in the form of IF THEN statements. Let u and v be universe of discourses for antecedent and consequent of the rules, then the rule of if x is A, then y is B. where x Э u, and y Э v, represents a relation between A and B, and extension to multiple rules and multiple antecedents can be easily done by specify in both composition and inference methods(Mendel 1995).

Rules are influential in selecting the number of variables and membership functions to be modeled with fuzzy logic because the model becomes exponentially more complex as the number of variables or membership functions increase.

FUZZY MODEL FOR PREDICTION OF LAND SOIL EROSION

The fuzzy logic based model was devised by using fuzzy logic toolbox in MATLAB program 2008 as shown in figure (2).

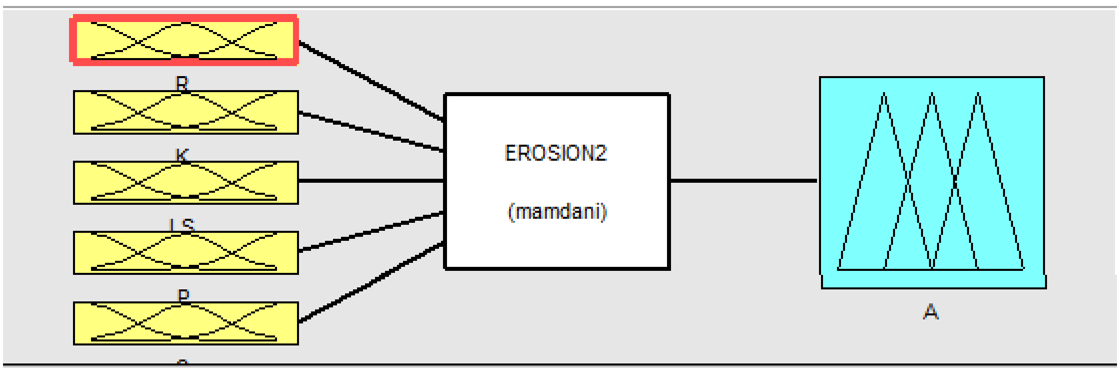

Fig.(2) Block diagram used for fuzzy modeling

A pervious experimental data are collected from available literature [Wisch-meier(1977), Nikami(1999), Navar(2000), Cooper(1997), and Dehaan (1992)]. These data (patterns) are divided into two groups; training data, and testing data. The training data are used to develop and train the fuzzy logic based model and the other data are used as a test set.

In developing the fuzzy logic based model the relation between the initiated fuzzy input and the required output is illustrated. Five inputs are captured and treated as antecedents, and the land soil erosion has been treated as linguistic output space. The membership functions for input parameters and output are choused depending on the experience gained, and its base values and some of them are shown in figures (3 to 6).

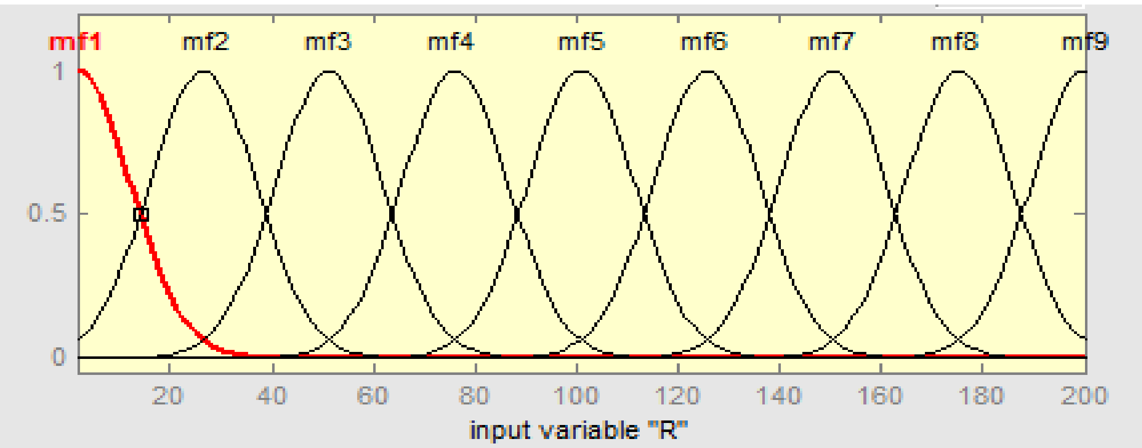

Fig.(3) Fuzzy input membership function used for rainfall coefficient (R)

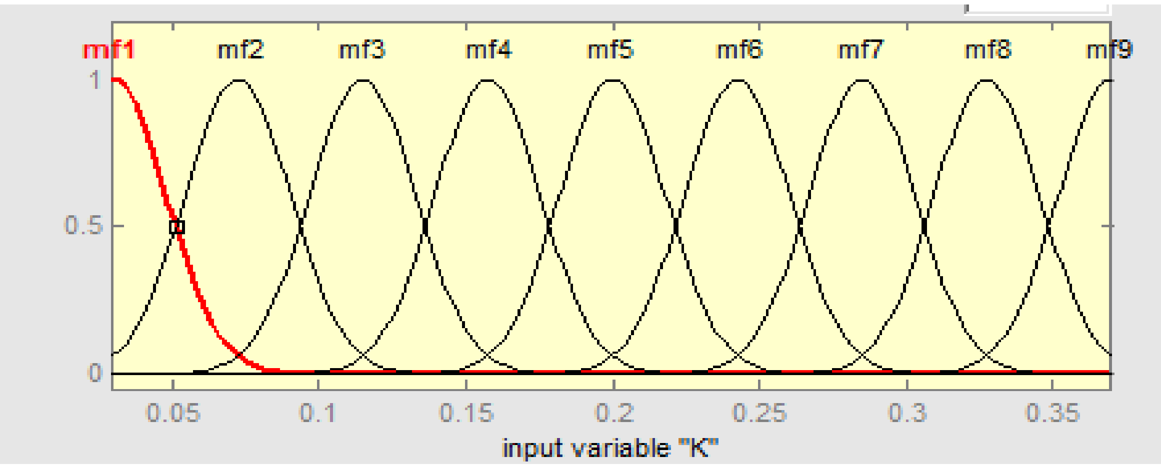

Fig. (4) Fuzzy input membership function used for soil erodibility factor (K)

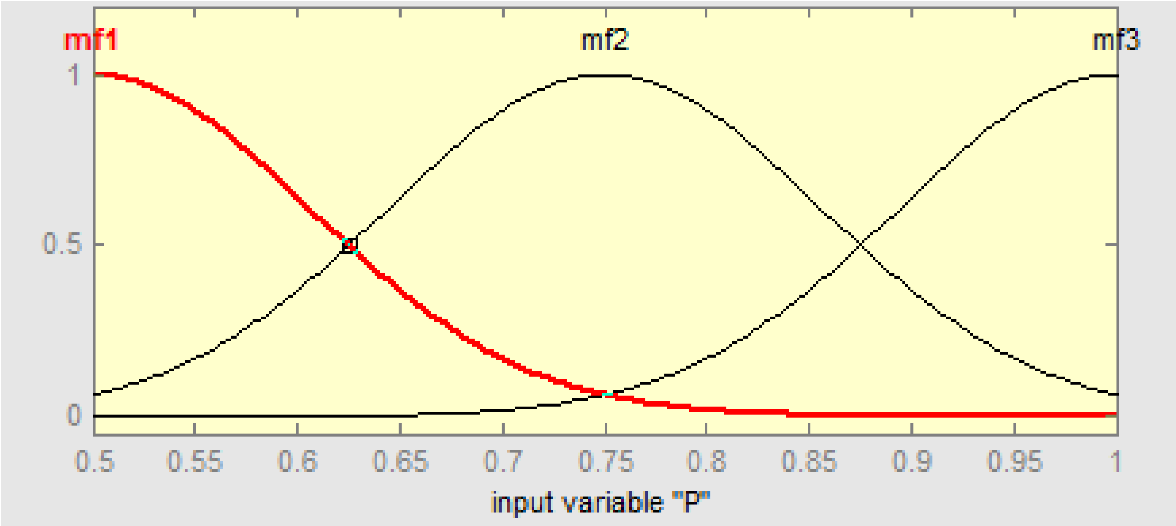

Fig.(5) Fuzzy input membership function used for supporting practices factor (P)

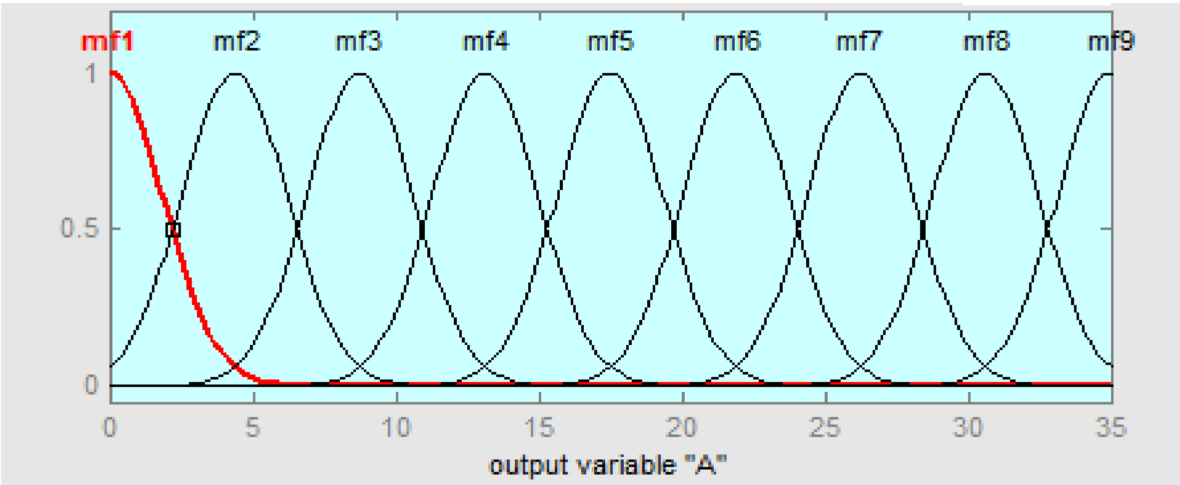

Fig.(6) Fuzzy output membership function used for land soil erosion (A)

The rules that relate the input membership functions to the output membership function are fixed and consist of 62 rules. These rules have been formulated with appropriate relation between input and output. The sample of the rule is shown in figure (7).

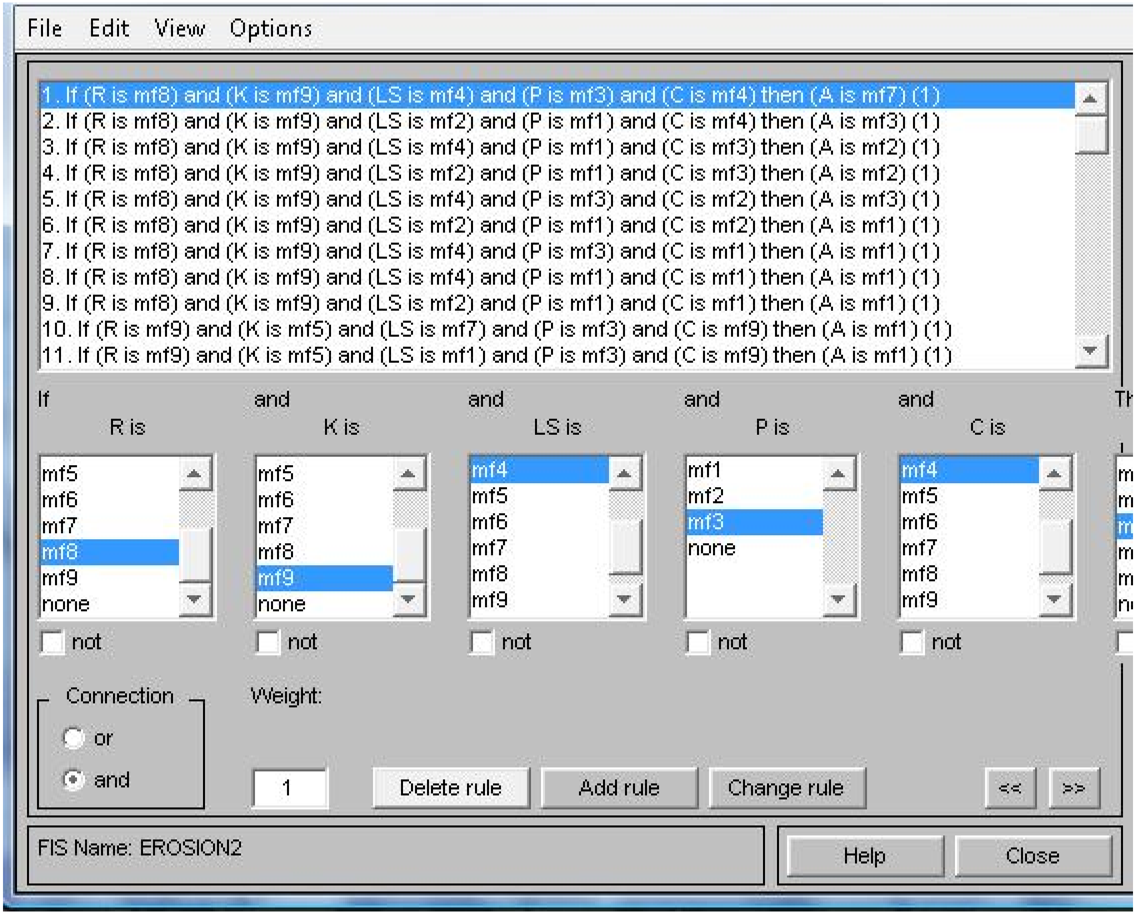

Fig.(7) A segment of the rule frame

The number of rule is an important of the FIS. Clearly, the appropriate number of rules depends on the complexity of the system. A large number of rules, similar to a high order model, will bias the model toward specific data that can be imprecise or even erroneous. On other hand, less number of rules will likely to increase the output error (Elstner 1956). A sample output of this work for given input is shown in figure (8).

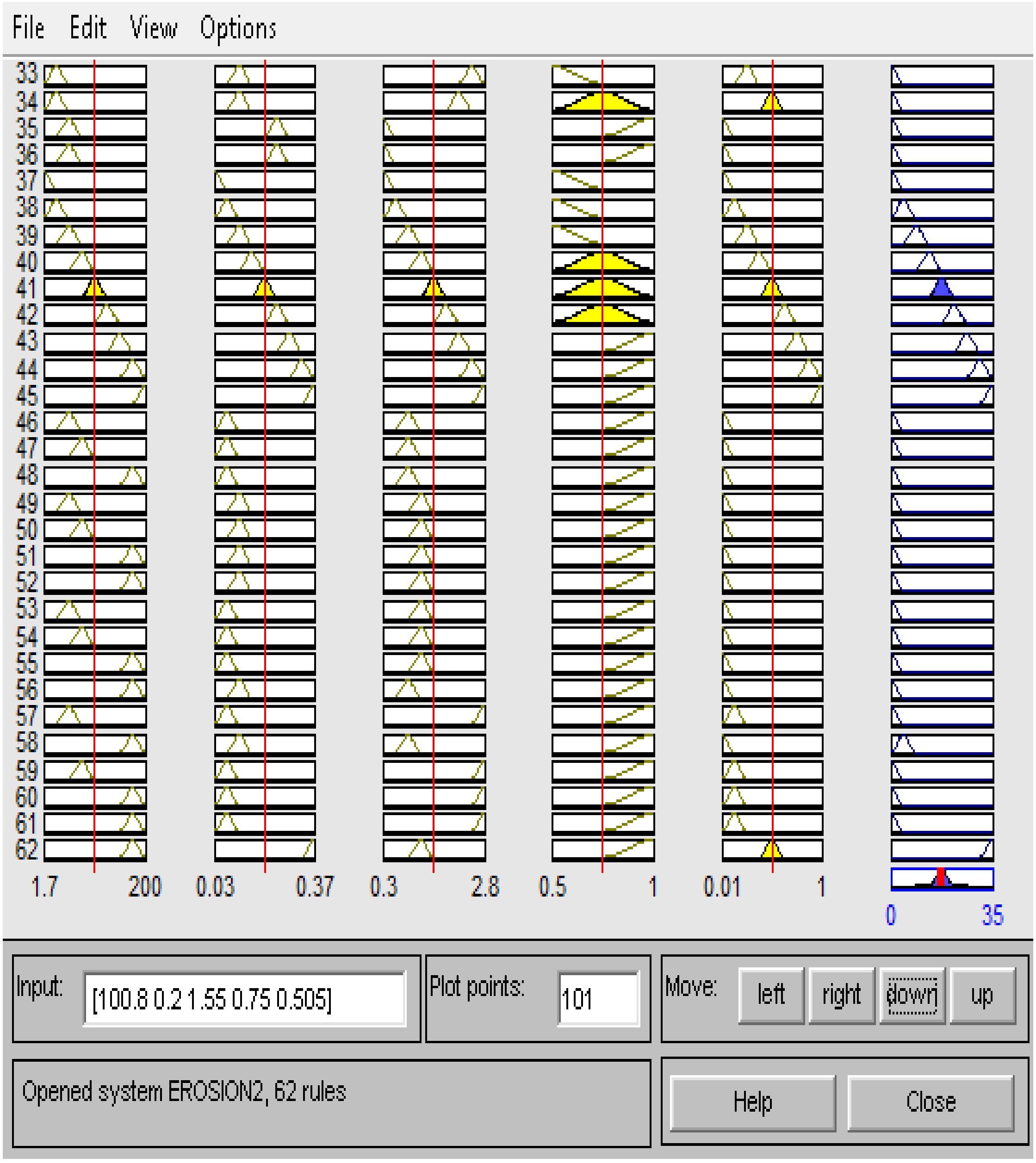

Fig.(8) Viewer rules

The relationship between actual and predicted land soil erosion are shown in figure (9), and the coefficient of correlation between actual and predicted land soil erosion is R=0.98.

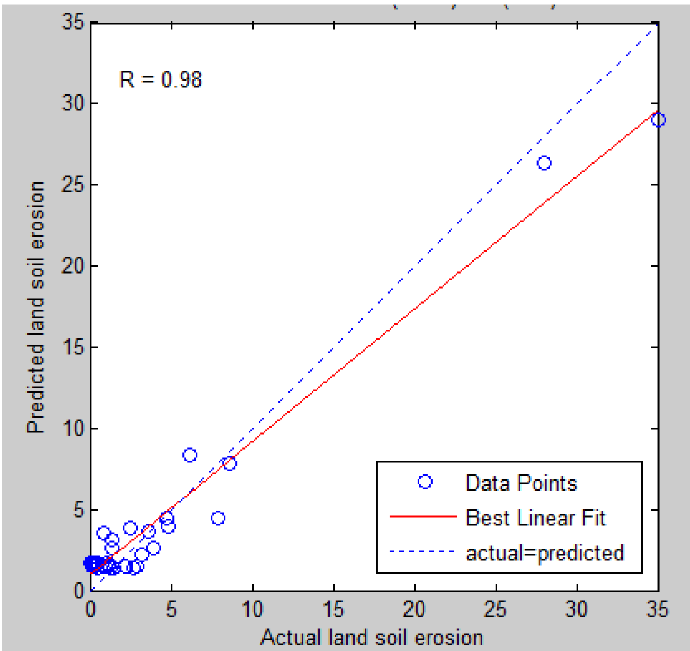

Fig. (9) Regression analysis between predicted and actual values of land soil erosion

VALIDATION OF FUZZY MODEL

Testing data are used to validate the developed model. Model validation must be carried out using the input – output that are not used for rules to evaluate the efficiency of the (FIS) in predicting land soil erosion. Figure (10) shows the relation between actual and predicted land soil erosion for testing data and the plot shows that the coefficient of correlation is R=0.94.

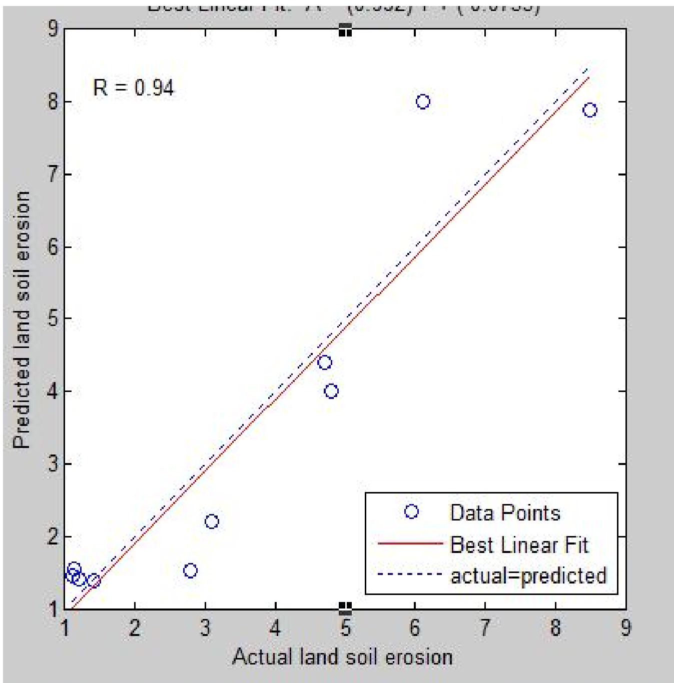

Fig.(10) Regression analysis between predicted and actual values of relative data for land soil erosion

Different defuzzification techniques was used to predict the land soil erosion using five input parameters such as centroid, bisection, mean of maximum, small of maximum, and large of maximum. The values of R for these different defuzification techniques are shown in Table (1) and figure (11) show these results.

Table (1) Values of R for different defuzzification techniques

Method	R
Centroid	0.98
Bisector	0.978
Mean of maximum	0.98
Small of maximum	0.976
Large of maximum	0.976

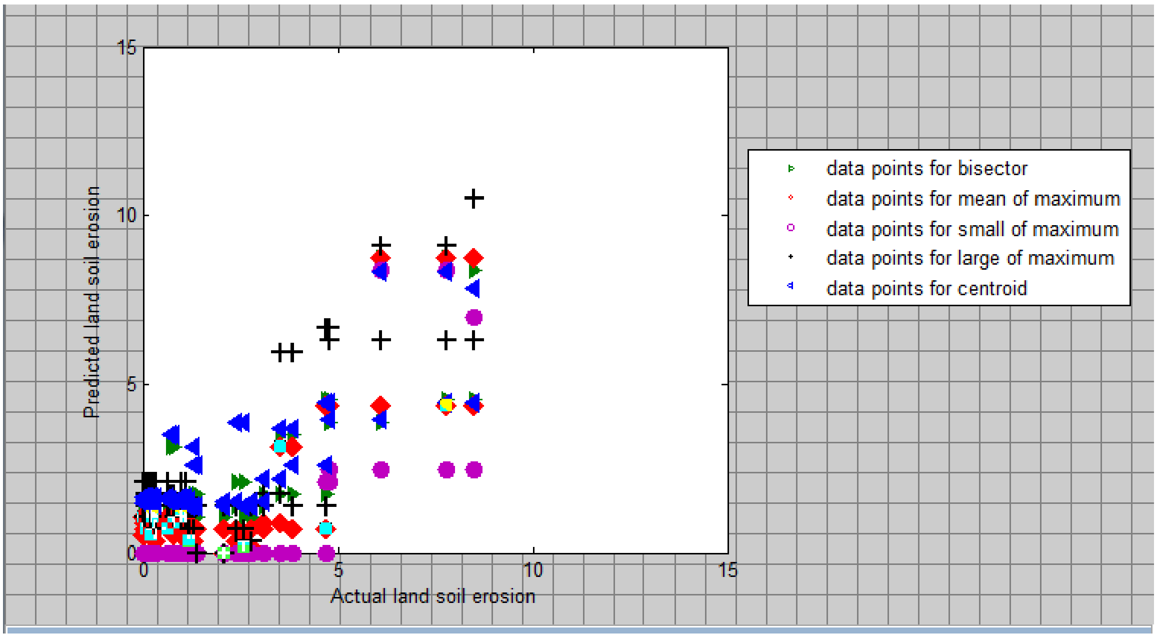

Fig. (11) Resulting using different defuzzification methods

CONCLUSIONS

This paper presented a Fuzzy Inference System for the prediction of land soil erosion in two stages model. In the first stage, developing the basic model using generalized Mamdani method is developed, and in the second stage, the validity of the basic model is conducted. To make the model; data driven, experimental data was used. The model was developed using MATLAB. The results of prediction were excellent, particularly with Centroid and Mean of maximum methods of defuzzification techniques. Furthermore, the average of error for prediction of the land soil erosion is 4.9%. Finally it has been felt that; Fuzzy logic concept would auger well for modeling of land soil erosion and that of relatively small set of data.

REFERENCES

Bezdek, J. (1994). “Fuzzy models- what are they, and why?” Fuzzy logic technology and applications, IEEE Technical Activities Board, pp. 5,

Chulmin, L. and Shrikanth, N., “Emotion recognition using a data- driven Fuzzy Inference System”, Dep., Elec., Engineering, University of Southern California, (2003).

Cooper, E. L.,"Agriscience: Fundamentals & Applications", Belmar publishers, Albany, New York, (1997).

Dehaan, R., "Integrated Erosion Control on Potato Land in Atlantic Canada", Atlantic Committee on Agricultural Engineering, (1992).

Dubois, P., “ Fuzzy sets and systems”, Academic press, Newyourk, (1980).

Elstner, R. C., and Hognestad, E., “Shearing strength of reinforced concrete slabs”, ACI Journal, vol. 289, No. 1, pp. 29-57, (1956).

Foster, G. R., “Modeling the erosion process” In: Haan, Johnson and Brakensiek (eds.),Hydrologic modeling of small watershed. An ASAE

Joongdae, C., Ye-Hwan, C., and Yong- cheol, S., “Soil erosion measurement and control techniques”, Division of agricultural engineering, Kangwon National University, Korea (2007).

Hellendoorn, H., and Driankn, D., “ Fuzzy model identification select approaches”, Springer, Berline, (1997).

Mendel, J. M., “ Fuzzy logic systems for engineering: A tutorial”, proceeding of the IEEE, VOL. 83(3), PP.345-377, (1995).

Merritt, W. S.,Letcher, R. A., Jakeman, A. J., “A review of erosion and sediment transport models”, Environ model softw.(8:761-799;(2003)).

Monograph No. 5, ASAE, 2950 Niles Rood, P. O. Box 410,st. Joseph, Michigan 49085, USA (1982).

Navar, J., and Synnott, T. J., "Surface Runoff, Soil Erosion, and Land Use in Northeastern Mexico", Uni. Nuevleon, P. O. Box 41967700 Linares, N. L. Mexico, (2000).

Nikkami, D., "Optimizing the Management of Soil Erosion Using GIS", ph. D., thesis, Dep. Of civil eng., Univ. of Concordia, Aug., (1999).

Ross, J. J., “Fuzzy logic with engineering application”, International edition, McGraw- Hill, Inc., (1997).

Wang, L. X., “Fuzzy systems are universal approximates”, Proc., vol. I, IEEE conf.,Fuzzy system, vol. 8, No.12, pp.1163-1170,(1992).

Wischmeier, W. H., "Soil Erosion Prediction and Control", Soil Conservation Society of America, 77-74183,(1977).

Zadeh, L. A., “From circuit to system theory”, Roc. of Institute of ratio engineering vol. 50, pp. 856-865, (1962).

Zadeh, L. A., “Fuzzy sets”, Journal of information and control”, No. 8, vol. 3, pp. 338-353, (1965).