ORDERED IDEAL INTUITIONISTIC FUZZY MODEL OF FLOOD ALARM

S. J. KALAYATHANKAL, G. S. SINGH, S. JOSEPH,
J. THOMAS AND P. C. SHERIMON

ABSTRACT. An efficient flood alarm system may significantly improve public safety and mitigate damages caused by inundation. Flood forecasting is undoubtedly a challenging field of operational hydrology and a huge literature has been developed over the years. In this paper, we first define ordered ideal intuitionistic fuzzy sets and establish some results on them. Then, we define similarity measures between ordered ideal intuitionistic fuzzy sets (OIIFS) and apply these similarity measures to five selected sites of Kerala, India to predict potential flood.

1. Introduction

Rainfall being the dominant component in most hydrological systems, reliable quantification of rainfall is absolutely essential for various ecological, meteorological, geo-morphological and disaster management studies. Since the occurrence and distribution of rainfall over a region is controlled by many independent factors, reliable forecasting becomes a complex exercise. A challenging task for catchment management and flood management in particular is the creation of a reliable quantitative rainfall forecast. Accurate forecasts of the spatial and temporal distribution of rainfall are useful for flood warning. A flood warning system for fast responding catchments may require a rainfall forecast to provide sufficient lead time for early warning.

In a society increasingly concerned by the threat of flood inundation, flood risk assessment is an essential tool to enable emergency and strategic planning. Several factors provide the motivation to improve on conventional methods of flood risk assessment. Recent evidence of non - stationarity in the flood generation process suggests that a process based model of catchments behaviour is required to replace the traditional 'curve-fitting' approach to flood frequency analysis. Further, it is no longer sufficient to limit the procedure to prediction of discharge; a distributed model of floodplain inundation based on sound hydraulic principles must be integrated into the analysis in order to support today's 'soft engineering' solutions to flood risk. The computation of flood extents and the identification of vulnerable elements help to determine high risk zones due to floods in advance, which helps to take mitigatory measures effectively and efficiently.

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Multiple criteria decision making (MCDM) is well-suited for eliciting and modeling the flood preferences of stakeholders and for improving the coordination among flood agencies, organizations and affected citizens. A flood decision support system (DSS) architecture is put forth that integrates the latest advances in MCDM, remote sensing, GIS, hydrologic models, and real-time flood information systems. The analytic network process (ANP), DSS and MCDM models can improve flood risk planning and management under uncertainty by providing data displays, analytical results, and model output to summarize critical flood information.

A flood warning system is a non-structural measure for flood mitigation. Several parameters are responsible for flood related disasters and a quick-responding flood warning system is required for effective flood mitigation measures. The flood risk assessment in any part of a river basin mainly depends upon the nature and quantity of flow in the river, which in turn, is controlled by the atmospheric and morphological parameters. The interdependent atmospheric parameters like wind speed, wind direction, relative humidity, atmospheric surface pressure ultimately control the intensity and amount of rainfall in a particular location. Hence, these five atmospheric parameters were chosen. In addition to this, the topography and river contribution (i.e., discharge) also determine the risk of flood. Since the discharge data of the rivers in the study area are not available, an alternative method considering the number of streams were used to indirectly calculate the river contribution (i.e., discharge).

Over the last few decades, fuzzy logic (FL) has been increasingly used in the hydrological forecasting research. A system environment is provided for the development of fuzzy prediction models (FPM) for tropical river systems. Compared to forecasts made by mathematical experts, the computation of the fuzzy forecasts is faster, more reliable and always transparent for interpretation. The models are flexible and efficient to adjust in case of new input data. The development efforts for the models are substantially smaller than with conventional models.

Flood forecasting is undoubtedly a challenging field of operational hydrology and a huge literature has been developed over the years. Since the initiation of fuzzy set theory [23], there have been propositions for non-classical and higher order fuzzy sets for different specialized purposes. Among them are "two fold fuzzy sets" by Dubois and Prade [5] which are fuzzy sets with two membership functions expressing the degrees of possibility and the degrees of necessity respectively, "L-fuzzy set" by Goguen [6], "Intuitionistic fuzzy sets" by Atanassov [1] which are fuzzy sets described by two functions : a membership function and a non - membership function, "Ordered intuitionistic fuzzy sets" [11] by Sunny Joseph Kalayathankal and G. Suresh Singh.

Atanassov himself gave one example where fuzzy sets are intuitionistic fuzzy sets, but the converse is not necessarily true. Where all problems which are dealt with fuzzy set theory can be well dealt with IFS theory, there may be many situations where fuzzy set theory cannot be suitably applied but IFS theory can be, to make a more fair analysis. Till now, exact determination of the membership values of the elements in a fuzzy set theory has been impossible. There is no universal formula to calculate membership values. All the problems of our real life situation cannot be classified into a single or at worst into an infinite number of classes. Even for a particular situation, membership values cannot be always determined, either due to insufficiency in the available information, or because of the vagueness in the information. The same problem arises in determining non-membership values. A part of such estimation naturally remains indeterministic. If the indeterministic part is zero, IFS theory coincides with the fuzzy set theory.

The TOPSIS method for measuring intuitionistic fuzzy information has been investigated in the past literature [16, 13]. This method considering both positive and negative-ideal solution is one of the popular methods in multi-attribute decision-making problem . It combined with intuitionistic fuzzy set has enormous chances of success for multi-criteria decision-making problems as it contains vague perception of decision makers opinions. Here, we extend the approach of TOPSIS to develop a methodology for solving multi-attribute decision making problems in fuzzy environments. Considering the fuzziness in the decision data, linguistic variables are used to assess the weight of each criterion and the rating of each alternative with respect to each criterion.

The importance of the membership degree varies in different situations. i.e. one parameter is important for one location and it may be unimportant for another location. So we need a generalization of intuitionistic fuzzy sets, which is called "ordered intuitionistic fuzzy sets" [11]. The location important parameters are termed as weighted indices. If the weighted indices are unity, then ordered intuitionistic fuzzy sets coincide with intuitionistic fuzzy sets. The past decade has witnessed a few applications of fuzzy logic approach to flood prediction and other related studies [2, 3, 14, 15, 12, 7, 8, 9, 10, 17, 18, 19, 20, 21]. We also develop ordered ideal intuitionistic fuzzy sets and establish some related results. An algorithm followed by simulation for flood alarm model is also developed and applied to five selected sites of Kerala to predict potential flood. What follows is a brief description of the theory of these higher order.

2. Model Formulation

Definition 2.1. [7] Let E be a fixed set and $A \subset E$. For $p, q \in N$, an ordered intuitionistic fuzzy (OIF) set in E is an object having the form

$$A_{p,q} = \{\langle x, (\mu_A(x))^p, (\nu_A(x))^q \rangle | x \in E\} \tag{1}$$

where, the functions $\mu_A^p : E \to [0,1]$ and $\nu_A^q : E \to [0,1]$ define the degree of membership and non-membership respectively of the element x to the set A. p and q are called weighted indices of the set A. Also $0 \leq (\mu_A(x))^p + (\nu_A(x))^q \leq 1, \pi_{A_{p,q}}(x) = 1 - (\mu_A(x))^p - (\nu_A(x))^q$ is called the ordered indeterministic part for x. Clearly $0 \leq \pi_{A_{p,q}}(x) \leq 1$. If $p = q = 1$, then $A_{1,1}$ is called intuitionistic fuzzy set.

Definition 2.2. [9] If $\mu_A(x)$ is the degree of the membership value of the element x to the set A, then the degree of the non-membership value is defined as

$$\nu_A(x) = \begin{cases} \frac{0.5*\alpha[1-\mu_A(x)]}{max[\mu_A(x), 1-\mu_A(x)]} & \text{if } \mu_A(x) \geq 0.5 \\ \frac{0.5*\alpha[(1-\mu_A(x)]^2}{min[\mu_A(x), 1-\mu_A(x)]} & \text{if } 0 < \mu_A(x) < 0.5 \\ 1 & \text{if } \mu_A(x) = 0 \end{cases}$$

where α is a dominating fuzzy index and $0 \leq \alpha \leq 1$.

In this paper, we extend the work done by Chen et al. [4] and Zeshui Xu [22]. Chen examined the similarity measures of fuzzy sets. This work was extended by Zeshui Xu to similarity measures between intuitionistic fuzzy sets. An overview of distance and similarity measures of intuitionistic fuzzy sets was done by Xu Z.S and Chen J [19]. Here, we introduce the similarity measures of ordered intuitionistic fuzzy sets [11]. Let $\Phi(X)$ be the set of all ordered intuitionistic fuzzy sets of X. Let $A_{p,q} \in \Phi(X)$ and $B_{r,s} \in \Phi(X)$ be two ordered intuitionistic fuzzy sets, where $p, q, r, s \in N$ and $w = p + q + r + s$. Let T_{d_k} be a mapping such that $T_{d_k} : (\Phi(X))^2 \to [0, 1]$, for $k = 1, 2, 3$.

Definition 2.3. [7] The similarity measure between two ordered intuitionistic fuzzy sets is defined as

$$T_{d_1}^{p,q,r,s}(A_{p,q}, B_{r,s}) =$$
$$1 - \frac{1}{2n}\sum_{i=1}^{n}[\mid M^{(p,r)}(i) \mid^{\frac{(p+r)}{2}} + \mid N^{(q,s)}(i) \mid^{\frac{(q+s)}{2}} + \mid I^{(p,q,r,s)}(i) \mid^{\frac{w}{4}}] \tag{2}$$

where

$$M^{(p,r)}(i) = (\mu_A(x_i))^p - (\mu_B(x_i))^r,$$
$$N^{(q,s)}(i) = (\nu_A(x_i))^q - (\nu_B(x_i))^s,$$
$$I^{(p,q,r,s)}(i) = \pi_{A_{p,q}}(x_i) - \pi_{B_{r,s}}(x_i)$$

and n is the number of attributes (parameters) of the system.
If $r = p$ and $s = q$, then the above formula becomes

$$T_{d_1}^{p,q}(A_{p,q}, B_{p,q}) = 1 - \frac{1}{2n}\sum_{i=1}^{n} \mid M^{(p,p)}(i) \mid^p + \mid N^{(q,q)}(i) \mid^q + \mid I^{(p,q)}(i) \mid^{\frac{p+q}{2}} \tag{3}$$

Definition 2.4. [7] Another form of similarity measure between two ordered intuitionistic fuzzy sets is defined as

$$T_{d_2}^{p,q,r,s}(A_{p,q}, B_{r,s}) =$$
$$1 - \sqrt{\frac{\sum_{i=1}^{n}[\mid M^{(p,r)}(i) \mid^{\frac{(p+r)}{2}} + \mid N^{(q,s)}(i) \mid^{\frac{(q+s)}{2}} + \mid I^{(p,q,r,s)}(i) \mid^{\frac{w}{4}}]}{\sum_{i=1}^{n}[\mid E^{(p,r)}(i) \mid^{\frac{(p+r)}{2}} + \mid F^{(q,s)}(i) \mid^{\frac{(q+s)}{2}} + \mid G^{(p,q,r,s)}(i) \mid^{\frac{w}{4}}]}} \tag{4}$$

where

$$E^{(p,r)}(i) = (\mu_A(x_i))^p + (\mu_B(x_i))^r,$$
$$F^{(q,s)}(i) = (\nu_A(x_i))^q + (\nu_B(x_i))^s,$$
$$G^{(p,q,r,s)}(i) = \pi_{A_{p,q}}(x_i) + \pi_{B_{r,s}}(x_i).$$

If $r = p$ and $s = q$, then the above formula becomes

$$T^{p,q}_{d_2}(A_{p,q}, B_{p,q}) = 1 - \sqrt{\frac{\sum_{i=1}^{n}[\mid M^{(p,p)}(i) \mid^p + \mid N^{(q,q)}(i) \mid^q + \mid I^{(p,q)}(i) \mid^{\frac{(p+q)}{2}}]}{\sum_{i=1}^{n}[\mid E^{(p,p)}(i) \mid^p + \mid F^{(q,q)}(i) \mid^q + \mid G^{(p,q)}(i) \mid^{\frac{(p+q)}{2}}]}} \quad (5)$$

Definition 2.5. [7] The degree of similarity measure from the set theorectic approach is defined as

$$T^{p,q,r,s}_{d_3}(A_{p,q}, B_{r,s}) = \frac{\sum_{i=1}^{n}[R^{(p,r)}(i) + S^{(q,s)}(i) + Q^{(p,q,r,s)}(i)]}{\sum_{i=1}^{n}[U^{(p,r)}(i) + V^{(q,s)}(i) + W^{(p,q,r,s)}(i)]} \quad (6)$$

where

$$R^{(p,r)}(i) = min[(\mu_A(x_i))^p, (\mu_B(x_i))^r],$$
$$S^{(q,s)}(i) = min[(\nu_A(x_i))^q, (\nu_B(x_i))^s],$$
$$Q^{(p,q,r,s)}(i) = min[\pi_{A_{p,q}}(x_i), \pi_{B_{r,s}}(x_i)],$$
$$U^{(p,r)}(i) = max[(\mu_A(x_i))^p, (\mu_B(x_i))^r],$$
$$V^{(q,s)}(i) = max[(\nu_A(x_i))^q, (\nu_B(x_i))^s],$$
$$W^{(p,q,r,s)}(i) = max[\pi_{A_{p,q}}(x_i), \pi_{B_{r,s}}(x_i)].$$

If $r = p$ and $s = q$, then

$$T^{p,q}_{d_3}(A_{p,q}, B_{p,q}) = \frac{\sum_{i=1}^{n}[R^{(p,p)}(i) + S^{(q,q)}(i) + Q^{(p,q)}(i)]}{\sum_{i=1}^{n}[U^{(p,p)}(i) + V^{(q,q)}(i) + W^{(p,q)}(i)]} \quad (7)$$

Remark 2.6. $0 \leq T^{p,q,r,s}_{d_k}(A_{p,q}, B_{r,s}) \leq 1$.

2.1. **Similarity Measures Between Ordered Ideal Intuitionistic Fuzzy Sets.** For multiple attribute decision making problem, let $\{L^1, L^2, ..., L^m\}$ be a set of important locations in Kerala and let $P = \{P_1, P_2, ..., P_n\}$ be a set of parameters. The ordered positive ideal and ordered negative ideal of ordered intutionistic fuzzy sets are respectively denoted by $L^+_{p,q}$ and $L^-_{p,q}$. Assume that the characteristics of the locations L^i represented by the ordered ideal intuitionistic fuzzy sets are shown as :

$$L^i_{p,q} = \{\langle P_j, (\mu_{L^i_{p,q}}(P_j))^p, (\nu_{L^i_{p,q}}(P_j))^q \rangle | P_j \in P\}, \quad (8)$$

$$L^+_{p,q} = \{\langle P_j, (\mu_{L^+}(P_j))^p, (\nu_{L^+}(P_j))^q \rangle | P_j \in P\}, \quad (9)$$

$$L^-_{p,q} = \{\langle P_j, (\mu_{L^-}(P_j))^p, (\nu_{L^-}(P_j))^q\rangle | P_j \in P\}. \tag{10}$$

where

$$(\mu_{L^+}(P_j))^p = \max_i \ [(\mu_{L^i_{p,q}}(P_j))^p], (\nu_{L^+}(P_j))^q = \min_i \ [(\nu_{L^i_{p,q}}(P_j))^q],$$
$$(\mu_{L^-}(P_j))^p = \min_i \ [(\mu_{L^i_{p,q}}(P_j))^p], (\nu_{L^-}(P_j))^q = \max_i \ [(\nu_{L^i_{p,q}}(P_j))^q],$$
$$\pi_{L^+_{p,q}}(P_j) = 1 - (\mu_{L^+}(P_j))^p - (\nu_{L^+}(P_j))^q,$$
$$\pi_{L^-_{p,q}}(P_j) = 1 - (\mu_{L^-}(P_j))^p - (\nu_{L^-}(P_j))^q,$$
$$(\mu_{L^i_{p,q}}(P_j))^p \in [0,1], (\nu_{L^i_{p,q}}(P_j))^q \in [0,1],$$
$$(\mu_{L^i_{p,q}}(P_j))^p + (\nu_{L^i_{p,q}}(P_j))^q \leq 1.$$

Next we define the degree of similarity of the ordered positive ideal $L^+_{p,q}$ and alternative L^i and the degree of similarity of the ordered negative ideal $L^-_{p,q}$ and alternative L^i.

Definition 2.7. The degree of similarity of the ordered positive ideal $L^+_{p,q}$ and alternative L^i based on $T^{p,q}_{d_1}$ is defined as

$$T^{p,q}_{d_4}(L^+_{p,q}, L^i_{p,q}) =$$
$$1 - \frac{1}{2n}\sum_{i=1}^{n}[\mid M^{(p,p)}_{L^+_{p,q}}(i) \mid^p + \mid N^{(q,q)}_{L^+_{p,q}}(i) \mid^q + \mid I^{(p,q)}_{L^+_{p,q}}(i) \mid^{\frac{p+q}{2}}] \tag{11}$$

where

$$M^{(p,p)}_{L^+_{p,q}}(i) = (\mu_{L^+}(x_i))^p - (\mu_{L^i}(x_i))^p,$$
$$N^{(q,q)}_{L^+_{p,q}}(i) = (\nu_{L^+}(x_i))^q - (\nu_{L^i}(x_i))^q,$$
$$I^{(p,q)}_{L^+_{p,q}}(i) = \pi_{L^+_{p,q}}(x_i) - \pi_{L^i_{p,q}}(x_i)$$

and n is the number of attributes (parameters) of the system.

Definition 2.8. The degree of similarity of the ordered negative ideal $L^-_{p,q}$ and alternative L^i based on $T^{p,q}_{d_1}$ is defined as

$$T^{p,q}_{d_4}(L^-_{p,q}, L^i_{p,q}) =$$
$$1 - \frac{1}{2n}\sum_{i=1}^{n}[\mid M^{(p,p)}_{L^-_{p,q}}(i) \mid^p + \mid N^{(q,q)}_{L^-_{p,q}}(i) \mid^q + \mid I^{(p,q)}_{L^-_{p,q}}(i) \mid^{\frac{p+q}{2}}] \tag{12}$$

where

$$M^{(p,p)}_{L^-_{p,q}}(i) = (\mu_{L^-}(x_i))^p - (\mu_{L^i}(x_i))^p,$$
$$N^{(q,q)}_{L^-_{p,q}}(i) = (\nu_{L^-}(x_i))^q - (\nu_{L^i}(x_i))^q,$$
$$I^{(p,q)}_{L^-_{p,q}}(i) = \pi_{L^-_{p,q}}(x_i) - \pi_{L^i_{p,q}}(x_i).$$

Definition 2.9. The degree of similarity of the ordered positive ideal $L^+_{p,q}$ and alternative L^i based on $T^{p,q}_{d_2}$ is defined as

$$T^{p,q}_{d_5}(L^+_{p,q}, L^i_{p,q}) = 1 - \sqrt{\frac{\sum_{i=1}^{n}[| M^{(p,p)}_{L^+_{p,q}}(i) |^p + | N^{(q,q)}_{L^+_{p,q}}(i) |^q + | I^{(p,q)}_{L^+_{p,q}}(i) |^{\frac{(p+q)}{2}}]}{\sum_{i=1}^{n}[| E^{(p,p)}_{L^+_{p,q}}(i) |^p + | F^{(q,q)}_{L^+_{p,q}}(i) |^q + | G^{(p,q)}_{L^+_{p,q}}(i) |^{\frac{(p+q)}{2}}]}} \tag{13}$$

where

$$E^{(p,p)}_{L^+_{p,q}}(i) = (\mu_{L^+}(x_i))^p + (\mu_{L^i}(x_i))^p,$$

$$F^{(q,q)}_{L^+_{p,q}}(i) = (\nu_{L^+}(x_i))^q + (\nu_{L^i}(x_i))^q,$$

$$G^{(p,q)}_{L^+_{p,q}}(i) = \pi_{L^+_{p,q}}(x_i) + \pi_{L^i_{p,q}}(x_i).$$

Definition 2.10. The degree of similarity of the ordered negative ideal $L^-_{p,q}$ and alternative L^i based on $T^{p,q}_{d_2}$ is defined as

$$T^{p,q}_{d_5}(L^-_{p,q}, L^i_{p,q}) = 1 - \sqrt{\frac{\sum_{i=1}^{n}[| M^{(p,p)}_{L^-_{p,q}}(i) |^p + | N^{(q,q)}_{L^-_{p,q}}(i) |^q + | I^{(p,q)}_{L^-_{p,q}}(i) |^{\frac{(p+q)}{2}}]}{\sum_{i=1}^{n}[| E^{(p,p)}_{L^-_{p,q}}(i) |^p + | F^{(q,q)}_{L^-_{p,q}}(i) |^q + | G^{(p,q)}_{L^-_{p,q}}(i) |^{\frac{(p+q)}{2}}]}} \tag{14}$$

where

$$E^{(p,p)}_{L^-_{p,q}}(i) = (\mu_{L^-}(x_i))^p + (\mu_{L^i}(x_i))^p,$$

$$F^{(q,q)}_{L^-_{p,q}}(i) = (\nu_{L^-}(x_i))^q + (\nu_{L^i}(x_i))^q,$$

$$G^{(p,q)}_{L^-_{p,q}}(i) = \pi_{L^-_{p,q}}(x_i) + \pi_{L^i_{p,q}}(x_i).$$

Definition 2.11. The degree of similarity of the ordered positive ideal $L^+_{p,q}$ and alternative L^i based on $T^{p,q}_{d_3}$ is defined as

$$T^{p,q}_{d_6}(L^+_{p,q}, L^i_{p,q}) = \frac{\sum_{i=1}^{n}[R^{(p,p)}_{L^+_{p,q}}(i) + S^{(q,q)}_{L^+_{p,q}}(i) + Q^{(p,q)}_{L^+_{p,q}}(i)]}{\sum_{i=1}^{n}[U^{(p,p)}_{L^+_{p,q}}(i) + V^{(q,q)}_{L^+_{p,q}}(i) + W^{(p,q)}_{L^+_{p,q}}(i)]} \tag{15}$$

where

$$R^{(p,p)}_{L^+_{p,q}}(i) = min[(\mu_{L^+}(x_i))^p, (\mu_{L^i}(x_i))^p],$$

$$S^{(q,q)}_{L^+_{p,q}}(i) = min[(\nu_{L^+}(x_i))^q, (\nu_{L^i}(x_i))^q],$$

$$Q^{(p,q)}_{L^+_{p,q}}(i) = min[\pi_{L^+_{p,q}}(x_i), \pi_{L^i_{p,q}}(x_i)],$$

$$U^{(p,p)}_{L^+_{p,q}}(i) = max[(\mu_{L^+}(x_i))^p, (\mu_{L^i}(x_i))^p],$$

$$V^{(q,q)}_{L^+_{p,q}}(i) = max[(\nu_{L^+}(x_i))^q, (\nu_{L^i}(x_i))^q],$$

$$W^{(p,q)}_{L^+_{p,q}}(i) = max[\pi_{L^+_{p,q}}(x_i), \pi_{L^i_{p,q}}(x_i)].$$

Definition 2.12. The degree of similarity of the ordered negative ideal $L^-_{p,q}$ and alternative L^i based on $T^{p,q}_{d_3}$ is defined as

$$T^{p,q}_{d_6}(L^-_{p,q}, L^i_{p,q}) = \frac{\sum_{i=1}^{n}[R^{(p,p)}_{L^-_{p,q}}(i) + S^{(q,q)}_{L^-_{p,q}}(i) + Q^{(p,q)}_{L^-_{p,q}}(i)]}{\sum_{i=1}^{n}[U^{(p,p)}_{L^-_{p,q}}(i) + V^{(q,q)}_{L^-_{p,q}}(i) + W^{(p,q)}_{L^-_{p,q}}(i)]} \tag{16}$$

where

$$R^{(p,p)}_{L^-_{p,q}}(i) = min[(\mu_{L^-}(x_i))^p, (\mu_{L^i}(x_i))^p],$$

$$S^{(q,q)}_{L^-_{p,q}}(i) = min[(\nu_{L^-}(x_i))^q, (\nu_{L^i}(x_i))^q],$$

$$Q^{(p,q)}_{L^-_{p,q}}(i) = min[\pi_{L^-_{p,q}}(x_i), \pi_{L^i_{p,q}}(x_i)],$$

$$U^{(p,p)}_{L^-_{p,q}}(i) = max[(\mu_{L^-}(x_i))^p, (\mu_{L^i}(x_i))^p],$$

$$V^{(q,q)}_{L^-_{p,q}}(i) = max[(\nu_{L^-}(x_i))^q, (\nu_{L^i}(x_i))^q],$$

$$W^{(p,q)}_{L^-_{p,q}}(i) = max[\pi_{L^-_{p,q}}(x_i), \pi_{L^i_{p,q}}(x_i)].$$

Definition 2.13. The relative similarity $S_k(L^i_{p,q})$ corresponding to the alternative L^i is defined as

$$S_k(L^i_{p,q}) = \frac{T^{p,q}_{d_k}(L^+_{p,q}, L^i_{p,q})}{T^{p,q}_{d_k}(L^+_{p,q}, L^i_{p,q}) + T^{p,q}_{d_k}(L^-_{p,q}, L^i_{p,q})} \tag{17}$$

for $k = 4, 5, 6$ and $p, q \in N$.
The bigger value of S_k is taken as the apt choice L^i.

Label	Location	Geographical desc.	Topography	Rivers/Backwaters
L_1	Trivandrum	Coastal Mid land	Moderate	River=1,Backwater=1
L_2	Alappuzha	Coastal Low land	Low	Backwater=1
L_3	Cochin AP	Coastal Low land	Low	River=1,Backwater=1
L_4	Palakkad	Inland (Mid land)	Moderate	River=1
L_5	Kozhikode	Coastal Mid land	Moderate	River=1

Table 1. Catchments Descriptions

2.2. **Similarity Measure Algorithm.**

(1) Selection of a desired number of locations (m).
(2) Selection of a desired number of parameters (n).
(3) Construction of ordered intuitionistic fuzzy sets $L^i_{p,q}$.
(4) Construction of ordered ideal intuitionistic fuzzy sets $L^+_{p,q}$, $L^-_{p,q}$.
(5) Calculating $T^{p,q}_{d_k}(L^+_{p,q}, L^i_{p,q})$ and $T^{p,q}_{d_k}(L^-_{p,q}, L^i_{p,q})$ for all i and $k = 4, 5, 6$.
(6) Calculating relative similarity measures S_k corresponding to the location L^i.
(7) Determination of L^i for which S_k is greatest.
(8) Obtain the optimal solution L^i.

3. **Experiment and Results**

3.1. **Study Area.** The area selected for the study is Kerala, a narrow segment in the south western part of Peninsular India, extending over a distance of $560Km$ along the west coast with width varying from 15 to $420Km$ within a limited area of $38,863Km^2$ and presents very wide variation in its physical features. Physiographically, Kerala is subdivided into highland (elev.$=> 75m$), midland (7.5-75m) and lowland ($< 7.5m$) regions. The lowland (coastal land) is unique in many ways, viz., high density of population, fragile nature of shoreline, presence of many rivers, estuaries, backwaters, bays etc. Natural calamities like flood and coastal erosion are common events in many regions in the lowlands of Kerala during the monsoon season.

Towards monitoring and assessing the flood system in the coastal lands of Kerala, five locations viz., Trivandrum (N. Lat. 08:31:00 and E. Long. 76:50:00), Alappuzha (N.Lat.09:30:00 and E.Long.76:50:00), Cochin AP (N.Lat.09:54:00 and E.Long.76:16:00), Kozhikode (N.Lat.11:17:01 and E.Long 75:50:00) and Palakkad (N.Lat:10:45:00 and E.Long.76:45:00) have been selected (Figure 1). The first four locations are in the low to mid-coastal region especially vulnerable to flood and have a relatively higher density of population. Palakkad, the "Rice Bowl of Kerala", a plateau devoid of a shore face, is located in the midland. The selected locations are natural laboratories in the tropical river systems of Kerala offering representative geographical regions enabling flood related studies based on the model discussed.

3.2. **The Result.** We define ordered ideal intuitionistic fuzzy set properties to establish an algorithm for a reliable prediction. Simulations are done using Java Server Pages technology by Sun microsystems allows web developers and designers

U	P_1	P_2	P_3	P_4	P_5	P_6	P_7
$L^1_{(p,q)}$	(.49,.1)	(.7,.04)	(.8,.1)	(.81,.05)	(1,0)	(.25,.25)	(.25,.25)
$L^2_{(p,q)}$	(.6,.04)	(.8,0)	(.8,0)	(.9,.05)	(.25,.25)	(1,0)	(.6,.04)
$L^3_{(p,q)}$	(.36,.04)	(.73,0)	(1,0)	(1,0)	(1,0)	(1,0)	(1,0)
$L^4_{(p,q)}$	(.81,.05)	(.6,.09)	(.49,.2)	(.8,.01)	(.25,.25)	(.25,.06)	(.16,.2)
$L^5_{(p,q)}$	(.25,.25)	(.81,.05)	(.64,.1)	(.81,.05)	(.25,.25)	(.25,.25)	(.81,.05)

Table 2. Ordered Intuitionistic Fuzzy Set

to easily develop and maintain dynamic web pages that leverage existing business systems. The five selected locations in Kerala, Trivandrum, Alappuzha, Cochin AP(Airport), Plaakkad and Kozhikode are denoted by L^1, L^2, L^3, L^4, and L^5. The parameter set $E = P_1, P_2, P_3, P_4, P_5, P_6, P_7$ respectively denotes *wind speed , wind direction, relative humidity, surface pressure, river contribution, topography, and rainfall amount.*

$L^i_{p,q} = \{\langle P_j, (\mu_{L^i_{p,q}}(P_j))^p, (\nu_{L^i_{p,q}}(P_j))^q\rangle | P_j \in E\}$, $i = 1,2,3,4,5$ and $j = 1,2,....,7$, where $(\mu_{L^i_{p,q}}(P_j))^p$ indicates the degree that the location L^i satisfies the parameter P_j, $(\nu_{L^i_{p,q}}(P_j))^q$ indicates the degree to which the location L^i does not satify the parameter P_j and $(\mu_{L^i_{p,q}}(P_j))^p \in [0,1], (\nu_{L^i_{p,q}}(P_j))^q \in [0,1], (\mu_{L^i_{p,q}}(P_j))^p + (\nu_{L^i_{p,q}}(P_j))^q \leq 1$. Let $\pi_{L^i_{p,q}}(P_j) = 1 - (\mu_{L^i_{p,q}}(P_j))^p - (\nu_{L^i_{p,q}}(P_j))^q$, for all $P_j \in E$.

The ordered intuitionistic fuzzy set is

$E = \{\{P_1\}, \{P_2\}, \{P_3\}, \{P_4\}, \{P_5\}, \{P_6\}, \{P_7\}\}$, where

$$\{P_1\} = \{L^1/((0.7)^2, (0.1)^1), L^2/((0.6)^1, (0.2)^2), L^3/((.6)^2, (0.2)^2), L^4/((.9)^2, (.05)^1), L^5/((.5)^2, (.25)^1)\},$$

$$\{P_2\} = \{L^1/((0.7)^1, (0.2)^2), L^2/((0.8)^1, (0.1)^3), L^3/((0.9)^3, (.05)^2), L^4/((.6)^1, (.3)^2), L^5/((.9)^2, (.05)^1)\},$$

$$\{P_3\} = \{L^1/((0.8)^1, (0.1)^1), L^2/((0.8)^1, (0.1)^3), L^3/((1)^1, (0)^1), L^4/((0.7)^2, (0.2)^1), L^5/((0.8)^2, (0.1)^1)\},$$

$$\{P_4\} = \{L^1/((0.9)^2, (.05)^1), L^2/((0.9)^1, (.05)^1), L^3/((1)^1, (0)^1), L^4/((0.8)^1, (0.1)^2), L^5/((0.9)^2, (.05)^1)\},$$

$$\{P_5\} = \{L^1/((1.0)^1, (0)^1), L^2/((0.5)^2, (.25)^1), L^3/((1.0)^1, (0)^1), L^4/((0.5)^2, (.25)^1), L^5/((0.5)^2, (.25)^1)\},$$

$$\{P_6\} = \{L^1/((0.5)^2, (.25)^1), L^2/((1)^1, (0)^1), L^3/((1.0)^1, (0)^1), L^4/((0.5)^2, (0.25)^2), L^5/((0.5)^2, (0.25)^1)\},$$

$$\{P_7\} = \{L^1/((0.5)^2, (.25)^1), L^2/((0.6)^1, (.2)^2), L^3/((1.0)^1, (0)^1), L^4/((0.4)^2, (.45)^2), L^5/((0.9)^2, (.05)^1)\}.$$

$L^i_{p,q}$	$T^{p,q}_{d_4}(L^+_{p,q}, L^i_{p,q})$	$T^{p,q}_{d_4}(L^-_{p,q}, L^i_{p,q})$	$S_4(L^i_{p,q})$
$L^1_{p,q}$	0.7623	0.7703	0.4973
$L^2_{p,q}$	0.8161	0.7637	0.5165
$L^3_{p,q}$	0.9693	0.5586	0.6344
$L^4_{p,q}$	0.6876	0.9049	0.4317
$L^5_{p,q}$	0.7299	0.8589	0.4594

TABLE 3. $T^{p,q}_{d_4}(L^+_{p,q}, L^i_{p,q})$, $T^{p,q}_{d_4}(L^-_{p,q}, L^i_{p,q})$ and $S_4(L^i_{p,q})$

$L^i_{p,q}$	$T^{p,q}_{d_5}(L^+_{p,q}, L^i_{p,q})$	$T^{p,q}_{d_5}(L^-_{p,q}, L^i_{p,q})$	$S_5(L^i_{p,q})$
$L^1_{p,q}$	0.5401	0.5170	0.5109
$L^2_{p,q}$	0.5429	0.4784	0.5315
$L^3_{p,q}$	0.8344	0.3417	0.7094
$L^4_{p,q}$	0.4596	0.6744	0.4052
$L^5_{p,q}$	0.5528	0.6316	0.4667

TABLE 4. $T^{p,q}_{d_5}(L^+_{p,q}, L^i_{p,q})$, $T^{p,q}_{d_5}(L^-_{p,q}, L^i_{p,q})$ and $S_5(L^i_{p,q})$

$L^i_{p,q}$	$T^{p,q}_{d_6}(L^+_{p,q}, L^i_{p,q})$	$T^{p,q}_{d_6}(L^-_{p,q}, L^i_{p,q})$	$S_6(L^i_{p,q})$
$L^1_{p,q}$	0.4995	0.5629	0.4701
$L^2_{p,q}$	0.6065	0.5711	0.5150
$L^3_{p,q}$	0.8500	0.3475	0.7098
$L^4_{p,q}$	0.3690	0.8041	0.3145
$L^5_{p,q}$	0.4334	0.6578	0.3971

TABLE 5. $T^{p,q}_{d_6}(L^+_{p,q}, L^i_{p,q})$, $T^{p,q}_{d_6}(L^-_{p,q}, L^i_{p,q})$ and $S_6(L^i_{p,q})$

From all the similarity measures, we get $L^3 > L^2 > L^1 > L^5 > L^4$.

4. **Conclusion**

An algorithm has been developed and implemented for the automated generation of flood alarm system. In our study we have considered five locations and seven parameters to predict the possibility of flood. The membership and non-membership degrees are designed from a prolonged study of available data. The seven parameters namely *wind speed, wind direction, humidity, surface pressure, river contributions, topographical characteristics* and *rainfall amount* are those which have a predominant role on the flood possibility.

One of the most notable difference in this fuzzy approach is that the membership degrees for each of these fuzzy variables are carefully derived from suitable relationships using standardized methods. Therefore the results of the fuzzy decisions are more reliable and dependable. In short, the statistical spatial temporal

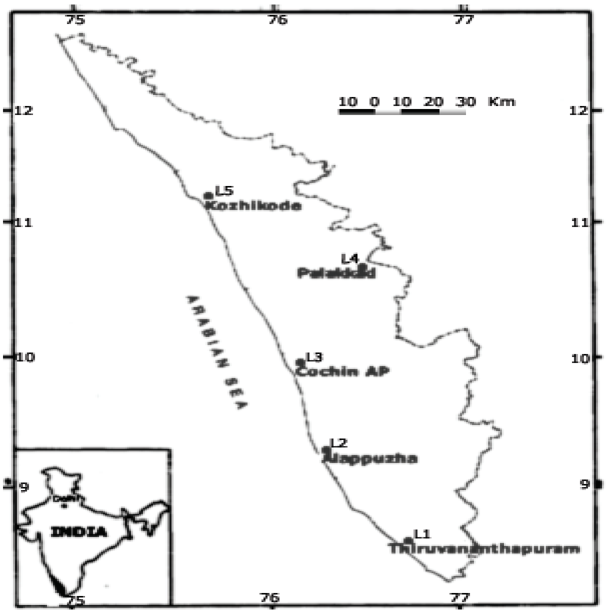

FIGURE 1. Catchment Location Map

model is replaced by a more generalized fuzzy decision system. This gives us a more consistent result. Moreover, the fuzzy decision system makes use of the fuzziness in decision making which is the predominating factor in making predictions and control of a given system.

This article, it is hoped, may go a long way in exploring the possibility of using fuzzy technology to model real time flood prediction. There are varieties of uncertainties in rainfall and flood prediction, and it is difficult to treat these uncertainties using traditional deterministic methods. In this article it has been demonstrated that Ordered ideal intuitionistic fuzzy set (OIIFS) model has its potential usage in flood prediction. The OIIFS model presented for flood warning system has furnished very promising results. This model is applied for five selected stations of Kerala, India. The five meteorological parameters collected for sixteen years (1981-1996; IMT Pune) for each station were analyzed and a membership and non membership degrees were given to each parameter. Two local parameters (river and topography) were also considered. Simulation done through the Java Server Pages shows that the highest possibility of flood occurrence is in Cochin AP, followed by Alappuzha. It provides a new way that helps disaster management studies to cope with fatal and rapid changes in highly sensitive parameters.

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Sunny Joseph Kalayathankal*, Department of Mathematics, K.E.College, Mannanam, Kottayam, 686561, Kerala, India

E-mail address: sunnyjose2000@yahoo.com

G. Suresh Singh, Department of Mathematics, University of Kerala, Trivandrum, 695581, Kerala, India

E-mail address: sureshsinghg@yahoo.co.in

Sabu Joseph, Department of Environmental Science, University of Kerala, Trivandrum, Kerala, India
E-mail address: jsabu2000@yahoo.co.in

Jobin Thomas, Department of Environmental Science, University of Kerala, Trivandrum, Kerala, India
E-mail address: jobin.gis@gmail.com

P. C. Sherimon, Department of Computer Studies, Arab Open University, Muscat, Sultanate of Oman
E-mail address: pcsheri@yahoo.com

*Corresponding author