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WEIGHT BASED INTUITIONISTIC FUZZY SET (WBIFS) AND IT'S APPLICATION TO FARMING

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Abstract:

Weight Based Intuitionistic Fuzzy Set (WBIFS) is proposed by utilizing the fuzzy hierarchical scale and external influencing factors with their weightage to resolve the higher order uncertainties in decision making. Analytic Hierarchy Process (AHP) is applied for the same to prioritize the alternatives. Further this paper uses the new intuitionistic fuzzy set to analyse the problems faced by farmers in choosing the most preferable crop for their cultivation in Mugaiyur Block, Villupuram District, Tamilnadu.

Key Words: Multi-Attribute Decision Making, Intuitionistic Fuzzy Set, Weight Based IFS, Weighted Average & Analytic Hierarchy Process

Introduction:

Fuzzy sets, a tool developed by Lotfi. A. Zadeh [17] in order to solve the uncertainty in the complex world has paved way for many methodologies and tools. The fuzzy set has been extended to various forms like Type-2 Fuzzy Set, Type-n Fuzzy Set, Intuitionistic Fuzzy Set, Hesitant Fuzzy Set and Fuzzy Multi sets. Zadeh and Bellman [2] in the year 1970 employed fuzzy set into the decision making process. Earlier, the work initiated by Zadeh and Bellman [2] develops the fuzzy decision making systems.

During the late 20th century, researchers throughout the world have applied fuzzy decision making tools in many areas such as Engineering, Medicine, Economics, Robotics, Artificial Intelligence, Biotechnology, Social Sciences, Biological and humanities, Information and Communication Technologies (ICT), Data Analysis, etc.., in order to handle hazy situations emerging during the investigations [3].

The concept of intuitionistic fuzzy sets was introduced by Atanassov in the year 1983 [1]. Setting the membership value has always been a problem in fuzzy set theory. Often fuzzy decision makers around the world had equipped their decision making tools with the fuzzy reference scale (scaling from 0 to 1), fuzzy numbers and common fuzzy functions like sigmoidal and bell shaped functions. Decision making methods are mainly of two major types, namely Multi - criteria (attribute) decision making and Multi - objective decision making methods.

Analytic Hierarchy Process is one of the popular decision making tool in multi-criteria decision making methods. It was developed in 1980 by T. L. Saaty [14] [15]. It is a systematic decision making method which includes both qualitative and quantitative techniques. It uses Saaty's pairwise comparison linguistic scale. In fuzzy AHP, the linguistic scales are replaced by membership scales. This method compares weights in pairs and is more straight forward and easier for use by the decision makers. Pathinathan. T and Rajkumar [11] [12] [13] studied exclusively and produced various results in stratified Analytic Hierarchy Process. They introduced Pentagonal Fuzzy Number concept into the Analytic Hierarchy Process to measure poverty level.

The models in the preliminary stage period extensively studied the main decision alternatives with their criteria's. Sometimes, other than alternative and criteria, the external factors play an important role in choosing the appropriate alternative. In AHP, the decision maker makes pair-wise comparison. The properties or characteristic intrinsic in the compared two elements are considered and the decision maker decides on them. Through this paper the external factors are given its due weightage along with the alternatives and its criteria. It is not uncommon for humans or decision makers to get influenced by opinions, comments and suggestions.

In this present study, an extension has been made by the Weight Based Intuitionistic Fuzzy Set along with the decision making tool AHP (Analytic Hierarchy process). We have examined the difficulty level in choosing the crops by the farmers in Mugaiyur Block, Villupuram District, Tamil Nadu. This study includes the opinion of five experts who have been cultivating various crops for the past three decades in the Mugaiyur block. Further this study incorporates fuzzy hierarchy scale in choosing the membership values.

This paper has been organized in the following manner. The concepts of fuzzy set, intuitionistic fuzzy set, intuitionistic fuzzy index, Analytic Hierarchy Process (AHP) have been introduced in section Two. Section Three presents Weight Based Intuitionistic Fuzzy Set (WBIFS) with an algorithm. Section Four gives an insight

on the case study and the basic details regarding the impact of the external factors. Section Five deals with the adaptation, results and interpretations of the problem and finally the paper is concluded in Section Six.

2. Basic Definitions and Notations:

Definition 2.1 (Fuzzy Set):

Let E be the universal set, let x be an element of E then the fuzzy subset $\underset{\sim}{A}$ of E is a set of ordered pairs. $\underset{\sim}{A} = \{(x \mid \mu_{\underset{\sim}{A}}(x))\}$, for all $x \in E$

where,

(i) $\mu_{\underset{\sim}{A}}(x)$ is the grade (or) degree of membership of x in $\underset{\sim}{A}$.

(ii) $\mu_{\underset{\sim}{A}}(x)$ takes the value from the membership set M = [0,1] and

(iii) $\mu_{\underset{\sim}{A}}(x)$ is the membership function or characteristic function.

Definition 2.2 (Intuitionistic Fuzzy Set)

Let X is a nonempty set. An intuitionistic fuzzy set $\underset{\sim}{A}$ in X is an object having the form

$$\underset{\sim}{A} = \left\{ \left\langle x, \mu_{\underset{\sim}{A}}(x), \gamma_{\underset{\sim}{A}}(x) \right\rangle : x \in X \right\}$$

with $\mu_{\underset{\sim}{A}}(x): X \to [0,1]$ and $\gamma_{\underset{\sim}{A}}(x): X \to [0,1]$, where,

(i) $\mu_{\underset{\sim}{A}}(x)$ represents the degree of membership

(ii) $\gamma_{\underset{\sim}{A}}(x)$ represents the degree of non-membership of the element $x \in X$ to the set $\underset{\sim}{A}$ where $\underset{\sim}{A} \subseteq X$, and for every element $x \in X$, $0 \le \mu_{\underset{\sim}{A}}(x) + \gamma_{\underset{\sim}{A}}(x) \le 1$.

Definition 2.3 (Intuitionistic Fuzzy Index)

The intuitionistic fuzzy index or hesitation margin of x in $\underset{\sim}{A}$ is defined by the formula,

$$\pi_{\underset{\sim}{A}}(x) = 1 - \mu_{\underset{\sim}{A}}(x) - \gamma_{\underset{\sim}{A}}(x)$$

where,

(i) $\pi_{\underset{\sim}{A}}(x)$ represents the degree of indeterminacy of $x \in X$ to the IFS $\underset{\sim}{A}$

(ii) $\mu_{\underset{\sim}{A}}(x)$ represents the degree of membership of $x \in X$ to the IFS $\underset{\sim}{A}$

(iii) $\gamma_{\underset{\sim}{A}}(x)$ represents the degree of non-membership of $x \in X$ to the IFS $\underset{\sim}{A}$

with $\pi_{\underset{\sim}{A}}(x): X \to [0,1]$ and $0 \le \pi_{\underset{\sim}{A}}(x) \le 1$ for every $x \in X$.

Note:

$\pi_{\underset{\sim}{A}}(x)$ expresses the lack of knowledge of whether x belongs to IFS $\underset{\sim}{A}$ or not.

Definition 2.4 (Fuzzy hierarchy scale)

The fuzzy hierarchy scale is made up of the set of possible truth values. The subjective statements made by the experts during the investigation are classified into the set of possible truth values. The set of possible truth values are classified into three major groups namely; preferable, neutral and unpreferable.

The set 'preferable' is classified into five stages namely, extremely preferable, more preferable, preferable, approximately (or possibly) preferable, less preferable.

The set 'neutral' takes the central value, where the expert stands midway among all the other possible truth values (i.e., shows partial favoritism and discrimination).

The set 'unpreferable' is classified into five elements namely, extremely unpreferable, more unpreferable, unpreferable, approximately (or possibly) unpreferable, and less unpreferable.

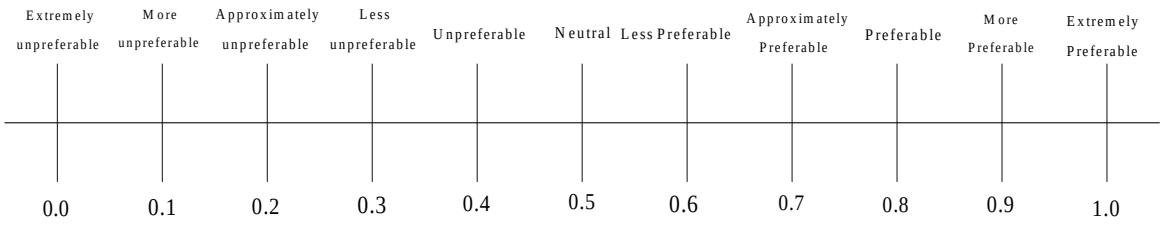

Figure 1: Fuzzy hierarchical reference scale

Definition 2.5 (Analytic Hierarchy Process (AHP))

Analytic Hierarchy Process (AHP) is one of multi criteria decision making methods that was originally developed by Prof. Thomas L. Saaty. Basically Analytic Hierarchy Process measures the degree of consistency from the paired comparisons. The input can be derived from the subjective opinion of the experts such as

satisfaction levels, agreement, and the preference over alternatives. This deviation is done with the help of relative scale developed by T. L. Saaty in the year 1980.

Next for a fixed criterion, the AHP assigns a score to each alternative according to the decision maker's pair-wise comparisons of the alternatives based on that criterion. Then AHP combines the criteria's fuzzy centre value and the alternatives fuzzy centre value. Finally, the overall value for each alternative has been made with its consequent ranking. AHP allows lower level of inconsistency in judgment as human decision could be inconsistent.

2.6 Procedures for AHP Calculation [13]

There are five basic procedures for AHP calculation, namely

(i) Pair-wise comparison matrix for each criterion

$$\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & A_3 & \cdots & A_n \end{array} \\ \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1m} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2m} \\ x_{31} & x_{32} & x_{33} & \cdots & x_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & x_{n3} & \cdots & x_{mn} \end{bmatrix} \end{array}$$

(ii) Normalizing the resulting matrix

$$\begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccccc} A_1 & A_2 & A_3 & \cdots & A_n \end{array} \\ \begin{bmatrix} X_{11} & X_{12} & X_{13} & \cdots & X_{1m} \\ X_{21} & X_{22} & X_{23} & \cdots & X_{2m} \\ X_{31} & X_{32} & X_{33} & \cdots & X_{3m} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & X_{n3} & \cdots & X_{mn} \end{bmatrix} \end{array}$$

Where $X_{ij} = \dfrac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$.

(iii) Calculating the Fuzzy Centre Values (FCV)

(iv) Combining each criteria's fuzzy centre value and the alternatives fuzzy centre value

(v) Calculate the rank value for each alternative

3. Proposed definitions and models

Definition 3.1 (Weight Based Intuitionistic Fuzzy Set) [WBIFS]

The weight based form of intuitionistic fuzzy set is a quintuple defined by;

$$\underset{\sim}{A} = \left\langle \mu_{\underset{\sim}{A}}(x),\ \gamma_{\underset{\sim}{A}}(x), \alpha_{\underset{\sim}{A}}(x), \beta_{\underset{\sim}{A}}(x), \bar{x}_w \right\rangle$$

where, $\mu_{\underset{\sim}{A}}(x)$ represents the membership value of x in the fuzzy set $\underset{\sim}{A}$

$\gamma_{\underset{\sim}{A}}(x)$ represents the non- membership value of x in the fuzzy set $\underset{\sim}{A}$

$$\alpha_{\underset{\sim}{A}}(x) = \begin{cases} \left(\dfrac{2\mu_{\underset{\sim}{A}}(x).\gamma_{\underset{\sim}{A}}(x)}{\mu_{\underset{\sim}{A}}(x)+\gamma_{\underset{\sim}{A}}(x)}\right) \pm \sum_{i=2n;\, j=2n+1} \left(\dfrac{w_i - w_j}{w_i + w_j}\right) & ; \quad \text{if } 0.1 \le |\mu_{\underset{\sim}{A}}(x) - \gamma_{\underset{\sim}{A}}(x)| \le 0.3 \\ \qquad\qquad (\text{where n = number of alternatives}) & \text{or,} \\ \mu_{\underset{\sim}{A}}(x) & ; \quad \text{if } |\mu_{\underset{\sim}{A}}(x) - \gamma_{\underset{\sim}{A}}(x)| = 0 \\ \left(\dfrac{2\mu_{\underset{\sim}{A}}(x).\gamma_{\underset{\sim}{A}}(x)}{\mu_{\underset{\sim}{A}}(x)+\gamma_{\underset{\sim}{A}}(x)}\right) & ; \quad \text{if } 0.3 < |\mu_{\underset{\sim}{A}}(x) - \gamma_{\underset{\sim}{A}}(x)| < 1 \end{cases}$$

$\alpha_{\underset{\sim}{A}}(x)$ represents the impact value and

$$\text{(i) If } |\mu_{\underset{\sim}{A}}(x) - \gamma_{\underset{\sim}{A}}(x)| \le 0.1 (\text{or}) 0.2 (\text{or}) 0.3; \text{ then } \alpha_{\underset{\sim}{A}}(x) = \left(\frac{2\mu_{\underset{\sim}{A}}(x).\gamma_{\underset{\sim}{A}}(x)}{\mu_{\underset{\sim}{A}}(x)+\gamma_{\underset{\sim}{A}}(x)}\right) \pm \sum_{i=2n;\, j=2n+1} \left(\frac{w_i - w_j}{w_i + w_j}\right)$$

where,

$$\alpha_{\underline{A}}(x)=\begin{cases}\left(\dfrac{2\mu_{\underline{A}}(x).\gamma_{\underline{A}}(x)}{\mu_{\underline{A}}(x)+\gamma_{\underline{A}}(x)}\right)+\sum_{i=2n;\,j=2n+1}\left(\dfrac{w_i-w_j}{w_i+w_j}\right); \text{if } w_2>w_3 \text{ and } w_4>w_5,..... \\ \qquad\qquad \text{(Positive impact)} \\ \left(\dfrac{2\mu_{\underline{A}}(x).\gamma_{\underline{A}}(x)}{\mu_{\underline{A}}(x)+\gamma_{\underline{A}}(x)}\right)-\sum_{i=2n;\,j=2n+1}\left(\dfrac{w_i-w_j}{w_i+w_j}\right); \text{if } w_2<w_3 \text{ and } w_4<w_5,..... \\ \qquad\qquad \text{(Negative impact)}\end{cases}$$

(ii) If $|\mu_{\underline{A}}(x)-\gamma_{\underline{A}}(x)|>0.3$; then $\alpha_{\underline{A}}(x)=\left(\dfrac{2\mu_{\underline{A}}(x).\gamma_{\underline{A}}(x)}{\mu_{\underline{A}}(x)+\gamma_{\underline{A}}(x)}\right)$

(iii) If $|\mu_{\underline{A}}(x)-\gamma_{\underline{A}}(x)|=0$; then $\alpha_{\underline{A}}(x)$ takes actual membership values.

$\beta_{\underline{A}}(x)$ represents the disbelief value and $\beta_{\underline{A}}(x)=1-\alpha_{\underline{A}}(x)$

$\bar{x}_w$ represents the weighted mean of the external factors and $\bar{x}_w=\dfrac{\sum_{i=1}^{k}w_i x_i}{\sum_{i=1}^{k}w_i}$;

(where k = number of influencing factors)

3.1.1 Algorithm on WBIFS applied to AHP

By incorporating the above defined form of weight based intuitionistic fuzzy set and fuzzy hierarchy scale; we propose a new algorithm as follows;

Step-1 Construction of the hierarchical structure with decision alternatives and criteria's

Step-2 Each decision maker is asked to express relative importance of the alternatives with help of a fuzzy hierarchy scale values: 0-1 scale

Step-3 Collect the score of pair wise comparison and form pair wise comparison matrices for each of the n alternatives with the help of external weight based intuitionistic fuzzy set

Step-4 Construction of a fuzzy decision matrix which is represented by the input values generated by the definition mentioned in the section 3.1

Step-5 Normalization of the fuzzy decision matrix

Step-6 Calculation of the fuzzy Centre Membership values

Step-7 Computation of the composite weight and ranking has been done for each alternative

4. Case study

Pathinathan. T and Johnson Savarimuthu [8] have been studying the problems faced by the farmers who are planting the rain fed crops in the Villupuram District. Pathinathan. T and Johnson Savarimuthu extended the study [9], [10] by analysing the rain fed cultivation in the same locality. They also observed [10] that the farmers of Villupuram district have shown interest in planting rain fed crops like millets, corn, johar, urid, bajra etc. The present paper extends the work by introducing the external weight based intuitionistic fuzzy set (WBIFS) and the study area cover Mugaiyur Block of Villupuram District. The pair-wise comparison is made between each alternative based on the definition proposed in the section 3.1. By taking the pair-wise comparison as the input values, the study follows the algorithm defined in the section 3.1.1.

4.1 Expert (from Mugaiyur Block)

We collected the detailed information (Table 4.1) from an expert in choosing the suitable crop, in the Mugaiyur Block, Villupuram District.

Table 4.1: Expert's information

Information	Particulars
Name	Mr. Murugan
Age	42
Years of farming experience	20 years
Place	Arkadu, Mugaiyur Block, Villupuram Dt
Agricultural land owned	20 Acres
Crops cultivated	Paddy, Sugarcane, Groundnut and Sesame

4.2 External Factor:

As we have mentioned earlier in the section 1, sometimes other than alternative and criteria, the external factors which are opinion makers play an important role in choosing an appropriate alternative. In our investigation, our expert Mr. A. Murugan gets influenced by the opinion from four external members as

mentioned in Table 4.2. We note that a person might get influenced in a positive manner or negative manner and sometimes external factors may remain in a neutral manner.

Table 4.2: External factors involved in choosing best suitable crop for cultivation

S.No	Name	Occupation	Kind of influence
1	*Mr. R. Sivakumar*	*Village Agricultural Officer*, Government Agricultural Department, Manampoondi, Tirukoilur, Villupuram (DT)	Neutral
2	*Mr. M. Paulraj*	*Farmer*, Owns 10 acres of agricultural land adjacent to our decision maker Murugan's land	Positive impact: They have good relationship Negative impact: There is no considerable negative opinion
3	*Mr. A. Veerappan*	*Farmer*, an experienced Farmer, owned 20 acres, with 30 years of farming experience, Arkadu	Positive impact: An elderly person who continues to guide many and has positive impact Negative impact: There is no considerable negative impact but there is a tendency to compare
4	*Mr. N. Muthuvel*	*Qualified Agricultural officer*, *Private Agricultural Farm*, Kandampakkam, Villupuram (DT)	Neutral

4.3 Relative Weights:

As per the influence level of the above mentioned external members or factors, we have given their weights in consultation with Mr. A. Murugan as follows:

Table 4.3: Objective and subjective classification of the external factors

S.No	**Name**	**Objective / Subjective Classification**		**Relative weight**
1	*Mr. R. Sivakumar*	Objective opinion		$w_1 = 0.15$
2	*Mr. M. Paulraj*	Subjective opinion	Positive impact weightage	$w_2 = 0.30$
			Negative impact weightage	$w_3 = 0.06$
3	*Mr. A. Veerappan*	Subjective opinion	Positive impact weightage	$w_4 = 0.31$
			Negative impact weightage	$w_5 = 0.03$
4	*Mr. N. Muthuvel*	Objective opinion		$w_6 = 0.15$

4.4 Alternatives:

Mugaiyur Block has 63 panchayat villages. The soil formation of the block is mainly made up of sandy loam. The maximum and minimum temperature in the block varies between 36 and 21 degree Celcius respectively. The average rainfall of the district is 1060.30mm and Mugaiyur Block will get moderate rainfall during North East and South West monsoon seasons.

As all the rivers are not perennial, the dependence on ground water increases throughout the District. But Mugaiyur Block falls under white category (as mentioned by Government of Tamil Nadu) [19] which means utilization of ground water is below 65%. Arkadu, Kalpet, Kodungal and Kadaganur have major water sources in the form of lakes. River Pennaiyar flows near to the Mugaiyur Block. One of the sugarcane mills named Chengalrayan Co-operative Sugarcane Mill is located at Periasevalai near Mugaiyur Block. There are so many private agricultural markets along with one regulated market (Arakandanallur) located near Mugaiyur Block.

The following are the major crops on which cultivation activity is taken place in Mugaiyur Block, Villupuram District. We took these cultivation activities as our alternatives.

A_1 – Paddy
A_2 - Sugarcane
A_3 - Groundnut
A_4 - Sunflower
A_5 - Sesame

4.5 Criteria's:

The following are the five main criteria, which are very useful in studying each alternative.

C_1 - Water requirements
C_2 - Chemical Fertilizers
C_3 - Climatic Condition
C_4 - Weed Control
C_5 - Soil Fertility

5. Adaptation of the Problem:

5.1 Adaptation of the Problem Using AHP (T.L. Saaty) [15]:

To obtain the importance of each criterion, the subjective opinion of the expert has been pair-wise compared and comparison is converted into numerical values by making use of Satty's reference scale [15]. The pair-wise comparison from the expert for the five alternatives is given below (Table 5.1.1);

Table 5.1.1: Fuzzy centre values using traditional AHP for alternatives

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	1/3	1/5	1/3	1/3	0.0667	0.1111	0.0244	0.0400	0.0685	0.3107	0.0621
A_2	3	1	3	1	3	0.2000	0.3333	0.3659	0.1200	0.6164	1.6356	0.3271
A_3	5	1/3	1	1	1/3	0.3333	0.1111	0.1220	0.1200	0.0685	0.7549	0.1510
A_4	3	1	1	1	1/5	0.2000	0.3333	0.1220	0.1200	0.0411	0.8164	0.1633
A_5	3	1/3	3	5	1	0.2000	0.1111	0.3659	0.6000	0.2055	1.4824	0.2965
Sum	15	3	8.2	8.3333	4.8667	1	1	1	1	1		

Table 5.1.2: Fuzzy centre values using traditional AHP for C_1

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	3	1/5	1/3	1	0.0968	0.5294	0.0361	0.0526	0.1429	0.8578	0.1716
A_2	1/3	1	3	1	3	0.0323	0.1765	0.5422	0.1579	0.4286	1.3374	0.2675
A_3	5	1/3	1	3	1	0.4839	0.0588	0.1807	0.4737	0.1429	1.3400	0.2680
A_4	3	1	1/3	1	1	0.2903	0.1765	0.0602	0.1579	0.1429	0.8278	0.1656
A_5	1	1/3	1	1	1	0.0968	0.0588	0.1807	0.1579	0.1429	0.6371	0.1274
Sum	10.3333	5.6667	5.5333	6.3333	7	1	1	1	1	1		

Table 5.1.3: Fuzzy centre values using traditional AHP for C_2

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	3	3	1/3	1/5	0.1034	0.2308	0.2432	0.1163	0.0698	0.7635	0.1527
A_2	1/3	1	1/3	1/3	1/3	0.0345	0.0769	0.0270	0.1163	0.1163	0.3710	0.0742
A_3	1/3	3	1	1/5	1/3	0.0345	0.2308	0.0811	0.0698	0.1163	0.5324	0.1065
A_4	3	3	5	1	1	0.3103	0.2308	0.4054	0.3488	0.3488	1.6442	0.3288
A_5	5	3	3	1	1	0.5172	0.2308	0.2432	0.3488	0.3488	1.6889	0.3378
Sum	9.6667	13	12.3333	2.8667	2.8667	1	1	1	1	1		

Table 5.1.4: Fuzzy centre values using traditional AHP for C_3

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	1	3	1/3	1	0.1579	0.3333	0.3913	0.0323	0.1200	0.8839	0.1768
A_2	1	1	3	3	3	0.1579	0.3333	0.3913	0.2903	0.3600	2.1242	0.4248
A_3	1/3	1/3	1	3	3	0.0526	0.1111	0.1304	0.2903	0.3600	0.7639	0.1528
A_4	3	1/3	1/3	1	1/3	0.4737	0.1111	0.0435	0.0968	0.0400	0.6842	0.1368
A_5	1	1/3	1/3	3	1	0.1579	0.1111	0.0435	0.2903	0.1200	0.5439	0.1088
Sum	6.3333	3	7.6667	10.3333	8.3333	1	1	1	1	1		

Table 5.1.5: Fuzzy centre values using traditional AHP for C_4

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	3	3	1/5	1/3	0.1034	0.6000	0.2000	0.0213	0.0685	0.9932	0.1986
A_2	1/3	1	3	3	3	0.0345	0.2000	0.2000	0.3191	0.6164	1.3701	0.2740
A_3	1/3	1/3	1	1/5	1/3	0.0345	0.0667	0.0667	0.0213	0.0685	0.2576	0.0515
A_4	5	1/3	5	1	1/5	0.5172	0.0667	0.3333	0.1064	0.0411	1.0647	0.2129
A_5	3	1/3	3	5	1	0.3103	0.0667	0.2000	0.5319	0.2055	1.3144	0.2629
Su	9.6	5.0	15.	9.4	4.86	1	1	1	1	1		

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Table 5.1.6: Fuzzy centre values using traditional AHP for C_5

	A_1	A_2	A_3	A_4	A_5	Normalization						FCV
A_1	1	3	3	1/3	1	0.1765	0.5294	0.2308	0.0435	0.1807	1.1609	0.2322
A_2	1/3	1	3	1	3	0.0588	0.1765	0.2308	0.1304	0.5422	1.1387	0.2277
A_3	1/3	1/3	1	1/3	1/3	0.0588	0.0588	0.0769	0.0435	0.0602	0.2983	0.0597
A_4	3	1	3	1	1/5	0.5294	0.1765	0.2308	0.1304	0.0361	1.1032	0.2206
A_5	1	1/3	3	5	1	0.1765	0.0588	0.2308	0.6522	0.1807	1.2990	0.2598
Sum	5.6667	5.66667	13	7.6667	5.53333	1	1	1	1	1		

Composite value is obtained by the product of fuzzy centre value of alternative with each of its criterion, and the values tabulated as follows;

Table 5.1.7: Ranking based on traditional AHP

FCV's of alternative	FCV of C_1	FCV of C_2	FCV of C_3	FCV of C_4	FCV of C_5	Composite Value	Rank
0.0621	0.1716	0.1527	0.2070	0.1986	0.2322	0.0598	5
0.3271	0.2675	0.0742	0.3066	0.2740	0.2277	0.3762	1
0.1510	0.2680	0.1065	0.1889	0.0515	0.0597	0.1018	4
0.1633	0.1656	0.3288	0.1530	0.2129	0.2206	0.1765	3
0.2965	0.1274	0.3378	0.1446	0.2629	0.2598	0.3358	2

The table 5.1.7 shows the preference ranking order relation as;

A_2 (Sugarcane) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower) $\succ$ A_3 (Groundnut) $\succ$ A_1 (Paddy).

5.2 Adaptation of the Problem Using Stratified FAHP [13]:

In stratified FAHP, the subjective opinion of the expert is pair-wise compared and input is made by incorporating pentagonal fuzzy numbers [13]. The Table 5.2.1 shows the pair-wise compared input pentagonal fuzzy number values for the five alternatives.

Table 5.2.1: Comparison of Alternatives

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1/7,1/6,1/5,1/4,1/3)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)
A_2	(1,2,3,4,5)	(1,1,1,1,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1,2,3,4,5)
A_3	(3,4,5,6,7)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)
A_4	(1,2,3,4,5)	(1,1,1,1,1)	(1,1,1,1,1)	(1,1,1,1,1)	(1/7,1/6,1/5,1/4,1/3)
A_5	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1/7,1/6,1/5,1/4,1/3)
FCV	0.2663	0.6327	0.5639	0.4935	0.5436

In the same way, the pair-wise comparison of each alternative with respect to each criterion has been constructed through the expert's opinion (Table 5.1.2 – Table 5.1.7);

Table 5.2.2: Comparison with respect to Water Requirement (C_1)

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1,2,3,4,5)	(1/7,1/6,1/5,1/4,1/3)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)
A_2	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1,2,3,4,5)
A_3	(3,4,5,6,7)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,1,1,1,1)
A_4	(1,2,3,4,5)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,1,1,1,1)
A_5	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,1,1,1,1)	(1,1,1,1,1)
FCV	0.4485	0.5537	0.6207	0.4886	0.3884

Table 5.2.3: Comparison with respect to Chemical Fertilizers (C_2)

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1/7,1/6,1/5,1/4,1/3)
A_2	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)
A_3	(1/5,1/4,1/3,1/2,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1/7,1/6,1/5,1/4,1/3)	(1/5,1/4,1/3,1/2,1)
A_4	(1,2,3,4,5)	(1,2,3,4,5)	(3,4,5,6,7)	(1,1,1,1,1)	(1,1,1,1,1)
A_5	(3,4,5,6,7)	(1,2,3,4,5)	(1,2,3,4,5)	(1,1,1,1,1)	(1,1,1,1,1)
FCV	0.5108	0.2690	0.4121	0.6541	0.6541

Table 5.2.4: Comparison with respect to Climatic Condition (C_3)

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)
A_2	(1,1,1,1,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)	(1,2,3,4,5)

A_3	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)
A_4	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)
A_5	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1,2,3,4,5)	(1,1,1,1,1)
FCV	0.4849	0.6142	0.5232	0.4224	0.4554

Table 5.2.5: Comparison with respect to Weed Control (C_4)

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)	(1/7,1/6,1/5,1/4,1/3)	(1/5,1/4,1/3,1/2,1)
A_2	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)	(1,2,3,4,5)
A_3	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1/7,1/6,1/5,1/4,1/3)	(1/5,1/4,1/3,1/2,1)
A_4	(3,4,5,6,7)	(1/5,1/4,1/3,1/2,1)	(3,4,5,6,7)	(1,1,1,1,1)	(1/7,1/6,1/5,1/4,1/3)
A_5	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1,2,3,4,5)	(3,4,5,6,7)	(1,1,1,1,1)
FCV	0.4811	0.5570	0.2447	0.6058	0.6115

Table 5.2.6: Comparison with respect to Soil Fertility (C_5)

	A_1	A_2	A_3	A_4	A_5
A_1	(1,1,1,1,1)	(1,2,3,4,5)	(1,2,3,4,5)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)
A_2	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1,2,3,4,5)
A_3	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1/5,1/4,1/3,1/2,1)
A_4	(1,2,3,4,5)	(1,1,1,1,1)	(1,2,3,4,5)	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)
A_5	(1,1,1,1,1)	(1/5,1/4,1/3,1/2,1)	(1,2,3,4,5)	(3,4,5,6,7)	(1,1,1,1,1)
FCV	0.5733	0.5733	0.2888	0.5673	0.4973

The below table (Table 5.1.7), represents the various fuzzy centre values of each alternative and criteria's.

Table 5.2.7: Fuzzy centre values

	FCV's of Alternatives	FCV of C_1	FCV of C_2	FCV of C_3	FCV of C_4	FCV of C_5
A_1 (Paddy)	0.2663	0.4485	0.5108	0.4849	0.4811	0.5733
A_2 (Sugarcane)	0.6327	0.5537	0.2690	0.6142	0.5570	0.5733
A_3 (Groundnut)	0.5639	0.6207	0.4121	0.5232	0.2447	0.2888
A_4 (Sunflower)	0.4935	0.4886	0.6541	0.4224	0.6058	0.5673
A_5 (Sesame)	0.5436	0.3884	0.6541	0.4554	0.6115	0.4973

Note:

- ✓ Composite value is obtained by multiplying the fuzzy centre value of each alternative to the fuzzy centre value of each criteria and adding it together.
- ✓ Defuzzification is done in such a way to make the composite value into a fuzzy value (i.e., in between 0 to 1). By using the formula given below, the defuzzification is carried out.

$$\text{Alternative} = \frac{x_i - \min x_i}{\max x_i - \min x_i}$$

Finally, the ranking is done for each alternative based on the defuzzification formula [13] as follows;

Table 5.2.8: Ranking of the alternatives

Alternatives	**Composite value**	**Defuzzification**	**Rank**
A_1 (Paddy)	0.6655	0.0000	5
A_2 (Sugarcane)	1.6244	1.0000	1
A_3 (Groundnut)	1.1781	0.5346	4
A_4 (Sunflower)	1.3512	0.7151	3
A_5 (Sesame)	1.4169	0.7836	2

From the above table it is clear that the Alternative (A_2 - Sugarcane) ranks first place with the membership value 1 and the alternative (A_5 - Sesame) ranks second position with the membership value 0.7836. The table 5.2.8 shows the preference ranking order relation as;

A_2 (Sugarcane) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower) $\succ$ A_3 (Groundnut) $\succ$ A_1 (Paddy).

5.3 Adaptation of the Problem Using Weight Based Intuitionistic Fuzzy Set (WBIFS) with AHP:

In fuzzy Hierarchy Reference scale, if the decision maker gets membership values closer to 0 or 1, the external factors, comments, opinions and suggestions may not have any impact. If the membership value stands around the mid way value of 0.5, we are assured that the external factors may excert a considerable impact. Hence we look upon external factors as a case that could induce the decision making process itself. First, comparison of main alternative has been made by using the subjective opinion recorded through an open interview.

(i) A sample calculation for comparing A_1 – Paddy with A_1 – paddy by our expert is given below.

Membership value $(\mu_{\underline{A}}(x))$ = 0.5 (as Paddy is a safe crop for cultivation in every aspect)

Non-membership value $(\gamma_{\underline{A}}(x))$ = 0.6 (But when compared with sugarcane and all other crops, paddy requires more water)

$$\text{Impact value}(\alpha_{\underline{A}}(x)) = \left(\frac{2\mu_{\underline{A}}(x).\gamma_{\underline{A}}(x)}{\mu_{\underline{A}}(x)+\gamma_{\underline{A}}(x)}\right) \pm \sum_{i=2n;\, j=2n+1}\left(\frac{w_i - w_j}{w_i + w_j}\right)$$

$$= \left(\frac{2\times 0.5\times 0.6}{0.5+0.6}\right)+\left(\frac{0.30-0.06}{0.30+0.06}\right)+\left(\frac{0.31-0.03}{0.31+0.03}\right) = 0.5454+0.6667+0.6757 = 1.8878 \approx 1(\text{Positive impact})$$

$$\text{Non-impact value, } \beta_{\underline{A}}(x) = 1-\alpha_{\underline{A}}(x) = 1-1 = 0$$

$$\text{Weighted mean of external factors}(\bar{x}_w) = \frac{\sum_{i=1}^{k} w_i f_i}{\sum_{i=1}^{k} w_i}$$

$$= \frac{w_1 f_1 + w_1 f_1 + w_1 f_1 + w_1 f_1 + w_1 f_1 + w_1 f_1}{w_1 + w_2 + w_3 + w_4 + w_5 + w_6}$$

$$= \frac{(0.9\times 0.15)+(0.8\times 0.30)+(0.6\times 0.06)+(0.7\times 0.31)+(0.4\times 0.03)+(0.7\times 0.15)}{0.15+0.30+0.06+0.31+0.03+0.15}$$

$$= 0.745$$

(ii) Pair-Wise Comparison of A_1 – Paddy with A_2 – Sugarcane:

Membership value $(\mu_{\underline{A}}(x))$ = 0.4 (compared with sugarcane, paddy cultivation is throughout the year, but sugarcane gives more profit: Sugarcane (per acre) = Rs. 1,40,000 approx and Paddy (per acre) = Rs. 32,000 approx) [18]. Non-membership value $(\gamma_{\underline{A}}(x))$ = 0.5 (Even though paddy cultivation is throughout the year, but sugarcane is a safe and secure crop in comparing with all criteria's).

(iii) Pair-Wise Comparison of A_2 – Sugarcane with A_3 - Groundnut

Membership value $(\mu_{\underline{A}}(x))$ = 0.6 (as Sugarcane is a highly protected crop than Groundnut from the domestic animals like rat, pig etc., also sugarcane gives more profit than groundnut: sugarcane (per acre) = Rs. 1,40,000 approx and groundnut (per acre) = Rs. 60,000 approx) [18]. Non-membership value $(\gamma_{\underline{A}}(x))$ = 0.5 (sometimes it may results in poor yield, because of water scarcity)

(iv) Pair-Wise Comparison of A_3 – Groundnut with A_4 – Sunflower:

Membership value $(\mu_{\underline{A}}(x))$ = 0.5 (as groundnut is a safe crop for cultivation than sunflower, which has seasonal cultivation). Non-membership value $(\gamma_{\underline{A}}(x))$ = 0.3 (sunflower need less protection care when compared with groundnut)

(v) Pair-Wise Comparison of A_4 – Sunflower with A_5 – Sesame:

Membership value $(\mu_{\underline{A}}(x))$ = 0.3 (sunflower yield more profit than sesame, but when compared with other crops expert shows less interest towards sunflower because of very less cultivation: sunflower (per acre) = Rs. 36,000 approx, sesame (per acre) = Rs. 42,000 approx) [18]. Non-membership value $(\gamma_{\underline{A}}(x))$ = 0.4 (frequent rain will cause damage to sesame when compared with sunflower, also sesame has high yield compared to sunflower)

We have collected the pair-wise opinion from the expert for the five main alternatives and his subjective opinion is recorded as proposed in definition 3.1. The recorded input values are tabulated below;

Table 5.3.1: Comparison of Alternatives

	A_1	A_2	A_3	A_4	A_5
A_1	.5,.6,1,0,.745	.4,.5, 1,0,.599	.3,.4, 1,0,.609	.4,.3, 1,0,.47	.4,.3, 1,0,.46
A_2	.6,.4, 1,0,.631	.5,.4, 1,0,.53	.6,.5,1,0,.492	.5,3,1,0,.309	.6,3,1,0,.286
A_3	.6,.4, 1,0,.563	.5,.3, 1,0,.487	.5,.4, 1,0,.438	.5,.3,1,0,.47	.4,.2,1,0,.505

A_4	.5,.6,1,.0,.448	.5,.6,1,0,.513	.5,.6,1,0,.43	.5,.4,1,0,.448	.3,.4,1,0,.193
A_5	.5,.6,1,0,.429	.6,.5, 1,0,.392	.4,.6,1,0,.337	.6,.4,1,0,.317	.5,.6,1,0,.186
FCV	0.5054	0.5120	0.5104	0.4890	0.4831

Similarly, we recorded the input values for the pair-wise comparison of each alternative with respect to each criterion. The input values are given in the following tables (Table 5.3.2 – 5.3.6);

Table 5.3.2: Comparison with respect to Water Requirement (C_1)

	A_1	A_2	A_3	A_4	A_5
A_1	.6,.5,1,0,.593	.6,.5,1,0,.549	.3,.4,1,0,.478	.4,.6,1,0,.447	.5,.6,1,0,.488
A_2	.6,.4,1,0,.621	.6,.5,1,0,.563	.6,.5,1,0,.619	.5,.3,1,0,.476	.6,.5,1,0,.22
A_3	.6,.3,1,0,.559	.5,.6,1,0,.451	.5,.4,0,1,.384	.6,.5,1,0,.517	.5,.3,.4444,.5556,.256
A_4	.4,.6,1,0,.411	.3,.6,1,0,.365	.4,.6,.48,.52,.347	.4,.3,1,0,.342	.5,.4,1,0,.359
A_5	.5,.6,1,0,.652	.4,.6,1,0,.533	.5,.7,0,1,.476	.6,.5,1,0,.342	.6,.4,1,0,.303
FCV	0.5284	0.5413	0.4670	0.4712	0.4920

Table 5.3.3: Comparison with respect to Chemical Fertilizers (C_2)

	A_1	A_2	A_3	A_4	A_5
A_1	.5,.4,1,0,.702	.6,.3,.3,.7,.593	.6,.5,1,0,.624	.4,.6,1,0,.547	.6,.3,1,0,.638
A_2	.5,.6,1,0,.631	.6,.5,1,0,.624	.4,.6,1,0,.59	.4,.6,.3,.7,.562	.4,.5,1,0,.578
A_3	.6,.5,1,0,.56	.5,.4,1,0,.614	.5,.6,1,0,.529	.3,.4,1,0,.503	.4,.6,1,0,.558
A_4	.6,.4,1,0,.47	.6,.5,1,0,.442	.6,.3,.42,.58,.477	.4,.3,.4997,.5003,.283	.5,.3,1,0,.315
A_5	.6,.3,.1,.0,.374	.6,.3,1,0,.343	.6,.3,1,0,.324	.6,.5,1,0,.242	.6,.4,1,0,.345
FCV	0.5088	0.5025	0.5201	0.4689	0.4997

Table 5.3.4: Comparison with respect to Climatic Condition (C_3)

	A_1	A_2	A_3	A_4	A_5
A_1	.6,.5,1,0,.655	.5,.6,1,0,.597	.6,.5,1,0,.547	.4,.3,1,0,.471	.5,.4,1,0,.503
A_2	.6,.5,1,0,.624	.6,.4,1,0,.571	.6,.4,1,.0,.563	.6,.5,1,0,.464	.6,.5,1,0,.427
A_3	.4,.6,1,0,.548	.5,.6,1,0,.479	.6,.5,1,0,.503	.6,.3,1,0,.4	.6,.4,1,0,.436
A_4	.4,.6,1,0,.47	.5,.7,1,0,.394	.6,.7,1,0,.409	.5,.4,1,0,.309	.4,.3,1,0,.337
A_5	.5,.6,1,0,.481	.4,.6,1,0,.425	.3,.6,1,0,.449	.6,.4,1,0,.273	.6,.4,1,0,.313
FCV	0.5141	0.5216	0.5047	0.4794	0.4803

Table 5.3.5: Comparison with respect to Weed Control (C_4)

	A_1	A_2	A_3	A_4	A_5
A_1	.6,.5,1,0,.694	.6,.5,1,0,.624	.6,.5,1,0,.594	.3,.5,1,0,.525	.4,.5,1,0,.577
A_2	.6,.5,1,0,.54	.6,.4,1,0,.53	.6,.5,1,0,.487	.6,.4,1,0,.436	.6,.5,1,0,.501
A_3	.6,.4,1,0,.459	.5,.4,1,0,.442	.5,.6,1,0,.461	.3,.5,1,0,.364	.4,.5,1,0,.419
A_4	.6,.5,1,0,.388	.6,.5,1,0,.356	.5,.4,1,0,.346	.2,.3,1,0,.246	.3,.4,1,0,.334
A_5	.6,.4,1,0,.415	.6,.4,1,0,.418	.6,.5,1,0,.364	.4,.2,1,0,.306	.3,.4,1,0,.312
FCV	0.5257	0.5249	0.4928	0.4703	0.4864

Table 5.3.6: Comparison with respect to Soil Fertility (C_5)

	A_1	A_2	A_3	A_4	A_5
A_1	.6,.5,1,0,.735	.6,.4,1,0,.584	.6,.3,1,0,.580	.4,.6,1,0,.427	.5,.6,1,0,.483
A_2	.6,.4,1,0,.637	.6,.5,1,0,.534	.6,.5,1,0,.515	.5,.6,1,0,.557	.6,.5,1,0,.518
A_3	.4,.6,1,0,.642	.5,.6,1,0,.546	.5,.6,1,0,509	.4,.6,1,0,.4	.4,.5,1,0,.428
A_4	.6,.4,1,0,.557	.6,.5,1,0,.5	.4,.2,1,0,.418	.4,.2,1,0,.419	.3,.4,1,0,.409
A_5	.6,.5,1,0,.542	.6,.3,1,0,.5	.6,.4,1,0,.442	.4,.3,1,0,.321	.5,.3,1,0,.385
FCV	0.5141	0.5175	0.4891	0.4854	0.4939

The below table (Table 5.3.7), represents the various fuzzy centre values of each alternative and criteria's.

Table 5.3.7: Fuzzy centre values

	FCV's of Alternatives	**FCV of C_1**	**FCV of C_2**	**FCV of C_3**	**FCV of C_4**	**FCV of C_5**
A_1 (Paddy)	0.5054	0.5284	0.5088	0.5141	0.5257	0.5141
A_2 (Sugarcane)	0.5120	0.5413	0.5025	0.5216	0.5249	0.5175
A_3 (Groundnut)	0.5104	0.4670	0.5201	0.5047	0.4928	0.4891
A_4 (Sunflower)	0.4890	0.4712	0.4689	0.4794	0.4703	0.4854
A_5 (Sesame)	0.4831	0.4920	0.4997	0.4803	0.4864	0.4939

Note:

- ✓ Composite value is obtained by multiplying the fuzzy centre value of each alternative to the fuzzy centre value of each criteria and adding it together.

- ✓ Defuzzification is done in such a way to make the composite value into a fuzzy value (i.e., in between 0 to 1). By using formula given below, the defuzzification is processed;

$$\text{Alternative} = \frac{x_i - \min x_i}{\max x_i - \min x_i}$$

Finally, the ranking is done for each alternative based on the defuzzification formula [13] as follows;

Table 5.3.8: Ranking of the alternatives

Alternatives	Composite value	Defuzzification	Rank
A_1 (Paddy)	1.3095	0.8519	2
A_2 (Sugarcane)	1.3353	1.0000	1
A_3 (Groundnut)	1.2626	0.5819	3
A_4 (Sunflower)	1.1615	0.0000	5
A_5 (Sesame)	1.1848	0.1340	4

5.3.1 Result and Interpretation:

From the above table it is clear that the Alternative (A_2 - Sugarcane) ranks first with the membership value 1 and the alternative (A_1 - Paddy) ranks second position with the membership value 0.8591.

Our process helps in finding the most preferable crop through the pair-wise comparisons between the alternatives. The table 5.2.8 shows the preference ranking order relation as

A_2 (Sugarcane) $\succ$ A_1 (Paddy) $\succ$ A_3 (Groundnut) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower),

(i.e.,) Alternative A_2 (Sugarcane) is ranked high, when compared with the other alternatives. It also shows that A_1 (Paddy) and A_3 (Groundnut) cultivation are the two crops, preferred by farmer Mr. A. Murugan.

5.4 Comparative Analysis:

From sections 5.1, 5.2 and 5.3, we have tabulated ranking results in the table below (Table 5.4). Table 5.4 compares the preference relation between the five alternatives over the criterion. We observe that A_2 – Sugarcane ranks first in the preference order in all the three methods. The newly introduced WBIFS based AHP gives us a different ranking order when compared with T. L. Satty's AHP except the first rank (A_2 - Sugarcane). This clearly shows that the WBIFS based AHP model is able to capture even the minute differences expressed by experts.

We have improved upon an analysis of decision making by an expert by introducing the external weightage factors. Often people get influenced by what is popular or highly publicized. This new methodology incorporates external weightage and as a result of which we are able to observe the minute differences of opinion expressed by the Expert.

Table 5.4: Comparative Analysis

Alternatives	AHP	Rank	Stratified AHP	Rank	IIFAHP	Rank
A_1 (Paddy)	0.0598	5	0.0000	5	0.8519	2
A_2 (Sugarcane)	0.3762	1	1.0000	1	1.0000	1
A_3 (Groundnut)	0.1018	4	0.5346	4	0.5819	3
A_4 (Sunflower)	0.1765	3	0.7151	3	0.0000	5
A_5 (Sesame)	0.3358	2	0.7836	2	0.1340	4

6. Conclusion:

Agriculture plays a vital role in the Villupuram District. Farming is the major livelihood in this district. Therefore, the study of choosing the most preferable crop for their cultivation is very essential and as well as important. In the present paper, choosing the best preferable crop is studied with the help of incorporating the newly introduced Weight Based Intuitionistic Fuzzy Set (WBIFS) into the analytic hierarchy process.

Also this paper, first discuss the preferable alternatives with the help of T. L. Satty's AHP and the result produced during this investigation is: A_2 (Sugarcane) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower) $\succ$ A_3 (Groundnut) $\succ$ A_1 (Paddy) [Table: 5.1.7]. Further the same study carried out by employing Stratified FAHP and it is observed to be effective by consolidating the composite values. The result produced through this method is given in the Table 5.2.8 such as A_2 (Sugarcane) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower) $\succ$ A_3 (Groundnut) $\succ$ A_1 (Paddy).

Then the same study is carried out with the newly introduced Weight Based Intuitionistic Fuzzy Set (WBIFS) and it is observed that the result produced have different ranking such as A_2 (Sugarcane) $\succ$ A_1 (Paddy) $\succ$ A_3 (Groundnut) $\succ$ A_5 (Sesame) $\succ$ A_4 (Sunflower). Further it is revealed that the farmers around Mugaiyur block, Villupuram District show interest in cultivating alternative A_2 (Sugarcane) in a large scale. Also WBIFS shows clear cut variation in the result with sharp boundaries by considering external factor into an account and also found to be more consistent.

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