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Original Article

Optimization of seed selection for higher product using interval valued hesitant fuzzy soft sets

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Abstract

Nowadays, seed selection is one of the main problems faced by farmers and research into agriculture because of the uncertainties in various factors, such as environmental conditions, quality of seeds etc. Soft set theory introduced by Molodtsov is an efficient modeling technique to handle uncertainty. Hybrid models have been found to be more useful than those relying on one technique. Tripathy *et al.* introduced very recently the concept of interval valued fuzzy soft sets through the membership function approach. Among the hybrid soft set models, we use the concept of interval valued fuzzy soft sets to select the optimal seeds. In order to illustrate the application of IVFSSs, a decision making algorithm using this notion is proposed and illustrated through an example. This algorithm was applied to a large rice seed data set and the results are encouraging.

Keywords: agriculture, decision making, interval valued fuzzy soft sets, soft sets, seed selection

1. Introduction

Good quality seeds are essential in agriculture, and are purchased from trusted sources. Good quality of the seeds facilitates getting a high quality of crop. Nowadays, farmers face various problems, such as drought, natural disasters etc. For selecting seeds, the farmer has to analyze environmental and other factors that influence the choice. For example, climate is an important factor affecting the seeds. Many studies have assessed how climate variations will affect the growth of tree seeds. However, factors like climate introduce uncertainties, so the importance of models that incorporate uncertainty arises.

Agriculture encompasses various specialties like soil and seed management, water and irrigation etc. The problems involved in these areas are complex because of many factors, such as climate conditions, location etc. So, as the complexity increases the uncertainties involved in these areas also increase. Several types of models can handle uncertainties. Some of the most popular uncertainty based models that are trending now are fuzzy sets, rough sets and soft sets. Fuzzy sets presented by Zadeh in 1965 have been observed as superior in handling uncertainty, and have been widely used in real life applications. However, a problem with fuzzy sets is that there is no unique way to define the membership function. Some applications of fuzzy logic in agriculture are discussed by Roseline *et al.*, including use in pest management, analysis of soil, and developing an expert system for various crops (Rosaline, 2009). Some applications of rough set models are discussed in (Jianping, 2009). These model types, however, lack parameterization tools.

1.1 Why soft sets

The concept of soft sets was introduced in 1999, as a parameterized family of subsets (Molodtsov, 1999). Later in 2015, Tripathy *et al.* introduced characteristic functions for soft sets (Tripathy *et al.*, 2015a). Similarly, membership functions for fuzzy soft sets (FSS)are introduced in (Sooraj *et al.*, 2016; Tripathy *et al.*, 2016b). Extending this approach further, the membership function for IVFSS was introduced.

The concept of soft involves parametric behavior. In soft sets, we can add an arbitrary number of parameters, whereas in fuzzy or rough sets such arbitrary parameterization

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is not possible. Later, after the introduction of soft sets, researchers introduced many hybrid models, like fuzzy soft sets, IVFSS etc. Maji *et al.* (2001) recognized that most of the parameters in soft sets have fuzzy behavior. This led them to introduce the concept of FSSs. Following this trend Maji *et al.* (2001) put forward the concept of FSS as a hybrid model of fuzzy set and soft set. In the case of FSSs, the grade of membership plays an important role. For example, we can say the seed is 80% tolerant to drought. So, it can be included as 'drought tolerant' with parametric value 0.8.

1.2 Why interval valued fuzzy soft sets (IVFSS)

IVFSS introduced by Yang is a more realistic model of uncertainty than the fuzzy set (Yang *et al.*, 2009). An application of IVFSS is discussed by Tripathy *et al.* (2016f). This concept is extended in (Tripathy *et al.*, 2016d) by taking parameters as fuzzy entities. Here, we follow the definition of soft set proposed in (Tripathy *et al.*, 2016a) in defining IVFSS. We also discuss how a decision making algorithm can be applied in agriculture to selecting good quality seed. This generalizes the algorithm introduced in (Sooraj *et al.*, 2016) while keeping the authenticity intact.

In some cases, when we are analyzing a collection of seeds we cannot effectively judge the exact membership degree. When we check, some seeds are 60% drought tolerant, some others are 70%, and few are 90% drought tolerant. In this case the need of IVFSSs emerges. So, we can have seeds with drought tolerance in the interval 60%-90%. Then, 'drought tolerant' parameter has value '0.6-0.9', and its value is an interval.

Good selection of seeds for a farm is complicated by the uncertainties involved in various factors such as the climate, the quality of seeds etc. Here, uncertainty models play a crucial role in selecting the best possible alternative from available choices.

Some applications of soft sets have been discussed (Molodtsov, 1999). Topics have included stability and regularization, Game theory, operational research, and soft analysis. In (Maji *et al.*, 2002) an application to Decision making is proposed. Decision making is the process of finding the best choice from all available choices. Decision making is classified into two categories, Individual decision making and Group decision making. If the decision is taken by an individual decision maker (expert), then this process is called single decision making process. Here, the expert has the full right to make the decisions. But in the case of real life problems, an expert is not allowed to alone call the decisions, instead more than one decision maker is necessary in many cases. The process of making decisions with more than one decision maker is called group decision making. Many decision making applications are discussed by Cagman *et al.* (Cagman & Serdar, 2010). They introduced uni-int decision making methods.

This study of soft sets was further extended to the context of FSSs by Sooraj *et al.* (2016), where they identified some drawbacks in (Maji *et al.*, 2012) and took care of these drawbacks, while introducing an algorithm for decision making. In this paper, we have carried this study further by using IVFSS in handling the problem of multi-criteria decision making. This notion is further extended in (Tripathy *et al.*, 2016b, c, e, f).

2. Mathematical Background of the Proposed Algorithm

By *P(U)* and *I(U)* we denote the power set and the fuzzy power set of *U* respectively.

Definition 2.1 (Soft Set): A pair *(F, E)* is called as a soft set over the universal set *U*, where

$$F : E \to P(U) \tag{2.1}$$

The pair (U, E), which is a combination of a universal set *U* and a parameter set *E* is called a soft universe.

Definition 2.2 (Fuzzy Soft set): We denote a FSS over *(U, E)* by *(F, E)* where

$$F : E \to I(U) \tag{2.2}$$

Let I([0, 1]) denote the set of all closed subintervals of [0, 1].

Definition 2.3 (Interval valued Fuzzy set): An IVFS X on a universe U is a mapping such that

$$\mu_X : U \to Int([0,1]) \tag{2.3}$$

Moreover, $\forall x \in U, \mu_X(x) = [\mu_X^-(x), \mu_X^+(x)] \subseteq [0,1]$. Here, $\mu_X^-(x)$ and $\mu_X^+(x)$ represent as the lower and upper degrees of membership of x to X.

Suppose 'U' is the set of seeds under consideration and 'E' is the set of parameters. Each parameter is a word or a sentence. Let us illustrate with the help of an example. We take, E= {quality of seeds, shelf life, cost of purchasing the seeds, soil characteristics, environmental factors}

Here, a soft set (F, E) describes the "selection of quality seeds", which a farmer is going to select. Suppose there are six types of seeds in the universe U, given by U= $\{s_1, s_2, s_3, s_4, s_5, s_6\}$, and E=$\{e_1, e_2, e_3, e_4, e_5\}$, where$e_1$=quality of seeds,$e_2$= shelf life, e_3= cost of purchasing the seeds,e_4= soil characteristics, and e_5= environmental factors. Suppose that $F(e_1) = \{s_2, s_4\}$, $F(e_2)=\{s_1, s_3\}$, $F(e_3)=\{s_3, s_4, s_5\}$, $F(e_4)=\{s_1, s_3, s_5\}$, $F(e_5)=\{s_1\}$. Thus we can view the soft set as the collection of approximations (F,E) = {quality of seeds= $\{s_2, s_4\}$, shell life= $\{s_1,s_3\}$, cost of purchasing the seeds= $\{s_3,s_4,s_5\}$, soil characteristics= $\{s_1, s_3,s_5\}$, environmental factors=$\{s_1\}$}.

3. Interval-Valued Fuzzy Soft Sets

In this section, we follow the membership function approach introduced in (Sooraj et al, 2016). The basic operations on IVFSS are also discussed. Let *(F, E)* be an IVFSS. We associate with (F, E) a family of parameterized membership functions $\mu_{(F,E)} = \{\mu^a_{(F,A)} \mid a \in E\}$ as in (3.1).

Definition 3.1: Given $a \in E$ and $x \in X$, the membership function is defined as below.

$$\mu^a_{(F,E)}(x) = [\alpha,\beta] \in I([0,1]) \tag{3.1}$$

where I([0, 1]) denotes the subsets of the intervals of [0, 1].

For any two IVFSS (F, E) and (G, E), the following operations are defined.

Definition 3.2: *(F, E)* is said to be interval valued fuzzy soft subset of *(G, E)*, $(F,E) \subseteq (G,E)$. Then $\forall a \in E$, $\forall x \in U$,

$$\mu^{a+}_{(F,E)}(x) \le \mu^{a+}_{(G,E)}(x) \ \ and \ \ \mu^{a-}_{(F,E)}(x) \le \mu^{a-}_{(G,E)}(x) \tag{3.2}$$

Where $\mu^{a-}_{(F,E)}$ and $\mu^{a+}_{(F,E)}$ denotes the lower and upper membership value of the IVFSS.

Definition 3.3: We say that *(F, E)* is equal to *(G, E)* written as *(F, E) = (G, E)* if $\forall x \in U$,

$$\mu^{a+}_{(F,E)}(x) = \mu^{a+}_{(G,E)}(x) \ \ and \ \ \mu^{a-}_{(F,E)}(x) = \mu^{a-}_{(G,E)}(x) \tag{3.3}$$

Definition 3.4: For any two IVFSSs *(F, E)* and *(G, E)* over a common soft universe *(U, E)*, we define the complement *(H, E)* of *(G, E)* in *(F, E)* as $\forall a \in E$ and $\forall x \in U$.

$$\mu^{a+}_{(H,E)}(x) = \max\{0, \mu^{a+}_{(F,E)}(x) - \mu^{a+}_{(G,E)}(x)\} \ \ and \ \ \mu^{a-}_{(H,E)}(x) = \max\{0, \mu^{a-}_{(F,E)}(x) - \mu^{a-}_{(G,E)}(x)\} \tag{3.4}$$

4. Application of IVFSS in Decision Making

In 2015, Tripathy *et al.* discussed some of the issues in (Maji *et al.*, 2002) and provided suitable solutions for the problems in (Tripathy *et al.*, 2016b). Also,the classification of parameters (negative and positive parameters) was discussed in (Tripathy *et al.*, 2016b).

If a person wants to purchase a car, then he has to consider some of the parameters related to the car. Some of the parameters he has to consider are beauty, color, price, mileage etc. As we know, as the price of car increases then there is less interest to purchase that car. Parameters that affect the decision adversely are called negative parameters.

i) If the value of the parameter is directly proportional to the interest of the customer then we say that is a positive parameter.

ii) If the value of the parameter is inversely proportional to the interest of the customer then we say that is a negative parameter.

For example ‘Beautiful’ is a positive parameter. If the value of parameter ‘Beautiful’ increases then the customer’s interest will also increase, whereas ‘Price’ is a negative parameter.

4.1 Algorithm

1. Input the priority data table. Get the priority of the parameters from the user which lies in [-1, 1]. The default priority value for a parameter is 0 (Zero) that means the parameter has no impact on decision making and can be opted out from further computation.

2. Input the IVFSS, in the form of a two dimensional array, where entities are intervals with end values lying in the unit interval [0, 1].

3. Extract the pessimistic, optimistic and neutral values from the interval valued fuzzy sets. Pessimistic value is the lower value in the interval, optimistic value is the higher value in the interval and neutral value lies in between the interval. We can use different formulas to find the neutral value.

4. Do the following steps for the computation of pessimistic, optimistic and neutral values of IVFSSs.

   a. Multiply the priority values with the corresponding parameter values to get the priority table.

   b. Compute the row sum of each row in the priority table(PT).

   c. Construct the comparison table(CT) by finding the entries as differences of each row sum with those of all other rows.

5. Construct the decision table based on the normalized score equation

$$\text{Normalized Score} = \frac{2*(|c|*|k|*|j| - \sum_{i=1, x\in K}^{i=|j|} RC_{ix})}{|k|*|j|*|c|*(|c|-1)}, \qquad (4.1)$$

where |c| is the number of candidates, k={optimistic, pessimistic , neutral}.So, k=3 and |j| is the number of judges. Rc_{ix} is the rank given by the i^{th} judge with respect to approach x.

6. The object having highest value in the final decision column or ranking column is to be selected. If more than one objectare having the same rank, then the object higher value under the highest absolute priority column is selected and it can be further continued.

4.2 Computational complexity of the algorithm

Computational complexity of the proposed algorithm as follows.
For a set of seeds S, let the number of candidates be given by |S|=n
For a set of parameters E, let the number of parameters be |E|=m
In the case of single decision making problems, the number of judges is |J|=1.

In real life scenarios, the number of parameters on which each seed is judged, is relatively small compared to the number of seeds. In the case of group decision making problems, the number of judges is larger. So, the same applies to the number of judges. In most cases, it is a small panel of judges, judging a large number of candidates on several parameters. So it is safe to assume that $n > m \text{ and } n > p$ in almost all the cases.

Now we calculate the time complexity of the algorithm as follows:
Step 1: In this step, we take input for the priority table. This operation costs $O(m)$. Then the priorities are ranked based on their absolute values. This would involve sorting, which would cost $O(m\log m)$.

Step 2: In this step, we input the IVIFSS. We take in n candidate's IVIFSS for each of the m parameters. The time complexity in this step is $O(mn)$.

Step3: The optimistic, pessimistic and neutral value tables can be constructed in a single scan of the IVIFSS table. The time complexity of this operation is $O(mn)$.

Step 4a: The time complexity for this matrix multiplication to obtain the priority table is $O(mn)$.

Step 4b: The comparison table for different candidates is constructed by comparing the row sums for each candidate computed in step 2.5.1 with those of all candidates. This process has the complexity $O(n^2)$. To be precise it is $\frac{n^2}{2}$ as the (j,i)th element of the matrix is negative of the (i, j)th element.

Step 5: The decision table is constructed based on the normalized score equation. The score computation has time complexity $O(n)$. Ranking the seeds based on their scores has time complexity $O(n\log n)$.

The construction of the rank matrix is carried out by taking the ranks from all the decision tables for each candidate. The time complexity for this task is $O(mn)$.The normalized score can be calculated in $O(n)$. The final ranks of these can be found by sorting the scores. This would cost $O(n\log n)$.

We note that since Step 4 can be carried out in parallel, the time complexity for the entire step 4 is dominated by that of Step 4.c., which is $O(n^2)$.

Hence, the time complexity of the entire algorithm which is the sum of the complexities of all the four steps comes out as $O(m\log m + n^2 + mn + n\log n)$ which reduces to $O(n^2)$.

4.3 Illustration of functionality of the algorithm

Here, we explain the algorithm with the help of a small example for better understanding, and then we apply it in a large data set. Consider the case of a farmer who needs to find the seeds which are suitable for his criteria. Some of the parameters the farmer considers are productivity of seeds, climate, size of the seeds, cost of purchasing the seeds, temperature, and type of soil.

We denote a set of seeds as U= {s_1,s_2,s_3,s_4,s_5,s_6} and the parameter set, E= {productivity of seeds, climate, genetic purity, cost of purchasing the seeds, physical purity, germinability}. We denote the parameters as e_1, e_2, e_3, e_4 and e_5 for further calculations, where e_1, e_2,e_3,e_4 and $e_5$denotes productivity of seeds, climate, size of the seed, cost of purchasing the seeds and temperature respectively. Consider an IVFSS*(U, E)*, which describes the 'selection of best seeds '.

Table 1 shows the values of various parameters of seeds in the IVFSS in a selection process. Here, in IVFSSs, we need to consider three cases.

(i) Pessimistic: It is the lowest value in an interval.

(ii) Optimistic: It is the highest value in an interval

(iii)Neutral: Neutral value lies within the interval. We can use different formulas to find the neutral value. Here, neutral values are obtained by taking the average of pessimistic values and optimistic values.

$$neutral\ value = \frac{pesimistic\ value + optimistic\ value}{2} \tag{4.2}$$

Table 1. Tabular representation of IVFSS

U	e_1	e_2	e_3	e_4	e_5
s_1	0.2-0.4	0.3-0.5	0.8-0.9	0.4-0.7	0.6-0.9
s_2	0.4-0.8	0.6-0.9	0.2-0.5	0.7-1	0.5-0.6
s_3	0.5-0.8	0.7-0.9	0.7-0.8	0.8-1	0.5-0.7
s_4	0.6-0.8	0.5-0.9	0.8-1	0.5-0.9	0.7-0.8
s_5	0.1-0.4	0.9-1	0.3-0.6	0.1-0.5	0.8-1
s_6	0.9-1	0.5-0.7	0.1-0.3	0.2-0.4	0.3-0.7

For example: If a seed s_1 has value for the parameter 'climate' as interval 0.2-0.5, then 0.2 is the pessimistic value, 0.5 is the optimistic value and 0.35 is the neutral value.

Then we have to consider three cases. a. Pessimistic decision making b. Optimistic decision making and c. Neutral decision making. Pessimistic ranking is the worst ranking, Optimistic ranking is the best ranking and Neutral is the average ranking. In pessimistic decision making, we consider the lower bound value of each parameter. In optimistic decision making we need to take the upper bound value of each parameter and in neutral decision making we need to take the average of pessimistic and optimistic values. First, we are considering the pessimistic case. The priorities of farmer for the parameters e_1, e_2, e_3, e_4 and e_5 are 0.7, 0.3, 0.2,-0.5, 0.4. The priority table obtained is shown below in Table 2. The comparison table is formed as in step 4c of the algorithm, and is shown in Tables 3 to 5.

Table 2. Priority table for pessimistic values

U	e_1	e_2	e_3	e_4	e_5
s_1	0.14	0.09	0.16	-0.2	0.24
s_2	0.28	0.18	0.04	-0.35	0.2
s_3	0.35	0.21	0.14	-0.4	0.2
s_4	0.42	0.15	0.16	-0.25	0.28
s_5	0.07	0.27	0.06	-0.05	0.32
s_6	0.63	0.15	0.02	-0.1	0.12

Table 3. Comparison table for pessimistic values

c_i \ c_j	s_1	s_2	s_3	s_4	s_5	s_6	Rowsum	Rank
s_1	0	0.08	-0.07	-0.33	-0.24	-0.39	-0.95	5
s_2	-0.08	0	-0.15	-0.41	-0.32	-0.47	-1.43	6
s_3	0.07	0.15	0	-0.26	-0.17	-0.32	-0.53	4
s_4	0.33	0.41	0.26	0	0.09	-0.06	1.03	2
s_5	0.24	0.32	0.17	-0.09	0	-0.15	0.49	3
s_6	0.39	0.47	0.32	0.06	0.15	0	1.39	1

Table 4. Comparison table for optimistic values

	s_1	s_2	s_3	s_4	s_5	s_6	Rowsum	Rank
s_1	0	-0.05	-0.15	-0.28	-0.23	-0.36	-1.07	6
s_2	0.05	0	-0.1	-0.23	-0.18	-0.31	-0.77	5
s_3	0.15	0.1	0	-0.13	-0.08	-0.21	-0.17	4
s_4	0.28	0.23	0.13	0	0.05	-0.08	0.61	2
s_5	0.23	0.18	0.08	-0.05	0	-0.13	0.31	3
s_6	0.36	0.31	0.21	0.08	0.13	0	1.09	1

Table 5. Comparison table for neutral values

	s_1	s_2	s_3	s_4	s_5	s_6	Row sum	Rank
s_1	0	0.015	-0.11	-0.305	-0.235	-0.375	-1.01	6
s_2	-0.015	0	-0.125	-0.32	-0.25	-0.39	-1.1	5
s_3	0.11	0.125	0	-0.195	-0.125	-0.265	-0.35	4
s_4	0.305	0.32	0.195	0	0.07	-0.07	0.82	2
s_5	0.235	0.25	0.125	-0.07	0	-0.14	0.4	3
s_6	0.375	0.39	0.265	0.07	0.14	0	1.24	1

In the same way, comparison tables for optimistic and neutral cases can be calculated and are shown in Tables 4 and 5. The final decision is the average of pessimistic, optimistic and neutral decision making, and it is shown in Table 6. From this table, we can see that seeds$_6$ is the best choice. The next ranked choices are in the order s_4, s_5, s_3, s_2 and s_1.

Table 6. Decision table

	Pessimistic	Optimistic	Neutral	Normalized Score	FINAL DECISION
s_1	5	6	6	0.211111	6
s_2	6	5	5	0.222222	5
s_3	4	4	4	0.266667	4
s_4	2	2	2	0.333333	2
s_5	3	3	3	0.3	3
s_6	1	1	1	0.366667	1

5. Experimental Analysis and Result

The algorithm was coded by using Python in a laptop having Intel Core i3 processor, 2GB RAM, 320GB HDD and 1.7GHZ clock speed. A data table having 172 rice seeds and 21 parameters was taken as input. The results are encouraging and we have not produced the tables because of space constraints and the complexity of computations. The study was conducted on various rice seeds available in the Southern part of India. The rice seed varieties are Aduthurai, Chithiraikkar, Akshayadhan, etc. Here, we use s1, s2, s3… to represent the rice seed varieties for brevity.

We applied the above mentioned algorithm to the rice seed data set and calculated the priority table, comparison table and decision table. As a result, we ranked the objects from 1 to 172 as per normalized scores. The object with the highest normalized score is the best seed for that farmer. In the following section, description of the parameters that we used in seed data is discussed.

5.1 Parameter description

1) Moisture content: a direct relationship exists between moisture content and deterioration rates, storability, susceptibility to mechanical damage, insect infestation level, and fungal attack. However, this is not a mandatory test in standard seed testing.
2) Cost of purchasing the seeds: As in other cases, cost or expense of purchasing any product can be treated as negative parameter. If the cost of purchasing the seeds is high, then the farmer will not prefer those seeds.
3) Soil Characteristics: Soil characteristics are another important positive parameter, where the farmer checks the quality of the soil and the availability of water in that soil area. Soil can be sandy, clay, muddy, alluvium and gravel. Soil can be saline or alkaline also.
4) Local and global market: This is another positive parameter, where the farmer thinks about the yield that he could get and prices at local or global markets for his products.
5) Watering: Whether watering facilities are available for that area or not. We can treat this parameter as a positive one.
6) Travel facility: This parameter describes how far the farm is located from the farmers place. If the farm is close to his place, then the farmer can give enough attention to his farm. This can be treated as a negative parameter because as the distance increases, then the care of that farm will be reduced.
7) Yield: This parameter deals with the yield that we will be getting from this seeds.
8) Market quality: This parameter indicates whether the seeds are purchased from a good market or from a low quality market.
9) Crop Duration: This parameter deals with the duration between planting and harvesting.
10) Quality of seed: Quality of seeds can be treated as positive parameter. So, the farmer will be giving more priority to the quality of the seed.
11) Temperature: This parameter informs about the temperature and climate conditions. That is, whether the temperature is affecting positively or negatively on the growth of seeds.
12) Environmental conditions: This parameter deals with the environmental conditions required for the growth of the seeds.
13) Variety purity: It is also called genetic purity. Genetic purity refers to trueness to type, or the degree of contamination of seeds caused by undesired genetic varieties or species.
14) Germinability: It means the degree of ability of a seed to germinate or sprout.
15) Physical purity: It means the physical composition of seed lots.
16) Vigour: Seed vigour is defined as "the Sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence".
17) Storability: It deals with where the seeds are stored and how the storage facility affects the seeds etc.
18) Physiological purity: It deals with the shape, size and color of the seeds.
19) Flood tolerant: It deals with survivability of a plant in flood situations.
20) Drought tolerant: It deals with survivability of a plant in drought conditions.
21) Shelf life: Seed vitality or shelf life is an important parameter. If you saved seed from last season or the season before or if you’ve been given seed and are not sure how long it’s been around, you might want to perform a seed vitality test a couple of weeks before you plan to sow.

Among the above mentioned parameters, we considered two of them as negative parameters and rest 19 as positive parameters. The negative parameters that we considered for calculations are cost of purchasing the seeds and the travel facility. Also, we gave zero priority to one parameter (seed size) because the farmer is not worrying about the size of the seeds. If we are not giving any priority to the seeds, then the system by default will treat it as a parameter with zero priority.

6. Results Obtained

Here we show the results obtained. We are showing only a part of the results due to the space restrictions. From the final decision Table 7, we can see that the 'seed120' is the best choice for the farmer.

Table 7. Decision table in sorted order

Seeds	Seed Name	Optimistic Rank	Pessimistic Rank	Neutral Rank	Normalised Score	Final rank
s120	Seela Rice	6	1	1	0.01160524	1
s172	Malakkannan	3	6	2	0.011571241	2
s112	Puzhuthi Samba	2	10	3	0.011525908	3
s138	Thinni	11	2	4	0.011503241	4
s166	Kozhivalan	5	9	5	0.011480575	5
s136	Kumaro-athikkalaari	10	24	7	0.011231243	6
s152	Velchi	16	20	9	0.011185911	7
s115	Sadakar	4	35	8	0.011163244	8
s107	Ponni Rice	1	45	6	0.011106578	9
s109	Poovan Samba	37	8	10	0.011072578	10
s111	Ondrarai Samba	18	26	13	0.011049912	11
s116	Samba	28	21	14	0.010981912	12
s170	Kuppakayama	27	22	15	0.010970579	13
s153	Veliyan	13	47	16	0.01083458	14
s131	Sooran Kuruvai	64	4	11	0.01080058	15

Table 8 shows the priority of the parameters assigned by the farmer. Here, the farmer has selected the priorities e_3 (Cost of purchasing the seeds) and e_6 (Travel facility) as negative parameters. As per the farmer's need, he is allowed to change the parameters' priority. Intermediate results are shown in Tables 9 and 10. Top 15 best rice seeds available for the farmer and for the selected region are shown in Table 7. We ranked all the rice seeds based on the normalized scores.

Table 8. Parameter priority table

Prioirty Data Table											
Parameters	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
Priority	0.3	0.2	-0.3	0.5	0.1	-0.2	0.4	0.1	0.8	0.35	0

7. Future Work

Some other hybrid soft set models like interval valued intuitionistic FSSs, hesitant fuzzy soft sets etc.can be extended in the same direction. Also, the above described algorithm can be applied in group decision making problems. For example, in the case of large agricultural industries the decision to select seeds is not only determined by a single decision maker. A number of stakeholders will act there as decision makers. As a result each stakeholder has to enter their own interests and according to that they have to find the results. In the final calculation of decision table, we can change the value of 'j' and according to that we will select the best seed.

Table 9. Priority table of pessimistic case

Priority Table												
	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11	Rowsum
s1	0.081	0.002	-0.045	0.15	0.031	-0.008	0.192	0.027	0.128	0.1575	0	0.7155
s2	0.036	0.062	-0.078	0.205	0.036	-0.066	0.084	0.043	0.072	0.1715	0	0.5655
s3	0.039	0.032	-0.126	0.165	0.045	-0.034	0.032	0.011	0.008	0.056	0	0.228
s4	0.09	0.04	-0.141	0.13	0.044	-0.048	0	0.047	0.28	0.0385	0	0.4805
s5	0.066	0.084	-0.033	0.065	0.045	-0.084	0.02	0.04	0.056	0.1505	0	0.4095
s6	0.045	0.02	-0.102	0.075	0.003	-0.08	0.172	0.04	0.224	0.1715	0	0.5685
s7	0.126	0.064	-0.069	0.245	0.035	-0.098	0.028	0.046	0.36	0.0175	0	0.7545
s8	0.012	0.034	-0.072	0.21	0.042	-0.044	0.028	0.034	0.056	0.147	0	0.447
s9	0.018	0.084	-0.036	0.24	0.05	-0.024	0.12	0.009	0.224	0.147	0	0.832
s10	0.072	0.044	-0.126	0.06	0.021	-0.05	0.04	0.025	0.28	0.105	0	0.471
s11	0.006	0.05	-0.123	0.14	0.029	-0.044	0.176	0.01	0.304	0.035	0	0.583
s12	0.03	0.05	-0.078	0.245	0.043	-0.084	0.08	0.019	0.008	0.0245	0	0.3375
s13	0.12	0.022	-0.042	0.105	0.023	-0.066	0.112	0.01	0.04	0	0	0.324
s14	0.069	0.042	-0.003	0.145	0.02	-0.046	0.012	0.03	0.112	0.0525	0	0.4335
s15	0.102	0.09	-0.084	0.135	0.05	-0.086	0	0.048	0.096	0.1015	0	0.4525
s16	0.003	0.078	-0.129	0.2	0.027	-0.002	0.064	0.042	0.296	0.112	0	0.691
s17	0.021	0	-0.033	0.24	0.027	-0.012	0.164	0.027	0.216	0.168	0	0.818
s18	0.15	0.036	-0.12	0.205	0.023	-0.06	0.02	0.041	0.384	0.007	0	0.686
s19	0.126	0.018	-0.147	0.025	0.029	-0.036	0.168	0.009	0.112	0.0385	0	0.3425
s20	0	0.022	-0.126	0.12	0.033	-0.022	0.124	0.001	0.032	0.084	0	0.268
s21	0.027	0.028	-0.081	0.005	0.012	-0.1	0.056	0.026	0.256	0.1295	0	0.3585
s22	0.126	0.01	-0.084	0	0.018	-0.042	0.084	0.032	0.216	0.0595	0	0.4195

Table 10. Comparison table of pessimistic case

s165	s166	s167	s168	s169	s170	s171	s172	Rowsum	Rank
-0.4535	-0.4255	-0.199	-0.247	-0.31	-0.3585	-0.3255	-0.4625	-11.079	100
-0.6035	-0.5755	-0.349	-0.397	-0.46	-0.5085	-0.4755	-0.6125	-36.879	135
-0.941	-0.913	-0.6865	-0.7345	-0.7975	-0.846	-0.813	-0.95	-94.929	171
-0.6885	-0.6605	-0.434	-0.482	-0.545	-0.5935	-0.5605	-0.6975	-51.499	148
-0.7595	-0.7315	-0.505	-0.553	-0.616	-0.6645	-0.6315	-0.7685	-63.711	159
-0.6005	-0.5725	-0.346	-0.394	-0.457	-0.5055	-0.4725	-0.6095	-36.363	134
-0.4145	-0.3865	-0.16	-0.208	-0.271	-0.3195	-0.2865	-0.4235	-4.371	92
-0.722	-0.694	-0.4675	-0.5155	-0.5785	-0.627	-0.594	-0.731	-57.261	154
-0.337	-0.309	-0.0825	-0.1305	-0.1935	-0.242	-0.209	-0.346	8.959	79
-0.698	-0.67	-0.4435	-0.4915	-0.5545	-0.603	-0.57	-0.707	-53.133	151
-0.586	-0.558	-0.3315	-0.3795	-0.4425	-0.491	-0.458	-0.595	-33.869	130
-0.8315	-0.8035	-0.577	-0.625	-0.688	-0.7365	-0.7035	-0.8405	-76.095	163
-0.845	-0.817	-0.5905	-0.6385	-0.7015	-0.75	-0.717	-0.854	-78.417	164
-0.7355	-0.7075	-0.481	-0.529	-0.592	-0.6405	-0.6075	-0.7445	-59.583	156
-0.7165	-0.6885	-0.462	-0.51	-0.573	-0.6215	-0.5885	-0.7255	-56.315	152
-0.478	-0.45	-0.2235	-0.2715	-0.3345	-0.383	-0.35	-0.487	-15.293	106
-0.351	-0.323	-0.0965	-0.1445	-0.2075	-0.256	-0.223	-0.36	6.551	82
-0.483	-0.455	-0.2285	-0.2765	-0.3395	-0.388	-0.355	-0.492	-16.153	108
-0.8265	-0.7985	-0.572	-0.62	-0.683	-0.7315	-0.6985	-0.8355	-75.235	162
-0.901	-0.873	-0.6465	-0.6945	-0.7575	-0.806	-0.773	-0.91	-88.049	170
-0.8105	-0.7825	-0.556	-0.604	-0.667	-0.7155	-0.6825	-0.8195	-72.483	160
-0.7495	-0.7215	-0.495	-0.543	-0.606	-0.6545	-0.6215	-0.7585	-61.991	157
-0.5225	-0.4945	-0.268	-0.316	-0.379	-0.4275	-0.3945	-0.5315	-22.947	115

8. Conclusions

Seed selection is one of the important problems faced by farmers. There are several parameters involved as characteristics of seeds. Also, these characteristics are uncertain by nature. So, to handle the uncertainties involved in the seed selection process, uncertainty based models are necessary, and these should have easy and efficient parameterization facilities. Therefore, soft set appears ideal among all the uncertainty models available at hand. We used the concept of IVFSS, which is a combination of interval valued fuzzy soft sets and soft sets. However, we followed the approach in (Tripathy & Arun, 2016) with characteristic function approach and its extension (Tripathy *et al.*, 2016b) to take care of FSS in order to define IVFSSs. The idea behind selecting IVFSSs instead of fuzzy set is that allocation of a single membership to the various characteristics of objects like seeds is more difficult than assigning an interval to them. Our primary objective was to propose a novel algorithm to handle decision making, which is to be applied in the selection of seeds, by providing the details in the form of IVFSS. For convenience we took a small example and illustrated the workings of the algorithm on it. Next, we presented the experimental set up, experimentation and result analysis fora large data set of rice seeds, also deriving the conclusion. This algorithm has in its scope any such real life situations in the field of agriculture, and can serve as an aid to experts also. The computational complexity of the algorithm is only average.

References

Çagman, N., & Enginoglu, S. (2010). Soft set theory and uni-int decision making. *European Journal of Operational Research, 207*, 848-855.

Jianping, Z. (2009). Study on agricultural knowledge discovery based on rough set theory. *Proceedings of 3rd International Symposium on Intelligent Information Technology Application 2009*, 701-704.

Maji, P. K., Biswas, R., & Roy, A. R. (2001). Fuzzy soft sets. *Journal of Fuzzy Mathematics*, *9*(3), 589-602.

Maji, P. K., Biswas, R., & Roy, A. R. (2002). An application of soft sets in a decision making problem. *Computers and Mathematics with Applications*, *44*, 1077-1083.

Maji, P. K., Biswas, R., & Roy, A. R. (2003). Soft set theory. *Computers and Mathematics with Applications, 45*, 555-562.

Mohanty, R. K., Sooraj, T. R., Tripathy, B. K. (2017). IVIFS and decision-making. *Advances in Intelligent Systems and Computing*, *468,* 319-330.

Molodtsov, D. (1999). Soft set theory - First results. *Computers and Mathematics with Applications*, *37*, 19-31.

Philomine Roseline, T., Ganesan, N., & Clarence, J. M. T. (2015). A study of applications of fuzzy logic in various domains of agricultural sciences. *International Journal of Computer Applications*, 15-18.

Sooraj, T. R., Mohanty, R. K., & Tripathy, B. K. (2016). Fuzzy soft set theory and its application in group decision making. *Advances in Intelligent Systems and Computing*, *452*, 171-178.

Tripathy, B. K., & Arun, K. R. (2015). A new approach to soft sets, soft multisets and their properties. *International Journal of Reasoning-based Intelligent Systems, 7*, 244–253.

Tripathy, B. K., Mohanty, R. K., & Sooraj, T. R. (2016). On intuitionistic fuzzy soft sets and its application in decision making. *Lecture Notes in Electrical Engineering, 396*, 67-73.

Tripathy, B. K., Mohanty, R. K., & Sooraj, T. R. (2016). On intuitionistic fuzzy soft set and its application in group decision making. *Proceedings of ICETETS-2016*, Thanjavur, India.

Tripathy, B. K., Mohanty, R. K., Sooraj, T. R., & Arun, K. R. (2016). A new approach to intuitionistic fuzzy soft sets and their application in decision making. *Advances in Intelligent Systems and Computing, 439*, 93-100.

Tripathy, B. K., Mohanty, R. K., Sooraj, T. R., & Tripathy, A. (2016). A modified representation of IFSS and its usage in GDM. *Smart Innovation, Systems and Technologies*, *50*, 365-375.

Tripathy, B. K., Sooraj, T. R., & Mohanty, R. K. (2016). A new approach to fuzzy soft set theory and its application in decision making. *Advances in Intelligent Systems and computing, 411*, 305-313.

Tripathy, B. K., & Panigrahi, A. (2016). Interval-valued intuitionistic fuzzy parameterized soft set theory and its application in decision making. *Proceedings of 10th international conference on intelligent systems and control (ISCO 2016), 2*, 385-390.

Yang, X. B., Lin, T. Y., Yang, J. Y., Li, Y., & Yu, D. (2009). Combination of interval-valued fuzzy set and soft set. *Computers and Mathematics with Applications, 58*, 521-527.

Zadeh, L. A. (1965). Fuzzy sets. *Information and Control, 8*, 338-353.