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An Interval Valued Fuzzy Soft Set Based Optimization Algorithm for High Yielding Seed Selection

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ABSTRACT

As seed selection is a challenging task due to the presence of hundreds of varieties of seeds of each kind, some homework is necessary for selecting suitable seeds as new varieties and kinds of seeds are introduced in the market every year having their own strengths and weaknesses. The complexities involved in the characteristics in the form of parameters results in uncertainties and as a result some uncertainty based model or hybrid models of more than is required to model the scenario and come out with a decision. Soft sets have enough of parameterization tools to support and hence is the most suitable one for such a study. However, as hybrid models are more efficient, the authors select a model called the interval valued fuzzy soft set (IVFSS) and propose a decision-making algorithm for the selection of seeds. A real database of seeds is used for experimental verification of the efficiency of the algorithm. This is the first attempt for such a study. The use of signed priorities and intervals for the membership of values for entities makes the study more efficient and realistic.

KEYWORDS

Agriculture, Decision Making, Interval Valued Fuzzy Soft Sets, Seed Selection, Soft Sets

INTRODUCTION

It is the opinion of many farmers that seed is where all begins and finishes: it is the beginning and the end. According to their own perceptions of seed selection, their aim is in selecting seed, and the effects of their practices on the genetic structure of their varieties. Some observers convey the impression that farmers who do not select seed before planting are “bad” or disinterested (Perrier 1982; Hernandez 1985; Sand Meier et al., 1986). The traditional methods adopted for seed selection have been continuously changing. However, scientific study for selection of seed is very important. These studies will support the farmers in their selection process by the way improving the production. A combination of experimental and survey data is used to relate farmers’ selection to variety characteristics; examine the effect of selection in the presence of genetic instability and record farmers’ perceptions of their own practices. Findings are likely to be relevant for, although not necessarily representative of, other systems (Louette et al., 1998).

Seed selection can be very challenging. There are several hundreds of varieties of seeds of each kind. Many new varieties and kinds are introduced in the market every year having their own strengths and weaknesses. So, it always requires a little homework before choosing seed varieties. Choosing the wrong one may be able to reduce the production by the way causing a lot of loss to the farmers. Yield is what drives profitability and hence high yielding varieties are always in a farmer’s mind.

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But the characteristics of the seeds also vary according to the soil type, whether the land is irrigated one or a dryland and the overall weather condition etc.

Farmers also replace, renew, or modify the seed stocks for their varieties by introducing seed obtained from other farmers within and outside the community. Although farmers rarely pool seed lots of different varieties, they commonly mix seed lots considered to be of the same variety to obtain needed seed quantities. Recognition of this practice led to the definition of a “seed lot” as the physical unit of seeds of a given variety used to produce the next season’s crop. Farmers appear to identify a seed lot as being of a variety if it resembles it phenotypically, meaning that a variety is then a set of farmers’ seed lots bearing the same name. Results of analysis of phenotypic diversity, both among the seed lots of a variety, and among varieties with seed lots bearing different names, support the hypothesis that a variety corresponds closely to that of a phenotype. The domain of agriculture has various branches 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.

Now a day farmers face lot of agricultural problems such as drought, natural disaster etc. There are few techniques to overcome these agricultural crises. Some of these are mentioned in (Devereux, 2002; Dercon, 2002). Farmers are the major users of seed in most countries (Tripp, 2001). For the selection of seeds, farmer has to analyze the environmental and other factors which influence the seeds. For example, climate is one of the important factors which affect the seeds. Colombo et al (Colombo, 2008) discussed how climate variations will affect the growth of tree seeds in Canadian areas. He also mentioned about the uncertainty in climate. Sometimes, the farmers or researchers who are working in this area cannot be able to realize the exact climate due to the uncertainties involved. Few factors which affect the climate are mentioned in (Colombo et al., 2007). So, the importance of uncertainty models arises.

The complexities of the characteristics of the seeds and the other conditions associated make it difficult for selection of seeds not only for the farmers but also for the experts. There are several uncertainties involved in the characteristics of the seeds. These characteristics are many a time cannot be measured in a crisp manner and requires uncertainty based measurements like the grading and even sometimes the values lie in intervals instead of being atomic.

There are several uncertainty-based models in the literature like the fuzzy sets (Zadeh, 1965), interval valued fuzzy Sets (Zadeh, 1975), rough sets (Pawlak, 1982) and soft sets (Molodtsov, 1999). Also, we have several hybrid models obtained by combining two or more of these models.

Some of the applications of fuzzy logic in agricultural fields are discussed in (Rosaline et al., 2009) are how fuzzy logic can be used in pest management, how it can be used to analyze the soil, how it can be used to develop an expert system for various crops. Some applications of the rough set model are discussed in (Zhu, 2009).

The problem with models like fuzzy sets is lack of parametrization. However, we have to deal with parameters efficiently in selecting seed. So, soft set seems to be an ideal model for this application. Also, hybrid models (Sooraj et al., 2017a, 2017b; Tripathy et al., 2016a, 2016b, 2016c, 2016d, 2016e, 2017; Mohanty et al., 2017) have been found to be more efficient than the individual ones. Since, interval valued fuzzy sets are more general models than fuzzy sets, we have chosen the hybrid model of interval valued fuzzy soft set as the model to capture the characteristics of this application of seed selection. Also, we have provisions for the farmer to specify his priority level for different characteristics, which obviously effect the selection of seeds according to his liking and suitability. We follow the concept of positive and negative parameters. Our approach has been detailed through a real-life data set and the results obtained are encouraging. The detail of the segments of this paper is as follows.

PRELIMINARIES

In this section, we present the definitions, notations and concepts required to be addressed in the paper.

Let U be a universe of discourse.

Definition 1: A fuzzy subset (FS) *X* of *U* is represented by its membership function denoted by μ_X and given as

$$\mu_X : U \to [0,1] \tag{1}$$

where $\mu_X(u) = \alpha \in [0,1]$ for $u \in U$.

Let Int ([0, 1]) the set of all closed sub intervals of the interval [0, 1].

Definition 2: An interval valued fuzzy subset X of U is represented by is a mapping μ_X such that

$$\mu_X : U \to \text{Int } ([0,1]) \tag{2}$$

where $\forall u \in U, \mu_X(u) = [\mu_X^-(u), \mu_X^+(u)] \subseteq [0,1]$. Here, μ_X^- and μ_X^+ represent the lower and upper membership functions of X.

An interval valued fuzzy set reduces to a fuzzy set when the lower and upper membership functions are identical.

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

Definition 3: A pair (F, E) is called as a soft set (SS) over the universal set *U,* where

$$F : E \to P(U) \tag{3}$$

such that $\forall e \in E$, F(e) is a subset of U.

In (Tripathy et al., 2015a) characteristic function approach to this definition was provided, which is more concise, rigour and easy to use as follows:

Definition 4: A SS is a pair (F, E), which is defined through a family of characteristic functions $\left\{\chi_{(F,E)}^a : a \in E\right\}$ given by

$\chi_{(F,E)}^a : U \to \{0,1\}$, where F is as defined above and

$$\chi_{(F,E)}^a(x) = \begin{cases} 1, & if\ x \in F(a); \\ 0, & Otherwise. \end{cases} \tag{4}$$

Definition 5: We denote a fuzzy soft set (FSS) over U by (F, E) where

$$F : E \to F(U) \tag{5}$$

such that $\forall e \in E$, F(e) is a fuzzy subset of U.

Definition 6: A FSS is a pair (F, E), which is defined through a family of membership functions $\{\mu^{a}_{(F,E)} : a \in E\}$ given by

$$\mu^{a}_{(F,E)} : U \to [0,1] \tag{6}$$

Where $\mu^{a}_{(F,E)}(x) = \alpha \in [0,1]$, where $\mu_{F(e)}(x) = \alpha$.

An Example: Suppose U is a set of seeds under consideration and E is a set of parameters. In general, each parameter is a word or a sentence.

In this example we take E= {quality of seeds, shell 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= $\{e_1, e_2, e_3, e_4, e_5\}$. Here, the parameters are more specifically defined as e_1 = quality of seeds, e_2 = shell life, e_3 = cost of purchasing the seeds, e_4 = soil characteristics, 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)= $\{s_1, s_3, s_5\}$ and F(e_5)= $\{s_1\}$.

Thus we can view the soft set as the collection of approximations as (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= $\{s_1\}$.

Let IVF(U) denote the set of all interval valued fuzzy sets defined over U.

Definition 7: A pair (F, E) is called as an interval valued fuzzy soft set (IVFSS) over the universal set *U,* where

$$F : E \to IVF(U) \tag{7}$$

such that $\forall e \in E$, F(e) is an interval valued fuzzy subset of U.

Definition 8: An IVFSS is a pair (F, E), which is defined through a family of membership functions $\left\{\mu^{a}_{(F,E)} : a \in E\right\}$ such that for every $x \in U$

$$\mu^{a}_{(F,E)}(x) = \left[\mu^{a-}_{(F,E)}(x), \mu^{a+}_{(F,E)}(x)\right] \tag{8}$$

Here, $\mu_{(F,E)}^{a-}$ and $\mu_{(F,E)}^{a+}$ are called the lower and upper membership functions associated with $\mu_{(F,E)}^{a}$.

Definition 9: Given two interval valued fuzzy soft sets (F, E) and (G, E) over a common soft universe (U, E), (F, E) is said to be interval valued fuzzy soft subset of (G, E), $\left(F,E\right) \subseteq \left(G,E\right)$ and $\forall a \in E$, $\forall x \in U$.

$$\mu_{(F,E)}^{a-}(x) \le \mu_{(G,E)}^{a-}(x)\ and\ \mu_{(F,E)}^{a+}(x) \le \mu_{(G,E)}^{a+}(x) \tag{9}$$

Definition 10: For any two interval valued fuzzy soft sets (F, E) and (G, E), we say that (F, E) is equal to (G, E) written as (F, E) = (G, E) and $\forall x \in U$,

$$\mu_{(F,E)}^{a-}(x) = \mu_{(G,E)}^{a-}(x)\ and\ \mu_{(F,E)}^{a+}(x) = \mu_{(G,E)}^{a+}(x) \tag{10}$$

MODEL SELECTION AND THE PROPOSED ALGORITHM

The concept of soft sets was introduced in (Molodtsov, 1999), which is a parameterized family of subsets. A characteristic function based definition was provided in (Tripathy et al., 2015a). The fuzzy soft set (FSS) model was introduced in (Maji et al., 2001) and the corresponding membership function approach is due to (Sooraj et al., 2016). An extension of FSS to the context of interval valued fuzzy soft sets (IVFSS) is due to Yang (Yang et al, 2009). The corresponding approach by using membership function approach is in (Tripathy et al., 2017).

Some applications of soft sets were discussed (Molodtsov, 1999). It includes stability and regularization, Game theory and operational research and soft analysis. In (Maji et al., 2002) an application to Decision making is proposed. Decision making is the process of taking decisions to find the best choice from the available choices. Decision making is classified into two categories. That is, 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 take the decisions. But in the case of real life problems, an expert is not sufficient enough take proper decisions. So, more than one decision maker is necessary in many cases. The process of taking decisions with the help of more than one decision maker is called group decision making. Many decision-making applications are discussed by Cagman et al. (Cagman and Serdar, 2010). They introduced uni-int decision making methods, to find the suitable choice. Many researchers introduced hybrid models of soft sets and fuzzy sets into decision making problems and game theory (Deng Feng Li, 2014, 2016; Deng Feng Li et al, 2010a, b; Wei et al, 2015).

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 mentioned under the parameter ‘drought tolerant’ with the value 0.8. 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 is aroused. So, we can mention the seeds drought tolerant lies in the interval of 60%-90%. Then, it can be mentioned under the parameter ‘drought tolerant’ with the value [0.6, 0.9]. Taking a good decision about the selection of seeds and the farm is becoming more complicated because of the uncertainties involved in various factors such as climate, the quality of seeds etc. Here, the uncertainty models play a crucial role to select the best possible alternative from the available choices.

An application of IVFSS is discussed by Tripathy et al (Tripathy et al, 2017). In this paper, we apply the model to the field of agriculture and here we take a real dataset for analysis instead of any synthetic dataset. As expressed earlier, we use the notions of negative parameters, priority of parameters in this paper. Several decision-making algorithms have been presented earlier by using these concepts in (Tripathy et al., 2016a, 2016b, 2016c, 2016d; Sooraj et al., 2016).

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 one has to consider are beautiful, color, price, mileage etc. As we know, as the price of car increases then the interest to purchase that car will reduce. i.e., the parameters which affect the decision adversely are called as negative parameters. Some of the situations where the positive or negative parameters can be used are as follows:

- If the value of the parameter is directly proportional to the interest of the customer then we say that is a positive parameter.
- 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. Lower price is always preferred and hence 'Price' is a negative parameter.

Algorithm

1. Input the priority data table. Get the priority of the parameters from the user which lie 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

$$\text{Normalized Score} = \frac{2*(|c|*|k|*|j| - \sum_{i=1,x\in K}^{i=|j|} RC_{ix})}{|k|*|j|*|c|*(|c|-1)} \tag{11}$$

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 object are having the same rank, then the object having higher value under the highest absolute priority column is selected and it can be further continued.

Computational Complexity of the Algorithm

Computational complexity of the proposed algorithm as follows.

For a set of seeds S, let the number of candidates, 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 be |J|=1.
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 IVFSS table. We take data of *n* seeds each having *m* parameters. Because each member of an interval consists of two membership values, the time complexity in this step is $O(2mn)$.
Step 3: The optimistic, pessimistic and neutral value tables can be constructed in a single scan of the IVFSS table. The time complexity of this operation is $O(mn)$.
Step 4a: The time complexity to obtain the priority table is $O(mn)$.
Step 4b: To compute the row sum in priority tables the time complexity is $O(n)$.
Step 4c: The comparison table for different candidates is constructed by comparing the row sums for each candidate with those of all other 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 takes the time complexity of $O(n)$. Ranking the seeds based on their scores has the 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 to be $O(m\log m + n^2 + mn + n\log n)$ which reduces to $O(n^2)$.

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 seed, 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 lower value in an interval.
II. **Optimistic:** It is the higher value in an interval
III. **Neutral:** Neutral value lies in between 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.

$$Neutral\ value = \frac{pesimistic\ value + optimistic\ value}{2} \tag{8}$$

For example: If a seed s1 has value under the parameter 'climate' as an 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 membership value of each parameter. In optimistic decision making we need to take the upper membership value of each parameter and in neutral decision making we need to take average of both pessimistic and optimistic values. First, we are considering the pessimistic case. The values of the pessimistic case are shown in Table 2.

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 3.

The comparison table is formed as in step 4c of the algorithm, which is shown in Tables 4 to 6.

In the same way, comparison table for optimistic and neutral cases can be calculated and is shown in Table 5 and Table 6.

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]

Table 2. Pessimistic values

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

Table 3. Priority Table for Pessimistic case

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 4. Comparison for Pessimistic case

s_j s_i	s_1	s_2	s_3	s_4	s_5	s_6	Row_sum	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 5. Comparison Table optimistic decision making

s_j s_i	s_1	s_2	s_3	s_4	s_5	s_6	Row_sum	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 6. Comparison Table for neutral decision making

s_j s_i	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

The final decision is the average of pessimistic, optimistic and neutral decision making and it is shown in Table 7.

From Table 7, we can see that seed s_6 is the best choice. The next choices are in the order of s_4, s_5, s_3, s_2 and s_1.

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 the computation. The study conducted on the various rice seeds available on the Southern part of India. The rice seed varieties are Aduthurai, Chithiraikkar, Akshayadhan, etc. Here, we use $s_1, s_2, s_3 \ldots$ to represent the rice seed varieties for brevity.

We applied the above-mentioned algorithm into 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 the normalized score equation. The object, which is having 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

Parameter Description

1. **Moisture Content:** A direct relationship exists between moisture content and deterioration rates, storability, susceptibility to mechanical damage, insect infestation level, and fungi attack. However, this is not a mandatory test with a standard seed testing.
2. **Cost of Purchasing the Seeds:** As in other cases, cost or expense of purchasing any products can be treated as negative parameter. If the cost of purchasing the seeds is high, then the farmer will not prefer that 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 local or global market 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 mentions how far the farm is located from the farmers place. If the farm is close to his place, then the farmer can give enough concentration to his farm. This

Table 7. Decision Table

	Pessimistic	Optimistic	Neutral	Normalized Score	FINAL RANKING
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

can be treated as a negative parameter because as the distance increases, then the care for that form will be reduced.

7. **Yield:** This parameter deals with the yield that we will be getting from these seeds.
8. **Market Quality:** This parameter says whether the seed purchased from a good market or from a low-quality market.
9. **Crop Duration:** This parameter deals with the duration of between the 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 says about the temperature and climate conditions. That is, whether the temperature is affecting positively or negatively for 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, "cost of purchasing the seeds" and "travel facility" are considered as negative and rest 19 come under positive category. Also, the parameter "seed size" has zero priority as farmers need not worry about the size of the seeds. It may be noted that the default priority value of a parameter is taken as "zero".

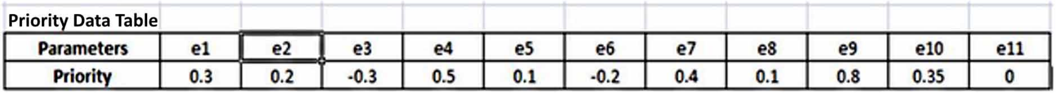
Results Obtained

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

Figure 1 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 (see Figures 2-8).

Top 15 best rice seeds available for the farmer for the selected region are shown in Figure 8. We ranked all the rice seeds based on the normalized score equation.

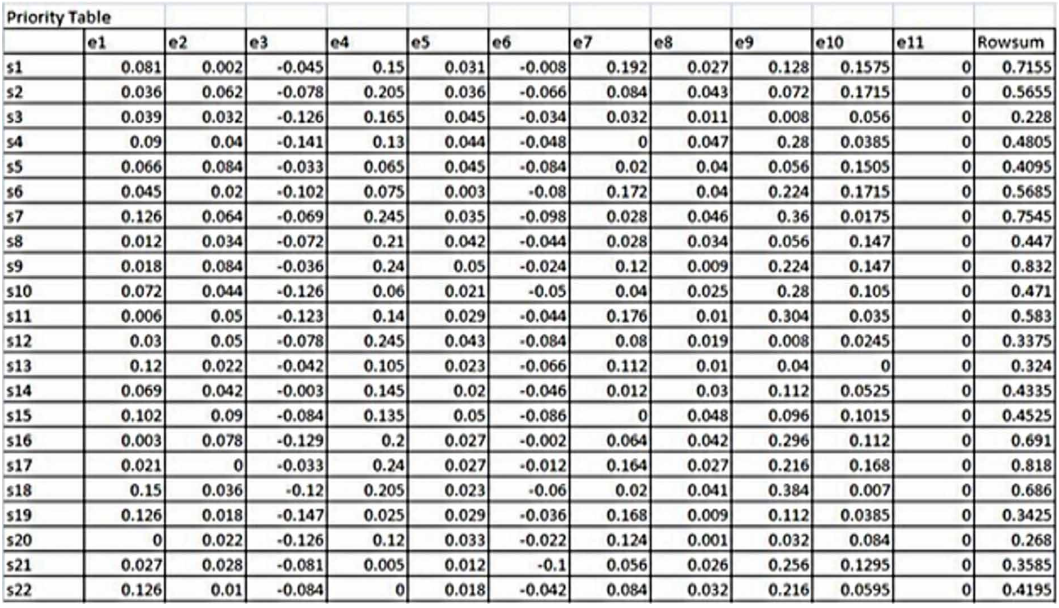
Figure 1. Parameter Priority Table



Priority 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

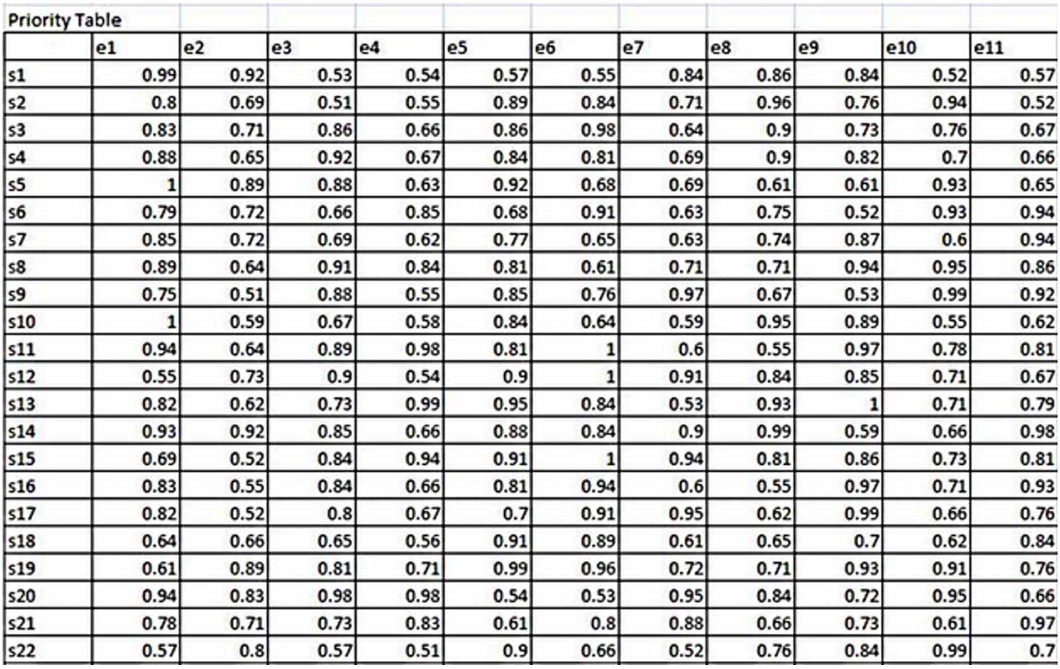
Figure 2. Priority Table of Pessimistic Case



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

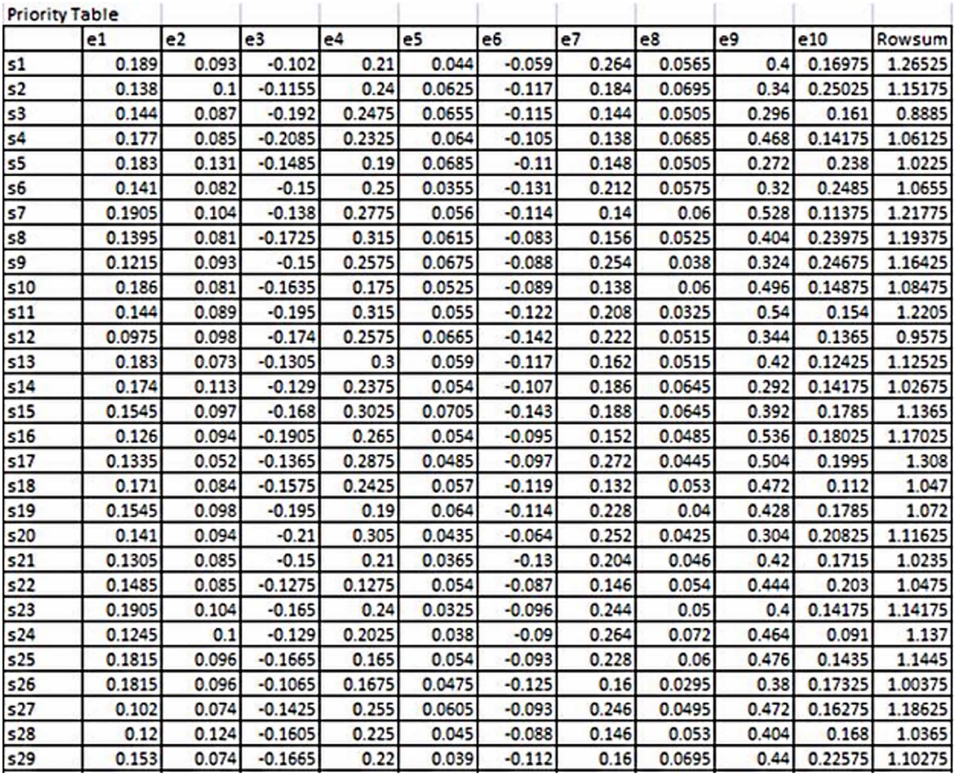
Figure 3. Priority Table for Optimistic case



Priority Table

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	e11
s1	0.99	0.92	0.53	0.54	0.57	0.55	0.84	0.86	0.84	0.52	0.57
s2	0.8	0.69	0.51	0.55	0.89	0.84	0.71	0.96	0.76	0.94	0.52
s3	0.83	0.71	0.86	0.66	0.86	0.98	0.64	0.9	0.73	0.76	0.67
s4	0.88	0.65	0.92	0.67	0.84	0.81	0.69	0.9	0.82	0.7	0.66
s5	1	0.89	0.88	0.63	0.92	0.68	0.69	0.61	0.61	0.93	0.65
s6	0.79	0.72	0.66	0.85	0.68	0.91	0.63	0.75	0.52	0.93	0.94
s7	0.85	0.72	0.69	0.62	0.77	0.65	0.63	0.74	0.87	0.6	0.94
s8	0.89	0.64	0.91	0.84	0.81	0.61	0.71	0.71	0.94	0.95	0.86
s9	0.75	0.51	0.88	0.55	0.85	0.76	0.97	0.67	0.53	0.99	0.92
s10	1	0.59	0.67	0.58	0.84	0.64	0.59	0.95	0.89	0.55	0.62
s11	0.94	0.64	0.89	0.98	0.81	1	0.6	0.55	0.97	0.78	0.81
s12	0.55	0.73	0.9	0.54	0.9	1	0.91	0.84	0.85	0.71	0.67
s13	0.82	0.62	0.73	0.99	0.95	0.84	0.53	0.93	1	0.71	0.79
s14	0.93	0.92	0.85	0.66	0.88	0.84	0.9	0.99	0.59	0.66	0.98
s15	0.69	0.52	0.84	0.94	0.91	1	0.94	0.81	0.86	0.73	0.81
s16	0.83	0.55	0.84	0.66	0.81	0.94	0.6	0.55	0.97	0.71	0.93
s17	0.82	0.52	0.8	0.67	0.7	0.91	0.95	0.62	0.99	0.66	0.76
s18	0.64	0.66	0.65	0.56	0.91	0.89	0.61	0.65	0.7	0.62	0.84
s19	0.61	0.89	0.81	0.71	0.99	0.96	0.72	0.71	0.93	0.91	0.76
s20	0.94	0.83	0.98	0.98	0.54	0.53	0.95	0.84	0.72	0.95	0.66
s21	0.78	0.71	0.73	0.83	0.61	0.8	0.88	0.66	0.73	0.61	0.97
s22	0.57	0.8	0.57	0.51	0.9	0.66	0.52	0.76	0.84	0.99	0.7

Figure 4. Priority Table for Neutral values



Priority Table

	e1	e2	e3	e4	e5	e6	e7	e8	e9	e10	Rowsum
s1	0.189	0.093	-0.102	0.21	0.044	-0.059	0.264	0.0565	0.4	0.16975	1.26525
s2	0.138	0.1	-0.1155	0.24	0.0625	-0.117	0.184	0.0695	0.34	0.25025	1.15175
s3	0.144	0.087	-0.192	0.2475	0.0655	-0.115	0.144	0.0505	0.296	0.161	0.8885
s4	0.177	0.085	-0.2085	0.2325	0.064	-0.105	0.138	0.0685	0.468	0.14175	1.06125
s5	0.183	0.131	-0.1485	0.19	0.0685	-0.11	0.148	0.0505	0.272	0.238	1.0225
s6	0.141	0.082	-0.15	0.25	0.0355	-0.131	0.212	0.0575	0.32	0.2485	1.0655
s7	0.1905	0.104	-0.138	0.2775	0.056	-0.114	0.14	0.06	0.528	0.11375	1.21775
s8	0.1395	0.081	-0.1725	0.315	0.0615	-0.083	0.156	0.0525	0.404	0.23975	1.19375
s9	0.1215	0.093	-0.15	0.2575	0.0675	-0.088	0.254	0.038	0.324	0.24675	1.16425
s10	0.186	0.081	-0.1635	0.175	0.0525	-0.089	0.138	0.06	0.496	0.14875	1.08475
s11	0.144	0.089	-0.195	0.315	0.055	-0.122	0.208	0.0325	0.54	0.154	1.2205
s12	0.0975	0.098	-0.174	0.2575	0.0665	-0.142	0.222	0.0515	0.344	0.1365	0.9575
s13	0.183	0.073	-0.1305	0.3	0.059	-0.117	0.162	0.0515	0.42	0.12425	1.12525
s14	0.174	0.113	-0.129	0.2375	0.054	-0.107	0.186	0.0645	0.292	0.14175	1.02675
s15	0.1545	0.097	-0.168	0.3025	0.0705	-0.143	0.188	0.0645	0.392	0.1785	1.1365
s16	0.126	0.094	-0.1905	0.265	0.054	-0.095	0.152	0.0485	0.536	0.18025	1.17025
s17	0.1335	0.052	-0.1365	0.2875	0.0485	-0.097	0.272	0.0445	0.504	0.1995	1.308
s18	0.171	0.084	-0.1575	0.2425	0.057	-0.119	0.132	0.053	0.472	0.112	1.047
s19	0.1545	0.098	-0.195	0.19	0.064	-0.114	0.228	0.04	0.428	0.1785	1.072
s20	0.141	0.094	-0.21	0.305	0.0435	-0.064	0.252	0.0425	0.304	0.20825	1.11625
s21	0.1305	0.085	-0.15	0.21	0.0365	-0.13	0.204	0.046	0.42	0.1715	1.0235
s22	0.1485	0.085	-0.1275	0.1275	0.054	-0.087	0.146	0.054	0.444	0.203	1.0475
s23	0.1905	0.104	-0.165	0.24	0.0325	-0.096	0.244	0.05	0.4	0.14175	1.14175
s24	0.1245	0.1	-0.129	0.2025	0.038	-0.09	0.264	0.072	0.464	0.091	1.137
s25	0.1815	0.096	-0.1665	0.165	0.054	-0.093	0.228	0.06	0.476	0.1435	1.1445
s26	0.1815	0.096	-0.1065	0.1675	0.0475	-0.125	0.16	0.0295	0.38	0.17325	1.00375
s27	0.102	0.074	-0.1425	0.255	0.0605	-0.093	0.246	0.0495	0.472	0.16275	1.18625
s28	0.12	0.124	-0.1605	0.225	0.045	-0.088	0.146	0.053	0.404	0.168	1.0365
s29	0.153	0.074	-0.1665	0.22	0.039	-0.112	0.16	0.0695	0.44	0.22575	1.10275

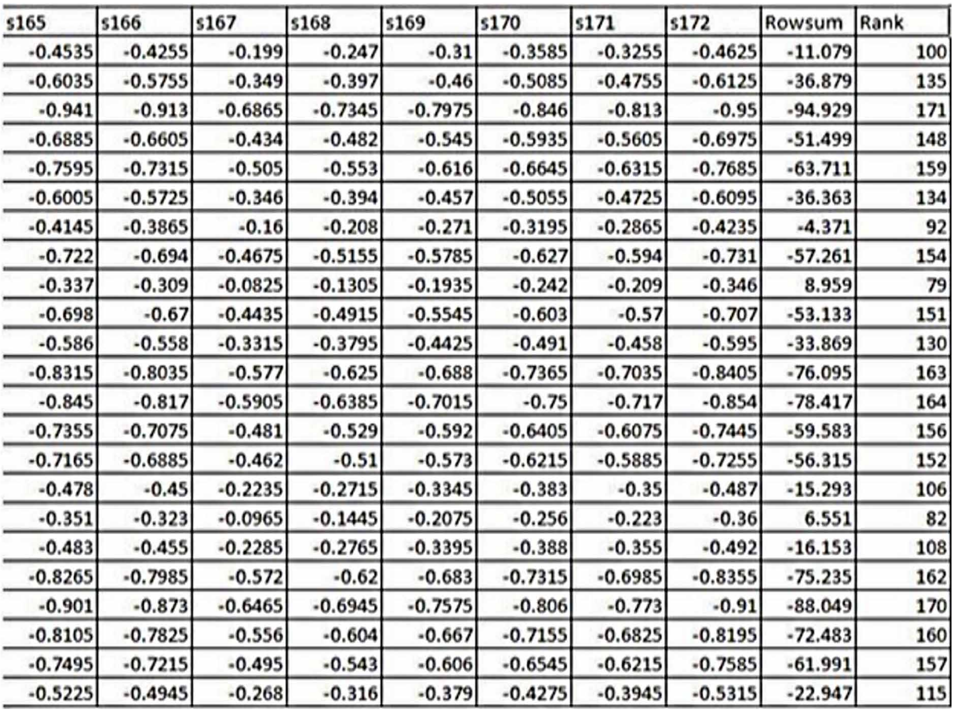
FUTURE WORK

The present algorithm can be extended to some more generalised hybrid models. Also, the above-mentioned algorithm can be modified suitably so that it can be applied to group decision making problems. In particular, in the above application, a farmer can be helped by a group of experts. Otherwise, in large agricultural industries the decision to select seeds is usually done by a board of experts. As a result each researcher has to enter their own interests and according to that they have to find the results. The seed selection algorithm can also be applied to other directions of agricultural research.

CONCLUSION

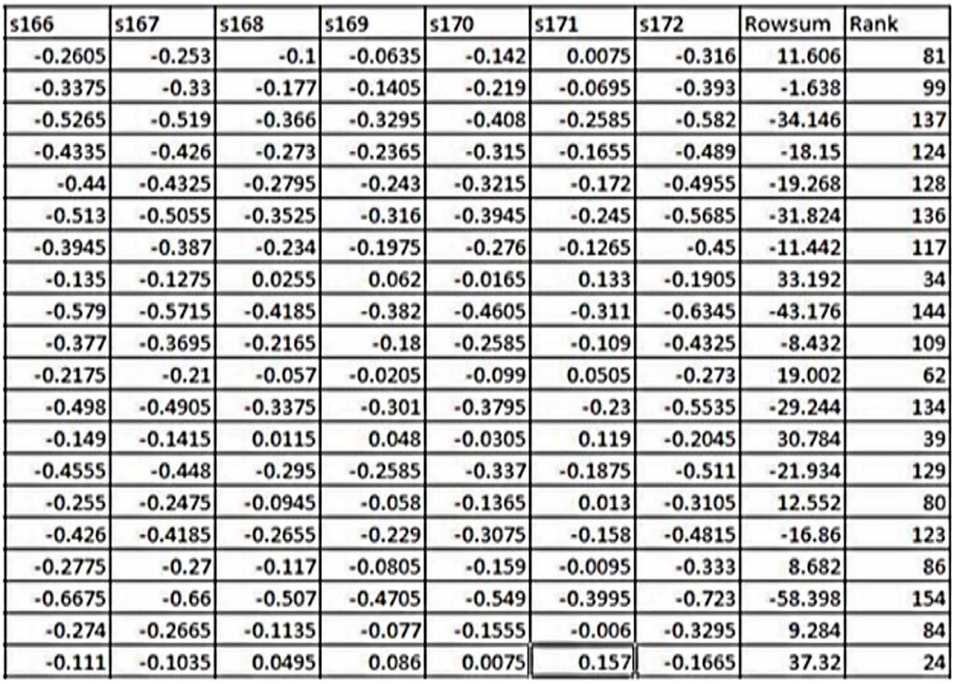
Seed selection is one of the important problems faced by farmers. There are several parameters involved as characteristics of seeds. Also, these characteristics are uncertain by nature. So, to handle the uncertainties involved in the seed selection process, uncertainty based models are necessary to handle them which should have easy and efficient parameterization facilities. Keeping this in mind, we selected a hybrid soft set modelfor our study and presented an algorithm which depends upon IVFSS. There is no other algorithm in the literature for this application, so far as our knowledge goes. We took a real data set, which is sufficiently large to perform experiment depending upon our algorithm and presented its output and analyzed. This algorithm has the scope to be applied to any such real-life situations in the field of agriculture, which will serve as an aid to experts also. The computational complexity of the algorithm is obtained, in order to estimate the time variation of computation of the results depending upon the data size.

Figure 5. Comparison Table of Pessimistic case



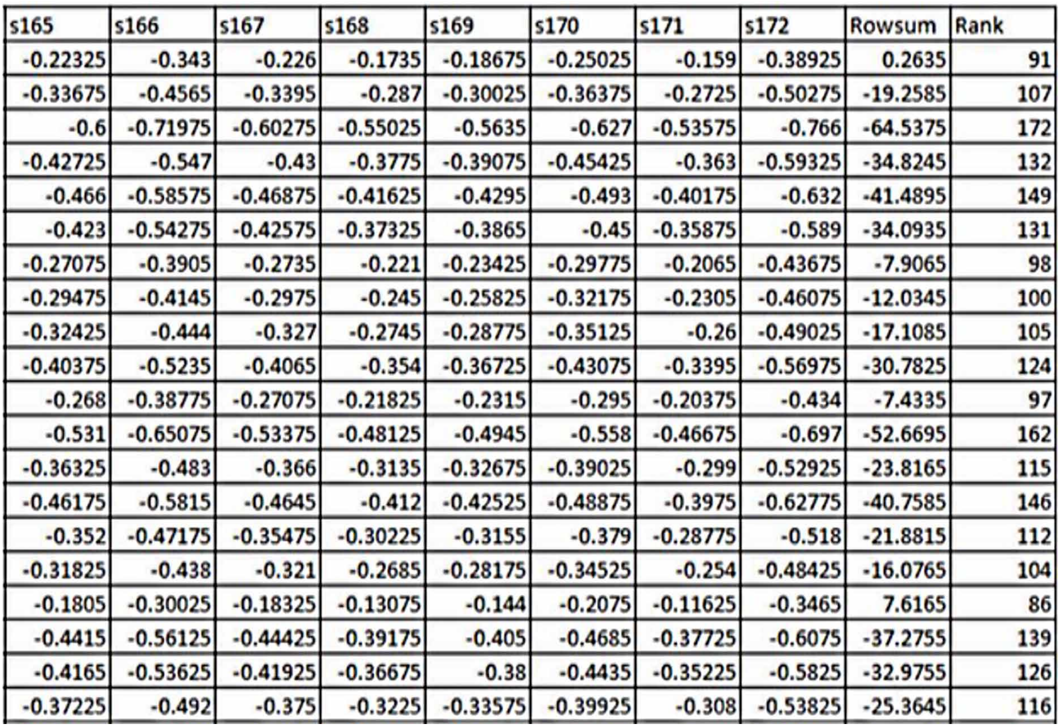
s165	s166	s167	s168	s169	s170	s171	s172	Rowsum	Rank
-0.4535	-0.4255	-0.199	-0.247	-0.31	-0.3585	-0.3255	-0.4625	-11.079	100
-0.6035	-0.5755	-0.349	-0.397	-0.46	-0.5085	-0.4755	-0.6125	-36.879	135
-0.941	-0.913	-0.6865	-0.7345	-0.7975	-0.846	-0.813	-0.95	-94.929	171
-0.6885	-0.6605	-0.434	-0.482	-0.545	-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

Figure 6. Comparison of Optimistic Case



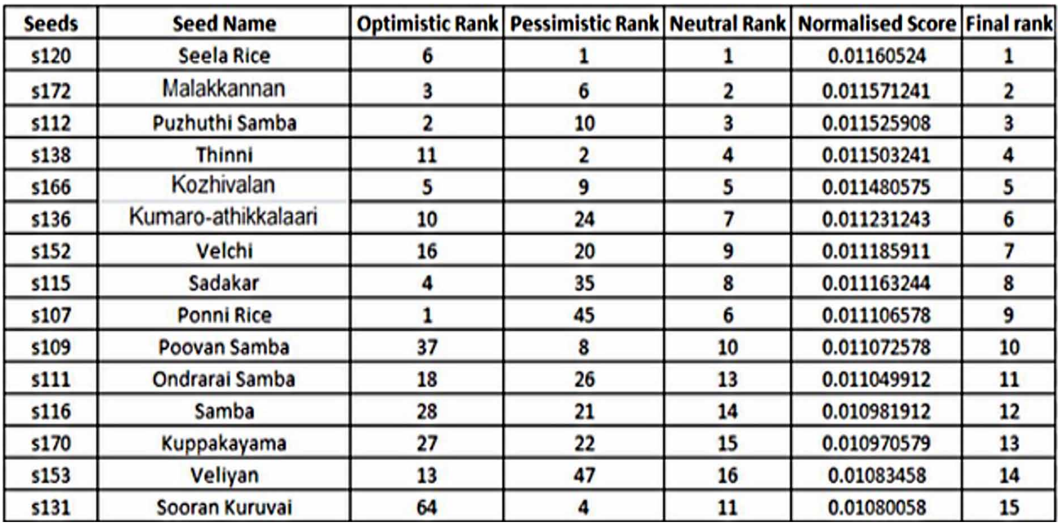
s166	s167	s168	s169	s170	s171	s172	Rowsum	Rank
-0.2605	-0.253	-0.1	-0.0635	-0.142	0.0075	-0.316	11.606	81
-0.3375	-0.33	-0.177	-0.1405	-0.219	-0.0695	-0.393	-1.638	99
-0.5265	-0.519	-0.366	-0.3295	-0.408	-0.2585	-0.582	-34.146	137
-0.4335	-0.426	-0.273	-0.2365	-0.315	-0.1655	-0.489	-18.15	124
-0.44	-0.4325	-0.2795	-0.243	-0.3215	-0.172	-0.4955	-19.268	128
-0.513	-0.5055	-0.3525	-0.316	-0.3945	-0.245	-0.5685	-31.824	136
-0.3945	-0.387	-0.234	-0.1975	-0.276	-0.1265	-0.45	-11.442	117
-0.135	-0.1275	0.0255	0.062	-0.0165	0.133	-0.1905	33.192	34
-0.579	-0.5715	-0.4185	-0.382	-0.4605	-0.311	-0.6345	-43.176	144
-0.377	-0.3695	-0.2165	-0.18	-0.2585	-0.109	-0.4325	-8.432	109
-0.2175	-0.21	-0.057	-0.0205	-0.099	0.0505	-0.273	19.002	62
-0.498	-0.4905	-0.3375	-0.301	-0.3795	-0.23	-0.5535	-29.244	134
-0.149	-0.1415	0.0115	0.048	-0.0305	0.119	-0.2045	30.784	39
-0.4555	-0.448	-0.295	-0.2585	-0.337	-0.1875	-0.511	-21.934	129
-0.255	-0.2475	-0.0945	-0.058	-0.1365	0.013	-0.3105	12.552	80
-0.426	-0.4185	-0.2655	-0.229	-0.3075	-0.158	-0.4815	-16.86	123
-0.2775	-0.27	-0.117	-0.0805	-0.159	-0.0095	-0.333	8.682	86
-0.6675	-0.66	-0.507	-0.4705	-0.549	-0.3995	-0.723	-58.398	154
-0.274	-0.2665	-0.1135	-0.077	-0.1555	-0.006	-0.3295	9.284	84
-0.111	-0.1035	0.0495	0.086	0.0075	0.157	-0.1665	37.32	24

Figure 7. Comparison Table for Neutral Values



s165	s166	s167	s168	s169	s170	s171	s172	Rowsum	Rank
-0.22325	-0.343	-0.226	-0.1735	-0.18675	-0.25025	-0.159	-0.38925	0.2635	91
-0.33675	-0.4565	-0.3395	-0.287	-0.30025	-0.36375	-0.2725	-0.50275	-19.2585	107
-0.6	-0.71975	-0.60275	-0.55025	-0.5635	-0.627	-0.53575	-0.766	-64.5375	172
-0.42725	-0.547	-0.43	-0.3775	-0.39075	-0.45425	-0.363	-0.59325	-34.8245	132
-0.466	-0.58575	-0.46875	-0.41625	-0.4295	-0.493	-0.40175	-0.632	-41.4895	149
-0.423	-0.54275	-0.42575	-0.37325	-0.3865	-0.45	-0.35875	-0.589	-34.0935	131
-0.27075	-0.3905	-0.2735	-0.221	-0.23425	-0.29775	-0.2065	-0.43675	-7.9065	98
-0.29475	-0.4145	-0.2975	-0.245	-0.25825	-0.32175	-0.2305	-0.46075	-12.0345	100
-0.32425	-0.444	-0.327	-0.2745	-0.28775	-0.35125	-0.26	-0.49025	-17.1085	105
-0.40375	-0.5235	-0.4065	-0.354	-0.36725	-0.43075	-0.3395	-0.56975	-30.7825	124
-0.268	-0.38775	-0.27075	-0.21825	-0.2315	-0.295	-0.20375	-0.434	-7.4335	97
-0.531	-0.65075	-0.53375	-0.48125	-0.4945	-0.558	-0.46675	-0.697	-52.6695	162
-0.36325	-0.483	-0.366	-0.3135	-0.32675	-0.39025	-0.299	-0.52925	-23.8165	115
-0.46175	-0.5815	-0.4645	-0.412	-0.42525	-0.48875	-0.3975	-0.62775	-40.7585	146
-0.352	-0.47175	-0.35475	-0.30225	-0.3155	-0.379	-0.28775	-0.518	-21.8815	112
-0.31825	-0.438	-0.321	-0.2685	-0.28175	-0.34525	-0.254	-0.48425	-16.0765	104
-0.1805	-0.30025	-0.18325	-0.13075	-0.144	-0.2075	-0.11625	-0.3465	7.6165	86
-0.4415	-0.56125	-0.44425	-0.39175	-0.405	-0.4685	-0.37725	-0.6075	-37.2755	139
-0.4165	-0.53625	-0.41925	-0.36675	-0.38	-0.4435	-0.35225	-0.5825	-32.9755	126
-0.37225	-0.492	-0.375	-0.3225	-0.33575	-0.39925	-0.308	-0.53825	-25.3645	116

Figure 8. 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

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