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# An inquisition on post-harvest losses of food grains during storage by using an approach focused on distance measure under interval-valued intuitionistic fuzzy group decision-making

C. Gladia Vincy [1*] and M. Mary Mejrullo Merlin[2]

**Abstract**

In many developed and developing countries, food grains production is the most requisite food for both human consumption and animal feed. Every year around the world, two billion tones of grains are rendered. Storage is a chain of food grain process which is also a prehistoric method of preserving goods. During the post-harvest period, the stored food is lost without any proper storing facilities. Most of the stored grains are infested by several species of insects and micro-organisms. Apart from these, the losses of food grains can also happen by a handful of other factors. By using a method established on distance measure in the fuzzy group decision making problem, we can find the most critical criterion in the existent real life scenario. The aim of this research work is to explore the factors which are accountable for post-harvest losses of grains under food grain storage methods.

**Keywords**

Post-harvest losses, Grain storage, Interval-valued intuitionistic fuzzy number, Interval-valued intuitionistic fuzzy set, Interval-valued intuitionistic fuzzy matrix.

**AMS Subject Classification**

03E72.

[1] *PG & Research Department of Mathematics, Holy Cross College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli-620002, Tamil Nadu, India.*

[2] *PG & Research Department of Mathematics, Holy Cross College (Autonomous), Affiliated to Bharathidasan University, Tiruchirappalli-620002, Tamil Nadu, India.*

*[*]**Corresponding author**: [1] gladiavincy23@gmail.com; [2]merlinprashanth@gmail.com

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## Contents



## 1. Introduction

Group decision making is an informal process of analyzing a problems with many individuals to rank the desired set of alternatives and identify a correct solutions for that problem.

In 1965, fuzzy set theory was initiated by Zadeh [1]. Later, Atanassov and Gargov developed the concept of interval-valued intuitionistic fuzzy set which is identified by the degree of satisfiability and non-satisfiability that values are taken in the form of intervals rather than real numbers [2].

In the current scenario, once in a while we cannot get an appropriate solution for some problems. For those types of cases distance measure helps to take correct solution among the alternatives. Atanassov established operations of Interval-valued intuitionistic fuzzy sets, some relations and their fundamental properties [3].

A number of similarity measures and distance measures of interval-valued intuitionistic fuzzy sets were introduced by Xu and Chen [15]. In the process of decision making based on intuitionistic fuzzy environment, Xu and Yager designated an uncertain intuitionistic fuzzy variable and also enhanced an operator which was named as an uncertain dynamic intuitionistic fuzzy weighted averaging (UDIFWA) operator. An algorithm based on this operator is eminently useful for multi-attribute decision making under interval uncertainity [22, 23].

The paper is ordered as follows: Some basic definitions of intuitionistic fuzzy sets are given in section 2, section 3 holds the procedure based on distance measure, sections 4 contains case study, section 5 provides problem explanation and methodology and the conclusion is deduced in section 6.

## 2. Preliminaries

**Definition 2.1.** *Let $X = \{x_1, x_2, ..., x_n\}$ be a finite universal set. Then an interval-valued intuitionistic fuzzy set A by X is explained by,*

$$A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$$

*where and $\mu_A(x)$ are intervals, $\forall x \in X : \sup \mu_A(x) + \nu_A(x) \leq 1$. [3].*

**Definition 2.2.** *For every interval-valued intuitionistic set, the pair $(\mu_A(x), \nu_A(x))$ is called an interval-valued intuitionistic fuzzy number.*

*Then an IVIFN is denoted by $\alpha = ([a,b],[c,d])$, where $[a,b] \subseteq [0,1], [c,d] \subseteq [0,1]$, $b+d \leq 1$ and $s(\alpha) = \frac{1}{2}(a-c+b-d)$ is the score of $\alpha$. Also $\alpha^* = [1,1],[0,0]$.*

**Definition 2.3.** *Let us take $P = (p_{ij})_{n\times n}$ be an $n \times n$ matrix. Consider, if all $p_{ij}(i, j = 1,2,...,n)$ are interval-valued intuitionistic fuzzy numbers (IVIFNs) and*

$$p_{ij} = ([a_{ij}, b_{ij}],[c_{ij}, d_{ij}]),$$

$$[a_{ij}, b_{ij}] \subseteq [0,1],[c_{ij}, d_{ij}] \subseteq [0,1],$$

*$b_{ij} + d_{ij} \leq 1$, $i, j = 1,2,...,n$ then we describe P as an interval-valued intuitionistic fuzzy matrix [24].*

**Definition 2.4.** *An interval-valued intuitionistic fuzzy matrix*

$$P = (p_{ij})_{n\times n},$$

*where*

$$p_{ij} = ([a_{ij}, b_{ij}],[c_{ij}, d_{ij}]),$$

*$i, j = 1,2,...,n$ is called an interval-valued intuitionistic fuzzy similarity matrix, if P satisfies the succeeding constraints:*

**(i)** $p_{ij} = ([1,1],[0,0])$, *i=1,2,...,n; (Reflexivity)*

**(ii)** $p_{ij} = p_{ji}$, *i.e.,* $[a_{ij}, b_{ij}] = [a_{ij}, b_{ij}], [c_{ij}, d_{ij}] = [c_{ij}, d_{ij}]$, $i, j = 1,2,...,n$ *(Symmetry).*

## 3. A procedure derived from distance measure for a group decision making with interval -valued intuitionistic fuzzy matrices

Based on the group decision making with interval-valued intuitionistic fuzzy matrices, we construct an intelligible and exact method which is illustrated as follows:

**STEP: 1**

In the group decision making problem, let us take a definite set of $X = \{x_1, x_2, ..., x_n\}$ alternatives as and the set of decision makers as $D = \{d_1, d_2, ..., d_n\}$ (whose weight vector is

$$\lambda = \{\lambda_1, \lambda_2, ..., \lambda_n\},$$

where $\lambda_k \geq 0, k = 1,2,...,m$ and $\sum_{k=1}^{m} \lambda_k = 1$). The decision makers $d_k(k = 1,2,...,m)$ support their interval-valued intutionistic fuzzy preferences for every pair of alternatives and establish the interval-valued intuitionistic fuzzy matrices

$$P_k = (p_{ij}^{(k)})_{n\times n} \; (k = 1,2,...,m),$$

where

$$p_{ij}^{(k)} = ([a_{ij}^{(k)}, b_{ij}^{(k)}],[c_{ij}^{(k)}, d_{ij}^{(k)}])$$

is an IVIFN,

$$[a_{ij}^{(k)}, b_{ij}^{(k)}] \subseteq [0,1],[c_{ij}^{(k)}, d_{ij}^{(k)}] \subseteq [0,1],$$

$$b_{ij}^{(k)} + d_{ij}^{(k)} \leq 1.$$

$[a_{ij}^{(k)}, b_{ij}^{(k)}]$ indicates the uncertain preference degree of the alternative $x_i$ by $x_j$, and $[c_{ij}^{(k)}, d_{ij}^{(k)}]$ indicates the uncertain preference degree of the alternative $x_j$ by $x_i$. To make it simple, let

$$p_i^{(k)} = (p_{i1}^{(k)}, p_{i2}^{(k)}, ..., p_{in}^{(k)})$$

be the preference vector equivalent to the alternative $x_i$ and the decision maker $d_k$.

**STEP: 2**

To find the uncertain intuitionistic fuzzy ideal solution (UIFIS), we have to compute

$$\alpha^* = (\alpha_1^*, \alpha_2^*, ..., \alpha_n^*),$$

where

$$\alpha_j^* = ([1,1],[0,0])(j = 1,2,...,n)$$

are the $n$ largest IVIFNs.

**STEP: 3**

By utilizing the Euclidean distance measure, we compute the distance between preference vector $p_i^{(k)}$ and the UIFIS $\alpha^*$:

$$d(p_i^{(k)}, \alpha^*) = \sqrt{\frac{1}{4}\sum_{j=1}^{n}\Big[(a_{ij}^{(k)}-1)^2 + (b_{ij}^{(k)}-1)^2 + (c_{ij}^{(k)}-0)^2 + (d_{ij}^{(k)}-0)^2\Big]}$$

**STEP: 4**

By utilizing the weighted averaging operator, we aggregate all the distances $d(p_i^{(k)}, \alpha^*)(k = 1, 2, ..., n)$:

$$d(p_i, \alpha^*) = \sum_{j=1}^{n} \lambda_k d(p_i^{(k)}, \alpha^*)$$

**STEP: 5**

Based on the distances $d(p_i, \alpha^*)(i = 1, 2, ..., n)$ we can rank all the alternatives $x_i(i = 1, 2, ..., n)$. Evidently, the lower the distance $d(p_i, \alpha^*)$, the nearer the alternative $x_i$ is to the UIFIS $\alpha^*$, and the more favorable the alternative, $x_i$.

The recommended method is very modest and easy to apply in practical situations. Firstly, we compute the distances of every alternative to the UIFIS equivalent to every decision maker. Then we can rank all the alternatives according to the aggregation of all these distances into the overall distance. The weighted averaging operator to aggregate preference information and the Euclidean distance measure are only used in this paper.

## 4. Factors responsible for the food grain losses during storage

In India cereal grains are staple food for human which are fruitful supplies of carbohydrates, fats, vitamins, minerals, proteins and oils. It helps us to survive the whole day with sufficient energy and also helps us to avoid heart disease, colon cancer, diverticular diseases and diabetes. Plague disease, malaria disease, lyme disease and several other diseases are caused by infested grain which are harmful to human. We need to store these grains for human consumption for a long time because they are yielded on seasonal basis. Bags, warehouses, silos, piles on the ground and containers are the grain storage methods that are developed. Many researchers have studied that at the stage of storage during post- harvest processes most of the food grains are lost by several factors which are biological factors, environmental factors, type of storage structure used and infrastructural facilities, lack of regular inspection, lack of cleaning and fumigation, and lack of proper aeration and drying capabilities. Due to the causes of these factors, weight losses, weak germination ability, deterioration, in quality, dissatisfactory market price occur.

**Biological factors:**

The biological factors comprise micro-organisms, birds, rodents, insects and pests. Most of the losses of cereal grains are caused by these factors.

(i) To avoid this we can use insect detection techniques ( X-ray imaging, Grain probes and insect traps, Pheromones, Electrical conductance, Visual lures, Berlese funnel method, Acoustical methods, Near-infrared spectroscopy) [21].

(ii) In godowns, we use nylon ropes, fumigation covers, insecticides and nets.

**Environmental factors:**

During storage, the quantitative loss of food grain is mainly evoked by these factors. Environmental factors take in both physical factors (temperature and humidity) and chemical factors (moisture and oxygen).

(i) To maintain the temperature and moisture level for each cereal grains properly [20].

**Lack of proper storage structure used and infrastructural facilities**

To overcome the lack of storage structure,

(i) Use airtight bins.

(ii) Using the storage structures which are user friendly for long time duration.

(iii) To keep down storage losses, use scientific and improved storage structures.

(iv) Improving good infrastructural facilities and following safe storage methods [19].

**Lack of regular inspection of grain stock**

Insufficiency of inspection of grain stock is also one of the causes for food grain losses during storage, to overcome this problem,

(i) To protect the grain stock there is a need to follow up of regular inspection and surveillance programme periodically [19].

(ii) To indentify the actual problem during storage, the process of inspection of stored grain must be executed perfectly and periodically by an educated and experienced staff who has awareness in that field.

**Lack of cleaning and fumigation**

To avoid the lack of cleaning and fumigation, the following steps should be adopted.

(i) In advance storing grains, the store must be perfectly white washed and mopped and also it should be free from dust particles, discarded matter, refuse material and webbing.

(ii) Fumigation is a remedy for stored grain pests that should be very effective, if the fumigant is handled with proper dosage along with favorable condition [18].

**Lack of proper aeration and drying capabilities**

The proper aeration and drying capabilities also promotes the healthy food grain during storage.

(i) Aeration is a process that helps us to enhance the duration of food grains in storage by controlling a cool and uniform temperature. It forbids moisture migration and minimizes insect activities and mold development [18].

(ii) Based on the system capability, aeration can be conditioned either cool or dry grain.

## 5. Problem description

In many developing countries, the losses of food grain increases in both quantitative and qualitative level. Exceptionally, at the time post- harvest activities during storage in grain supply chains, six factors are accountable for the losses of stored grain. In a group decision making problem of interval-valued intuitionistic fuzzy matrices, the uncertain desire degree of the alternative $x_i$ over $x_j$ is taken as $[a_{ij}^{(k)}, b_{ij}^{(k)}]$ and the uncertain desire degree of the alternative $x_j$ over $x_i$ be taken as $[c_{ij}^{(k)}, d_{ij}^{(k)}]$. The desire vector analogous to the alternative $x_i$ and the decision maker $d_k$ is taken as

$$p_i^{(k)} = (p_{i1}^{(k)}, p_{i2}^{(k)}, ..., p_{in}^{(k)}).$$

Based on the collection of decision maker's information we can choose our critical factor.

### 5.1 Methodology

Every pair of criteria is analyzed and the interval-valued intuitionistic fuzzy desire degree is given by the decision maker's in the form of interval-valued intuitionistic fuzzy matrices, $p_k = (p_{ij}^{(k)})_{n\times n}$ $(k = 1,2,3)$ that is based on six criteria which are given below:

$x_1$ $\rightarrow$ Biological factors,

$x_2$ $\rightarrow$ Environmental factors,

$x_3$ $\rightarrow$ Types of storage structure used and infrastructural facilities,

$x_4$ $\rightarrow$ Lack of regular inspection of grain stock,

$x_5$ $\rightarrow$ Lack of cleaning and fumigation,

$x_6$ $\rightarrow$ Lack of proper aeration and drying capabilities.

**STEP: 1**

**Interval-valued intuitionistic fuzzy matrix $P_1$ :**

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ |
|---|---|---|---|---|---|---|
| $x_1$ | ([0.5,0.5], [0.5,0.5]) | ([0.6,0.8], [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_2$ | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) |
| $x_3$ | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) |
| $x_4$ | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6]' [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) |
| $x_5$ | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) |
| $x_6$ | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8] [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) |

**Interval-valued intuitionistic fuzzy matrix $P_2$ :**

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ |
|---|---|---|---|---|---|---|
| $x_1$ | ([0.5,0.5] [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_2$ | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.5], [0.5,0.5]) | ([0.2,0.4], [0.4,0.6]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_3$ | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.2,0.4], [0.4,0.6]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_4$ | ([0.4,0.6], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.2,0.4], [0.4,0.6]) | ([0.5,0.5], [0.5,0.5]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) |
| $x_5$ | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.5], [0.5,0.5]) | ([0.4,0.6], [0.2,0.3]) |
| $x_6$ | ([0.6,0.8], [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.5], [0.5,0.5]) |

**Interval-valued intuitionistic fuzzy matrix $P_3$ :**

| | $x_1$ | $x_2$ | $x_3$ | $x_4$ | $x_5$ | $x_6$ |
|---|---|---|---|---|---|---|
| $x_1$ | ([0.5,0.5], [0.5,0.5]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_2$ | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.5], [0.5,0.5]) | ([0.2,0.4], [0.4,0.6]) | ([0.4,0.6], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) |
| $x_3$ | ([0.6,0.8], [0.1,0.2]) | ([0.2,0.4], [0.4,0.6]) | ([0.5,0.5], [0.5,0.5]) | ([0.4,0.6], [0.2,0.3]) | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) |
| $x_4$ | ([0.4,0.6], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.4,0.6], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) |
| $x_5$ | ([0.6,0.8], [0.1,0.2]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) | ([0.4,0.6], [0.2,0.3]) |
| $x_6$ | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.4,0.6], [0.2,0.3]) | ([0.5,0.7], [0.2,0.3]) | ([0.5,0.5], [0.5,0.5]) |

**STEP: 2**

Let $p_i^{(k)} = (p_{i1}^{(k)}, p_{i2}^{(k)}, p_{i3}^{(k)}, p_{i4}^{(k)}, p_{i5}^{(k)}, p_{i6}^{(k)})$ be the desire vector equivalent to the criterion and the decision maker $d_k$. By utilizing the Euclidean distance measure, determine the distance between the desire vector $p_i^{(k)}$ and the UIFIS $\alpha^*$.

$$d(p_1^{(1)},\alpha^*) = 0.82,\quad d(p_1^{(2)},\alpha^*) = 0.91,\quad d(p_1^{(3)},\alpha^*) = 0.88,$$
$$d(p_2^{(1)},\alpha^*) = 0.91,\quad d(p_2^{(2)},\alpha^*) = 1,\quad d(p_2^{(3)},\alpha^*) = 1.07,$$
$$d(p_3^{(1)},\alpha^*) = 0.82,\quad d(p_3^{(2)},\alpha^*) = 1.02,\quad d(p_3^{(3)},\alpha^*) = 1.02,$$
$$d(p_4^{(1)},\alpha^*) = 0.94,\quad d(p_4^{(2)},\alpha^*) = 1.07,\quad d(p_4^{(3)},\alpha^*) = 1.03,$$
$$d(p_5^{(1)},\alpha^*) = 0.88,\quad d(p_5^{(2)},\alpha^*) = 0.85,\quad d(p_5^{(3)},\alpha^*) = 0.93,$$
$$d(p_6^{(1)},\alpha^*) = 0.85.\quad d(p_6^{(2)},\alpha^*) = 0.79.\quad d(p_6^{(3)},\alpha^*) = 0.94.$$

**STEP: 3**

By utilizing the weighted averaging operator, in accordance with the weight vector $\lambda = (0.4, 0.4, 0.2)$. We can collect all the distances $d(p_i^{(k)}, \alpha^*)(k = 1,2,3)$ into the final distance $d(p_i, \alpha^*)$ equivalent to the criterion $x_i$:

$$d(p_1,\alpha^*) = 0.87,\quad d(p_4,\alpha^*) = 1.01$$
$$d(p_2,\alpha^*) = 0.98,\quad d(p_5,\alpha^*) = 0.88$$
$$d(p_3,\alpha^*) = 0.94,\quad d(p_6,\alpha^*) = 0.85.$$

**STEP: 4**

Based on the distance measure, all the criteria are graded.

$$x_6 \succ x_1 \succ x_5 \succ x_3 \succ x_2 \succ x_4$$

**STEP: 5**

$x_6$ is the most determinative criterion.

## 6. Conclusion

Based on the group decision making, finally we decided that the lack of proper aeration and drying capabilities is the most critical factor. Aeration and drying capabilities comforts the duration of food grain for a long time. Storage is a process in post-harvest activities which is mainly for human consumption. So, we need to select best storage methods and follow the procedure at right time to control the food grain losses.

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