



Fuzzy based multi-criteria method for sustainable green chamber farming practices

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ABSTRACT

Ranking of vegetable cash crop is an important factor in the sustainable green chamber farming practices. In sustainable farming, a careful strategy based on the multi-criteria decision making is required. The present research stresses the cash crop ranking in the Saudi Arabia and takes into account wide standards linked with sustainable green chamber vegetable cash crop harvest. Considering the specialists' opinion and wide-ranging review of the literature, important criteria connected to sustainable green chamber agricultural practices apply for cash crops harvest. The twelve important criteria were chosen based on environmental conditions, social, economic and nutrient of soil for ranking the vegetable cash crops in the green chamber system modelled to attain the sustainability for the vegetable cash crop production. A mathematical model has been developed keeping in account the fuzzy-based multi-criteria method (FMCM). The model will also help the different stakeholder involved in the green chamber harvesting system and ministry of agriculture to develop the policies related to sustainable green harvesting practices and also improve the self-sufficiency of the farming sector subsequently improve the national gross domestic product.

Key words: Crop ranking, Fuzzy-TOPSIS, Sustainable farming, Vegetable cash crop

Since the late 1970s, the worldwide agricultural production has increased much faster than the population in recent decades, leading to a steady increase in per capita agricultural output and a steady drop in world prices for most agricultural commodities (FAOSTAT 2006). This was mainly achieved by a technological revolution that increased yields by advanced technology inputs—irrigation, improved seeds, pesticides, fertilizers and mechanized machineries. Not all countries have shared the success of agriculture production. In particular, Saudi Arabia could not increase its agricultural production in order to keep pace with population growth.

In Saudi Arabia, a wide range of vegetables are grown, which are very important as high-value cash crops for farmers. Sustainable farming practices can help to increase yield efficiently. Sustainable agriculture includes environmental, economic, social aspects for improvement of human society, animals and the environment. Multi-Criteria Decision Making (MCDM) methods are becoming popular in sustainable agriculture. MCDM methods have inherent properties that make it practical. Some of these properties (Belton and Stewart 2002) are—it seeks to take explicit account of multiple, conflicting criteria (objectives), helps

to structure the management problem, provides a model that can serve as a focus for discussion and offers a process that leads to rational, justifiable, and explainable decisions. The enhanced sustainable farming activities and fuzzy based multi criteria decision making model (FMCM) can help to increase yield in as viable manner. Nambiar *et al.* (2001) developed an index to obtain sustainability factors for the important socio-economic and ecological criteria. Rezaei-Moghaddam and Karami (2008) developed AHP based model for different criteria in sustainable agricultural practices. For the crop system in India River basin a fuzzy based decision model is developed by (Gupta *et al.* 2000). Sydorovych and Wossink (2008) examined and analyzed economic, social and environmental parameters. The green chamber's increased productivity can help increase the profitability, professional aspects and self-sufficiency of agricultural activities.

The current research was carried out to provide a comprehensive framework for sustainable farming practices covering different criteria in the selection of green chamber vegetable cash crop and to provide Fuzzy-Multi-Criteria method based on qualitative and quantitative criteria for sustainable farming practices for the green chamber vegetable cash crop. The fuzzy TOPSIS methodology used in the present problem helps to derive crop selection compared to other MCDM methods, such as the Analytic Hierarchy Process (AHP), in which the derived weights are based on criteria comparisons.

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MATERIALS AND METHODS

Framework for Cash Crops Grown in Green Chamber Farming and Ranking: A framework has been developed for the selection of vegetable cash crops. On the basis of an in-depth review of the literature and the opinion of experts, 12 criteria and 5 vegetable cash crops for sustainable green chamber farming practices have been identified. In the studied region (Abha KSA), the most of the vegetable cash crops used for annual consumption in the food sector, i.e. Green pepper, Cucumber, Tomato, Okra, Egg Plant are grown in this region. Farmers can therefore meet their annual vegetable needs and generate additional income for sustainability and future agricultural practices. Thus, the selected vegetable cash crops in the sustainable green chamber farming practices are better off with climate factors, available resources and the economic consideration of farmers. The selected criteria are assessed on the basis of their importance in sustainable farming practices using triangular fuzzy numbers (TFN). Based on the opinion of the experts, the weight of 12 linguistic criteria is established. TFN is synthesized later to obtain the Best Nonfuzzy Performance (BNP). In sustainable green chamber farming practices, alternative vegetable cash crops are assessed on the basis of selected criteria for sustainable farming practices. The fuzzy-TOPSIS approach used to rank the green chamber harvests have been established that meet the sustainability of agricultural practices. The adopted framework is shown in Fig 1.

Multi-Criteria Decision-Making Using Fuzzy Sets Theory: The basic introduction of fuzzy set theory is mentioned in Zadeh 1970.

FMCM Methods : There are two methods which were used in fuzzy multi-criteria methods (FMCM) these methods having their own advantage and disadvantage.

The Fuzzy TOPSIS Method: The system approach based modeling for green chamber harvesting is suggested using fuzzy TOPSIS to rank the vegetable cash crops under KSA circumstances for sustainable farming. The first level uses twelve factors selected on specialists' feedback and detail (analysis of the works) listed as irrigation cost per unit area of the land, harvesting, value of the harvested vegetables, demand of the harvested vegetables, facility of the harvested vegetable storage, availability of water, quality suitability of water for irrigation, nutrition value of soil, procedure

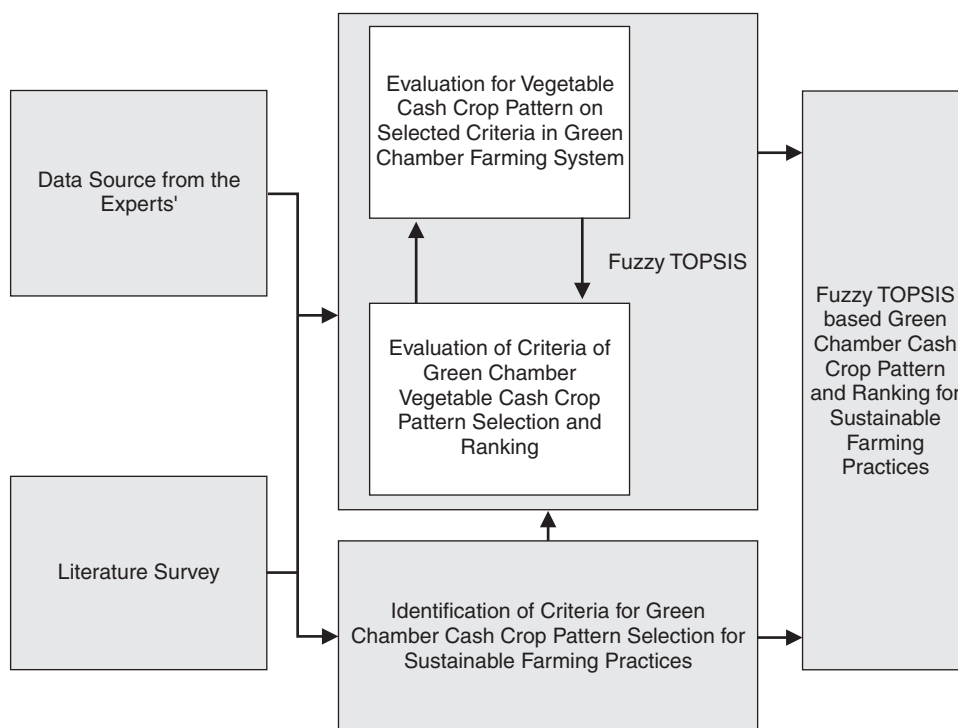


Fig 1 Fuzzy TOPSIS based framework for green chamber cash crop pattern selection and ranking

used for irrigation system, consumptive use of water (ET), climatic conditions. In the second level five vegetable cash crops (Green pepper, Cucumber, Tomato, Okra, Egg plant) to rank the vegetable cash crop harvest. The survey questionnaire circulated among four experts to get their opinion and have been evaluated to rank the vegetable cash crop harvest for the sustainable agricultural procedures. In order to form the comparative importance of each factor the questions were framed. Wang and Chang (1995) advised five verbal variables adopted here were very high (VH), high (H), medium (M), low (L) and very low (VL) along with the TFN values as (7/10,9/10,10/10), (5/10,7/10,9/10), (3/10,5/10,7/10), (1/10,3/10,5/10) and (0/10,1/10,3/10). For sustainable green chamber harvesting the crops were ranked by using the weights and their relative importance. In order to find the presentation of each vegetable cash crop harvested the model questions ranked as Green pepper, Cucumber, Tomato, Okra, Eggplant represented as A1, A2, A3, A4, and A5 respectively.

Preparing the Fuzzy Matrix for Ranking of Green Chamber Harvest: For available m options of Green chamber vegetable harvest, k experts and n factors the following equation describes the algorithm of green chamber harvest to rate the specific crops as a policy issue for harvesting purposes as below mentioned equation (1).

$$\tilde{D} = \begin{bmatrix} A_1 & a_{11} & a_{12} \dots & a_{1n} \\ A_2 & a_{21} & a_{22} & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_3 & a_{m1} & a_{m2} \dots & a_{mn} \end{bmatrix} \quad i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (1)$$

Here A_1, A_2, A_m options available are, viz. $C_1, C_2, \dots, C_n$ are the sustainability factors, $\tilde{D}_{ij}$ denotes the ranking

of the option A_i with regard to factor C_j assessed by k professional. The TFN were used and the mean value is adopted to manage the subjective professional opinion.

To incorporate the fuzzy performance score $\tilde{X}_{ij}$ for k professional for given criteria,

$$\tilde{X}_{ij} = \frac{1}{k} (\tilde{X}_{ij}^1 + \tilde{X}_{ij}^2 + \dots + \tilde{X}_{ij}^k) \quad (2)$$

Where, $\tilde{X}_{ij}^k$ represents alternative A_i for a selected factor C_j assessed by the k^{th} choice maker and $\tilde{X}_{ij}^k = (a_{ij}^k, b_{ij}^k, c_{ij}^k)$.

Normalization of the Fuzzy Decision Matrix for Green Chamber Vegetables Cash Crop Pattern Selection: To select Green chamber vegetable cash crops pattern were normalized. Linear scales transform normalization function has been approved. To keep the property that the ranges of normalized TFN numbers is included in $[0, 1]$. If $\tilde{R}$ gives the normalized fuzzy decision matrix, then

$$\tilde{R} = [\tilde{r}_{ij}]_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (3)$$

$$\text{Where, } \tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^+}, \frac{b_{ij}}{c_j^+}, \frac{c_{ij}}{c_j^+} \right)$$

$$C_j^+ = \max_i C_{ij}$$

Formulation of Fuzzy Choice Matrix for Green Chamber Vegetables Harvest: Taking the various weight of each criterion, considering the different weight of individual factors, the weighted fuzzy choice matrix was estimated by getting the product of weights of valuation factor and the entries in the fuzzy choice matrix. The fuzzy choice matrix is given as follows equation 5:

$$\tilde{v} = [\tilde{v}_{ij}]_{m \times n}, i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (5)$$

$$\tilde{v}_{ij} = r_{ij} \otimes \tilde{w}_j \quad (6)$$

In this $\tilde{w}_j$ is the weight of factor C_j found as in equation 7

$$\tilde{w}_j = \frac{1}{k} (\tilde{w}_j^1 + \tilde{w}_j^2 + \dots + \tilde{w}_j^k) \quad (7)$$

In this k is the professional number of the policy group and $\tilde{w}_j^k$ signifies the fuzzy weight of j factor assessed by the k professional.

Estimation of Positive and Negative Point: The positive and negative point in the range of $[0, 1]$ in fuzzy environment is written as follows:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots, \tilde{v}_n^+) \quad (8)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \quad (9)$$

In this $\tilde{v}_j^+ = (1, 1, 1)$ and $\tilde{v}_j^- = (0, 0, 0), j = 1, 2, \dots, n$

Estimation of Positive and Negative points for Each Green Chamber Vegetable Harvest in Fuzzy Environment: The Positive and Negative points for each Green Chamber

Vegetable Harvest in Fuzzy Environment are estimated as follows:

$$d_i^+ = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^+), i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (10)$$

$$d_i^- = \sum_{j=1}^n d(\tilde{v}_{ij}, \tilde{v}_j^-), i = 1, 2, \dots, m; j = 1, 2, \dots, n \quad (11)$$

In this, $d(\tilde{v}_a, \tilde{v}_b)$ signifies the distance between consecutive fuzzy numbers, d_i^+ indicates the alternate distance of A_i and d_i^- is the alternative distance of A_i from the positive and negative points.

Computation of Closeness Coefficient and Prioritize the Available Options: The closeness coefficient (CC) is computed; the available options are ranked, given the choice the decision makers to select best. The formula given below is used to compute the closeness coefficient

$$cc_i = \frac{d_i^-}{d_i^+ + D_i^-}, i = 1, 2, 3, \dots, m \quad (12)$$

The option with cc_i close to 1 depicts the positive ideal reference point (FPIRE) and far from the fuzzy negative ideal reference point. A high CC indicates a good show of the option A_i .

RESULTS AND DISCUSSION

The Green Chamber Cash Crops Pattern Selection of KSA for Sustainable Farming Activities: For sustainable green chamber harvesting of vegetable cash crops the

Table 1 Fuzzy importance weight, BNP and rank of each criterion

Criteria	Fuzzy Importance Weight	BNP Values	Rank
C1 Tariff of the Irrigation Water (TIW)	(0.6600, 0.8600, 0.9800)	0.8333	1
C2 Farming (F)	(0.5800, 0.7800, 0.9200)	0.7600	6
C3 Value of Cash Crop (VCC)	(0.6200, 0.8200, 0.9600)	0.8000	2
C4 The demand for the Cash Crop (DCC)	(0.6200, 0.8200, 0.9600)	0.8000	2
C5 Facility of Cash Crop Storage (CCS)	(0.1400, 0.3400, 0.5400)	0.3400	11
C6 Water Availability (WA)	(0.5800, 0.7800, 0.9400)	0.7667	5
C7 Quality of Irrigation Water (QIW)	(0.5800, 0.7800, 0.9200)	0.7600	6
C8 Texture of Soil (ST)	(0.6200, 0.8200, 0.9400)	0.7932	4
C9 Irrigation Techniques (IT)	(0.5400, 0.7400, 0.9000)	0.7266	8
C10 Consumptive use of Water (CUW)	(0.0400, 0.1800, 0.3800)	0.2000	12
C11 Precipitation (R)	(0.1800, 0.3800, 0.5800)	0.3800	10
C12 Environmental Situation (ES)	(0.3000, 0.5000, 0.7000)	0.5000	9

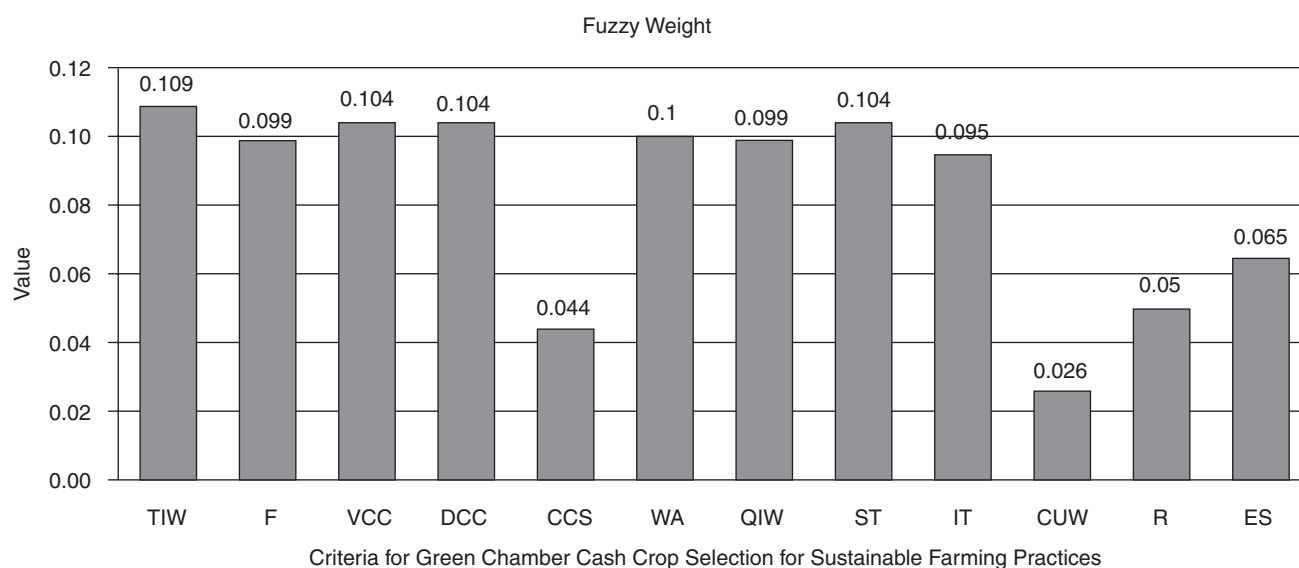


Fig 2 Fuzzy weight of green chamber cash crops

ranking is important in KSA as the soil with natural nutrient and water natural resources important for harvesting is scarce. The method adopted here fuzzy TOPSIS is going to help in general for the sustainable ranking of the crops as a policy issue. A case study related Green Chamber farming harvesting is taken here under the local condition of KSA to rank the vegetable cash crop for sustainable harvesting practices.

Calculation of the Synthetic Importance Weights of Evaluation Criteria: The questionnaire used in data collection by the professional, they facilitated the information required in given format by giving the presences required for green chamber harvesting and ranking the vegetable cash crops. The linguistics variables used (Wang and Chang 1995) are very high, high, medium, low and very low joint with TFN (7/10,9/10,1), (5/10,7/10,9/10), (3/10,5/10,7/10), (1/10,3/10,5/10) and (0,1/10,3/10) correspondingly. As described in equation (8) the fuzzy weight matrices constructed using mean value and depicted in Table 1. The method proposed by (Zhao and Govind 1991) used to defuzzify the TFNs in best non-fuzzy performance (BNP) values are mentioned in Table 1.

The model depicts the ranking in decreasing order Tariff of the Irrigation Water > Value of Cash Crop, Demand of the Cash Crop > Texture of Soil > Availability of Irrigation Water > Farming > Quality of Irrigation Water > Irrigation Techniques > Environmental situation > Precipitation > Facility of Cash Crop Storage > Consumptive use of Water. Greater sign '>' indicates liking over other factors (Fig.2). The model used here gives the fuzzy weights of the twelve important factors selected (0.8332, 0.8000, 0.8000, 0.7932, 0.7666, 0.7600, 0.7600, 0.7266, 0.5000, 0.3800, 0.3400, 0.2000).

Construction of the Fuzzy Decision Matrix: The regression examination of different factors required for ranking the green chamber harvest especially vegetable crops for sustainable farming in the multi-factor decision-making farming cases. The professional opinion involved

in linguistic forms i.e. very good, good, fair, poor and very poor along with TFN. In order to produce distinct decisions the fuzzy performance ranking of individual factors was averaged.

Evaluation of Normalized Weighted and Fuzzy Matrix: By using the linear rule functions the normalized TFN was incorporated in the range [0, 1].

Computation of the Positive and Negative Best Fuzzy Points: The range for triangular fuzzy number is from 0, 1 so the fuzzy positive ideal reference point (FPIRP) and fuzzy negative ideal reference point (FNIRP) are defined as:

$$A^+ = \left[\begin{matrix} (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1), \\ (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1), (1,1,1) \end{matrix} \right] \quad (13)$$

$$A^- = \left[\begin{matrix} (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0), \\ (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0), (0,0,0) \end{matrix} \right] \quad (14)$$

Calculation for the Distance of Each Green Chamber Vegetable Harvest for Sustainable Activities: Equation (11)–(12) are used to calculate the gap of each green chamber vegetable harvest to the fuzzy negative ideal reference point (FNIRP) and fuzzy positive ideal reference point (FPIRP).

Computation of Closeness Coefficient (CC) for Green Chamber Vegetable Harvest: After computing the distance of green chamber vegetable harvest type from positive and negative, the CC can be obtained with Equation (13). CC thus calculated for all green chambers vegetable harvest type is shown in Table 2.

The green chamber harvesting system a mathematical model has been developed keeping in account the fuzzy-based multi-criteria method. The proposed research work will be of great help in green chamber farming of the cash crop production. The proposed fuzzy-based method i.e. Fuzzy TOPSIS has the advantage over the MCDM classical methods because it overcomes the biases and uncertainty in the ranking procedure. In the present situation, the twelve criteria for five green chamber vegetable cash crops ranking and integrated sustainable harvesting in KSA condition

Table 2 Positive and negative distances and closeness coefficients of green chamber cash crops

Cash Crop Alternatives	d_i^+	d_i^-	cc_i	Cash Crop Ranking
Cucumber	6.4747	6.6001	0.505	5
Tomato	6.6104	6.5082	0.496	4
Okra	6.7491	6.3437	0.484	3
Eggplant	7.2002	5.8394	0.448	2
Green Pepper	7.8867	5.0738	0.391	1

was taken into account. The ranking of the green chamber harvested vegetables in KSA conditions: Cucumber > Tomato > Okra > Eggplant > Green pepper. The greater sign represents the choice over the harvested green vegetable crops. The green chamber cash crop vegetables ranked here is excessive stand up.

The process of selecting vegetable cash crop in green chamber for sustainable agriculture is complex in nature. Especially when it is derived under the influence of a large number of criteria that influence sustainability, it poses many challenges. Without sufficient vegetable cash crop production resources, the problem of cash crops harvest becomes more complicated. The present methodology will therefore be of great help to stakeholders in agriculture in these environments. Fuzzy-based methodology has an advantage, as comparison depends on experts' subjective judgment. By using fuzzy-based methods, biases and vagueness in decision-making can be largely overcome. The fuzzy-based multi-criteria method will help farmers and agricultural policymakers to formulate a comprehensive policy for sustainable agricultural practices, which is an ongoing urgent requirement for sustainable agricultural practices worldwide. Future prospects of the research may include adaptation and mitigation options for better sustainable agricultural practices resulting from climate change problems in order to improve decision

making process.

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