Chapter 6

CROP PATTERN SELECTION- A COMPARATIVE ANALYSIS OF MOORA AND TOPSIS WITH FUZZY-TOPSIS

The chapter discuss a different set of crops as an alternative and the attributes based on which the feasibility of crop combination is defined in a decision space. Multi-Criteria Decision-Making technique is employed to assign a rank/ preference to the alternatives. MOORA (Multi-Objective Optimization by Ratio Analysis) and TOPSIS (Technique of Order Preference by Similarity to Ideal Solution) is employed for the evaluation. A comparative analysis of the results is done.

6.1 Introduction

Agriculture is the backbone of the Indian economic system. According to the report of the Food and Agriculture Organization (FAO), nearly 70% of the country's population is engaged in agriculture and its related sectors. The sector is an essential contributor in GDP (Gross Domestic Product) and economic development of a country. In 2017-18 India is emerging as the largest producer, consumer, and importer of pulses across the world. Apart from its primary role of food production it contributes to viability of the rural areas by ensuring food security and preserves environmental health too. These additional streams of the sectors are termed as non-trade as economically, it does not contribute to the sector. Since we live in an era of theory-based actions hence, there is a need for conceptual agricultural model (Rezaei-Moghaddam & Karami, 2008).

With the increase in population there is a boost in agricultural demand. Consequently, there is an exponential growth in demand and supply ratio too. Because of growing population, the demand and supply ratio laid a pressure on sustainable farm practices. However, the food demand increases with the population growth thus, there is a need for ample crop production with desired yield rate and sustainability. Due to technological enhancement, there is a favorable paradigm shift in farm production. Sustainable farm practice provides a solution to such challenges in the sector. "Sustainable Agriculture" practice integrates social, economic and ecological aspects that provide a space for the optimized boom or improvisation in a sector. The economic approach covers crop production cost, yield and crop productivity. Increased crop yield and productivity boost up the economy leading it towards the self-reliant sector. According, to the PRS Legislative Report, (2020) agriculture sector showed a growth of 6.3%

in 2016-17. A social aspect focusses for yield enhancement and the ecological aspect covers sustainable practices.

The social, ecological, and economy are the three most important parameters in examining the cropping pattern in a region. To overcome the challenges faced by the sector a model for cropping pattern and crop combination is taken under investigation. Earlier (Chapter 3) it is discussed that crop pattern and crop production are two important aspects of agriculture. Furthermore, the sector being complex deals with the multiple criteria simultaneously as the crop productivity does not depends on any single parameter. Moreover, in crop planning there are some conflicting objectives that need to be considered simultaneously thus, making it difficult for decision-makers to opt for desired alternatives among the available one. Different definition is being quoted by different authors to explain the cropping pattern (Zeng et al., 2010c). (J. Huang et al., 2012; Wineman & Crawford, 2017c) defines crop pattern as a system that determines the crop allocation on the basis of climatic conditions. Cropping pattern is expressed as a process of optimal utilization of resources (Biswas & Pal, 2005; Manos et al., 2010).

Along with crop patterns, farm location too plays an important role in determining crop productivity. To evaluate the sustainability of the rice production system, an index was developed by (Gowda & Jayaramaiah, 1998) with nine indicators listed under three dimensions of sustainability i.e. economic, social, and ecological. The farmers were further grouped on the basis of the source of the irrigation. Indexing of the parameters/criterion is carried out to promote agricultural sustainability. Indexing provides a real estimation of a system. (Nambiar et al., 2001) developed a sustainability criterion for the defined index. These indices may vary depending on input and output costs. So far, the indexes defined by the researchers consider only biophysical measures and do not permit comparisons over a different region, management activities and agronomical conditions. Thus, there is a need to develop an index that considers all the elements of agricultural sustainability.

From the literature reviewed and by interviewing the farmers in a region it is concluded that; crop production depends majorly on topographical and climatic factors. (Qureshi et al., 2018) explain that the crop production significantly depends on 7M’s that are: management, manpower, machine, material, method, capital and marketing. Among all these parameters, management is the most important factor that directly impacts or influences crop production. Then comes, manpower that includes both skilled and unskilled labour that contributes to enhance the yield. Machines and material include all the mechanized inputs that reduce the losses due to poor operational farm practices. However, along with the seeds, fertilizers manure, compost, the scheduling of irrigation plays a crucial role in optimizing crop production. (Pereira et al., 2013) provides an optimal irrigation plan to multiple crop pattern systems. However, if all these parameters are managed judiciously then came the last and the most important aspect i.e., marketing. Some of the parameters among these 7M's are scarce, thus, imposing a challenge for sustainable integrated farm practice.

Another major aspect in farm planning is financial constraint. During the farm survey financial issues emerges as one of the most common constraint faced by the farmer in a growing season. Depending on the capital they need to plan their fields for the entire season. Furthermore, it is observed that there are many crops that is not cultivated or practiced by farmers due to financial constraint.

Thus, from sustainability perception there is a need to take a strategic decision that will contribute to maximize the revenue by practicing optimal crop pattern. The selection of an optimized pattern with a sustainable approach craters a way of high productivity, reduces the risk and uncertainty involved in a sector. Cropping scenario in Rajasthan is based on three major climatic variations or seasons that include Kharif (July-October), Rabi (October -March) and Zaid (March-July). Zaid season is the short cultivation period between Rabi and Kharif season. The crops in the aforementioned season are practiced as a single crop, mixed crop or the crop is cultivated in rotation with another crop i.e., multiple-cropping. The selection of appropriate crop pattern is quite complex due to change in socioeconomic conditions, resource availability & accessibility that varies from region to region.

The region focussed for analysis showed an intensified crop production particularly in Rabi season. Thus, MCDM techniques is used to evaluate the available crop alternative in a decision space on the basis of the different set of criteria for the crops cultivated in Rabi season only. However, due to inadequate availability of water resources in Kharif season small dataset is available. Hence, dataset does not provide a complete information for the criteria defined in a decision space, making it difficult to evaluate the crop preferences. Thus, only Rabi season crops were identified and evaluated.

Moreover, along with crop pattern the crop yield is a challenging issue for the sector. Dependency on climatic conditions like rainfall, humid content, temperature, rate of evaporation and precipitation make it complex to investigate the parameter that largely influences the yield. International researchers were trying to identify the agricultural production by developing genetically modified variety of hybrid seeds that will tolerate both temperature and precipitation variation in the environment.

Further, the socioeconomic aspect and scarce availability of resources made farmers depend on state-sponsored subsidies. Thus, from the aforementioned discussions it can be interpreted that not only environmental, topographical, operational, and climatic parameters impact the cropping pattern but there are some other parameters too that influence the crop pattern in a region. There are many factors in sustainable farming that are conflicting in nature. Thus, to get an optimized result there is a need to consider the criteria carefully. Criteria such as literacy rate, environmental and climatic conditions, water availability, operational farm practices play a crucial role in promoting sustainable farm practices. Thus, selecting a feasible set of crops became a challenge for growers to generate optimal farm revenues.

Researchers employ different mathematical and statistical tools to evaluate the optimality of the decision variables. Most of the researchers now-a day's use hybrid MCDM techniques to evaluate the land suitability for different crop (Joerin et al., 2001; Mustafa et al., 2011). Thus, MCDM techniques applied in the chapter will provide a direction to the growers to opt for the crop based on the rank order assigned. Many researchers use various multivariate tools and techniques to support policy-makers and growers. (Bournaris et al., 2015; Xevi & Khan, 2005c) focusses their work to support the growers with water allocation management in their fields. (Rehman & Romero, 1993) explains the need to maintain a balance among multiple objectives and goals to be achieved in agriculture scenarios. This perspective is true irrespective for the tier at which decisions is made and applies equally to all the growers and policymakers based on their challenges and constraints.

The chapter focusses on the crop selection pattern that will consider the comprehensive criteria for sustainable farm practices. Based on extensive literature review, the sustainable agricultural practices in the Rabi season are identified. Multi-Criteria Decision-Making technique is adopted by considering twelve criteria and eight crops as an alternative cultivated in the region. MCDM techniques evaluates an appropriate alternative with respect to multiple criteria in decision space. These alternatives are initially evaluated with respect to each other based on criterion, which are then aggregated into overall performance of an alternative. However, in MCDM model selection of proper weighting method plays a significant role in solving a problem. Thus, Standard Deviation (SDV) approach is used to assign weights to an attribute.

Formulation and the technique adopted will support the farmers in a region to choose the crops based on their preferences and defined criterion. MOORA and TOPSIS approach is used to determine the crop preference for optimal results.

6.2 Pedagogy for Crop Selection Pattern

On the basis of literature reviewed, survey and by interviewing the farmers 12 criteria and 8 alternatives were identified for sustainable farm practice to develop a framework for the cropping pattern in Rabi season. In Rabi season major crops cultivated include: wheat, barley, gram, Rabi cereals and pulses along with mustard, spices and vegetables. Crops of only Rabi season were taken under consideration as in this season-high percent of arable land is under cultivation as compared to that in Kharif and Zaid season.

According to report by National Bulk Handling Corporation (NBHC) in 2018-19 the production of cereal, pulses and oilseeds is declined by 9.72%, 10.12% & 3.76% respectively than 2017-18. However, wheat production has shown a marginal rise of 0.64% than 2017-18.

In Rabi season climatic conditions, available resources and economic parameters are quite favorable to support the sector. The criterion is selected by evaluating the major parameters that pose a challenge in crop cultivation. TOPSIS and MOORA method is used for analysis. The framework followed for evaluation is illustrated in Fig. 6.1.

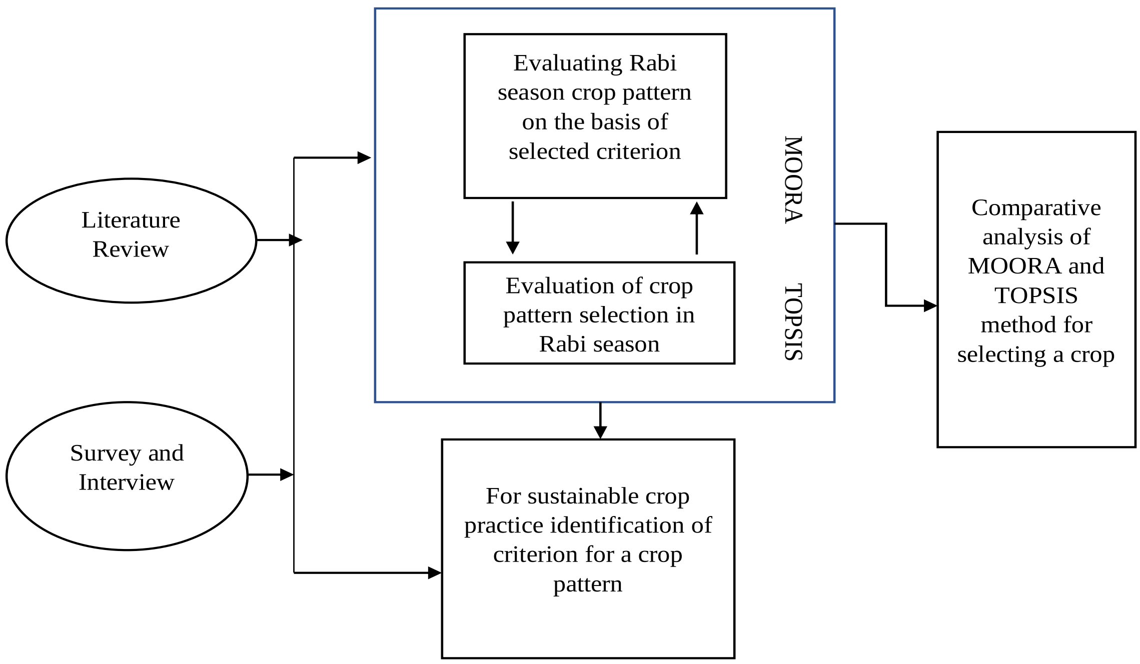

Fig. 6.1: Framework for MOORA and TOPSIS- for Crop Selection

The proposed methodologies are used for selecting a cropping pattern for sustainable agricultural practices. Fig. 6.2 represents the stage-wise procedure for sustainable agricultural practice. Stage 1 depicts the 12 criteria taken for formulation and stage 2 represents the set of crops. The experts were concerned for the validation of the questionnaire that is used as a tool to analyse the cropping scenario adopted by the growers. The questionnaire is based to evaluate the challenges and the cost involved in each farm operation during cultivation/growing period. Water cost, cultivation cost, evaporation, crop value, crop demand, water quality, soil texture, evapotranspiration, crop storage cost, water availability and environmental conditions were taken as a criterion to evaluate the overall crop preference. The questionnaire is subjective in nature thus, enables us to determine some hidden risk parameters too, such as pest attack, criteria for crop planning based on the previous season, procurement of seeds, and fertilizers. For evaluating the criteria such as water quality, evapotranspiration, soil texture secondary data is used.

After establishing relative importance weights are assigned to the different criterion. 8 crops majorly cultivated in a region is taken as an alternative. Though the farm was supported by some sub-crops too due to lower production those were not included for evaluation. (Zelany, 1974) explains that the attributes in a decision space are closely related to alternatives. Any elimination or change in alternatives will lead to change in ranking or performance/ choice of alternative as it might give more importance to some other criterion. (Hwang & Yoon, 1981) argues that the selected alternative must be closer to a positive ideal point and farthest from a negative ideal point. Thus, an alternative crop must be close to a positive ideal point and far from a negative ideal point. The techniques used to solve the problem is discussed in the following sections.

The results of MCDM methods are sensitive to criteria weights. Thus, selecting a weighting method to solve MCDM problem is of paramount importance. The selection of assigning weights to an attributes depends entirely on a decision problem. (Hajkowicz & Higgins, 2008b) use 5 weighting methodologies to weight 6 economic, environmental and social criteria. Comparative analysis is carried out to access an appropriate value of the weights that will help to clarify the decision problem. The results of the study conclude that in general, the same value of the weights is assigned to the attributes with different methods by decision makers. However, most of the researchers use mean weight technique for assigning values.

In MCDM model it is undesirable to rely on any one weighting method. (Eckenrode, 1965) explain that none of the MCDM techniques is superior than other, the method applied to any problem depends on scale (ordinal, nominal, interval or ratio) used for evaluation. Thus, on the basis of the measurement scale the method used to evaluate a problem of assigning weights to the attributes is decided. Fig. 6.2 represents the attributes and the alternatives that were taken under study.

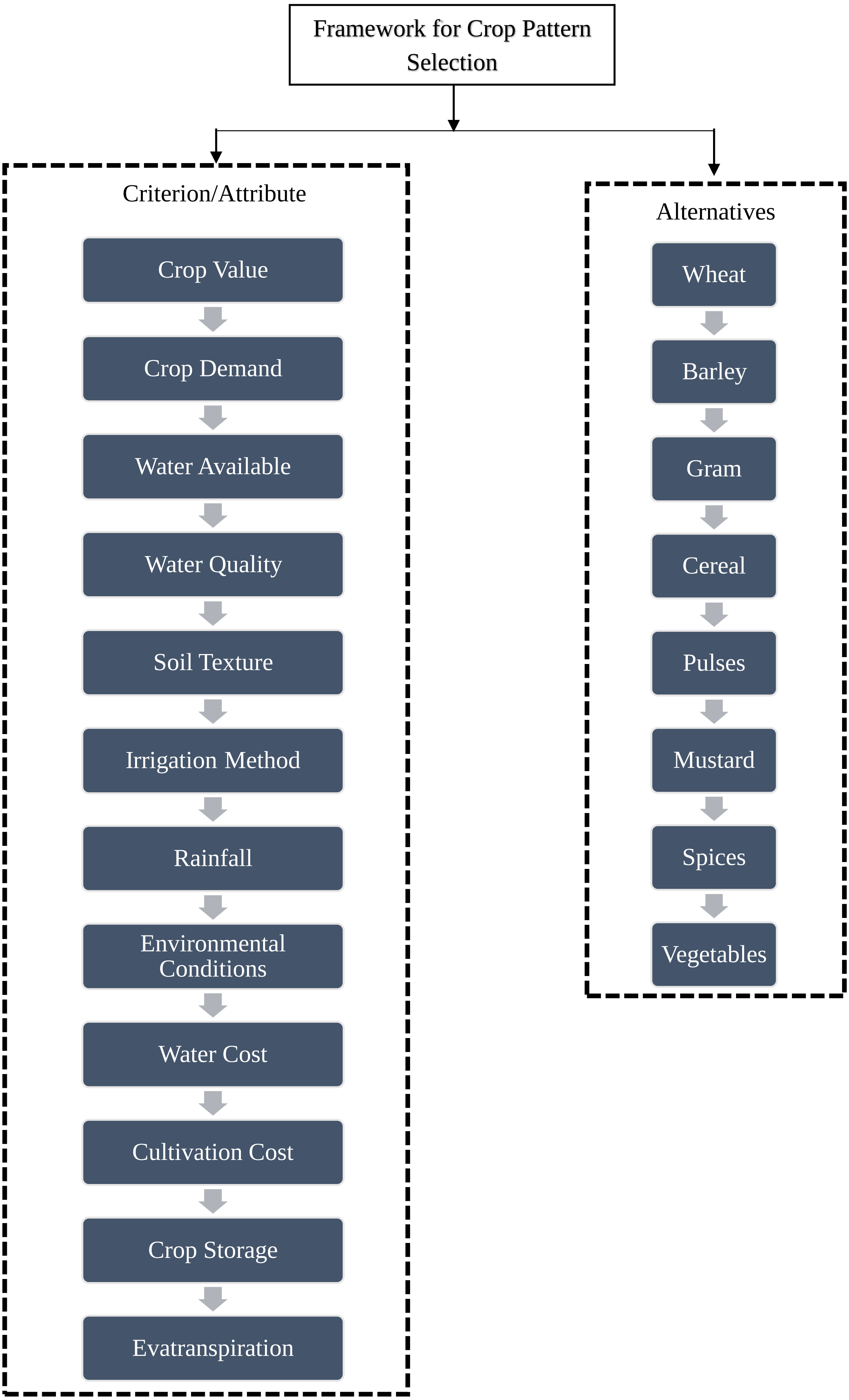

Fig. 6.2: Framework for Crop Pattern Selection of Rabi Crops

6.3 Methodology

6.3.1 Classification of Weighing Method

(Pöyhönen & Hämäläinen, 2001; Stewart et al., 1992) proposed a different technique to assign weights to the criteria. The simplest approach to assign weights to the criteria is "equal weights method" that assigns the same value to all the criteria considered. Assigning weights to the criteria is one of the most crucial aspect in multi-criteria analysis as the final output of the analysis majorly depend on it. The purpose of assigning the weight is to assign cardinal or ordinal values to different criteria to evaluate their importance in decision making analysis. These values are then used to evaluate the optimized and appropriate alternatives among the available choices. According to Zardari et al. (2015) classification of weighing method is based on internal and external parameters that are further sub-categorised as shown in Fig. 6.3.

The methodology of assigning equal weight to the criteria is been criticized by the statisticians, as this approach ignores the relative importance among the criteria and treats all the criteria equally important. Thus, to overcome this challenge the rank order weighting methodology comes into play and criteria weight are distributed among the criteria as:

$$w_1 \geq w_2 \geq w_3 \ldots \geq w_n \geq 0$$

$$\sum_{j=1}^{n} w_j = 1 \qquad (6.1)$$

The rank-order method is further classified into subjective weighting method, objective weighing method (Fig. 6.4) and combination weighting method by (J.-J. Wang et al., 2009). In subjective weighting method criteria preference depends completely on decision makers. Contrarily, in objective approach; weights assigned to criteria is mathematically driven based on the initial data set. However, subjective weighing method is more efficient for precise evaluation as compared to that of objective method. Since the weights assigned to criteria depends on decision makers knowledge or judgement thus, none of the two methodologies is perfect. Thus, it is evaluated that an integrated approach is more effective than an individual method.

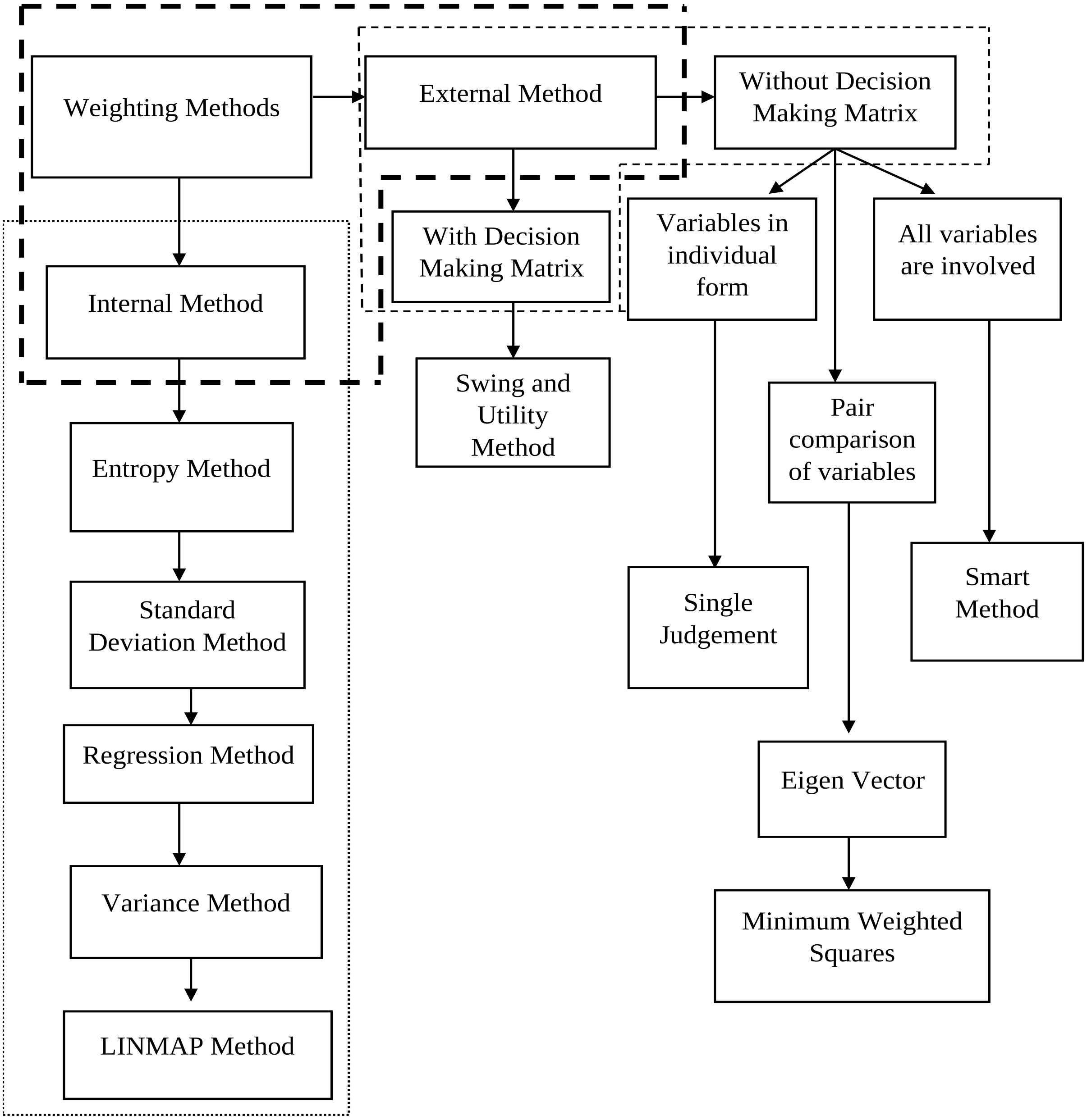

Fig. 6.3: Systematic diagram for calculating weights

All these weighting methods have its own advantage and disadvantage. However, different criterion weights are produced by different weighting methods. Since, MCDM techniques were sensitive to criteria weights thus, choosing an appropriate weighting methodology is a crucial step in analysis. In this chapter we use Standard Deviation Method to assign a weight to different attributes.

6.3.1.1 Standard Deviation Method

The weights associated with each criterion were evaluated by standard deviation method. Standardization is carried out to transform the different units into a same common measurable unit in order to improvise the optimal results by comparing the weights.

$$x'_{ij} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \qquad 1 \leq j \leq n \qquad (6.2)$$

N is the matrix after normalization max x_{ij} and min x_{ij} is the maximum and minimum value of the decision criteria of evaluation j. The values of all the criteria after normalization must lie between 0 and 1. The standard deviation of each value is calculated as follows:

$$SDV_j = \frac{\sqrt{\left(x_{ij} - x''_{ij}\right)}}{\sqrt{m}} \qquad (6.3)$$

m is the number of alternatives available in a system and x''_{ij} denotes mean value of the normalised criterion. After we get normalised matrix, next is to evaluate the weight.

$$Wj = \frac{SDVj}{\sum_{j=1}^{n} SDVj} \qquad (6.4)$$

Once the weights are assigned to the criterion the alternatives are ranked by using different MCDM techniques such as WSM, WPM, GRA, TOPSIS, MOORA and so on. Table 6.1 indicates the weights assigned to different attributes in decision space.

Table 6.1: Calculation of Weights of evaluation criteria for Rabi Crops

Criteria	**Description of criteria**	**Weight**	**Rank**
C_1	Crop Value	0.104735	1
C_2	Crop Demand	0.102525	2
C_3	Water Available	0.066653	12
C_4	Water Quality	0.070206	11
C_5	Soil Texture	0.078057	8
C_6	Irrigation method	0.080404	5

C_7	Rainfall	0.079285	6
C_8	Environmental conditions	0.07918211	7
C_9	Water Cost	0.089779203	4
C_{10}	Cultivation Cost	0.096961063	3
C_{11}	Storage Cost	0.078052	9
C_{12}	Evapotranspiration	0.074162	10

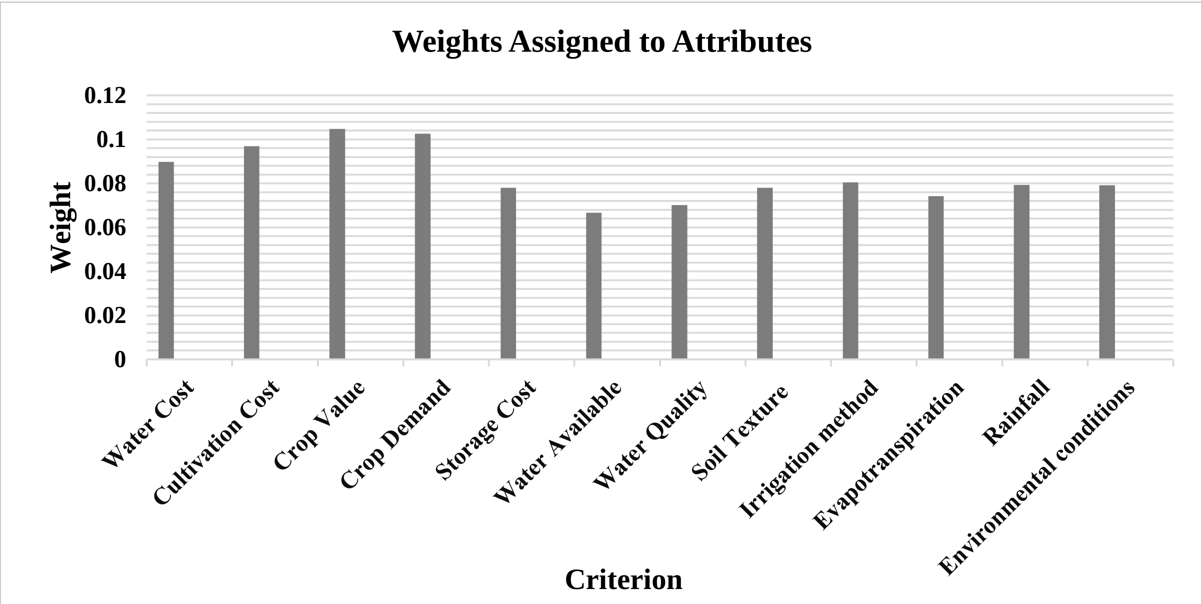

Fig. 6.4: Criteria and Weights Assigned to Attributes for Rabi Season Crop Pattern Selection

6.3.2 Role of Assigning Weights in MCDM Method

Many MCDM methods use criteria weights for their evaluation. To evaluate overall performance/ preferences of an alternative, weights assigned to the criterion plays a crucial role. Because of different aggregation rule different methods of allotting weights to an attribute is practised. Thus, different weighting methods have been developed. It is important to choose an appropriate technique for assigning weights to the attributes by decision makers. Classification of weighting methods is shown in Fig. 6.5. Relative weights assigned to the attributes helps to evaluate the importance of different criteria in decision-making.

Weighted Sum Model (WSM) is one of the methods that is widely used by decision makers. Due to some lacunae of the tool WSM is modified by WPM (Weighted Product Model). In

1977, analytical hierarchy process (AHP) is proposed by Saaty, which is one of the most popular tools in MCDM (Odu, 2019) was introduced.

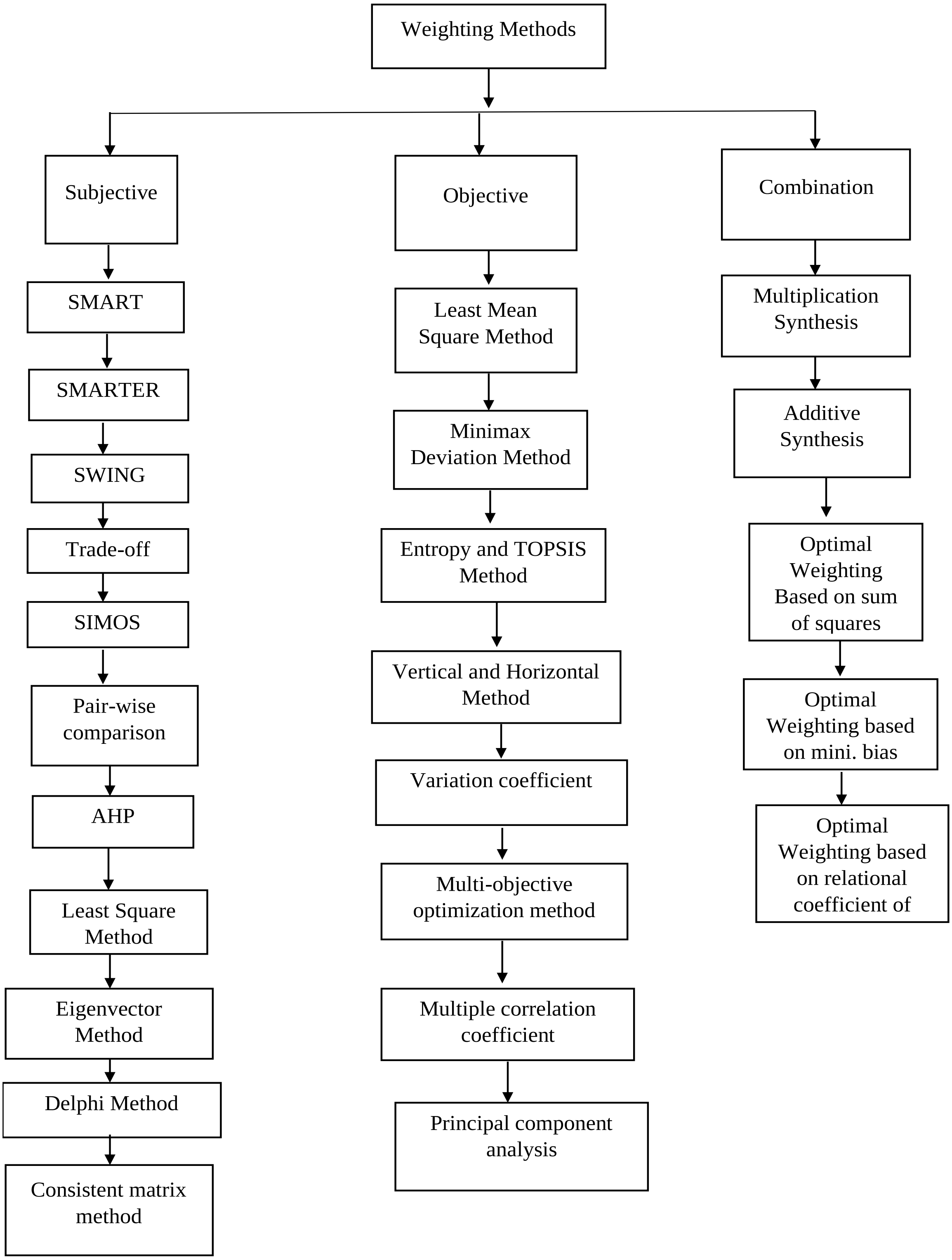

Fig. 6.5: Classification of Weighting Method in Multi-Criteria Decision Making

6.4 Construction of Decision Matrix for Rabi Season Crop Selection

With m alternatives for Rabi crops and n selection criterion a Rabi season crop pattern decision matrix D is described by equation [A].

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots\ldots & C_n \end{array} \\ \begin{pmatrix} x_{11} & x_{12} & \ldots\ldots & x_{1n} \\ x_{21} & x_{22} & \ldots\ldots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \ldots\ldots & x_{mn} \end{pmatrix} \end{array} \qquad [A]$$

Where, $A_1, A_2, \ldots, A_m$ are the alternatives available in decision space and $C_1, C_2, \ldots, C_n$ are the criteria or attributes. x_{ij} represents the performance rating of i^{th} alternative with respect to j^{th} criteria; w_j is the weight of j^{th} attribute; m is the number of alternatives available and n is the number of criteria in decision space.

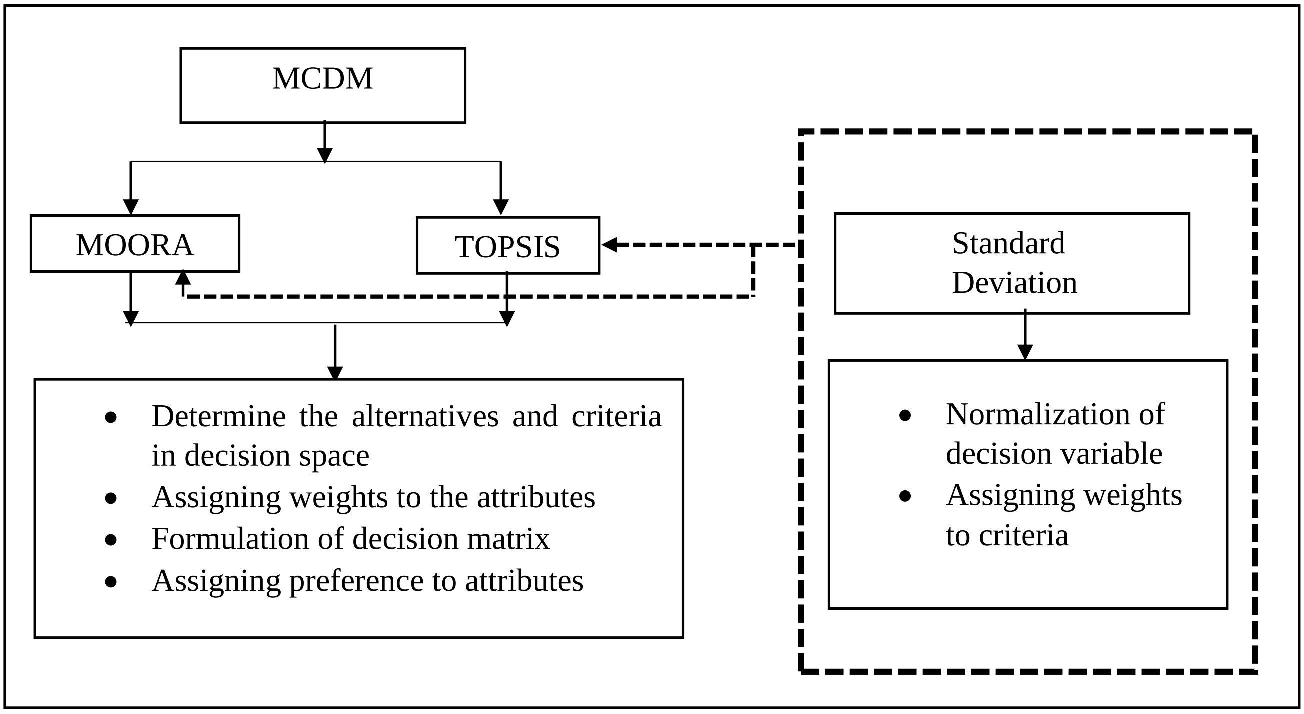

Fig. 6.6: Methodological Framework

6.5 MOORA Method

Multi-Objective Programming or Multi-Criteria Decision Making is the process of simultaneously optimizing two or more conflicting objectives subject to a certain constraint. The Multi-Objective Optimization by Ratio Analysis (MOORA) is one of the multi-criteria tools to solve a complex decision-making problem. First step is to construct a decision matrix that shows a performance of different alternatives with respect to various attributes (Rajesh Chakraborty et al., 2016).

Step 1: To determine the objective and to identify the set of alternatives and criteria decision matrix is formulated as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \ldots\ldots & C_n \end{array} \\ \begin{pmatrix} x_{11} & x_{12} & \ldots\ldots & x_{1n} \\ x_{21} & x_{22} & \ldots\ldots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \ldots\ldots & x_{mn} \end{pmatrix} \end{array} \qquad [A]$$

$$W= \left[w_1, w_2, w_3, \ldots\ldots, w_n \right] \qquad (6.5)$$

$$\sum_{j=1}^{n} w_j = 1 \qquad (6.6)$$

Where, A_1, A_2, …., A_m are the alternatives available in decision space and C_1, C_2, …, C_n are the criteria or attributes. x_{ij} represents the performance rating of i^{th} alternative with respect to j^{th} criteria; w_j is the weight of j^{th} attribute; m is the number of alternatives available and n is the number of criteria in decision space.

Step 2: In MCDM models, criteria in decision space has different measures of unit. In order to evaluate all the criteria on the same scale normalization procedure is performed. The method of normalizing decision matrix (Table 6.2) is as follows:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (5.7)$$

Step 3: Formulate weighted normalized decision-matrix. Weights associated with different attributes is calculated by standard deviation method explain in previous section. Table 6.3 illustrates weighted normalized matrix.

Weighted normalised matrix $N_{ij} = w_j * n_{ij}$ (6.8)

Step 4: For each alternative calculate, overall benefit and cost criterion. The overall rating is calculated by summing up all the beneficiary criterion and denoted as:

$$S_i^+ = \{x_{ij} | \, j \in J^{Max}\} \qquad (6.9)$$

For cost criteria i.e., for non-beneficiary criterion overall rating is calculated as:

$S_i^- = \{x_{ij} | j \in J^{Min}\}$ (5.10)

Step 5: For each alternative an overall performance index S_i is calculated. It is the difference between overall rating of benefit and cost criterion respectively.

$S_i = S_i^+ - S_i^-$ (5.11)

Step 6: The last step (Table 6.4) is to assign a rank/ select the most efficient alternative. The alternative with highest value of S_i, get the priority.

$R^* = \{ R_i | \max S_i \}$ (5.12)

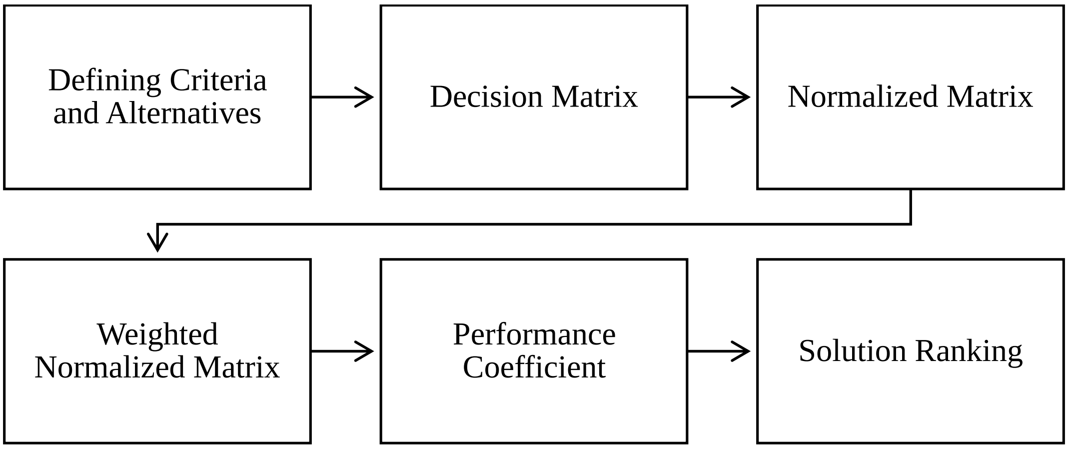

Fig. 6.7: Systematic View of MOORA Method

Table 6.2: Normalized Decision Matrix of Rabi Season Crop

Alternatives	Criterion											
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	0.236462	0.4329	0.318999	0.374425	0.4901	0.375376	0.387594	0.45	0.303196	0.218526	0.567953	0.402167
A_2	0.204934	0.15361	0.243941	0.216772	0.235974	0.154566	0.142798	0.15	0.063831	0.050429	0.395846	0.275167
A_3	0.204934	0.181539	0.131353	0.078826	0.036304	0.044162	0.040799	0.016667	0.015958	0.033619	0.395846	0.021167
A_4	0.204934	0.181539	0.356529	0.256186	0.344885	0.507861	0.346794	0.383333	0.175534	0.218526	0.292582	0.359834
A_5	0.362576	0.293255	0.356529	0.335012	0.127063	0.287052	0.346794	0.216667	0.27128	0.117668	0.395846	0.1905
A_6	0.488689	0.460829	0.506646	0.532078	0.526403	0.24289	0.428393	0.283333	0.526603	0.55472	0.189318	0.486834
A_7	0.488689	0.460829	0.394058	0.453251	0.381189	0.507861	0.469192	0.483333	0.494688	0.55472	0.223739	0.4445
A_8	0.457161	0.460829	0.394058	0.374425	0.381189	0.419537	0.428393	0.516667	0.526603	0.5211	0.189318	0.402167

Table 6.3: Normalized Weighted Decision Matrix of Rabi Crop

Alternatives	Criterion											
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	0.02476587	0.044383	0.021262	0.026287	0.038256	0.030182	0.03069	0.040401	0.029398	0.017056	0.04212	0.031886
A_2	0.02146375	0.015749	0.016259	0.015219	0.018419	0.012428	0.011307	0.013467	0.006189	0.003936	0.029357	0.021817
A_3	0.02146375	0.018612	0.008755	0.005534	0.002834	0.003551	0.003231	0.001496	0.001547	0.002624	0.029357	0.001678
A_4	0.02146375	0.018612	0.023764	0.017986	0.026921	0.040834	0.02746	0.034415	0.01702	0.017056	0.021698	0.028529
A_5	0.03797433	0.030066	0.023764	0.02352	0.009918	0.02308	0.02746	0.019452	0.026304	0.009184	0.029357	0.015104
A_6	0.05118280	0.047246	0.033769	0.037355	0.041089	0.019529	0.033921	0.025437	0.05106	0.043297	0.01404	0.038598
A_7	0.05118280	0.047246	0.026265	0.031821	0.029754	0.040834	0.037152	0.043393	0.047965	0.043297	0.016593	0.035242
A_8	0.04788068	0.047246	0.026265	0.026287	0.029754	0.033732	0.033921	0.046386	0.05106	0.040673	0.01404	0.031886

Table 6.4: Ideal Solution of Rabi Crops

Alternatives	Performance	Crop Ranking
A_1	0.135766	4
A_2	0.063013	7
A_3	0.03027	8
A_4	0.127151	5
A_5	0.115286	6
A_6	0.142535	3
A_7	0.164551	1
A_8	0.153814	2

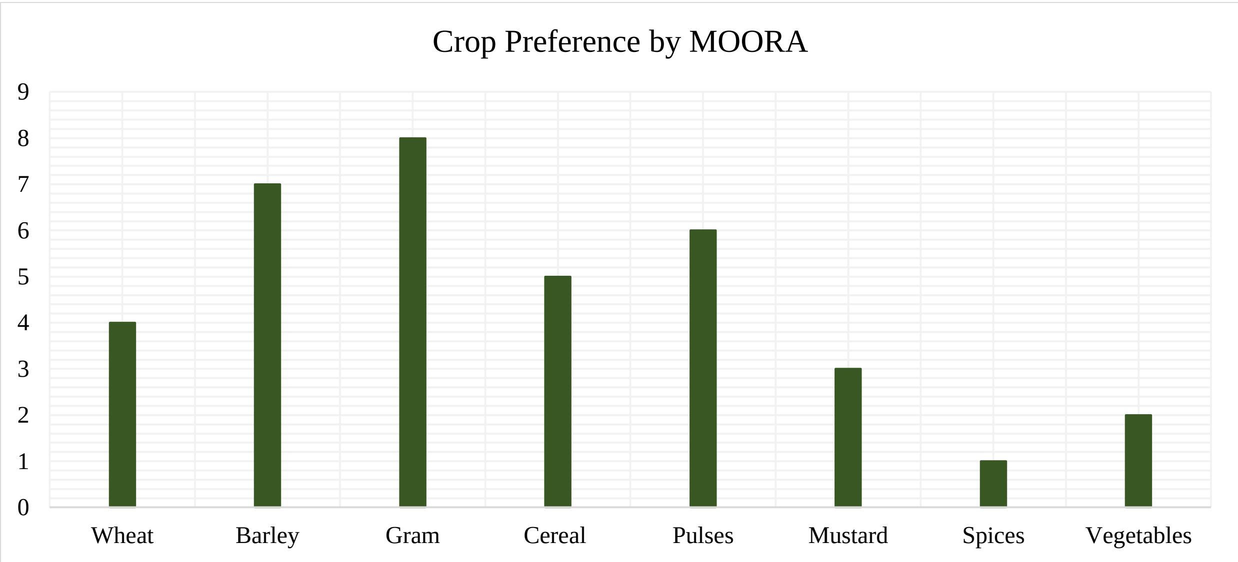

Fig. 6.8: Ranking of Rabi Season Crops based on Performance Index

6.6 TOPSIS Method

Hwang and Yoon (1981) developed a Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The tool evaluates the best suitable alternative by maximizing a distance from negative ideal solution and minimizing a distance from positive ideal solution. Thus, an alternative can be ranked on the basis of their closeness to an ideal solution.

TOPSIS model assumes that each attribute in decision matrix is either monotonically increasing or monotonically decreasing (Hwang & Yoon, 1981) . In simpler words, more is the attribute outcome, the greater will be the preference for "benefit" criterion and lesser to the "cost" criterion. Since all the criterion in decision space are not of equal importance set of weights is assigned to the attributes by the decision makers. The step involved to perform TOPSIS analysis is as follows:

Step 1: To determine the objective and to identify the set of alternatives and criteria. Initial decision matrix is as follows:

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots\dots\dots & C_n \end{array} \\ \begin{pmatrix} x_{11} & x_{12} & \dots\dots & x_{1n} \\ x_{21} & x_{22} & \dots\dots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & \dots\dots & x_{mn} \end{pmatrix} \end{array} \qquad [A]$$

Where, A_1, A_2, …., A_m are the alternatives available in decision space and C_1, C_2, …, C_n are the criteria or attributes. x_{ij} represents the performance rating of i^{th} alternative with respect to j^{th} criteria; w_j is the weight of j^{th} attribute; m is the number of alternatives available and n is the number of criteria in decision space.

Step 2: Converting various dimensions of attributes into one-dimensional attributes by performing normalization.

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (6.13)$$

Step 3: Formulate weighted normalized decision-matrix. Weights associated with different attributes is calculated by standard deviation method explain in section 6.3.1.1.

$$N_{ij} = w_j * n_{ij} \qquad (6.14)$$

Table 6.5 represents weighted normalized decision matrix.

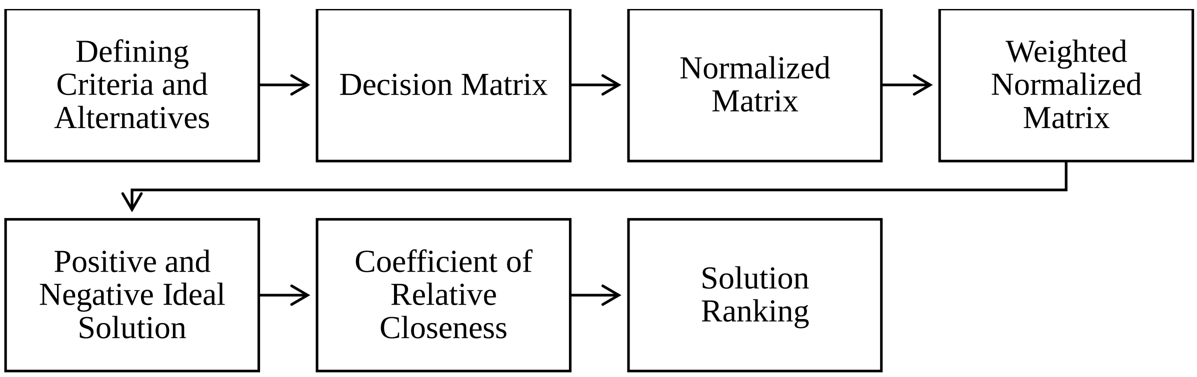

Fig. 6.9: TOPSIS Method

Table 6.5: Weighted Normalized Decision- Matrix

Alternatives	Criterion											
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
A_1	0.024766	0.044383	0.021262	0.026287	0.038256	0.030182	0.03073	0.035632	0.027221	0.021189	0.04433	0.029825
A_2	0.021464	0.015749	0.016259	0.015219	0.018419	0.010216	0.011322	0.011877	0.005731	0.00489	0.030897	0.020407
A_3	0.021464	0.018612	0.008755	0.005534	0.002834	0.002919	0.003235	0.00132	0.001433	0.00326	0.030897	0.00157
A_4	0.021464	0.018612	0.023764	0.017986	0.026921	0.033568	0.027495	0.030353	0.015759	0.021189	0.022837	0.026686
A_5	0.037974	0.030066	0.023764	0.02352	0.009918	0.018973	0.027495	0.017156	0.024355	0.011409	0.030897	0.014128
A_6	0.051183	0.047246	0.033769	0.037355	0.041089	0.016054	0.033965	0.022435	0.047278	0.053786	0.014777	0.036104
A_7	0.051183	0.047246	0.026265	0.031821	0.029754	0.033568	0.0372	0.038271	0.044413	0.053786	0.017463	0.032965
A_8	0.047881	0.047246	0.026265	0.026287	0.029754	0.02773	0.033965	0.040911	0.047278	0.050526	0.014777	0.029825

Step 3: Calculate ideal positive solution (Table 6.6) and ideal negative (Table 6.7) of weighted normalised matrix.

Positive and negative matrix is formulated as follows:

$$N^{+} = \{(\max x_{ij} | j \in J), (\min x_{ij} | j \in J')\} \quad (6.15)$$

$$N^{-} = \{(\min x_{ij} | j \in J), (\max x_{ij|} | j \in J')\} \quad (6.16)$$

Where J represents beneficiary criterion and J' represents cost criterion.

Step 4: Evaluate the distance of each alternative from an ideal solution (Table 6.8).

The distance from Positive ideal solution is:

$$S_i^{+} = \sqrt{(\sum_{i=1}^{m} N_{ij} - N^{+})^2} \quad (6.17)$$

The distance from Negative ideal solution is:

$$S_i^{-} = \sqrt{(\sum_{i=1}^{m} N_{ij} - N^{-})^2} \quad (6.18)$$

Step 5: Calculate relative closeness coefficient:

$$CC_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \quad (6.19)$$

Step 6: The alternatives are ranked on the basis of their descending value of CC_i **(Table 6.8).**

$$R^* = \{ R_i | \max S_i \} \quad (6.20)$$

Table 6.6: Positive-Ideal Weighted Normalized Matrix

Alternatives	Criterion											
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	0.05118280	0.04724648	0.03376941	0.03735480	0.04108941	0.03356800	0.03719975	0.04091075	0.00143266	0.00325977	0.01477667	0.00156975
A_2	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.001569758
A_3	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975
A_4	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975
A_5	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975
A_6	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975
A_7	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975
A_8	0.05118280	0.04724648	0.03376941	0.037354804	0.041089418	0.033568008	0.037199751	0.040910757	0.001432667	0.003259771	0.014776676	0.00156975

Table 6.7: Negative-Ideal Weighted Normalized Matrix

Alternatives	Criterion											
	C_1	**C_2**	**C_3**	**C_4**	**C_5**	**C_6**	**C_7**	**C_8**	**C_9**	**C_{10}**	**C_{11}**	**C_{12}**
A_1	0.021463757	0.015748827	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_2	0.021463757	0.015748827	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_3	0.021463757	0.01861225	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_4	0.021463757	0.01861225	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_5	0.021463757	0.030065943	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_6	0.021463757	0.047246481	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_7	0.021463757	0.047246481	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432
A_8	0.021463757	0.047246481	0.008755032	0.005534045	0.002833753	0.002918957	0.003234761	0.001319702	0.047278015	0.05378622	0.044330028	0.036104432

Table 6.8: Positive and Negative Distances and Closeness Coefficients of Rabi Crops

Alternatives	S_i^+	S_i^-	CC_i	Crop Ranking
A_1	0.061094	0.082786	0.424616	8
A_2	0.076679	0.071882	0.516143	2
A_3	0.093409	0.077639	0.546098	1
A_4	0.061703	0.077059	0.444669	7
A_5	0.060114	0.07038	0.460665	6
A_6	0.080659	0.080132	0.50164	3
A_7	0.074936	0.082485	0.476023	5
A_8	0.074142	0.078808	0.484747	4

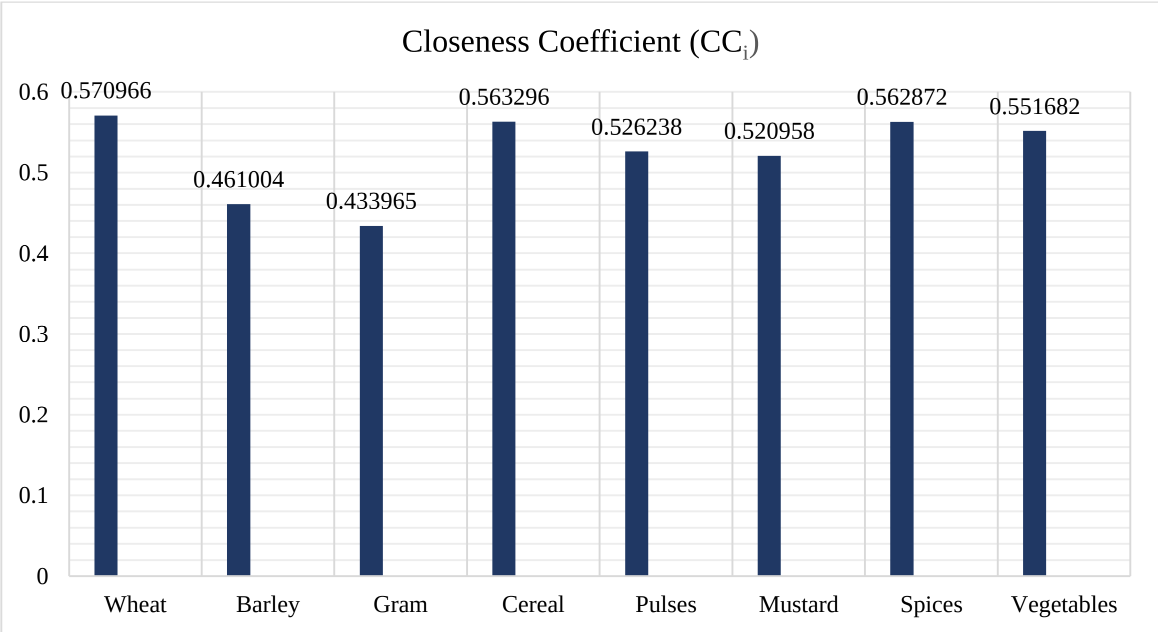

Fig. 6.10: Ranking of Rabi Season Crops based on Closeness Coefficient

6.7 Results and Discussions

The chapter deals with twelve criteria for eight crops cultivated in Rabi season, to get pattern selection for sustainable farm practice. MOORA method shows the respective weights of descending preference as: spices > vegetables > cereal > pulses > barley > gram > mustard > wheat and crop preference according to TOPSIS method is: spices > vegetables > mustard> cereal > gram > wheat> pulses > barley. The weights assigned to 12 attributes obtained by SDV method are (0.104735, 0.102525, 0.066653, 0.070206,0.078057, 0.080404, 0.079285,

0.07918211, 0.089779, 0.096961, 0.078052, 0.074162). The crop pattern obtained by MOORA and TOPSIS method indicates the crop preference over the other crop. The crop pattern obtain is important for sustainable agriculture practice and for improving the yields too. The model formulated will help the farmers and policy-makers for sustainable agricultural practices.
The model can be elaborated by defining more criteria and alternatives in decision space. Crop selection poses lots of challenges when considered under fuzzy environment. However, problem become more complicated if the desired yields were not obtained. The results can be further improved by considering the uncertainty involved in sector.

Table 6.9: MOORA and TOPSIS Overall Crop Performance Comparative Analysis

Alternatives	TOPSIS	MOORA	Fuzzy-TOPSIS (Qureshi et al., 2018)
A_1	8	4	4
A_2	2	7	7
A_3	1	8	8
A_4	7	5	5
A_5	6	6	6
A_6	3	3	2
A_7	5	1	1
A_8	4	2	3

Results obtained by MOORA model is quite similar to that obtained by Fuzzy-TOPSIS method Fig. 6.11. Thus, for the proposed model crop preference obtain by MOORA model would be considered for crop-pattern selection in Rabi season**.** In TOPSIS the performance scores of different attributes is to be expressed in same measurement units. This limits the scope of TOPSIS as the true experimental values cannot be used as a input directly (Wu & Abdul-Nour, 2020). Not every MCDM technique uses same interpretation of weights for criteria. TOPSIS and most of the fuzzy techniques reveals that each criteria has some generic importance and the weights reflect this importance of criteria (Buede & Maxwell, 1995). However, in MCDM model none of the model can be considered superior to another.

Simple interpretation of MCDM model sometimes become an issue of concern for its application. WSM and WPM are easy techniques that can be easily evaluated. It is not necearry to apply sophisticated and complex technique that make it difficult for decision-makers to interpet the results. Some reesearchers explain that the selection of appropriate tool for MCDM model is the biggest obstacle for decision makers. The model can be elaborated further, by adding a supporting crops that were cultivated with the main crop. This will provide more alternatives to the farmers to choose the crops among the available alternatives.

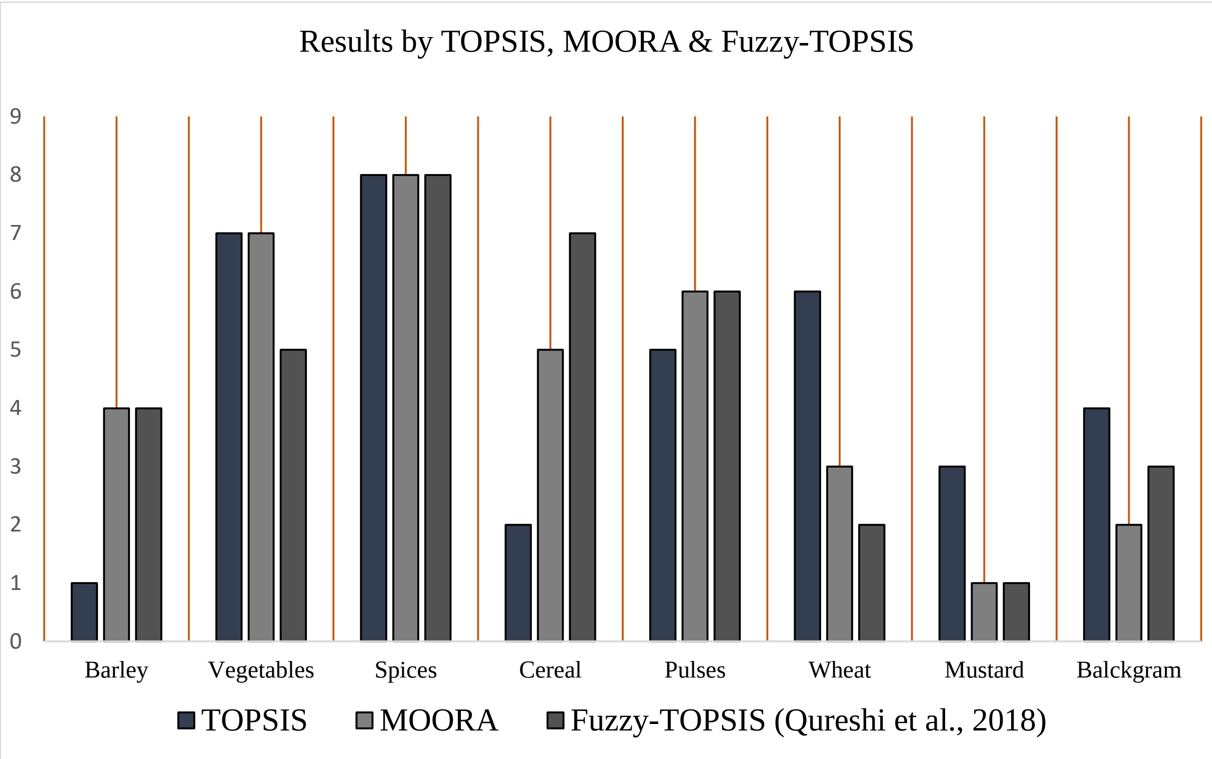

Fig. 6.11: MCDM Methodologies Result for Crop Pattern Analysis in Rabi Season