Multi-criteria governmental crop planning problem based on an integrated AHP-PROMETHEE approach

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Abstract: The study uses analytic hierarchy process (AHP) and preference ranking organisation method for enrichment evaluations (PROMETHEE) to deal with the crop planning problem as a multi-criteria decision-making problem, for governmental lands in Gaza Strip under two conditions: the normal economy condition and the resistant economy condition. These two conditions are studied from the governmental point of view. The study goal is to rank crops according to some considered criteria. Crops are divided into eight types that include vegetables, fruits, citrus, olives, palms, export crops, field crops and medical and aromatic crops. The developed AHP and PROMETHEE compare crops with respect to seven main criteria, namely; economical, financial, marketing, environmental, technical, political and social criteria. AHP is used to obtain criteria weights to be used as input for PROMETHEE to outrank alternatives.

The results indicate that in resistant economy condition, field crops, olives and palms are the most important crops, while in normal economy condition, vegetables, citrus and export crops are the most important crops.

Keywords: governmental; crop planning; multi-criteria decision-making; MCDM; analytic hierarchy process; AHP; preference ranking organisation method for enrichment evaluations; PROMETHEE; outrank; resistant economy.

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1 Introduction

In recent years, the Ministry of Agriculture (MOA) in Gaza Strip has been attempting to develop a crop plan as an effective agricultural strategy to deal with problems associated with the agricultural sector. Such a process of developing a suitable and effective crop plan is a complex decision-making problem involving multiple objectives. This study aims to help MOA make a strategic decision of selecting the most proper crops (MOA, 2009).

Crop planning problem in Gaza Strip is studied under two conditions. The first condition is the normal economy condition, in which most of borders and crossings are opened, and all agricultural production inputs including seeds, pesticides and fertilisers are available in market. Further, there is a surplus in the production of some crops and so, many agro-industries can be established. When the cultivation cost of a certain crop is more than its importing cost, it is more preferable to import it, excluding the basic food like cereal. Therefore, the strategic crops in normal condition are the crops that greatly contribute to the gross domestic product (GDP) and can compete against foreign crops.

However, the siege imposed on Gaza Strip since 2005 has created a different condition characterised by preventing the importing of the agricultural inputs. Thus, farmers would tend to grow certain crops. With siege, the importance of achieving a state of self-sufficiency and food security, without the dependency on import, emerged. In addition, siege prevents exporting crops and thus it reduces the possibility of cultivating crops that are normally intended for foreign markets, like strawberries and flowers. This condition is known as resistant economy condition.

MOA defines the resistant economy as: the ability to adapt different agricultural policies to support the steadfastness over land through: First, achieving a state of food security and self-sufficiency of the products that can be produced locally. Second, reducing surplus from the local crops and thus cultivate the available spaces with other crops that are normally imported. Third, using natural resources especially water without compromising the needs of future generations. Now, MOA focuses on sustainable agriculture as a main strategy to deal with the severe shortage in many resources including water and land.

This study performs crops ranking using multi-criteria decision-making (MCDM) methods. Analytic hierarchy process (AHP) is used to determine the importance of criteria, then preference ranking organisation method for enrichment evaluations

(PROMETHEE) is used for final crops ranking. The selection of AHP in this study is due to the fact that it is able to structure a problem hierarchically, thus; provides users with a better focus on specific criteria and sub-criteria when allocating the weights. Furthermore, qualitative and quantitative criteria can be evaluated on the same preference scale of nine levels. While PROMETHEE was selected due to its simplicity and strength comparing with other multi-criteria methods such as PROMETHEE I which does not aggregate good scores on some criteria and bad scores on other one. Further, PROMETHEE is used so that all the alternatives are comparable (Albadvi et al., 2007).

In this paper, sections are organised as follows: Section 2 presents a literature review, while the methodology is given in Section 3. The case of Gaza Strip is discussed in Section 4. Section 5 presents the results and analysis. The last section presents the conclusions and recommendations.

2 Literature review

Many agricultural decisions involve multiple and conflicting objectives, thus, multi-criteria decision analysis plays a considerable role in agricultural decisions. The literature reviewed in this study mainly includes journal publications in the area of multi-criteria crop planning.

Sarker and Quaddus (2002) formulated the crop planning problem as a goal programme using three different goals. These goals are:

1 maximise the return
2 minimise the dependency on import of basic food like the cereal
3 minimise the investment required for cultivation.

Wei et al. (2009) suggested an optimal crop planting scheme for Sichuan province. They used multi-objective programming modelling and solved crop planning problems for optimal production of several seasonal crops in a planning year based on the scientific principle of circular economy and the character of Sichuan province dry land agriculture.

Ragkos and Psychoudakis (2008) used a multi-objective programming approach to achieve environmental goals such as the reduction of agrochemical and irrigation water use as well as acceptable farm incomes. While developing crop plans for River Strymonas region in Greece. The results revealed considerable possibilities for reducing input usage as well as severe impact on incomes in term of gross margin.

Linear programming and fuzzy optimisation models were developed by Sahoo et al. (2006) for planning and management of available land-water-crop system of Mahanadi-Kathajodi delta in eastern India. The models were used to optimise the economic return, production and labour utilisation, and to allocate the related cropping patterns and intensities with specified land, water, fertilisers and labour availability, and water use pattern constraints.

Mohaddes and Mohayidin (2008) developed fuzzy multi-objective mathematical programming model. The developed model focused on attaining three objectives; namely, profit maximisation, employment maximisation and erosion minimisation. Results of the model indicated that, when compared with the current cropping structure, the implementation of the optimal cropping pattern could increase profit and employment and decrease soil erosion significantly. Other fuzzy multi-objective studies include that of Gupta et al. (2000), Sinha et al. (1988), Biswas and Pal (2005), Zhou et al. (2007) and Toyonaga et al. (2005).

Haouari and Azaiez (2001) proposed a mathematical model for optimal cropping patterns under water deficits in dry regions. They identified, the area and the irrigation level, allocated to a given crop while taking into account the possible successors and predecessors of this crop. Both annual and seasonal crops were examined in the same study. The model started with identifying the optimal operating policy for each grower in the region having a given stock of irrigation water. Then, in order to allocate water efficiently among growers, the model determined the global optimal cropping plan of entire region.

Although there are many studies related to crop planning, this study differs from previous ones in:

1 AHP and PROMETHEE are integrated for the first time according to the known literature to deal with the crop planning problem.

2 More criteria are considered in this study, since the existing studies focused on resources consumption criteria such as land, water, fertilisers, labour, …., etc. Other criteria should be considered to develop an effective long-term crop plan. Examples may include self-sufficiency, food security, intercropping, organic agriculture, and post harvest storage.

3 The previous studies formulated crop planning problem in normal conditions, while this study considered two conditions, the normal economy and the resistant economy condition.

4 Some of the specific agricultural problems in Gaza Strip are not included in the existing studies. So, there is a need for new study because Gaza Strip lacks this type of study.

3 Methodology

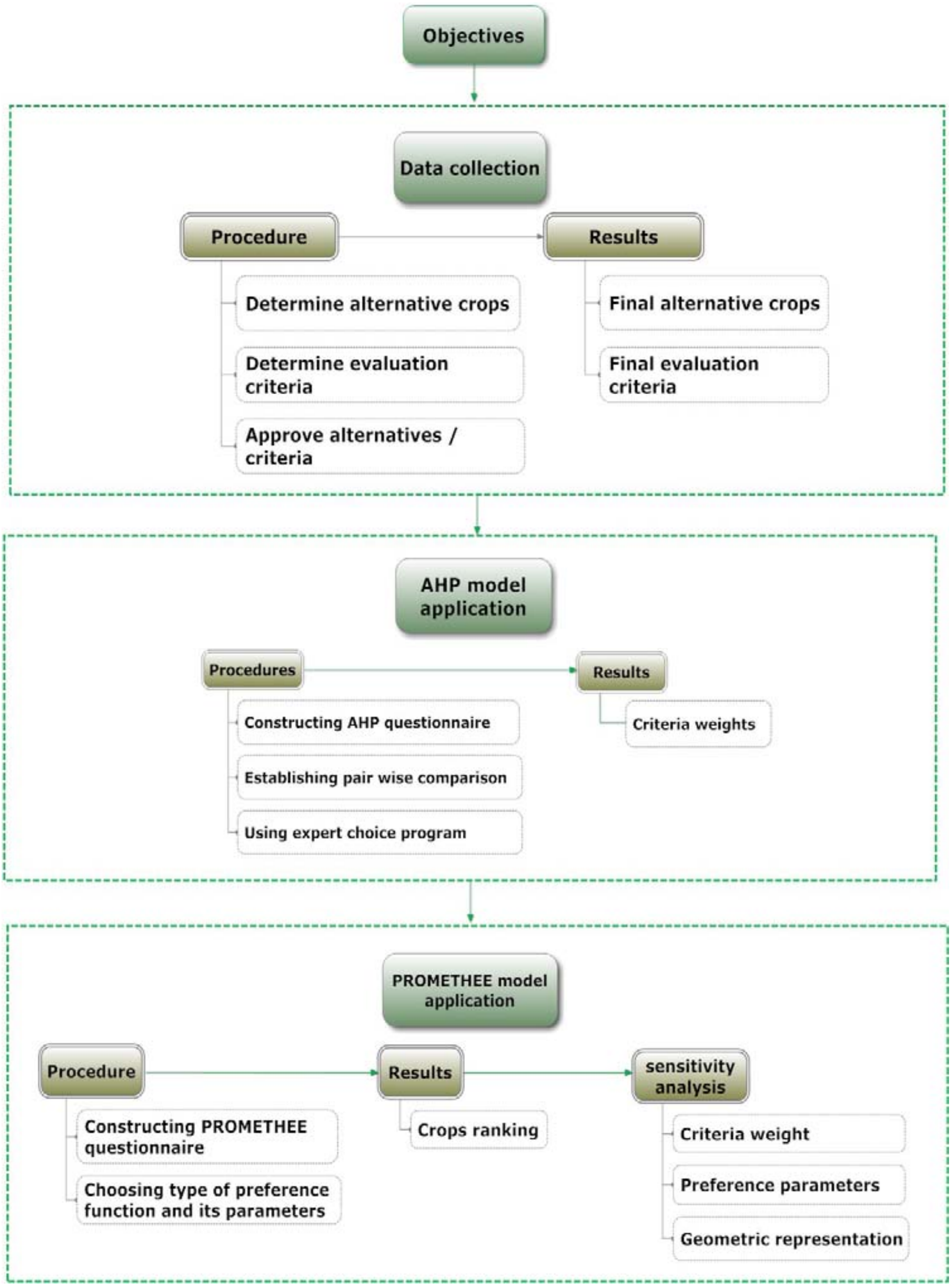
The methodology followed in this study is shown in Figure 1. The data needed to perform the crop planning study are: the criteria, sub-criteria, and types of crops to be cultivated; in other words; the alternatives. The required data were collected from:

1 literature review

2 the policies of the MOA in Gaza Strip

3 interviews with experts and agricultural engineers from the MOA and some associations such as the Society of Agricultural Relief, and the Institute of Environmental Research.

Figure 1 Study methodology (see online version for colours)



3.1 Analytic hierarchy process

AHP is one of the MCDM methods. It was originally developed by Thomas L. Saaty in the mid 1970s. It combines tangible and intangible aspects to obtain the priorities associated with the alternatives of the problem.

According to Saaty (1980), the steps for applying AHP are:

- Define the problem and determine its goal.
- Structure the hierarchy from the top (the objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.
- Construct a set of pair-wise comparison matrices. The decision-maker compares two alternatives a_i and a_j using a criterion and assigns a numerical value to obtain their relative weights. The result of the comparison is expressed in a fundamental scale of values ranging from one (a_i, a_j contribute equally to the objective) to nine (the evidence favouring a_i over a_j is of the highest possible order of affirmation). Given that the n elements of a level are evaluated in pairs using an element of the immediately higher level, an $n*n$ comparison matrix is obtained.
- There are $n*(n - 1) / 2$ judgements required to develop the set of matrices in the previous step. Reciprocals are automatically assigned in each pair-wise comparison.
- Hierarchical synthesis is now used to weigh the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
- Having made all the pair-wise comparisons, the consistency is determined using the eigenvalue, λmax, to calculate the consistency index (CI) as follows:

  $$CI = (\lambda_{\max} - n)/(n-1),$$

  where n is the matrix size.

Judgement consistency is checked using consistency ratio (CR) which equals CI/RI where RI is random index with the appropriate values in Table 1. Judgement is said to be consistent if the value of CR does not exceed 0.10, otherwise, the judgement is inconsistent and it has to be reviewed and improved.

Table 1 Average random consistency

Size of matrix	1	2	3	4	5	6	7	8	9	10
Random consistency	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

3.2 Preference ranking organisation method for enrichment evaluations

PROMETHEE is one of the outranking methods for multiple criteria problems. In this study, PROMETHEE II is used for complete ranking, so all the alternatives are comparable (Brans and Vincke, 1985).

The first information required by PROMETHEE is evaluation table as shown in Table 2, where: f_1, f_2,…,f_k are the evaluation criteria, while a_1, a_2,…,a_n present the alternatives. F_j (a_i) is the score assigned to alternative a_i with respect to criteria f_j (Brans and Vincke, 1985).

Table 2 PROMETHEE evaluation table

	$f_1(.)\, f_2(.)\, \ldots\, f_j(.)\, \ldots\, f_k(.)$
a_1	
a_2	
…	
a_i	$f_j\,(a_i)$
…	
a_n	

The preference structure of PROMETHEE is based on pair wise comparisons. In this case, the deviation between the evaluations of two alternatives on a particular criterion is considered. For small deviations, the decision-maker will allocate a small preference to the best alternative and even possibly no preference if he considers that this deviation is negligible. The larger the deviation, the larger the preference is. This means that for each criterion, the decision-maker has in mind a preference function:

$$P_j(a,b) = F_j\left[d_j(a,b)\right] \;\forall a,b \in A \tag{1}$$

where

$$d_j(a,b) = f_j(a) - f_j(b) \tag{2}$$

There are six types of preference functions as shown in Table 3. The table shows three thresholds as follows:

- q is a threshold or indifference which is the largest deviation which is considered negligible by the decision-maker
- p is a threshold of strict preference which is the smallest deviation which is considered sufficient to generate a full preference
- s is an intermediate value between p and q.

Ideally, a decision-maker is interested in finding an optimal alternative '$\hat{a}$' which dominates all other alternatives, and has the highest value for all criteria compared to other alternatives, so:

$$f_h(\hat{a}) \geq f_h(a), \forall a \in K, \forall h \tag{3}$$

In general, such an optimal solution does not exist, and indeed, the dominance relationship between the alternatives defined as: 'a' dominates 'b' if and only if:

$f_h(a) \geq f_h(b)$, $\forall h \in \{1, 2, \ldots, k\}$ is poor between all the two-by-two alternatives. PROMETHEE tries to enrich the dominance relationship between the alternatives.

Considering two alternatives 'a' and 'b', PROMETHEE gives a numerical value between 0 and 1 to the preference relationship by introducing the preference function $P(a, b)$ such that:

$$P(a,b)=\begin{cases}0 & \text{if } f_h(a)\le f_h(b)\\ P\left[f_h(a),f_h(b)\right] & \text{if } f_h(a)>f_h(b)\end{cases} \tag{4}$$

where

$$0<P\left[f_h(a),f_h(b)\right]\le 1 \tag{5}$$

For practical applications, it is then reasonable to assume that:

$$P\left[f_h(a),f_h(b)\right]=P\left[f_h(a)-f_h(b)\right] \tag{6}$$

Let $D_h(a, b)$ be the difference between alternative ‘*a*’ and alternative ‘*b*’ for criterion *h* as shown in equation (7):

$$D_h(a,b)=f_h(a)-f_h(b) \tag{7}$$

Then, PROMETHEE uses the weighted preference index $p(a, b)$ to give an integrated overall preference of alternative ‘*a*’ over ‘*b*’ shown in equation (8):

$$\pi(a,b)=\frac{\sum_{h=1}^{k}W_hP_h(a,b)}{\sum_{h=1}^{k}W_h} \tag{8}$$

where W_h is the weight of criterion *h* which is defined by the decision-makers. To build the outranking relation among the alternatives, PROMETHEE introduces three outranking measures for each alternative as follows:

- Outgoing flow:

  $$\varnothing^{+}(a)=\sum_{x\in K}\pi(a,x) \tag{9}$$

  The larger outgoing flow, the more alternative ‘*a*’ outranks the other alternatives in the set *k*.

- Incoming flow:

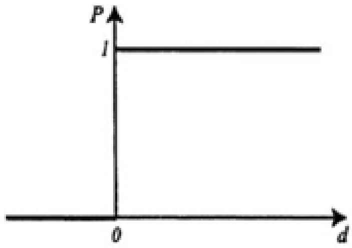
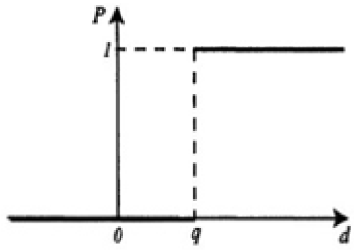
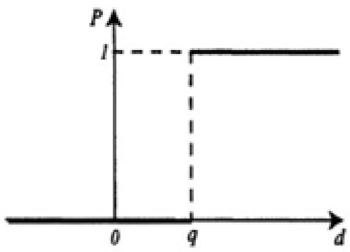
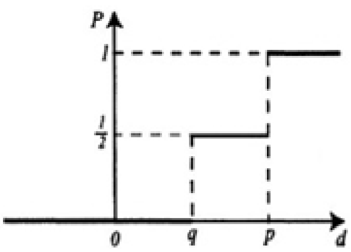
  $$\varnothing^{-}(a)=\sum_{x\in K}\pi(x,a) \tag{10}$$

  The smaller incoming flow, the less alternative ‘*a*’ has been outranked by other alternatives in the set *k*.

- Net flow

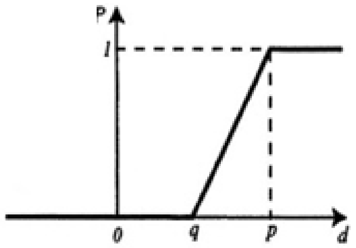
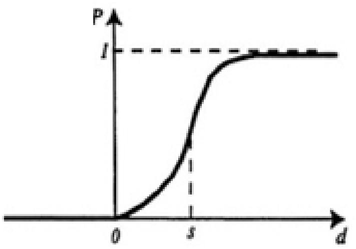
  $$\varnothing(a)=\varnothing^{+}(a)-\varnothing^{-}(a) \tag{11}$$

Table 3 Types of generalised criteria [*P*(*d*): preference function]

Generalised criteria	*Definition*	*Parameters*
Type 1 Usual criterion 	$P(d)=f(x)=\begin{cases}0, & d\le 0\\ 1, & d>0\end{cases}$	-
Type 2 U-shape criterion 	$P(d)=f(x)=\begin{cases}0, & d\le q\\ 1, & d>q\end{cases}$	q
Type 3 V-shape criterion 	$P(d)=\begin{cases}0, & d\le 0\\ \frac{d}{p}, & 0<d\le p\\ 1, & d>p\end{cases}$	p
Type 4 Level criterion 	$P(d)=\begin{cases}0, & d\le q\\ \frac{1}{2}, & q<d\le p\\ 1, & d>p\end{cases}$	p, q

Source: Figueira et al. (2005)

Table 3 Types of generalised criteria [$P(d)$: preference function] (continued)

Generalised criteria		*Definition*	*Parameters*
Type 5	V-shape with indifference criterion 	$P(d)=\begin{cases} 0, & d \le q \\ \dfrac{d-q}{p-q}, & q < d \le p \\ 1, & d > p \end{cases}$	p, q
Type 6	Gaussian criterion 	$P(d)=\begin{cases} 0, & d \le 0 \\ 1-e^{\frac{d^2}{2s^2}} & d > 0 \end{cases}$	s

Source: Figueira et al. (2005)

4 Governmental crop planning based on multi-criteria decision analysis: the case of Gaza Strip

For this crop planning problem, there are seven main criteria, including: economic, financial, marketing, environmental, technical, political and social criteria. These criteria are divided into sub-criteria. The sub-criteria for the normal economy and resistant economy conditions along with the alternatives are shown in Figures 2 and 3.

Nationwide, there are many classifications of crops. In this study, crops are classified in such a way that experts can compare according to the considered criteria. Crops with similar characteristics are grouped in one alternative. Final groups (alternatives) of crops were adopted after presenting them to experts and engineers from MOA and other agricultural societies. The final alternatives are: vegetables, fruits, citrus, olives, palms, export crops, field crops and medical and aromatic crops.

For more details on criteria, sub-criteria and alternatives, refer to Agha (2011).

AHP is used in this study to identify weights to be used as input for PROMETHEE. A hierarchy of four levels was constructed for two conditions, normal economy condition as well as resistant economy condition. These hierarchies are shown in Figures 2 and 3.

To conduct the pair wise comparisons, a questionnaire was designed and distributed individually among nine experts. Those experts were from the MOA since the study is from the governmental view. In this questionnaire, experts were asked to assign a value from one to nine for each pair wise comparison.

Figure 2 Main, sub criteria and alternatives for crop planning problem under normal condition (see online version for colours)

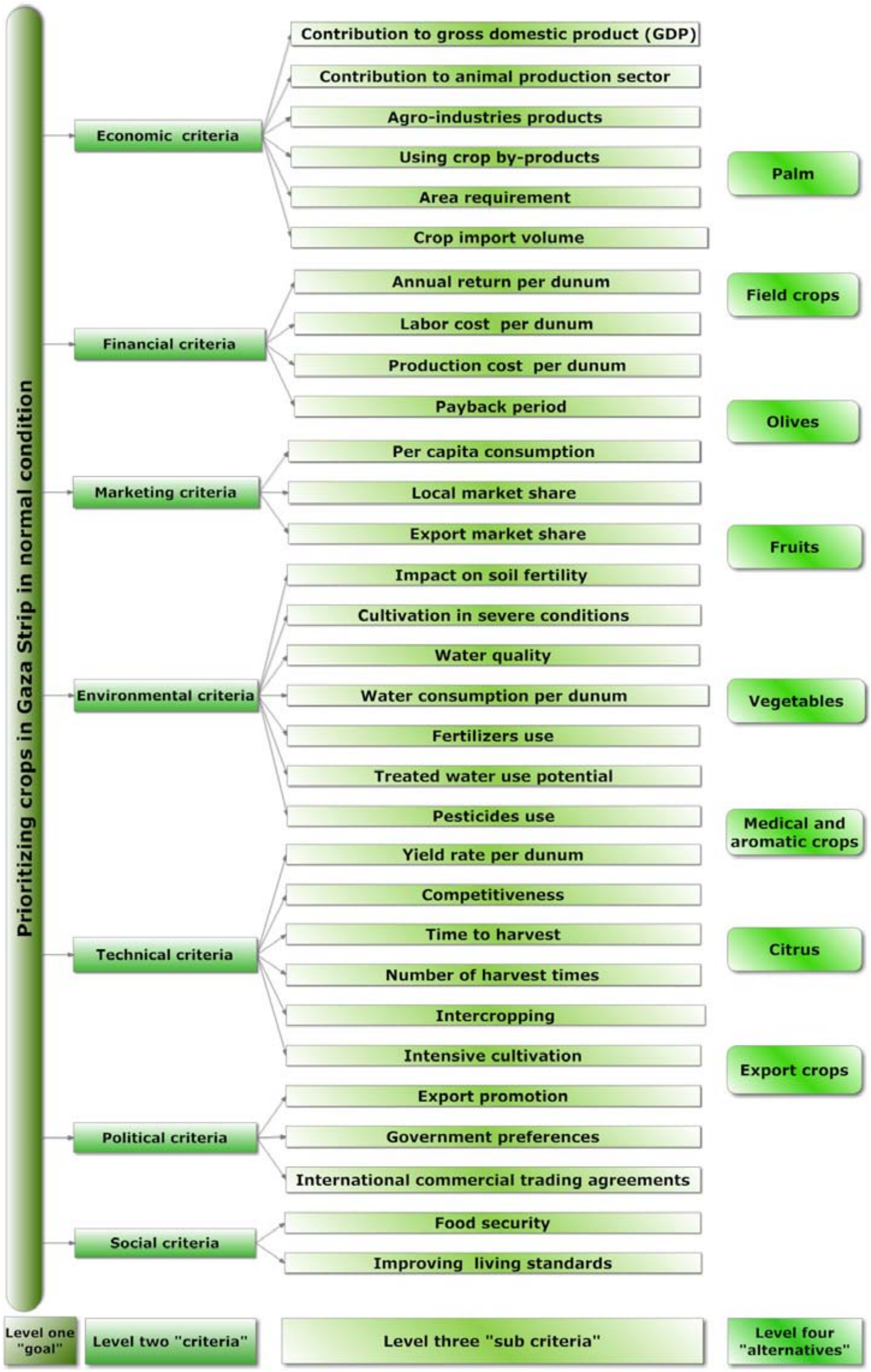
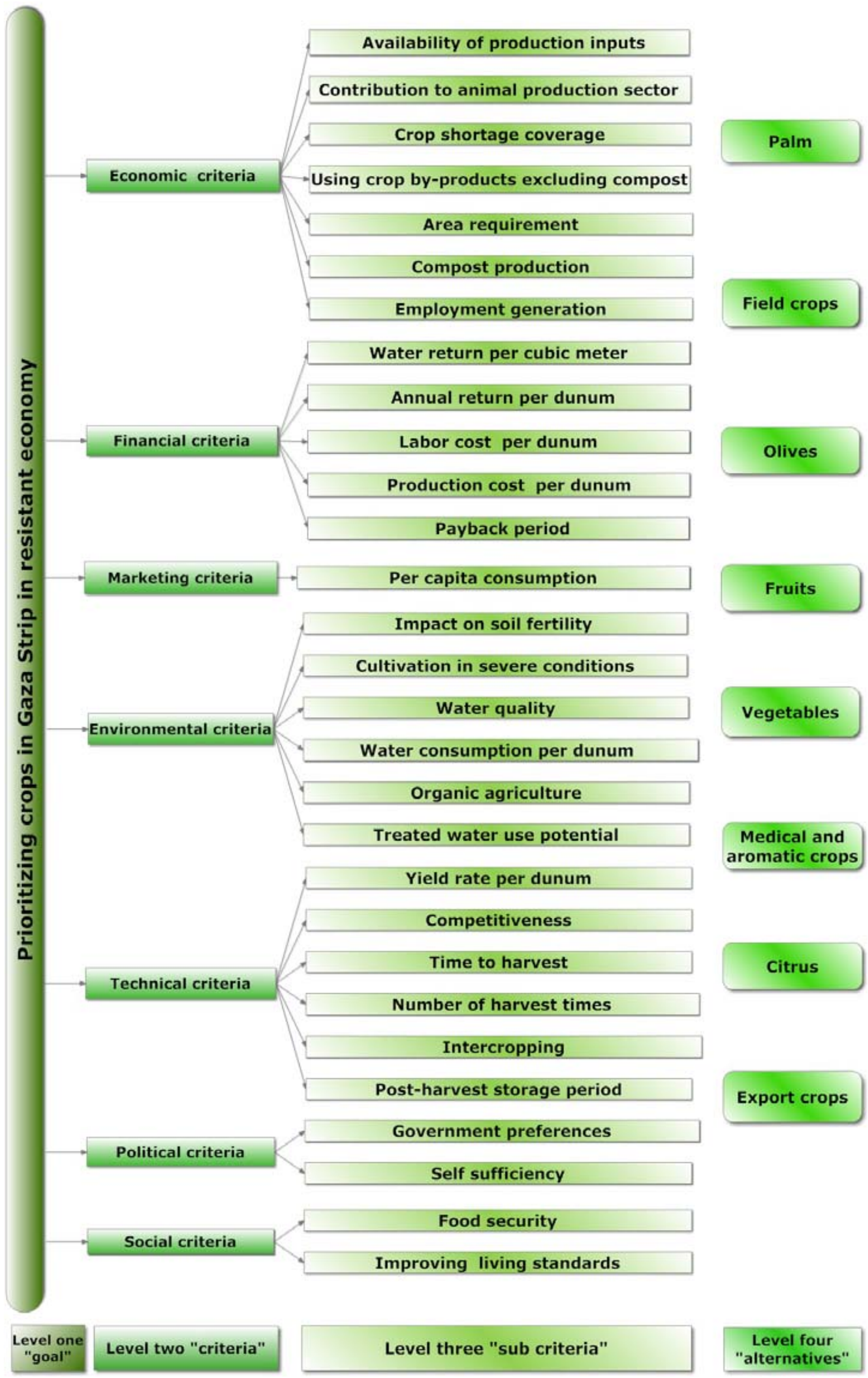


Figure 3 Main, sub criteria and alternatives for crop planning problem under resistant economy condition (see online version for colours)



After receiving the questionnaires from experts, the CR of each questionnaire was calculated. It was observed that some of the pair-wise comparisons have CR values larger than 0.1 which meant that they are inconsistent. Therefore, experts were asked to refill questionnaire again after being told of the inconsistencies.

Once the judgements of each of the nine experts were obtained for both conditions and tested for the consistency, the average for each comparison was computed to get the final comparison matrices for each condition. The average scores were entered to expert choice (E.C 11.5) (Expert Choice Inc., 2004) software. Criteria and sub-criteria weights for normal and resistant economy conditions are shown in Table 4.

PROMETHEE, as described earlier, is used for outranking alternatives. For complete ranking, PROMETHEE II is used so all the alternatives are comparable.

The first information required by PROMETHEE is the evaluation table. Since PROMETHEE has only one level of comparison, the alternatives are compared relative to the main criteria to obtain the evaluation table. But for the problem under study, it is difficult to compare alternatives with respect to main criteria directly without considering the sub-criteria. So, the experts would compare the alternatives with respect to sub-criteria first.

To obtain data needed for PROMETHEE from experts, questionnaires were designed for both conditions in which experts were asked to assign a score that represents the performance of the alternative with respect to sub-criteria, using a scale from 1–9, where 1 refers to very low, 3 means low, 5 means medium, 7 means high, and 9 means very high.

For each comparison, the average of the experts' scores is computed and used to obtain the evaluation table through the weighted average method using the AHP sub-criteria weights shown in Table 4. For example, Table 5 shows the average scores assigned by experts to the performance of vegetables with respect to economic sub-criteria under resistant economy condition. To obtain the final score of vegetables with respect to economic criteria, the weighted average method is used as follows:

$$\text{Final score} = \sum \begin{bmatrix} \text{average of the assigned score obtained from Table 5} \times \text{local} \\ \text{weight of the corresponding sub-criteria obtained from Table 4} \end{bmatrix}$$

$$\begin{aligned} \text{Final economic score for vegetable} &= 2.333 * 0.262 \times 6 * 0.116 + 6.667 \times 0.298 + 4.667 \\ &\quad \times 0.04 + 6 \times 0.138 + 6.667 \times 0.31 + 7 \times 0.115 \\ &= 5.320 \end{aligned}$$

The results shown in Table 6 are obtained in a similar fashion to get the final evaluation table for resistant economy condition. An evaluation table similar to Table 6 is constructed for the normal economy condition.

After constructing the evaluation tables for the problem under study, a preference function has to be selected. Therefore, the level criterion (Type 4) was used for all criteria. The other types were not used for the following reasons; Types 1 and 6 are very seldom used in the literature, while Types 3 and 5 are normally used for quantitative criteria. The remaining types are Types 2 and 4. Both of them are suitable for qualitative criteria, as in our case. Type 4 was used because it is more general.

Table 4 Local and global weights for criteria and sub-criteria under resistant and normal economy conditions

Main criteria			*Sub-criteria*	*Local weight*	
Criteria	*Global weight*			*Resistant*	*Normal*
	Resistant	*Normal*			
Economic	0.107	0.333	Availability of production inputs	0.262	-
			Contribution to animal production sector	0.116	-
			Crop shortage coverage	0.298	-
			Using crop by-products excluding compost	0.040	-
			Area requirement	0.138	0.225
			Compost production	0.031	-
			Employment generation	0.115	-
			Contribution to GDP	-	0.308
			Agro-industries products	-	0.163
			Using crop by-products	-	0.067
			Crop import need volume	-	0.087
Financial	0.107	0.133	Return per cubic metre of water	0.209	-
			Annual return per dunum	0.123	0.529
			Labour cost per dunum	0.090	0.227
			Production cost per dunum	0.271	0.108
			Payback period	0.308	0.137
Marketing	0.101	0.133	Per capita consumption	1.00	0.108
			Local market share	-	0.238
			Export market share	-	0.654
Environmental	0.420	0.135	Impact on soil fertility	0.077	0.083
			Cultivation in severe conditions	0.166	0.064
			Water quality	0.174	0.191
			Water consumption per dunum	0.358	0.231
			Organic agriculture	0.117	-
			Treated water use potential	0.108	0.076
			Fertilisers use	-	0.090
			Pesticides use	-	0.265
Technical	0.052	0.067	Yield rate per dunum	0.187	0.17
			Competitiveness	0.323	0.439
			Time to harvest	0.156	0.077
			Number of harvest times	0.133	0.073
			Intercropping	0.074	.057
			Post-harvest storage period	0.127	-
			Intensive cultivation	-	0.160

Table 4 Local and global weights for criteria and sub-criteria under resistant and normal economy conditions (continued)

Main criteria			*Sub-criteria*	*Local weight*	
Criteria	*Global weight*			*Normal*	*Resistant*
	Resistant	*Normal*			
Political	0.178	0.113	Government preferences	0.162	0.114
			Self-sufficiency	0.838	-
			Export promotion	-	0.607
			International commercial trading agreements	-	0.279
Social	0.037	0.086	Food security	0.806	0.333
			Improving living standards	0.194	0.667

Table 5 Average scores for vegetables with respect to economic sub-criteria under resistant economy condition

Economic sub-criteria (E.S.C.)	*E.S.C. 1*	*E.S.C. 2*	*E.S.C. 3*	*E.S.C. 4*	*E.S.C. 5*	*E.S.C. 6*	*E.S.C. 7*
Average of the assigned scores	2.333	6	6.667	4.667	6	6.667	7

Table 6 PROMETHEE evaluation table for resistant economy condition

Criteria crop	*Economic*	*Financial*	*Marketing*	*Environmental*	*Technical*	*Political*	*Social*
Vegetables	5.320	4.672	7.667	3.441	6.224	3.279	6.418
Fruits	4.883	4.697	5.667	3.753	4.237	5.829	4.517
Citrus	3.628	3.745	4	2.912	4.596	3.613	2.925
Olives	5.444	5.717	4.667	6.114	5.469	7.946	6.463
Palms	6.746	5.373	4	6.146	4.137	6.603	6.333
Export crops	2.495	2.331	1	1.385	4.254	1.279	1.453
Field crops	4.537	5.157	7.333	5.929	4.574	3.883	6.224
Medical crops	3.472	5.567	2	4.712	3.555	4.324	3.806

Table 7 PROMETHEE modelling for resistant economy condition

Social	*Political*	*Technical*	*Environmental*	*Marketing*	*Financial*	*Economic*	
0.037	0.178	0.052	0.42	0.101	0.107	0.107	AHP weight
max	max	max	max	max	max	max	max/min
Type 4	Type 4	Type 4	Type 4	Type 4	Type 4	Type 4	Preference function
0.626	0.833	0.333	0.595	0.833	0.423	0.531	*p* threshold
0	0	0	0	0	0	0	*q* threshold

For the required thresholds; Rogers and Bruen (1998) proposed an approach for specifying realistic limits for 'p_i', the preference threshold and 'q_i', the indifference threshold. As shown in equation (12), for the preference threshold 'p_i' a value equal to the difference between the maximum and the minimum for each criterion divided by the number of alternatives 'n', is adopted in the present framework.

$$P_i = (1/n)\left[V_i \ddot{\imath}_{\max} - V_i \ddot{\imath}_{\min}\right] \quad (12)$$

where V_i is the score assigned to the alternative for the given criteria.

The p threshold is calculated using equation (12). For simplicity, the indifference threshold 'q' was taken equal to zero in all cases (Rogers and Bruen, 1998).

PROMETHEE modelling information are shown in Table (7), the outranking flows can be calculated using equations (8), (9), (10), (11). The positive and negative outranking flows thus are used for partial ranking; while the net outranking flow is used for complete ranking (PROMETHEE II).

5 Results and analysis

5.1 Resistant economy condition

For the resistant economy condition, the positive outranking flow for each alternative is given in Table 8. The positive outranking flow expresses how an alternative is outranking all the others, thus olives have the highest outranking score and their power is superior. The ranking of alternatives according to the positive outranking flows is: olives, palms, field crops, fruits, medical crops, vegetables, citrus and export crops.

Table 8 PROMETHEE results

Alternative	*Normal condition*				*Resistant economy*			
	Φ+	Φ–	Φ	*Complete rank*	Φ+	Φ–	Φ	*Complete rank*
Vegetables	0.705	0.172	0.534	1	0.387	0.492	–0.105	6
Fruits	0.406	0.452	–0.046	5	0.468	0.461	0.007	4
Citrus	0.602	0.297	0.304	4	0.204	0.697	–0.493	7
Olives	0.567	0.262	0.305	3	0.801	0.096	0.705	1
Palms	0.293	0.591	–0.298	6	0.736	0.134	0.602	2
Export crops	0.601	0.289	0.313	2	0.015	0.976	–0.961	8
Field crops	0.249	0.667	–0.419	7	0.592	0.267	0.325	3
Medical crops	0.134	0.828	–0.694	8	0.433	0.513	–0.080	5

Notes: Φ+ is the positive flow; Φ– is the negative flow; Φ is the net flow; Φ = (Φ+) – (Φ–)
The complete rank based on Φ, PROMETHEE II.

The negative outranking flow expresses how an alternative is outranked by all others. As shown in Table 8, the negative outranking flows for the alternatives in the resistant condition shows that export crops is the highest. Note that the lower the negative outranking flow, the better the alternative. The ranking of alternatives according to the negative flow is olives, palms, field crops, fruits, vegetables, medical crops, citrus and export crops.

It is clear that both flows produce different rankings because the priorities of medical crops and vegetables are different. For a complete ranking, PROMETHEE II is used. The net outranking flows are computed as shown in Figure 4. When PROMETHEE II is considered, all alternatives are comparable. No incomparabilities remain; the resulting rank is: olives, palms, field crops, fruits, medical crops, vegetables, citrus and export crops. This result is expected by the experts because the first three ranked alternatives are compatible with the sustainable agricultural concept which is followed by MOA to deal with the existing problems in Gaza Strip.

The information about a complicated decision problem that has *k* criteria can be represented in\k-dimensional space. *Co-plot technique* is used to locate each alternative in a two-dimensional space in which the location of each action is determined by all criteria simultaneously. The input for this software is the PROMETHEE evaluation matrix. The co-plot method produces three results:

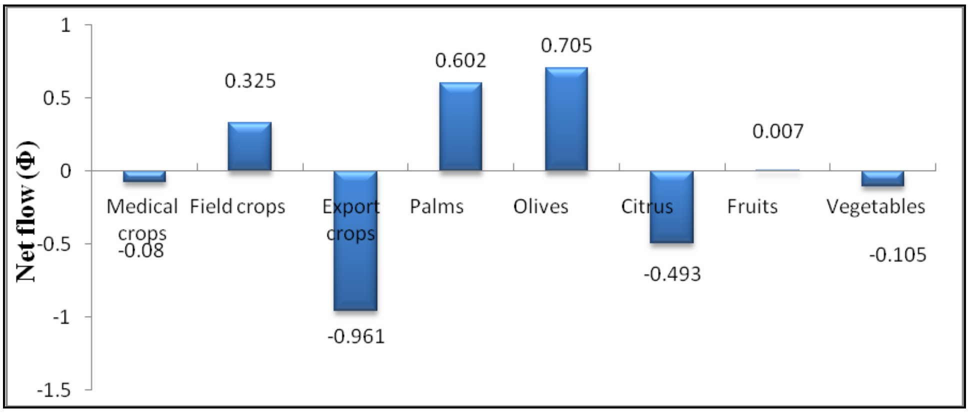
1 similarity among actions by the composite of all criteria involved

2 the structure of correlations among the criteria

3 the mutual relationship between the actions and the criteria (Raveh, 2000).

To have more insights into the performance of the different alternatives with respect to criteria, the original evaluation matrix '$X_{8\times7}$' was submitted to co-plot software. Figure 5 shows the eight crops (alternatives) located in a two-dimensional space, where the alternatives are represented by circles, and criteria by axes. The coefficient of alienation for this plot is 0.006 which is acceptable and indicates that there is a small variation between variables (Pedhazur, 1997).

Figure 4 Net outranking flow for the alternatives under resistant economy condition (see online version for colours)

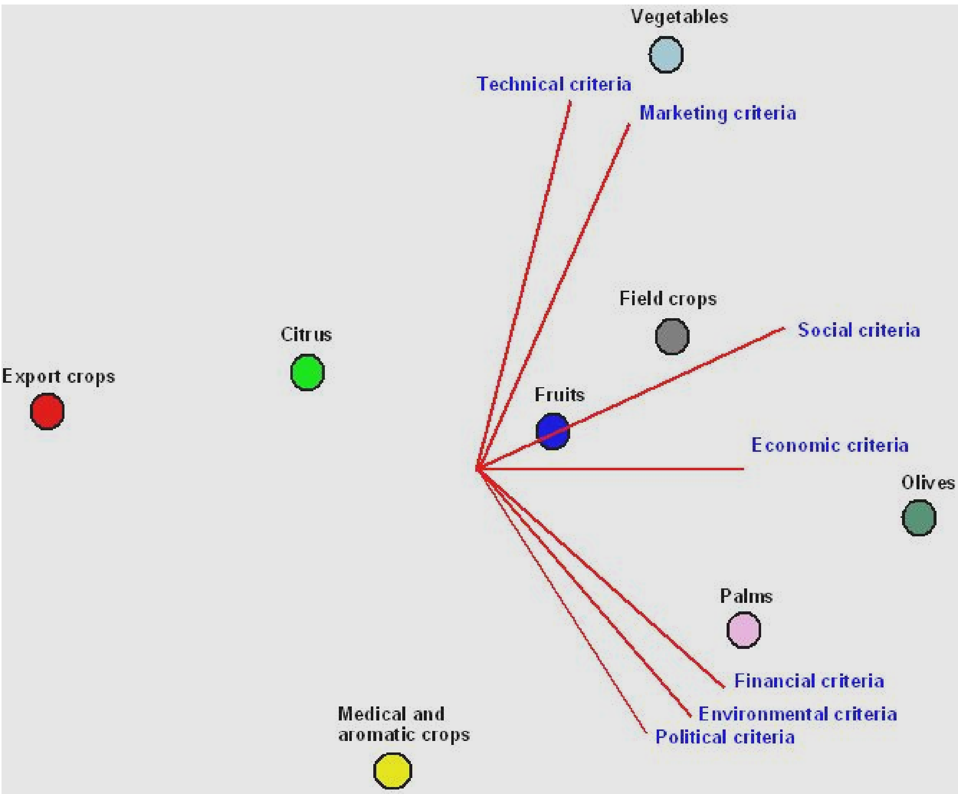


The dispersion of the arrows in opposite directions indicates the presence of conflicting criteria. For instance, it can be seen from Figure 5 that technical and marketing criteria are somehow in conflict with financial, environmental and political criteria. The criteria which have similar preferences are oriented in the same direction. Further, Figure 5 shows that export crops are dissimilar to olives; palms and vegetables. Olives and palms are quite similar to each other since their locations are along the directions of the same criteria and specifically along economic, financial, environmental and political criteria. In other words, they perform favourably with respect to these criteria. It is noted here that MOA encourages farmers to cultivate these crops in support of its pursuit of sustainable agriculture technique.

Furthermore, it is obvious from Figure 5 that vegetables are especially good with respect to the technical and marketing criteria, export crops are not good with respect to the economic criterion.

Figure 5 shows that export crops have the worst overall performance. Although these crops have very high competitive characteristic in Gaza Strip, they consume very large amounts of high quality water. Knowing that, the water consumption is one of the environmental criteria, which have the largest weight according to AHP and with the characteristics of resistant economy condition, MOA avoids cultivating these crops.

Figure 5 Co-plot graphic display of crops and the considered criteria under resistant economy condition (see online version for colours)

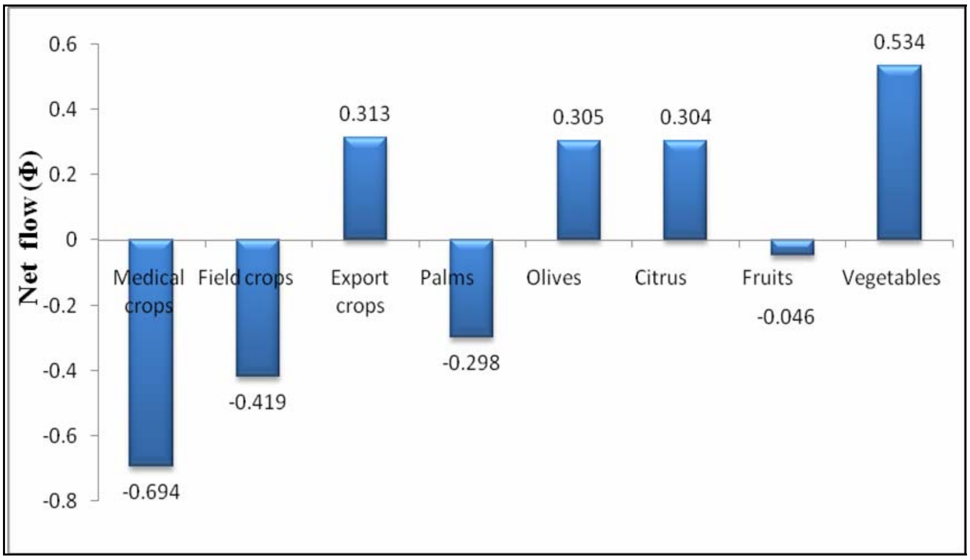


5.2 Normal economy condition

For the normal economy condition, the positive outranking flow for each alternative is given in Table 8. According to this flow, crops can be ranked as: vegetables, citrus, export crops, olives, fruits, palms, field crops and medical crops.

PROMETHEE I, partial ranking also considers the negative outranking flow for alternatives as shown in Table 8. According to this flow, the rank of crops is: vegetables, olives, export crops, citrus, fruits, palms, field crops and medical crops. It is noted that the two ranks based on the positive and negative outranking flows are different, so for complete ranking, PROMETHEE II, is used in which the net flow of each alternative is computed. The results of PROMETHEE II are shown in Figure 6, the new rank of alternatives is: vegetables, export crops, olives, citrus, fruits, palms, field crops and medical crops.

Figure 6 Net outranking flow for the alternatives under normal condition (see online version for colours)

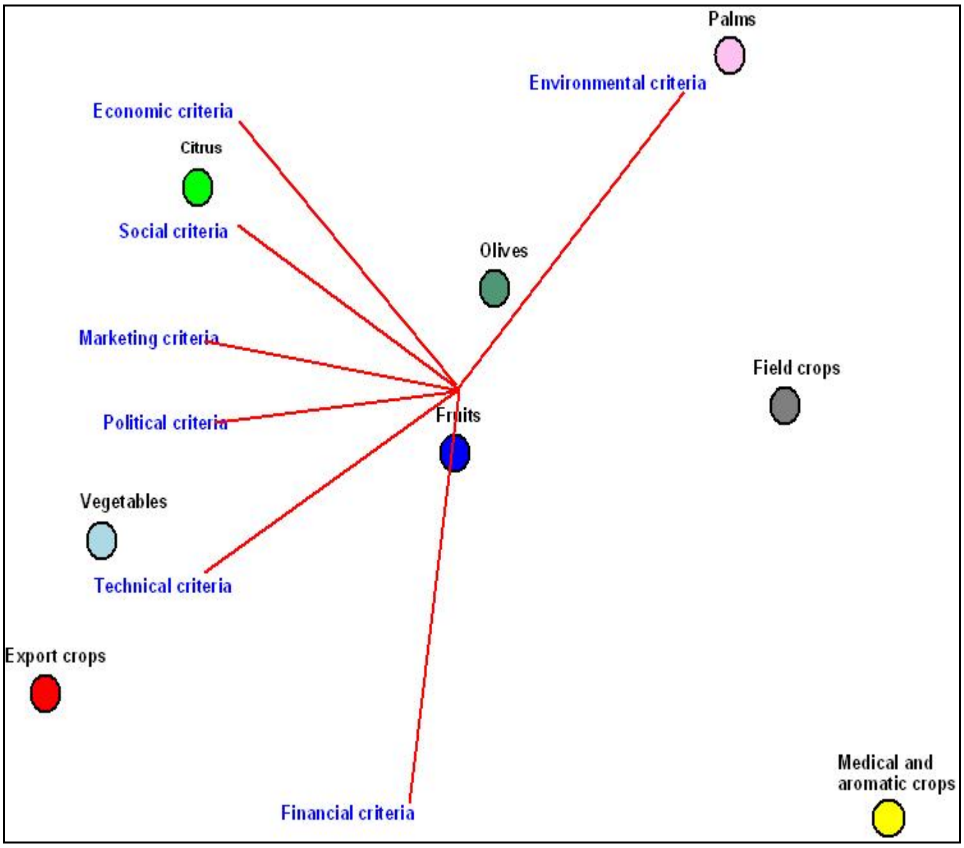


The output of co-plot software is shown in Figure 7. The coefficient of alienation for this plot is 0.011which is acceptable and indicates that there is a small variation between variables.

The eight crops (alternatives) are plotted in a two-dimensional space along with the criteria in Figure 7. The two most dissimilar alternatives are palms and export crops which are the farthest apart. It is clear that palms in this case performs very well with respect to environmental criteria (located in environmental criteria direction), while, export crops perform well with respect to technical and financial criteria. The dispersion of the arrows in opposite directions indicates the presence of conflicting criteria; for instance, technical and financial criteria versus environmental criterion. The criteria which have similar preferences are oriented in the same direction. In Figure 7, economic, social, marketing, political and technical criteria have the same preferences. Palms are especially good with respect to the environmental criterion and this alternative is not good with respect to the technical criteria, as shown in Figure 7.

According to Figure 7; field and medical crops have the worst overall performance.

Figure 7 Co-plot graphic display of crops and the evaluation criteria under normal condition (see online version for colours)



6 Conclusions

The need for crop planning is growing since many problems associated with agriculture can be controlled by successful crop planning. This study presents a new methodology for dealing with crop planning problem as an MCDM problem and develops two models for this problem using an integrated AHP and PROMETHEE approach. There are many factors that affect the comparison of crops; this study considered around 39 criteria that could help in developing better decisions. PROMETHEE results show that the most important crops are olives and palms in the resistant economy condition, on the other hand, vegetables and export crops are the most important crops during the normal economy condition.

Through this study, some shortcomings associated with PROMETHEE are observed. PROMETHEE results in ranking, not rating. Because of the outranking principles, no independent ratings, but rankings, are only produced by PROMETHEE. The inclusion of new alternatives and criteria requires the repetition of pair wise comparisons for re-establishing a ranking order. But, repetition of comparisons has to be performed even in other MCDM models too, if alternatives and new criteria are added.

Various sources of uncertainty in the application of PROMETHEE, especially during the definition of criteria weights and the assignment of criteria performance values, are observed. Dealing with crops as groups forced the researchers to approximate data. So, it is recommended for future work to apply this study to individual crops.

To generalise the developed crop planning model, it is recommended to include the non-governmental agriculture sector in the model. This can be applied by subtracting the non-governmental agriculture production from total demand, then distributing the remaining crops demands to the governmental area under consideration.

References

Agha, S. (2011) 'A multi criteria crop planning model based on the 'resistive economy' characterizing the situation in Gaza Strip', submitted *8th International Conference on Islamic Economics and Finance*, Doha, Qatar.

Albadvi, A., Chaharsooghi, K. and Esfahanipour, A. (2007) 'Decision making in stock trading: an application of PROMETHEE', *European Journal of Operational Research*, Vol. 177, No. 1, pp.673–683.

Biswas, A. and Pal, B. (2005) 'Application of fuzzy goal programming technique to land use planning in agricultural system', *Omega*, Vol. 33, No. 5, pp.391–398.

Brans, P. and Vincke, P. (1985) 'A preference ranking organization method: the PROMETHEE method for multiple criteria decision-making', *Management Science*, Vol. 31, No. 6, pp.647–656.

Expert Choice Inc. (2004) *Expert Choice, Expert Choice Software and Manual*, 4922 Ellsworth Ave., Pittsburgh.

Figueira, J., Greco, M. and Ehrgott, M. (2005) *Multicriteria Decision Analysis*, Springer International Series, Boston.

Gupta, A.P., Harboe, R. and Tabucanon, M.T. (2000) 'Fuzzy multiple-criteria decision making for crop area planning in Narmada river basin', *Agricultural Systems*, Vol. 63, No. 1, pp.1–18.

Haouari, M. and Azaiez, M. (2001) 'Optimal cropping patterns under water deficits', *European Journal of Operation Research*, Vol. 130, No. 1, pp.133–146.

Ministry of Agriculture (MOA) (2009) *Annual Report for 2010*, available at http://www.moa.gov.ps/PDFFiles/Annualreportof2010.pdf (accessed on 5 September 2009).

Mohaddes, A. and Mohayidin, G. (2008) 'Application of the fuzzy approach for agricultural production planning in a watershed, a case study of the Atrak watershed, Iran', *American-Eurasian Journal of Agricultural and Environmental Science*, Vol. 3, No. 4, pp.636–648.

Pedhazur, J. (1997) *Multiple Regression in Behavioral Research*, Harcourt-Brace, New York.

Ragkos, A. and Psychoudakis, A. (2008) 'Minimizing adverse environmental effect of agriculture: a multi-objective programming approach', *Operation Research International Journal*, Vol. 9, No. 3, pp.267–280.

Raveh, A. (2000) 'Co-plot: a graphic display method for geometrical representations of MCDM', *European Journal of Operational Research*, Vol. 125, No. 1, pp.670–678.

Rogers, M. and Bruen, M. (1998) 'Choosing realistic values of indifference, preference and veto thresholds for use with environmental criteria within ELECTRE', *European Journal of Operational Research*, Vol. 107, No. 3, pp.542–551.

Saaty, T.L. (1980) *The Analytic Hierarchy Process*, McGraw-Hill, New York.

Sahoo, B., Lohani, K. and Sahu, K. (2006) 'Fuzzy multiobjective and linear programming based management models for optimal land-water-crop system planning', *Water Resources Management*, Vol. 20, No. 6, pp.931–948.

Sarker, A. and Quaddus, A. (2002) 'Modeling a nationwide crop planning problem using a multiple criteria decision making tool', *Computers and Industrial Engineering*, Vol. 42, Nos. 2–4, pp.541–553.

Sinha, S., Rao, K. and Mangarag, B. (1988) 'Fuzzy goal programming in multi-criteria decision systems: a case study in agricultural planning', *Socio-Economic Planning Sciences*, Vol. 22, No. 2, pp.93–101.

Toyonaga, T., Itoh, T. and Ishii, H. (2005) 'A crop planning problem with fuzzy random profit coefficients', *Fuzzy Optimization and Decision Making*, Vol. 4, No. 1, pp.51–59.

Wei, W., Liu, Y., Hu, Z. and Zhao, Y. (2009) 'An optimal model of dry land multiple-cropping circular economy systems', *World Journal of Modeling and Simulation*, Vol. 5, No. 3, pp.203–210.

Zhou, H., Peng, H. and Zang, C. (2007) 'An interactive fuzzy multi-objective optimization approach for crop planning and water resources allocation', *Bio-Inspired Computational Intelligence and Applications*, Vol. 4688, No. 1, pp.335–346.