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Using AHP and PROMETHEE Multicriteria Decision-Making Approaches to Rank Available Fruit Crops for Orchard Expansion in Nangarhar, Afghanistan

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Abstract

Fruit production is a significant contributor to the Afghan economy's gross domestic product and earnings. However, Afghan farmers often receive low profits from fruit cultivation, which various factors can influence. One of the critical issues is the absence of published literature to aid stakeholders and farmers in selecting appropriate fruit types during orchard establishment. Therefore, this study aimed to rank five perennial fruit species (peach, persimmon, lemon, sweet and sour oranges) considered suitable for expanding the fruit industry in Nangarhar province, Afghanistan. Multicriteria Decision Analysis (MCDA) combined with Analytical Hierarchy Process (AHP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) approaches were employed to outrank the five alternatives (fruits) by a panel of seven local fruit experts. The ranking criteria for the fruits were yield rate, water requirement, productive lifespan, shelf life, early bearing, postharvest management cost, market value, net income, and consumer preference. The results indicated that sweet orange was the top-ranked fruit, followed by lemon, peach, persimmon, and sour orange. The net income was the most significant feature that positively contributed to the net flow (the balance between the positive and the negative outranking flows) score of sweet orange, lemon, and peach, considered innovative fruit species suitable for commercial orchards in national and foreign markets. However, for persimmon and sour orange, two fruit species traditionally grown in the area mainly for local and domestic consumption, net income was the main feature that negatively contributed to their net flow score. The net flow score of the alternatives did not change considerably when the criteria weight was assumed to be the same in the sensitivity analysis test, except for peach, which obtained the greatest negative score in the net flow. The outcomes can assist local farmers, professionals, and, more particularly, public stakeholders in choosing the most appropriate fruit type for the future of Nangarhar fruticulture.

Keywords Afghan fruticulture · Fruit selection · MCDA · Orchard establishment · Sensitivity analysis

Introduction

Afghanistan boasts a rich heritage in fruit cultivation and is renowned for its high-quality produce. It is also home to a unique collection of fruit tree species, which possess significant value for the global horticulture community due to their genetic diversity. The environmental conditions in the country are highly conducive to growing a wide range of subtropical and temperate fruit species. Citrus, olive, loquat, peach, and persimmon are commercially cultivated in

Availability of data and material All data are available with this manuscript.

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the eastern region, while deciduous, stone, and nut fruits are grown in the southern, central, western, and northern areas of the country. Given that the livelihoods of a significant proportion of the Afghan population depend on fruit cultivation, international donors in the agriculture sector have been focused on increasing fruit production by establishing new orchards (Masini and Giordani 2016). As a long-term investment, new orchards must be well-planned in all respects. One of the essential prerequisites is selecting the appropriate fruit crop since an incorrect choice can have long-term, detrimental effects on both rural areas and the overall economy of Afghanistan.

A common complaint among Afghan farmers is the low profitability of fruit production. According to a report, one of the main causes of this problem is the lack of knowledge among farmers (Yousufi 2016). Most farmers do not obtain market information or consult with experts when establishing new orchards. Furthermore, there is a great deficiency in the literature that describes the suitability of local topography for growing fruits, even for expert reference. To the best of our knowledge, no studies have been conducted that comprehensively consider criteria for selecting fruit crops for orchard establishment in Afghanistan. Therefore, to ensure farmers' profit, a study is essential that defines the suitability of specific fruit crops, considering various influencing factors in a particular area.

Previous studies (Masini and Giordani 2016), which have been corroborated by documents from the Ministry of Agriculture and Livestock of Afghanistan, indicate that Nangarhar Province is well-known for the presence and production of perennial fruit species such as peach (*Prunus persica* L. Batsch), persimmon (*Diospyros kaki* Thunb), sweet orange (*Citrus sinensis* [L.] Osbeck), sour orange (*Citrus aurantium* L.) and lemon (*Citrus limon* [L.] Osbeck). Among these species, persimmon and sour orange, and to a lesser extent, peach, have traditionally been grown and used domestically, along with other woody plants and vegetables in home gardens (bagh) or local pasture lands. However, their commercial cultivation is still in its early stages, despite previous attempts to establish a fruit industry in the area in the last century. All the quoted species are relevant for the local market and have a high potential economic value about fruit export from Afghanistan (Ahmad and Siddiqui 2015; Fitrat and Verma 2014). Multicriteria decision analysis (MCDA) is a fundamental approach when selecting, ranking, or prioritizing among multiple factors (Kabir and Sumi 2014). According to Rozman et al. (2017), MCDA is used to decide among available alternatives using different criteria. This approach ranks the alternatives based on all the decision-making criteria to reach a compromised result. MCDA integrates various techniques, including promising methods like the analytical hierarchy process (AHP), preference ranking organization method for enrichment of evaluations (PROMETHEE 2013), best–worst method (BWM), full consistency method (FUCOM), and technique for order of preference by similarity to ideal solution (TOPSIS). The approaches mentioned above have been used alone or in integration with geographic information systems (GIS) or remote sensing (RS) techniques (Sari et al. 2020; Everest et al. 2022a, b). MCDA has a wide range of applications, but it is primarily used for assessing land suitability for crop selection in agriculture. For instance, Everest (2021) used GIS-MCDA to identify suitable sites for pistachio cultivation in the Gulf of the Edremit region of Turkey. Trigoso et al. (2020) assessed land suitability for potato farming using AHP and RS-GIS techniques to enhance crop productivity for small-scale farmers. Similarly, Herzberg et al. (2019) evaluated the potential of agricultural land for growing various crops in a hilly region of Central Vietnam. Maleki et al. (2017) selected 21 ecological inputs for GIS-MCA to analyze land suitability for saffron cultivation in Azadshahr town, Iran. Additionally, MCDA has been used to assess the suitability of fruit crops or varieties for specific geographies (Agha et al. 2012; Nedeljković et al. 2022a, b; Rozman et al. 2015; Srdjevic et al. 2004).

This paper aims to rank five perennial fruit crops for the first time and decide which is the best choice for expanding orchard lands in Nangarhar province of Afghanistan using the MCDA method. The novel contribution of this study is the comparison of different fruit species, while most previous studies have focused on different varieties of a single fruit species. The findings of the paper help Afghan farmers, experts, international donors, and policymakers make decisions on the most appropriate fruit crop for establishing new orchards in the studied area.

Methodology

Study Area

This study was conducted in Nangarhar province, Afghanistan, which is located in the eastern part of the country at 34.171831°N latitude and 70.621679°E longitude with an average elevation of 826 m above sea level (Fig. 1). The subtropical climate of this province is suitable for growing a variety of fruits and vegetables throughout the year. According to the Köppen classification, Nangarhar falls under the BWh (hot desert climate) and BSh (hot semi-arid climate) zones. The warmest and coldest months of the year are July and January, respectively, with peak temperatures of 46 °C and –3 °C. The annual precipitation in the region ranges from 90 to 200 mm, and the area experiences over 300 days of sunshine annually due to the scarcity of rainfall. The topography of the region is characterized by

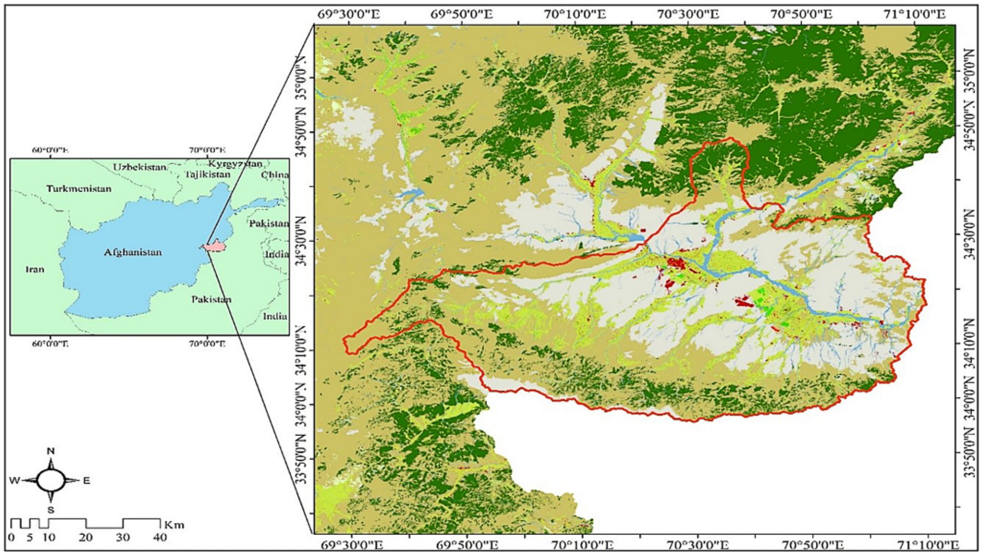

Fig. 1 Area of study (Nangarhar Province, map and boundaries)

irrigated and rainfed land, rivers, bare soil, rocky terrain, and snow-covered mountains. The capital city, Jalalabad, is located in a plain and serves as the center for the three provinces. The towering Safed Koh mountain range forms a natural boundary with Pakistan in the elevated south, and the lower slopes of this range are covered with nearly barren forests of pine and deodar cedar. Two main rivers, Kabul and Kunar, join each other near Jalalabad and flow across the province, draining into Pakistan. Although no comprehensive study has been conducted to provide data on soil properties, a study reported that the soil texture near river basins and paddy fields is sandy loam or loam (Masunaga et al. 2014).

The total area of Nangarhar is 7727 km^2, which currently has a population of about 1,735,531 (NASIA 2022). The plains of this province play a significant role in agriculture and livestock production. Coupled with the crucial trade route connecting Kabul with Peshawar, Nangarhar is one of the economically important provinces of Afghanistan. Torkham is one of the major border crossings between Afghanistan and Pakistan, serving as the busiest port of entry between the two countries and a major economic hub for the province.

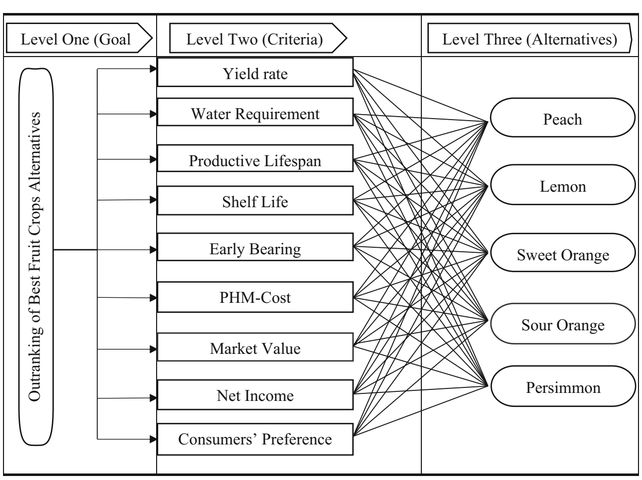

Fig. 2 Model of a three-level hierarchical structure

AHP

The Analytical Hierarchy Process was developed by Saaty (1977, 1980) and is one of the most applied methods in MCDA for calculating weights based on pairwise comparison judgments for each multiple conflicting criterion in decision-making (Sari et al. 2020). The hierarchical process involves the development of a model that defines the problem in terms of objectives, criteria, and alternatives and the relationships between them (Saaty 2008; Everest et al. 2021), which is presented in Fig. (2).

As already stated, the aim of this study is to rank and propose the best alternatives for fruit crops. The criteria were selected based on contextual demand and included yield rate (YR), water requirement rate (WR), productive lifespan of the tree (PL), shelf life at room temperature (SL), early bearing of fruits (EB), postharvest management cost (PHMC), market value (MV), net income (NI), and consumer preference (CP). The alternatives (fruit types) were peach, persimmon, sweet orange, sour orange, and lemon. Seven experts affiliated with different sectors within the agriculture domain were invited to fill out the questionnaire based on their personal judgments. For each criterion, the experts were asked to determine which of the two elements is more and to what extent is important, using the fundamental 1–9 scale proposed by Saaty (1977, 1980). Scores of 1 indicate that the two elements are equally important, while scores of 3, 5, 7, and 9 indicate increasingly stronger preferences. Scores of 2, 4, 6, and 8 correspond to intermediate values between the two adjacent judgments. The score of 9 denotes that one element in a pairwise matrix is significantly more important than the other. Once the data were collected through the questionnaire, the calculation process followed the following steps:

Step 1 The pairwise comparison matrix (A) was established (Table 1). Then, the pairwise comparison matrix (A) was normalized by dividing each entry by the column sum of the corresponding column, and criteria weights (W) were obtained by taking the average of the corresponding row, as presented in Table 2. The sum of the relative importance of

Table 1 Pairwise comparison matrix (A)

Criteria	YR	WR	PL	SL	EB	PHMC	MV	NI	CP
YR	1	8	1	3	3	8	1/3	1/9	1/5
WR	1/8	1	1/8	1/2	1/5	1	1/7	1/9	1/7
PL	1	8	1	3	3	8	1/3	1/9	1/5
SL	1/3	2	1/3	1	1/4	3	1/7	1/9	1/7
EB	1/3	5	1/3	4	1	6	1/5	1/9	1/4
PHMC	1/8	1	1/8	1/3	1/6	1	1/7	1/9	1/6
MV	3	7	3	7	5	7	1	1/4	1
NI	9	9	9	9	9	9	4	1	3
CP	5	7	5	7	4	6	1	1/3	1
Column sum	20	48	20	35	26	49	7	2	6

YR Yield rate, *WR* Water requirement, *PL* Productive lifespan, *SL* Shelf life, *EB* Early bearing, *PHMC* Post-harvest management cost, *MV* Market value, *NI* Net income, *CP* Consumer preference

Table 2 Normalized pairwise comparison matrix (A) and the criteria weights (W)

Criteria	YR	WR	PL	SL	EB	PHMC	MV	NI	CP	Weight (W)
YR	0.05	0.17	0.05	0.09	0.12	0.16	0.05	0.05	0.03	0.08
WR	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.02	0.02
PL	0.05	0.17	0.05	0.09	0.12	0.16	0.05	0.05	0.03	0.08
SL	0.02	0.04	0.02	0.03	0.01	0.06	0.02	0.05	0.02	0.03
EB	0.02	0.10	0.02	0.11	0.04	0.12	0.03	0.05	0.04	0.06
PHMC	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.03	0.02
MV	0.15	0.15	0.15	0.20	0.20	0.14	0.14	0.11	0.16	0.16
NI	0.45	0.19	0.45	0.26	0.35	0.18	0.55	0.45	0.49	0.37
CP	0.25	0.15	0.25	0.20	0.16	0.12	0.14	0.15	0.16	0.18
–	–	–	–	–	–	–	–	–	Sum	1.00

YR Yield rate, *WR* Water requirement, *PL* Productive lifespan, *SL* Shelf life, *EB* Early bearing, *PHMC* Post-harvest management cost, *MV* Market value, *NI* Net income, *CP* Consumer preference

Table 3 Matrix (AW), calculation of eigenvalue, λmax, and CR

Criteria	YR	WR	PL	SL	EB	PHMC	MV	NI	CP	Weight	AW	λmax	CI	RI	CR=CI/RI
YR	0.05	0.17	0.05	0.09	0.12	0.16	0.05	0.05	0.03	0.08	0.86	10.15	0.14	1.45	0.095
WR	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.02	0.02	0.17	9.25			
PL	0.05	0.17	0.05	0.09	0.12	0.16	0.05	0.05	0.03	0.08	0.86	10.15			
SL	0.02	0.04	0.02	0.03	0.01	0.06	0.02	0.05	0.02	0.03	0.28	9.48			
EB	0.02	0.10	0.02	0.11	0.04	0.12	0.03	0.05	0.04	0.06	0.55	9.35			
PHMC	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.05	0.03	0.02	0.17	9.23			
MV	0.15	0.15	0.15	0.20	0.20	0.14	0.14	0.11	0.16	0.16	1.69	10.88			
NI	0.45	0.19	0.45	0.26	0.35	0.18	0.55	0.45	0.49	0.37	4.17	11.14			
CP	0.25	0.15	0.25	0.20	0.16	0.12	0.14	0.15	0.16	0.18	1.98	11.32			
–	–	–	–	–	–	–	–	–	–	λmax		10.10			

YR Yield rate, *WR* Water requirement, *PL* Productive lifespan, *SL* Shelf life, *EB* Early bearing, *PHMC* Post-harvest management cost, *MV* Market value, *NI* Net income, *CP* Consumer preference, *CI* Consistency index, *RI* Random consistency index, *CR* Consistency ratio

Table 4 Saaty (1980) random consistency index (RI)

N	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 5 PROMETHEE evaluation table

Alternative/ criteria	YR (ton/ha)	[a]WR (1–5 scale)	PL (years)	SL (days)	EB (year)	PHMC (AFN/ton)	MV (AFN/kg)	NI (AFN/kg)	[a]CP (1–5 scale)
Peach	24	5	10	4	3	9000	45	30	4
Lemon	28	2	25	21	4	7000	55	35	3
Sweet Orange	20	3	25	21	6	5000	60	35	5
Sour Orange	20	1	30	14	7	3000	18	10	1
Persimmon	30	4	20	14	3	10000	40	25	2

[a] The scale value of 1–5 respectively shows the weakest and strongest levels, *YR* Yield rate, *WR* Water requirement, *PL* Productive lifespan, *SL* Shelf life, *EB* Early bearing, *PHMC* Post-harvest management cost, *MV* Market value, *NI* Net income, *CP* Consumer preference, *AFN* Afghanistan currency

Table 6 PROMETHEE modeling

Criteria/ Measurement	YR (ton/ha)	zWR (1–5 scale)	PL (years)	SL (days)	EB (years)	PHMC (AFN/ton)	MV (AFN/kg)	NI (AFN/kg)	CP (1–5 scale)
Weight	0.08	0.02	0.08	0.03	0.06	0.02	0.16	0.37	0.18
Max/Min	Max	Min	Max	Max	Min	Min	Max	Max	Max
Preference Fn	Type V	Type III	Type III	Type III	Type III	Type III	Type III	Type III	Type V
Threshold	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute	Absolute
Q: Indifference	3.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1
P: Preference	8.8	2	14.83	13.69	3.53	5454.72	31.74	20.43	3

[a] The scale value of 1 to 5 respectively shows the weakest and strongest levels, *YR* Yield rate, *WR* Water requirement, *PL* Productive lifespan, *SL* Shelf life, *EB* Early bearing, *PHMC* Post-harvest management cost, *MV* Market value, *NI* Net income, *CP* Consumer preference, *AFN* Afghanistan currency

the different criteria (weights) should not be less or more than one (Brans and Mareschal 2005).

Step 2 The consistency ratio (CR) of the pairwise comparison matrix (A) is checked. For that, the consistency index is tested with the equation given below: $CI = (\lambda max - n) / (n - 1)$, where λmax is the maximum eigenvalue and n is the size of the comparison matrix. Hence, a matrix (AW) is created (Table 3) by multiplying the comparison matrix (A) with its corresponding weight (priority) matrix (W). Then, a vector λ is created by dividing the elements in AW by the corresponding elements of W. λmax is calculated by taking the average of the values in λ. The stepwise equations and the results are given below:

$$\lambda max = 10.10$$

Next, the consistency index (CI) is determined by the following equation.

$$CI = (\lambda max - n)/(n - 1)$$

where λmax is the maximum eigenvalue and N is the size of the comparison matrix which is nine. The equation solved for the CI is below:

$$CI = (10.10 - 9)/(9 - 1) = 0.13$$

Finally, the consistency ratio is calculated by the following equation:

$$CR = CI/RI$$

The RI is determined based on the number of the corresponding size of the square matrix. The matrix size is 9 so $n = 9$, which corresponds to $RI = 1.45$, is shown in (Table 4).

The CR is solved below with the obtained figures:

$$CR = 0.13/1.45 = 0.095$$

The judgment is considered consistent when CR is ≤ 0.10; otherwise, it is inconsistent, and the comparison matrix has to be reviewed and improved.

Table 7 PROMETHEE II result of complete ranking based on net flow (Φ)

Alternatives	Φ	$Φ^+$	$Φ^-$	Complete Ranking
Sweet orange	0.3370	0.4271	0.0901	1
Lemon	0.3198	0.3718	0.0521	2
Peach	0.0426	0.2597	0.2171	3
Persimmon	–0.0924	0.1991	0.2915	4
Sour orange	–0.6070	0.0854	0.6924	5

PROMETHEE

PROMETHEE is a popular MCDA method developed by Brans (1982). It was further developed over the years by Vincke and Brans (1985). The visual interaction module GAIA, which is a graphical representation of the PROMETHEE method, was proposed by Brans and Mareschal (1988). However, PROMETHEE I and II calculate partial and complete rankings, respectively. In this study, PROMETHEE II is used for the full ranking of alternatives. PROMETHEE II is based on a pairwise comparison with each recognized criterion. The alternatives are weighed against the previously established criteria, which need to be either maximized or minimized (Behzadian et al. 2010).

The PROMETHEE algorithm begins by establishing an evaluation table that should essentially contain numerical data (Macharis et al. 2004). The alternatives and criteria can be expressed as an (m × n) evaluation matrix. In this study, an evaluation table was created and filled out by the experts, as shown in Table 5.

Once the evaluation table is set, then PROMETHEE typically requires two more types of essential information: (1) the information for weights (w j): The weights represent the relative importance of each criterion in the decision. PROMETHEE does not have specific guidelines to obtain criteria weights but believes that the decision-maker can evaluate the weights of the criteria. As mentioned earlier, we have obtained the weights by using AHP. (2) The information of the preference function (Pj): The preference function defines how the pairwise evaluation differences are translated into degrees of preference ranging from 0 to 1. Brans and Vincke (1985) proposed six basic types of preference to facilitate the selection of the preference function. Given the typology of the data used in this research, the Type III: V-shape preference function and Type V: Linear preference function are suited. As the above specified information is acquired, a PROMETHEE model is created, as shown in Table 6.

Results and Discussion

After applying the PROMETHEE method, the ranking was determined based on the values of outranking flows. The results of ranking the alternatives, which is based on net outranking flow, are given in Table 7. The sweet orange is ranked first, followed by lemon, peach, persimmon and sour orange. The results of the complete and partial ranking of alternatives are given in Fig. 3.

PROMETHEE I provides a partial ranking by considering both the negative and positive outranking flows. In this case, the result shows that both lemon and sweet orange have high outranking flows but are incomparable. Additionally, peach is preferred over persimmon, while sour orange is the least preferred alternative. Although PROMETHEE I can provide a partial ranking, it may not offer adequate information about the best alternatives. Therefore, PROMETHEE II, which uses the net flow to represent the balance between the positive and negative outranking flows (Brans and Mareschal 2005), was used to show the complete ranking of alternatives. The results indicate that sweet orange is preferred over lemon, followed by peach, persimmon, and sour orange, with sweet orange being highly close to lemon in the complete ranking.

The PROMETHEE Rainbow provides a disaggregated view of the PROMETHEE II outranking results. The net flow (Φ) of the PROMETHEE II outranking, which highlights the strong and weak features of each option, is illustrated in Fig. 4. The results reveal that sweet orange (A3) scores high on several criteria, contributing positively to its net flow score. In addition to its sweet and juicy taste, sweet orange is considered a significant source of nutrients and vitamins, making it a healthy fruit among the local population. Moreover, the lack of availability of sweet oranges throughout the year leads to importing citrus fruits from Pakistan, resulting in a high market value and locally relevant net income (Grosso et al. 2013). Orange trees have a long productive lifespan, and fruit harvest and postharvest management are relatively simple compared to peach and persimmon. Oranges also have a significantly longer storage and shelf life than other crop alternatives, as Girardi et al. (2021) and Spadaro and Gullino (2004) noted. The highly positive aspects of sweet orange contrast with its weak features, such as early bearing and yield rate. On the other hand, the other two citrus alternatives show positive features that are considered lower than those observed for sweet orange, such as consumer preference for both lemon and negative features for most criteria for sour orange.

In more detail, all criteria contributed positively to lemon except postharvest management (A2). Similarly, the most significant feature of lemon is net income. For sour orange (A5), yield and early bearing contributed positively, while the remaining criteria had a negative contribution.

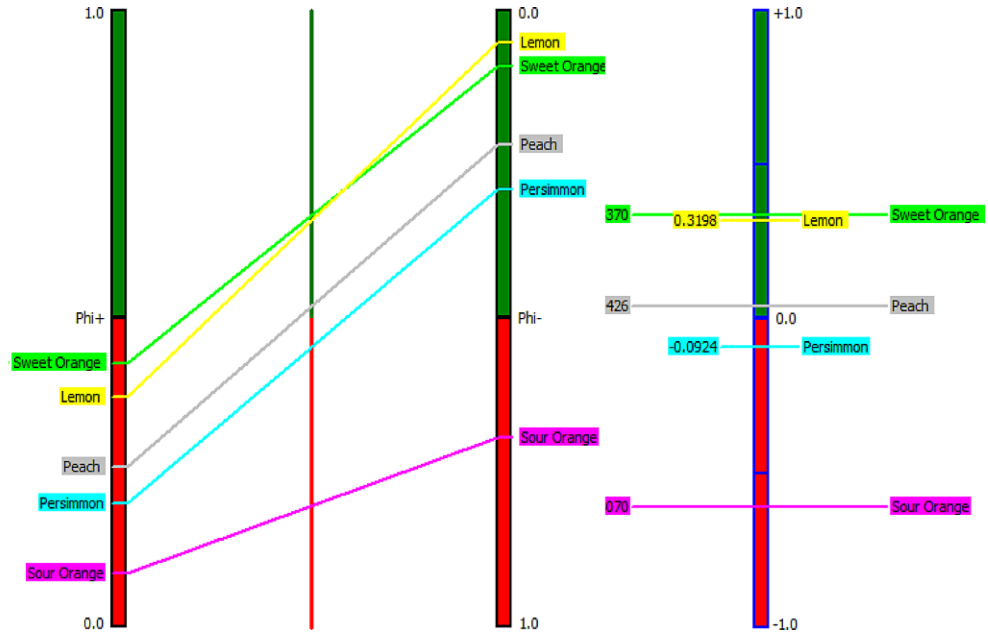

Fig. 3 The representation of partial ranking (*left*) and complete ranking (*right*) with flow scores

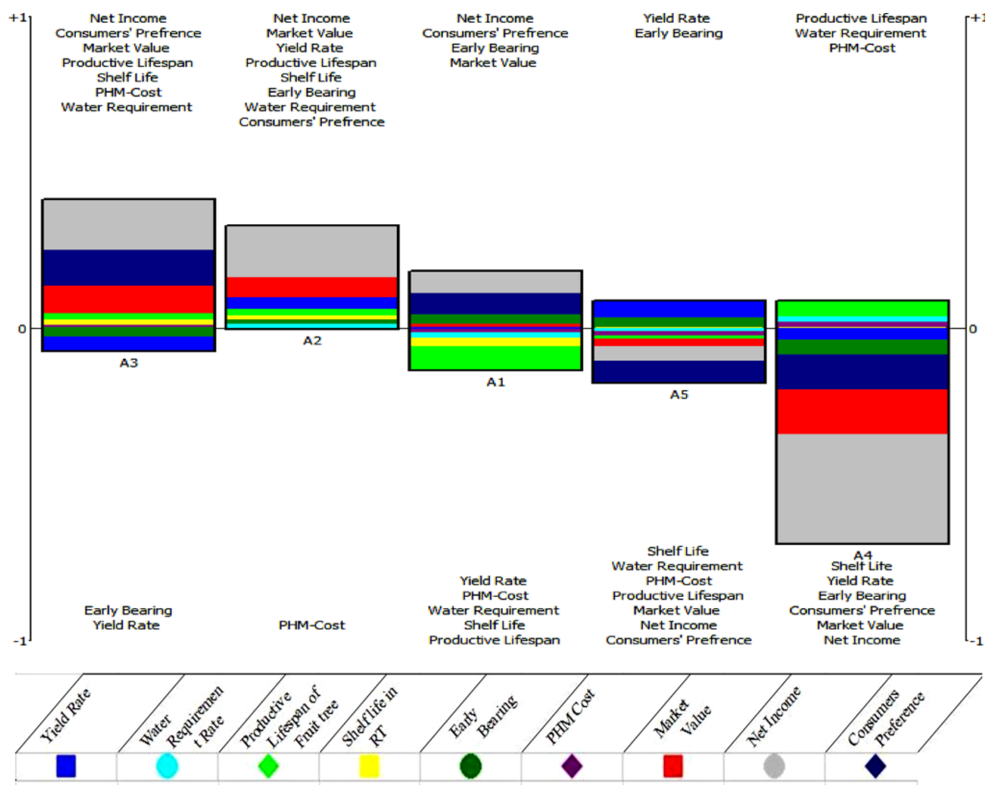

Fig. 4 Disaggregated view of the PROMETHEE II outranking. It is a visual demonstration of the Phi net flow computation, emphasizing the strong and weak features of each action. The result is taken from the Visual-PROMETHEE Software (PROMETHEE-Gaia 2013) where *A1* = Peach, *A2* = Lemon, *A3* = Sweet orange, *A4* = Sour orange, *A5* = Persimmon

Consumer preference played a significant negative role in the ranking of sour orange, resulting in a negative net flow score for this alternative. Sour orange is a traditional crop that has been increasingly replaced by newer and more valuable citrus crops in the past 20 years (Bayani et al. 2018). For peach (A1), four criteria contributed positively, while the other five had negative contributions. Despite having more weak features, peach's net flow score remained positive due to its higher demand and income value among consumers. Peach is a relatively new crop in Nangarhar province, and its commercial cultivation is hindered by challenges such as postharvest management and limited shelf life, particularly in hot climates (Pan et al. 2019).

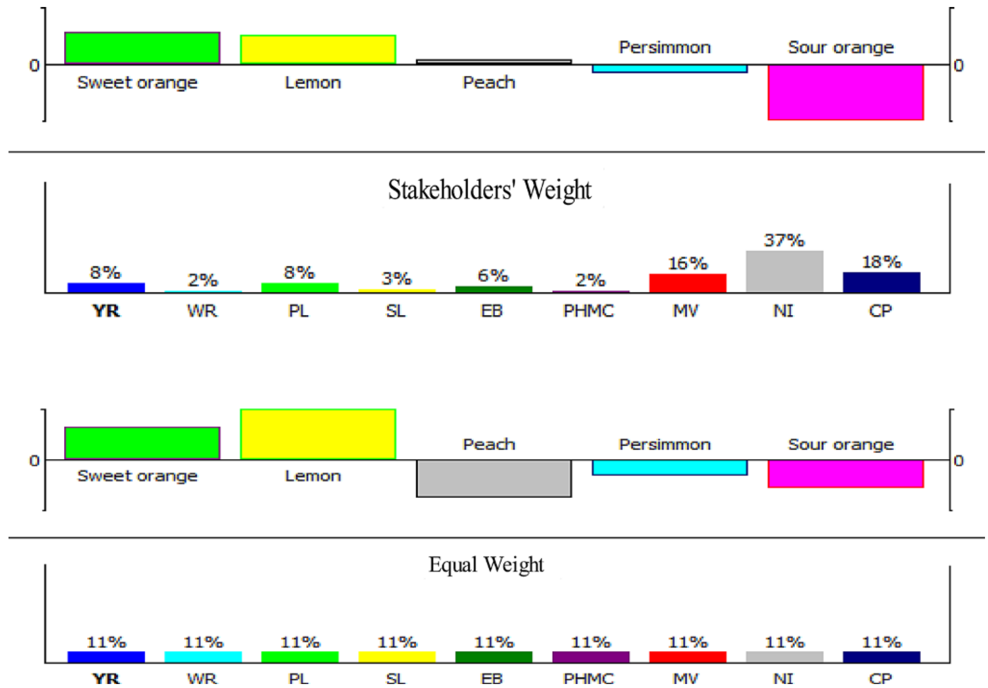

Fig. 5 The upper part shows the result considering the stakeholders' weights, and the lower part exhibits the result obtained using the sensitivity analysis. The results were generated by the Visual PROMETHEE Software (PROMETHEE-Gaia (2013). *YR* Yield Rate, *WR* Water Requirement, *PL* Productive Lifespan, *SL* Shelf Life, *EB* Early Bearing, *PHMC* Post-Harvest Management Cost, *MV* Market Value, *NI* Net Income, *CP* Consumer Preference

Finally, persimmon (A4) was ranked with three positive slices and six negative features. Among the negative traits, the most significant was net income, followed by low market value and consumer preference. Persimmon is represented locally by sparse trees and is perceived as a crop with a complex value chain due to the astringency of its fruits (Arnal and Del Río 2003).

Overall, three alternatives (sweet orange, lemon, and peach) had positive net flow scores, and two others (sour orange and persimmon) had negative net flow scores. The essential criteria that affected the net flow scores were consumer preferences, income, and market value. For sweet orange and peach, consumer preference played an important role, while for lemon, it is close to zero. In contrast, sour orange and persimmon have consumer preference as their main negative feature. The sweet orange, lemon, and peach are the alternatives that have had the highest demand in terms of net income, whereas the persimmon and sour orange were the lowest in this criterion. In terms of market value, sweet orange obtained the highest value, which was not significantly different from that of lemon.

Sensitivity Analysis

The weights of the criteria have a substantial impact on the analysis conclusion, particularly when there are significantly competing criteria (Mareschal 2013). Therefore, it is important to perform weight sensitivity analysis to answer the "what if" question or understand how stable each alternative is when changing the weights of individual criteria. In this procedure, we assume equal importance (weights) to all the criteria and then compare the results of the stakeholders' weights (obtained by experts) and the equal weights. To perform this analysis, the Visual PROMETHEE software has a specialized "walking weights" feature that allows decision-makers to interactively modify the weights and observe the result. In line with this analysis, lemon and sweet orange were the only alternatives with a positive net flow and ranked first and second, respectively (Fig. 5). In contrast, peach showed significant deviation by obtaining a negative score on the net flow. There was a slight change in persimmon, while the negative value of the sour orange was slightly decreased.

The present study showed that sweet orange is the best fruit crop alternative, followed by lemon and peach, while sour orange and persimmon have more negative aspects. When equal weights were assigned to the criteria, lemon was ranked as the best alternative and peach as the worst. It is important to note that different methodological approaches, alternatives, criteria, and related parameters can significantly impact the results of MCDA studies. To compare with other similar studies, Banaeian et al. (2022) used the novel decision-making method of ELECTRE IV to rank oranges, tangerines, persimmons, and kiwi fruits by environmental, energy, and technological criteria. The study indicated that kiwi fruit was the most sustainable selection, followed by orange, persimmon, and tangerine. Nedeljković et al. (2022a) used a fuzzy multicriteria decision model to assess seven different pear varieties in some economic and technical criteria, with 'Šampionka' and 'Konferans' being the best indicators for raising a new orchard of pears. The same authors used the same model of MCDA and expert evaluation for the apple varieties ranking (Nedeljković et al. 2022b), with 'Jonagold' having the best results and 'Gala' showing the worst results for the new orchard establishment in Bosnia and Herzegovina. Market assessment is crucial in determining customer willingness to consume a particular fruit type. Puška et al. (2022) conducted a market assessment of six varieties of pears commonly grown in Serbia using 10 criteria, which were determined through the fuzzy CRITIC (Criteria Importance Through Intercriteria Correlation) and fuzzy CRADIS (Compromise Ranking of Alternatives from Distance to Ideal Solution) methods for criteria weights and pear variety rankings, respectively. The results showed that the highest market demand exists for 'Konferans' and 'Viljamovka'. Rozman et al. (2017) applied the DEX multicriteria model to seven varieties of plums in the Western Balkans and found that 'Stanley' is the most suitable variety for starting new fruit orchards, while 'Čačanská lepotica' and 'Čačanská rodna' are also very suitable. In sensitivity analysis, 'Stanley' and 'Čačanská rodna' were the only varieties that remained "very acceptable" when criteria values were assumed to be equal for all plum varieties. Similarly, five varieties of walnuts were evaluated in seven criteria using the AHP multi-criterion evaluation method, and 'Rasna' ranked first, followed by 'Macva', 'Sejnovo', 'Franquette', and 'Kasni rodni' (Srdjevic et al. 2004). The suitability of different emerging fruit crops (pistachio, almond, walnut, and strawberry) for cultivation in the Beira Baixa region of Portugal was assessed based on AHP-GIS analysis, and it was found that 63% of the total available area had the highest potential for walnut, 16% for pistachio and strawberry each (Quinta-Nova et al. 2020). In Brazil, Almeida and Almeida-Filho (2012) evaluated the suitability of banana, guava, orange, apple, papaya, mango, tangerine, and grape for future contracts using the PROMETHEE I method and considering criteria such as perishability, price oscillation, and market size. The result showed that grape is the best suited for negotiations using futures markets.

Conclusions

Programming and decision-making for rural development require solid approaches based on realistic assumptions that consider suitable criteria to choose the most appropriate alternatives. In our study, we used MCDA to evaluate a preselected set of potential fruit crops based on botanical, agronomic, and market parameters, which limited the number of alternatives. However, our study has certain limitations related to the number and type of criteria used. Despite these factors, which are common in similar studies in the agricultural sector, MCDA can be considered a valuable tool to support decision-making. Nevertheless, the results should be subject to further consideration and discussion with stakeholders, professionals, and farmers.

The fruit crops were assessed based on several criteria including yield rate, water requirement, productive lifespan, shelf life, early bearing to fruits, postharvest management cost, market value, net income, and consumer preference. The results revealed that sweet orange ranked first followed by lemon, peach, persimmon, and sour orange. The positive features for sweet orange were net income and consumer preference, whereas sour orange scored negatively in these criteria. The sensitivity analysis ranked lemon as the top fruit crop and peach as the least preferred. Therefore, the recommended ranking for future orchard expansion in Nangarhar province of Afghanistan would be based on the determined criteria.

The current findings will be beneficial for local government, researchers, and decision-makers in Nangarhar province of Afghanistan, enabling them to develop policies to strengthen the modern citrus industry in the area.

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Author Contribution M. H. Mohammadi and E. Giordani conceptualized and designed the project; Z. Hejazi and M. A. Saeedi collected the data; M. H. Mohammadi performed data analysis and drafted the manuscript. Z. Hejazi and E. Giordani reviewed and revised the manuscript.

Conflict of interest M. H. Mohammadi, Z. Hejazi, M. A. Saeedi and E. Giordani declare that they have no competing interests.

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