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Performance evaluation of IPARD-II rural development programs with integrated DIBR-RAWEC methods

IPARD-II kırsal kalkınma programlarının bütünleşik DIBR-RAWEC yöntemleriyle performans değerlendirmesi

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Abstract

Rural development is a concept that has garnered increased emphasis in contemporary development plans. This phenomenon, which should be approached from a different perspective compared to urban development, entails a strategy that enhances the living standards of the rural population through the implementation of central policies. This study seeks to ascertain the priority of rural development programs (RDP) coordinated by the Agriculture and Rural Development Support Institution (ARDSI) in Türkiye. The weight of the criteria utilized to determine these priorities is calculated using the DIBR (Defining Interrelationships Between Ranked criteria) method. It has been determined that the criterion with the highest degree of importance is the Total Financial Support Value. Subsequently, the RAWEC (Ranking Alternatives with Weights of Criterion) method is utilized to establish the efficiency ranking of the seventeen rural development programmes implemented during the IPARD-II (Instrument for Pre-Accession Assistance Rural Development) period. According to the analysis conducted, it has been determined that the most effective rural development program is "Red Meat Producing Agricultural Enterprises". To assess the stability of the rankings obtained through the RAWEC method, the sensitivity of these rankings to different criterion weights is tested by gradually altering these weights.

Keywords: Rural development, ARDSI, IPARD, MCDM, DIBR, RAWEC.

Öz

Kırsal kalkınma, çağdaş kalkınma planlarında giderek daha fazla önem verilen bir kavramdır. Kentsel kalkınmaya göre farklı bir bakış açısıyla ele alınması gereken bu olgu, uygulanan merkezi politikalar ile kırsal nüfusun yaşam standartlarını artıran bir yaklaşım olarak karşımıza çıkmaktadır. Bu çalışma, Türkiye'de Tarım ve Kırsal Kalkınmayı Destekleme Kurumu (TKDK) tarafından koordine edilen kırsal kalkınma programlarının (KKP) önceliğini tespit etmeyi amaçlamaktadır. Bu önceliklerin tespiti amacıyla kullanılan kriterlerin ağırlığı DIBR (Defining Interrelationships Between Ranked criteria) yöntemiyle hesaplanmış ve en önemli kriterin Toplam Finansal Destek Tutarı olduğu belirlenmiştir. Sonrasında, IPARD-II (Instrument for Pre-Accession Assistance Rural Development) döneminde uygulanan on yedi kırsal kalkınma programının etkinlik sırasını belirlemek amacıyla RAWEC (Ranking Alternatives with Weights of Criterion) yönteminden yararlanılmıştır. Bu analiz neticesinde en etkili olan kırsal kalkınma programının "Kırmızı Et Üreten Tarımsal İşletmeler" programı olduğu belirlenmiştir. RAWEC yöntemiyle elde edilen sıralamaların istikrarlı bir yapıda olup olmadığını test etmek amacıyla kriter ağırlıklarına kademeli değişim uygulanarak bu sıralamaların farklı kriter ağırlıklarına karşı duyarlılıkları test edilmiştir.

Anahtar Kelimeler: Kırsal kalkınma, TKDK, IPARD, ÇKKV, DIBR, RAWEC.

1 Introduction

Rural development is a comprehensive concept that encompasses various aspects such as education, health, housing, public services, cultural heritage, and various sectoral and general economic concerns for individuals residing in rural areas. In other words, it can be defined as a permanent and sustainable process of economic, social, cultural, and environmental transformations aimed at enhancing the long-term welfare of a country's society [1]. Therefore, rural development refers a multidimensional process that simultaneously tackles economic, socio-cultural, and environmental objectives in a sustainable manner [2].

Agricultural economics essentially covers issues such as farm production, marketing of agricultural products, food demand, agricultural and food policies. However, the scope of rural economics is not limited to these concepts, but it is a broader approach that encompasses issues such as the economic welfare of rural residents, the promotion of the activities of agriculture-related institutions, income inequality, food security, access to basic public services such as health and education, individuals' freedoms, rule of law, human rights [3].

From this perspective, rural development assumes a greater significance due to its substantial contribution to global food production and its added value to the environment, upon which human survival depends. It is specifically emphasized by the Organisation for Economic Co-operation and Development (OECD) that prioritizing the objective of minimizing barriers to innovative entrepreneurship in rural areas is of utmost importance. Specifically, individuals residing in rural areas face considerable challenges in terms of accessing the necessary infrastructure required for implementing innovative initiatives. Therefore, it is of paramount importance to offer incentives to bolster the endeavours of rural inhabitants, particularly young entrepreneurs. Furthermore, studies on social entrepreneurship and innovation within the context of rural development programs is crucial in order to provide these regions with new opportunities for growth [4].

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In the course of Türkiye's ongoing accession negotiations with the European Union (EU), the establishment of an Instrument for Pre-Accession Assistance-Rural Development (IPARD) Agency in accordance with EU criteria has been proposed. This initiative aims to address and implement policies related to Chapter 11, which focuses on Agriculture and Rural Development. The Agriculture and Rural Development Support Institution (ARDSI), established in accordance with these principles, is responsible for various tasks. These include facilitating the modernization of the agricultural sector, promoting the adherence of agricultural enterprises to European Union (EU) standards in areas such as food safety, animal health, plant health, and environmental regulations, as well as supporting the diversification of economic activities in rural areas. Financial aid allocated to Türkiye by the EU for rural areas and sectors identified under IPARD programs is distributed to entrepreneurs under the coordination of this institution [5].

As of 2024, the coordinatorships associated with ARDSI are situated in the provinces specified in Figure 1.

As of 2024, IPARD-I and IPARD-II programmes have been accomplished and it is planned to transfer 785 million Euros of grant support to entrepreneurs within 7 years with the implementation of IPARD-III programme. During the IPARD-I period, which spanned from 2007 to 2013, a total of 15 Calls for Projects were carried out. Within the framework of investments amounting to approximately 6.8 billion TL, grant payments totalling about 3.1 billion TL were disbursed to investors, resulting in the creation of approximately 57 thousand employment opportunities. On the other hand, the IPARD-II period covered the years 2014-2020 and within the scope of 6 Call for Projects implemented as of 2019, a grant payment of 777 million TL was provided for a total investment of 3.1 billion TL [5].

Considering the inevitable importance of rural development and the attitude of Türkiye in this regard, this study aims to determine the performance order of 17 financial support programmes implemented as of 2019 within the scope of IPARD-II.

In the initial section of the study, the significance of rural development and the practitioner organisation of rural development in Türkiye are discussed. Within the same section, a comprehensive literature review is provided, encompassing the matter of rural development as well as the methodologies employed in this study. In the second section, an explanation of the DIBR and RAWEC methods that were applied are provided. Subsequently, in the third section, the success order of 17 distinct financial support programmes is determined through the implementation of these aforementioned methods. In the final section, a general evaluation of the findings obtained within the scope of the study is conducted.

Since there is a dearth of performance evaluation for rural development programs implemented within the scope of IPARD in Türkiye, the primary contribution of this study will be addressing this gap in the existing literature. Therefore, the primary objective is to ascertain the areas that take precedence and those that are amenable to be enhanced during policymaking about rural development. In addition, integration of the DIBR and RAWEC techniques, which are highly contemporary in the realm of multi-criteria decision making methods, can be regarded as the secondary contribution of the study.

2 Literature review

The literature review is conducted through the examination of two dimensions: the support provided by ARDSI and the methods of DIBR & RAWEC employed in the study. Initially, the studies examining the support for ARDSI can be summarized as follows.

Özkul and Bozkurt [6] conducted a survey involving 109 firms located in the Isparta province. Their objective was to ascertain the impact of the IPARD-I program on the development of the agricultural industry, as well as its influence on employment and income growth within the region. To achieve this, the researchers employed a range of statistical techniques. Acar and Çağlar [7] analysed the individual, familial and social contributions of women benefiting from ARDSI grants who engaged in entrepreneurship activities in rural areas.

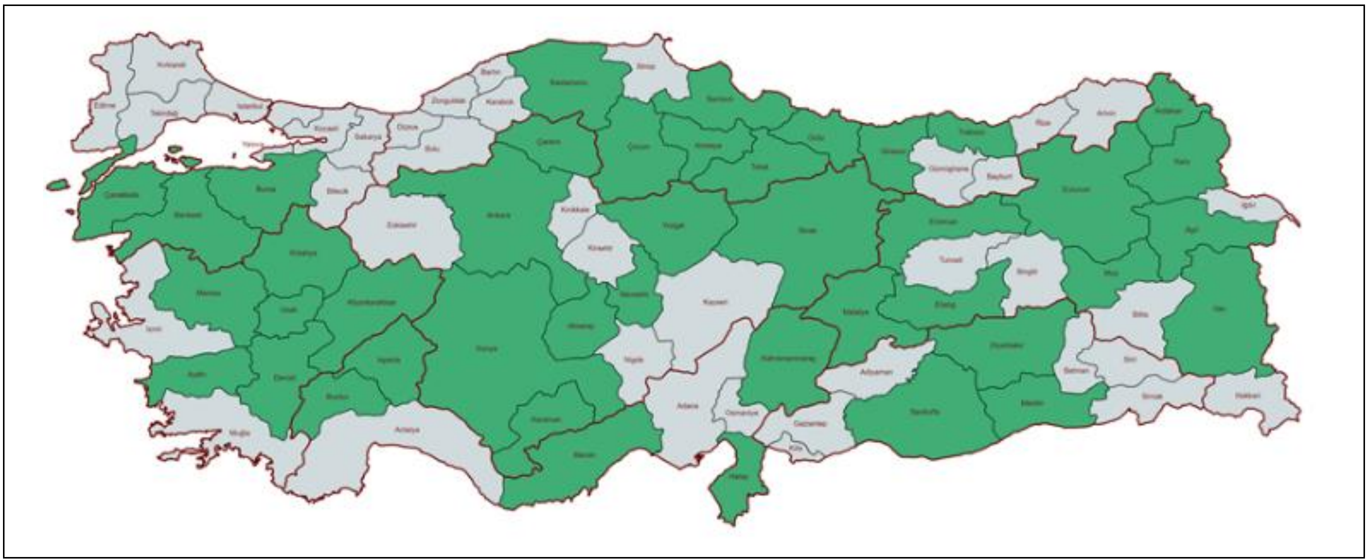

Figure 1. ARDSI Coordinatorships operating in Türkiye.

Increased personal self-confidence of these women, increased income for families, and their positive contribution to the region in terms of socio-economic and employment aspects constitute the prominent findings of the study. Gülçubuk et al. [8] examined the economic, environmental and socio-cultural contributions of the dairy and livestock breeding programmes supported and implemented by ARDSI between the years 2011-2014. In his study analysing the supports provided by ARDSI for rural development, Bahtiyar [9] indicates that the active participation of citizens living in rural areas is accelerated with the EU accession process. In addition, he emphasises that there has been an increase in investments and employment in rural areas and that education projects in these areas should be intensified.

The studies utilizing the DIBR and RAWEC methods can be summarized as follows.

In a study conducted by Božanić et al. [10] to ascertain the priority ranking of six distinct lean production methods, the DIBR-II approach was favoured for the purpose of assigning weights to five criteria. In order to select a suitable assault boat for use in military operations, Tešić et al. [11] employed the DIBR-II method for the prioritisation and weighting of the criterion set consisting of draft, capacity, price, speed, armour, range and armament. Radovanović et al. [12] carried out the prioritisation and weighting of the eight criteria used in the unmanned aerial vehicle selection problem by utilising the DIBR method. Tešić and Marinković [13] used a combination of DIBR and DIBR-II methods to determine the weights of 5 criteria in a complex automatic combat system selection problem. Pamucar et al. [14] employed the DIBR method in their study for prioritisation of sustainable transport systems consisting of electric vehicles, autonomous electric vehicles, electric bicycles and electric scooters in Belgrade, Serbia. Žnidaršič et al. [15] utilised the DIBR method to determine the infantry landing site. In order to identify the sustainable performance of solar power plants, Kara et al. [16] employed the DIBR-II method by using spherical fuzzy sets.

As the proposer of the method, Puška et al. [17] presented the RAWEC approach for a selection problem of an agricultural distribution centre planned to be constructed in the Brčko Region of Bosnia and Herzegovina. For a similar objective, Petrović et al. [18] utilised the RAWEC method to examine the sustainability of different forms of transport systems such as road, air, rail, and water transport in the European Union.

On the other hand, there are also a number of studies in the literature that can directly or indirectly contribute to the issue of rural development by using multi-criteria decision-making methods. Gök Kısa [19] aimed to identify renewable energy resources in TR83 region by employing CRITIC based grey relational analysis approach. Uyan [20] aimed at geographical information system supported mapping of areas where solar power plants can be established by employing Analytical Hierarchical Process method.

3 Materials and methods

This study, which endeavours to establish the performance ranking of seventeen distinct programs implemented by ARDSI under the IPARD-II framework, consists of three stages. Initially, the criteria used for each programme are determined by DIBR method. In the second stage, the aforementioned programs are considered as alternatives, and the RAWEC method is utilized to establish an appropriate ranking for these programs. In the final phase, a sensitivity analysis is performed to determine the stability of the obtained orders.

The flowchart depicting the procedural steps utilized in the study is presented in Figure 2.

3.1 DIBR method

Introduced by Pamucar et al. in 2021, DIBR is a subjective criterion weighting method which enables one or more decision makers to present their preferences. Within the framework of this methodology, decision-makers engage in comparisons among various criteria, with the aim of establishing a hierarchy based on their relative superiority. Specifically, the relative significance of two consecutive criteria in relation to each other is established through the use of a percentage fraction.

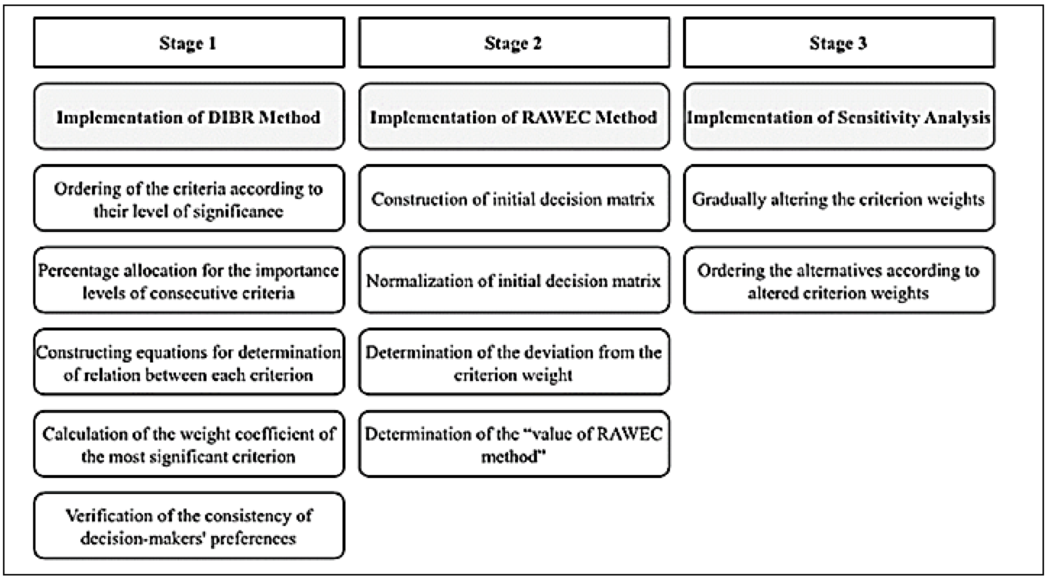

Figure 2. Procedural steps of the research.

By doing so, this approach provides the opportunity to avoid the inconsistencies that arise in some subjective criterion weighting methods such as Analytical Hierarchical Process (AHP) [21] Best-Worst Method (BWM) [22] and Full Consistency Method (FUCOM) [23] applications, especially in the presence of a high number of criteria. In this research, DIBR approach is employed since the method includes simpler and more comprehensible steps and generates more consistent results in comparison with complex weighting methods.

The steps followed within the method are presented below [24].

Step 1. Ordering of the criteria according to their level of significance

The criteria used in the study which are in the set of $C = \{C_1, C_2, C_3, \ldots, C_n\}$ are ordered according to the level of importance, where n indicates the number of criteria. To illustrate, consider that the order of importance of the criteria is $C_1 > C_2 > C_3 > \cdots > C_n$.

Step 2. Percentage allocation for the importance levels of consecutive criteria

Total importance level of 100% is shared among consecutively ordered criteria with a ratio of λ. Allocation between each consecutive criterion is symbolized as $\lambda_{1,2}, \lambda_{2,3}, \lambda_{3,4}, \ldots, \lambda_{n-1,n}$. For instance, if a ratio such as $\lambda_{1,2} = 0.45$ is assigned between C_1 and C_2, it should be interpreted as 55% of the overall importance is attributed to criterion C_1 and 45% of the overall importance is attributed to criterion C_2. In case of equality, the λ value should be determined as 0.5 for each criterion. In addition, allocation between the most important and the least important criterion is also carried out at the last stage and indicated as $\lambda_{1,n}$. An important point to be considered in this allocation is that the sum of importance ratios between consecutive criteria and the most important and least important criteria should be 100% and the conditions $\lambda_{n-1,n} \in [0,1]$ and $\lambda_{1,n} \in [0,1]$ should be satisfied. Taking these considerations into account, the percentage relationships between the criteria are formulated by Equation set (1) as follows;

$$\begin{gathered} \omega_1 : \omega_2 = (1-\lambda_{1,2}) : \lambda_{1,2} \\ \omega_2 : \omega_3 = (1-\lambda_{2,3}) : \lambda_{2,3} \\ \omega_3 : \omega_4 = (1-\lambda_{3,4}) : \lambda_{3,4} \\ \ldots \\ \omega_{n-1} : \omega_n = (1-\lambda_{n-1,n}) : \lambda_{n-1,n} \\ \omega_1 : \omega_n = (1-\lambda_{1,n}) : \lambda_{1,n} \end{gathered} \tag{1}$$

Step 3. Constructing equations for determination of relation between each criterion

Considering the percentage distribution between their significance levels, the relations of each criterion with the most important one are calculated by means of Equation sets (2).

$$\begin{gathered} \omega_2 = \frac{\lambda_{1,2}}{(1-\lambda_{1,2})} . \omega_1 \\ \omega_3 = \frac{\lambda_{2,3}}{(1-\lambda_{2,3})} . \omega_2 = \frac{\lambda_{1,2} . \lambda_{2,3}}{(1-\lambda_{1,2}) . (1-\lambda_{2,3})} . \omega_1 \\ \ldots \\ \omega_n = \frac{\lambda_{n-1,n}}{(1-\lambda_{n-1,n})} . \omega_{n-1} \\ = \frac{\lambda_{1,2} . \lambda_{2,3} . \ldots . \lambda_{n-1,n}}{(1-\lambda_{1,2}) . (1-\lambda_{2,3}) . \ldots . (1-\lambda_{n-1,n})} . \omega_1 \\ = \frac{\prod_{i=1}^{n-1} \lambda_{i,i+1}}{\prod_{i=1}^{n-1} (1-\lambda_{i,i+1})} . \omega_i \end{gathered} \tag{2}$$

Step 4. Calculation of the weight coefficient of the most significant criterion

According to the condition of $\sum_{i=1}^{n} \omega_i = 1$, the equation; $\omega_1 + \frac{\lambda_{1,2}}{(1-\lambda_{1,2})} . \omega_1 + \frac{\lambda_{1,2} . \lambda_{2,3}}{(1-\lambda_{1,2}) . (1-\lambda_{2,3})} . \omega_1 + \cdots + \frac{\prod_{i=1}^{n-1} \lambda_{i,i+1}}{\prod_{i=1}^{n-1} (1-\lambda_{i,i+1})} . \omega_1 = 1$ will be simplified as Equation (3) in order to determine the weight coefficient of the most significant criterion.

$$\omega_1 = \frac{1}{1 + \frac{\lambda_{1,2}}{(1-\lambda_{1,2})} + \frac{\lambda_{1,2} . \lambda_{2,3}}{(1-\lambda_{1,2}) . (1-\lambda_{2,3})} + \cdots + \frac{\prod_{i=1}^{n-1} \lambda_{i,i+1}}{\prod_{i=1}^{n-1} (1-\lambda_{i,i+1})}} \tag{3}$$

Based on the relations defined in Step 3, weight coefficients of remaining criteria $\omega_2, \omega_3, \ldots, \omega_n$ are also calculated.

Step 5. Verification of the consistency of decision-makers' preferences

The relation $\omega_n = \frac{\lambda_{1,n}}{(1-\lambda_{1,n})} . \omega_1$ defined in Step 1 is also used to validate the equation $\omega_n = \frac{\prod_{i=1}^{n-1} \lambda_{i,i+1}}{\prod_{i=1}^{n-1} (1-\lambda_{i,i+1})} . \omega_1$ defined in Step 2 and hence, the ultimate consistency of the relevant decision maker's preferences. For this purpose, the relation between the most and least significant criterion are additionally calculated by Equation (4).

$$\hat{\lambda}_{1,n} = \frac{\omega_n}{\omega_1 + \omega_n} \tag{4}$$

The proposers of the method state that a difference greater than 10% between $\lambda_{1,n}$ and $\hat{\lambda}_{1,n}$ indicates inconsistencies. In this case, the relationships between the criteria should be redefined.

3.2 RAWEC method

Introduced to literature by Puška et al., RAWEC method enables computation in relatively fewer steps in comparison to many other MCDM approaches since it integrates the criteria weighting and deviation from the criteria weights. This situation results in a high degree of simplicity for the method. This approach is notable for its distinction from many other methods, as it not only arranges the alternatives based on the values presented in the decision matrix, but also considers the deviations from the ideal values. The persuasive arguments presented for this method rendered it as the preferred approach for ranking 17 rural development programs implemented under the IPARD - II framework.

The procedure steps of the RAWEC method are listed as follows [25].

Step 1. Construction of initial decision matrix

In the first stage of the research m alternatives, n criteria and predetermined values are allocated in the matrix X_{mxn} as indicated in Equation (5).

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \qquad \begin{matrix} i = 1,2,3, \ldots\ldots, m \\ j = 1,2,3, \ldots\ldots, n \end{matrix} \tag{5}$$

Step 2. Normalization of initial decision matrix

A double normalization procedure is implemented in this step for the initial decision matrix.

In the first stage, all criteria are converted into benefit criteria by means of Equation (6) or Equation (7) according to the type of criterion and ϑ_{mxn} is obtained.

$$\vartheta_{ij} = \frac{x_{ij}}{\max\limits_{j} x_{ij}}; benefit\ type \tag{6}$$

$$\vartheta_{ij} = \frac{\min\limits_{j} x_{ij}}{x_{ij}}; cost\ type \tag{7}$$

$$\boldsymbol{\vartheta} = \begin{bmatrix} \boldsymbol{\vartheta_{11}} & \cdots & \boldsymbol{\vartheta_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{\vartheta_{m1}} & \cdots & \boldsymbol{\vartheta_{mn}} \end{bmatrix}$$

In the second stage of the normalization process, all criteria are converted into cost criteria by using Equation (8) or Equation (9) according to the type of criterion and ϑ'_{mxn} is obtained.

$$\vartheta'_{ij} = \frac{x_{ij}}{\max\limits_{j} x_{ij}}; cost\ type \tag{8}$$

$$\vartheta'_{ij} = \frac{\min\limits_{j} x_{ij}}{x_{ij}}; benefit\ type \tag{9}$$

$$\boldsymbol{\vartheta'} = \begin{bmatrix} \boldsymbol{\vartheta'_{11}} & \cdots & \boldsymbol{\vartheta'_{1n}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{\vartheta'_{m1}} & \cdots & \boldsymbol{\vartheta'_{mn}} \end{bmatrix}$$

Step 3. Determination of the deviation from the criterion weight

Weighting of the data acquired from both normalization processes and calculation of deviations from the criterion weights are implemented in an integrated manner through Equation (10) and Equation (11) where the symbol ω denotes the weight assigned to each criterion.

$$\delta_i = \sum_{i=1}^{n} \omega_j.\left(1 - \vartheta_{ij}\right) \tag{10}$$

$$\delta'_i = \sum_{i=1}^{n} \omega_j.\left(1 - \vartheta'_{ij}\right) \tag{11}$$

In the initial stage of this calculation, the deviation of all normalized data from the maximum value of 1 is ascertained. In the second stage, total deviation from the criterion weight is determined through multiplication of these deviations with each criterion weights. Total deviation in the first δ_i matrix is desired to be in minimum level, while total deviation in the second δ'_i matrix is preferred to be as large as possible.

Step 4. Determination of the "value of RAWEC method"

Once the total amount of deviation from the criterion weight for each alternative is determined, the "RAWEC method value", which may range between -1 and +1, is calculated through the Equation (12).

$$\varrho_i = \frac{\delta'_i - \delta_i}{\delta'_i + \delta_i} \tag{12}$$

The alternative with the highest "RAWEC method value" will be regarded as the optimal choice in the entire ranking.

3.3 Sensitivity analysis

In MCDM operations, sensitivity analysis methods are frequently recoursed in order to confirm whether the method employed yields sound results or to determine to what extent it is reliable. In the literature, several approaches are discussed in terms of the implementation of these sensitivity analyses. In some publications [26]-[32] the impact of a change in the weight of the most important criterion on the priority order of alternatives is addressed. The other method [33], [34] which is based on the variation of the criteria within certain limits and therefore involves a similar approach, is a sensitivity test that is also frequently preferred. In addition to these techniques, comparison of the MCDM method employed in the research with other existing methods [35]-[38] is another tool utilized. In some cases, [39]-[41] sensitivity analyses can also be performed to examine the effects of varying parameter values, such as alpha or beta, which are utilized in the equations of the implemented methodology.

In this research, impact of the changes of criterion weights on the ordering results [42] of RAWEC method is employed. In the context of this sensitivity analysis, the weight assigned to the most significant criterion is decreased by 1% in the initial phase and by 2% in subsequent iterations. The remaining criteria weights corresponding to each decreased value of the most important criterion weight are determined by Equation (13) over 20 scenarios.

$$w_n: (1 - w_D) = w_n^*: (1 - w_D^*) \tag{13}$$

In Equation (13), w_D, w_D^*, w_n and w_n^* represents the original weight of the most dominant criterion, the adjusted weight of the most dominant criterion, the initial weight of the n^{th} criterion and the adjusted weight of the n^{th} criterion sequentially.

In addition, comparison with other MCDM methods is implemented and Pearson correlation coefficients among each method are determined.

4 Evaluation of rural development programs

4.1 Prioritization of each criterion

The criteria used to determine the performance of 17 different rural development programmes are obtained from 2019-2023 Strategic Plan published by ARDSI. The prioritisation and weighting of these criteria is carried out with participation of five Decision Makers (DM) consisting of project teams from the Chamber of Agriculture, Commodity Exchange, Agricultural Credit Cooperative, Directorate of Agriculture and Forestry and Chamber of Agricultural Engineers. The criteria referenced in the study are presented in Table 1.

Therefore, the evaluation was made on the basis of the number of project submissions for each title of the programme, the amount of financial support provided, the total amount of financial support allocated to the projects and the amount of payments provided for the projects represented in Table 1.

As indicated in the initial stage of the DIBR methodology, the prioritization sequence of the criteria articulated by each decision maker has been established as follows:

$$DM_1: C_3 > C_2 > C_4 > C_1$$
$$DM_2: C_3 > C_2 > C_4 > C_1$$
$$DM_3: C_2 > C_3 > C_4 > C_1$$
$$DM_4: C_3 > C_4 > C_2 > C_1$$
$$DM_5: C_2 > C_4 > C_3 > C_1$$

As prescribed in the second step, the proportional significance distribution between each consecutive criterion is ensured by Equation set (1). The same procedure is performed between the criteria with the highest importance and the criteria with the lowest importance as well. The final status of the comparisons realised by each DM is presented in Table 2.

Referring the third step of method, relations of each criterion with the most important one are calculated by means of Equation sets (2) as presented in Table 3.

In order to calculate of the weight coefficient of the most significant criterion defined by each DM, Equation (3) is implemented in accordance with fourth step. An exemplary calculation of the most significant criterion defined by DM_1 is;

$$\omega_3 = \frac{1}{1 + \frac{0.45}{0.55} + \frac{0.45}{0.55}\cdot\frac{0.48}{0.52} + \frac{0.45}{0.55}\cdot\frac{0.48}{0.52}\cdot\frac{0.47}{0.53}} = 0.3083$$

Based on the relations defined in third step and indicated in Table 3, weight coefficients of remaining criteria are also calculated. In similar manner, an exemplary calculation of remaining criteria defined by DM_1 is;

$$\omega_2 = \frac{0.45}{0.55} * \omega_3 = \frac{0.45}{0.55} * 0.3083 = 0.2523$$

$$\omega_4 = \frac{0.48}{0.52} * \omega_2 = \frac{0.48}{0.52} * \frac{0.45}{0.55} * \omega_3 = \frac{0.48}{0.52} * \frac{0.45}{0.55} * 0.3083 = 0.2329$$

$$\omega_1 = \frac{0.47}{0.53} * \omega_4 = \frac{0.47}{0.53} * \frac{0.48}{0.52} * \omega_2 = \frac{0.47}{0.53} * \frac{0.48}{0.52} * \frac{0.45}{0.55} * \omega_3 = \frac{0.47}{0.53} * \frac{0.48}{0.52} * \frac{0.45}{0.55} * 0.3083 = 0.2065$$

By implementing these equations for all criteria expressed by each DM, weight coefficients and their arithmetic means are derived as indicated in Table 4.

In order to verify of the consistency of DMs' preferences, the relation between the most and least significant criterion are additionally calculated by Equation (4) and summarized in Table 5.

Table 1. List of criteria.

Abbreviation	Criteria
C_1	Number of Funded Projects
C_2	Total Investment Value (₺)
C_3	Total Financial Support Value (₺)
C_4	Paid Grant Value (₺)

Table 2. The Proportional importance distribution between each criterion.

DM_1	DM_2	DM_3	DM_4	DM_5
$\omega_3:\omega_2 = 0.55:0.45$	$\omega_3:\omega_2 = 0.53:0.47$	$\omega_2:\omega_3 = 0.52:0.48$	$\omega_3:\omega_4 = 0.53:0.47$	$\omega_2:\omega_4 = 0.51:0.49$
$\omega_2:\omega_4 = 0.52:0.48$	$\omega_2:\omega_4 = 0.52:0.48$	$\omega_3:\omega_4 = 0.51:0.49$	$\omega_4:\omega_2 = 0.52:0.48$	$\omega_4:\omega_3 = 0.54:0.46$
$\omega_4:\omega_1 = 0.53:0.47$	$\omega_4:\omega_1 = 0.56:0.44$	$\omega_4:\omega_1 = 0.54:0.46$	$\omega_2:\omega_1 = 0.54:0.46$	$\omega_3:\omega_1 = 0.52:0.48$
$\omega_3:\omega_1 = 0.65:0.35$	$\omega_3:\omega_1 = 0.60:0.40$	$\omega_2:\omega_1 = 0.60:0.40$	$\omega_3:\omega_1 = 0.65:0.35$	$\omega_2:\omega_1 = 0.60:0.40$

Table 3. Relations of each criterion with the most important one.

DM_1	DM_2	DM_3	DM_4	DM_5
$\omega_2 = \frac{0.45}{0.55}\cdot\omega_3$	$\omega_2 = \frac{0.47}{0.53}\cdot\omega_3$	$\omega_3 = \frac{0.48}{0.52}\cdot\omega_2$	$\omega_4 = \frac{0.47}{0.53}\cdot\omega_3$	$\omega_4 = \frac{0.49}{0.51}\cdot\omega_2$
$\omega_4 = \frac{0.48}{0.52}\cdot\omega_2$	$\omega_4 = \frac{0.48}{0.52}\cdot\omega_2$	$\omega_4 = \frac{0.49}{0.51}\cdot\omega_3$	$\omega_2 = \frac{0.48}{0.52}\cdot\omega_4$	$\omega_3 = \frac{0.46}{0.54}\cdot\omega_4$
$\omega_1 = \frac{0.47}{0.53}\cdot\omega_4$	$\omega_1 = \frac{0.44}{0.56}\cdot\omega_4$	$\omega_1 = \frac{0.46}{0.54}\cdot\omega_4$	$\omega_1 = \frac{0.46}{0.54}\cdot\omega_2$	$\omega_1 = \frac{0.48}{0.52}\cdot\omega_3$
$\omega_1 = \frac{0.35}{0.65}\cdot\omega_3$	$\omega_1 = \frac{0.40}{0.60}\cdot\omega_3$	$\omega_1 = \frac{0.40}{0.60}\cdot\omega_2$	$\omega_1 = \frac{0.35}{0.65}\cdot\omega_3$	$\omega_1 = \frac{0.40}{0.60}\cdot\omega_2$

Table 4. Weight coefficients and arithmetic means of each criterion.

	DM_1	DM_2	DM_3	DM_4	DM_5	**Mean**
ω_1	0.2065	0.1921	0.2119	0.2049	0.2137	0.2058
ω_2	0.2523	0.2648	0.2805	0.2406	0.2829	0.2642
ω_3	0.3083	0.2986	0.2589	0.2939	0.2315	0.2783
ω_4	0.2329	0.2445	0.2487	0.2606	0.2718	0.2517

Table 5. Relation between the most and least significant criterion.

DM_1	DM_2	DM_3	DM_4	DM_5
$\boldsymbol{\lambda_{3,1} = 0.35}$	$\lambda_{3,1} = 0.40$	$\lambda_{2,1} = 0.40$	$\lambda_{3,1} = 0.35$	$\lambda_{2,1} = 0.40$
$\boldsymbol{\hat{\lambda}_{3,1} = 0.40}$	$\hat{\lambda}_{3,1} = 0.39$	$\hat{\lambda}_{2,1} = 0.43$	$\hat{\lambda}_{3,1} = 0.41$	$\hat{\lambda}_{2,1} = 0.43$
$\boldsymbol{\lvert\lambda_{3,1} - \hat{\lambda}_{3,1}\rvert = 0.05}$	$\lvert\lambda_{3,1} - \hat{\lambda}_{3,1}\rvert = 0.01$	$\lvert\lambda_{2,1} - \hat{\lambda}_{2,1}\rvert = 0.03$	$\lvert\lambda_{3,1} - \hat{\lambda}_{3,1}\rvert = 0.06$	$\lvert\lambda_{2,1} - \hat{\lambda}_{2,1}\rvert = 0.03$

An exemplary calculation of consistency for DM_1 is;

$$\hat{\lambda}_{3,1} = \frac{\omega_1}{\omega_3 + \omega_1} = \frac{0.2065}{0.3083 + 0.2065} = 0.40$$

The absolute differences indicated in Table 5 reveal that there is no difference greater than 10% between λ and $\hat{\lambda}$ values. Therefore, we can conclude that consistency of DMs' preferences are endured and it is not required to redefine the relationships between the criteria.

As a consequence, the weights of the four criteria utilised in the study are determined as;

$\omega = \{0.2058, 0.2642, 0.2783, 0.2517\}$.

4.2 Ordering rural development programs

17 rural development programmes (RDP), specified in the 2019-2023 Strategic Plan of Agriculture and Rural Development Support Institution and implemented within the scope of IPARD-II, are involved as alternatives in this multi-criteria decision-making problem as indicated in Table 6.

The rural development programmes in Table 6 refer to the sectors that can be funded by ARDSI.

As stated in the first step of RAWEC method, initial decision matrix X_{mxn} is constructed by Equation (5) where the criterion values for each alternative are indicated in Table 7.

In accordance with the instructions stated in the second step, both benefit and cost normalizations are performed by Equations (6), (7), (8) and (9). Since all the criteria in the initial decision matrix are benefit type criterion, Equations (7) and (9) are omitted and the ϑ_{ij} and ϑ'_{ij} matrixes presented in Table 8 are derived.

The benefit and cost type normalized values in the matrix are obtained as;

Table 6. Rural development programmes implemented.

	Rural Development Programs
RDP_1	Milk Producing Agricultural Enterprises
RDP_2	Red Meat Producing Agricultural Enterprises
RDP_3	Poultry Meat Producing Agricultural Enterprises
RDP_4	Egg Producing Agricultural Enterprises
RDP_5	Processing and Marketing of Milk and Dairy Products
RDP_6	Processing and Marketing of Red Meat and Meat Products
RDP_7	Processing and Marketing of Poultry Meat and Meat Products (White Meat)
RDP_8	Processing and Marketing of Aquaculture Products
RDP_9	Processing and Marketing of Fruit and Vegetable Products
RDP_{10}	Diversification of Crop Production, Processing and Packaging of Crop Products
RDP_{11}	Production, Processing and Packaging of Beekeeping and Bee Products
RDP_{12}	Rural Tourism and Recreation Activities
RDP_{13}	Aquaculture
RDP_{14}	Machine Parks
RDP_{15}	Renewable Energy Facilities
RDP_{16}	Craftsmanship and Value Added Products
RDP_{17}	Technical Support

Table 7. Initial decision matrix.

RDP	C_1	C_2	C_3	C_4
RDP_1	127	512,178,377	262,922,411	108,169,751
RDP_2	244	726,564,879	384,402,467	217,069,810
RDP_3	47	92,185,222	51,433,034	30,894,601
RDP_4	6	18,701,524	11,243,600	7,620,138
RDP_5	44	178,042,329	73,381,597	45,211,300
RDP_6	17	125,438,186	51,189,195	19,352,003
RDP_7	3	15,649,639	5,379,420	3,185,824
RDP_8	3	14,602,931	5,938,679	1,523,485
RDP_9	78	351,102,659	158,448,088	98,388,592
RDP_{10}	1,453	188,469,565	100,484,559	67,965,709
RDP_{11}	409	44,879,579	25,223,947	20,457,152
RDP_{12}	67	452,879,981	241,745,761	42,212,955
RDP_{13}	5	25,153,341	12,806,845	3,607,283
RDP_{14}	23	8,546,508	5,079,767	4,195,494
RDP_{15}	67	178,823,725	81,919,167	57,071,962
RDP_{16}	73	209,072,954	113,755,463	48,898,642
RDP_{17}	18	5,614,486	5,614,485	1,306,087

Table 8. Normalized decision matrix.

	Benefit Type Normalized Matrix (ϑ_{ij})				Cost Type Normalized Matrix (ϑ'_{ij})			
RDP	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
RDP_1	0.0874	0.7049	0.6840	0.4983	0.0236	0.0110	0.0193	0.0121
RDP_2	0.1679	1.0000	1.0000	1.0000	0.0123	0.0077	0.0132	0.0060
RDP_3	0.0323	0.1269	0.1338	0.1423	0.0638	0.0609	0.0988	0.0423
RDP_4	0.0041	0.0257	0.0292	0.0351	0.5000	0.3002	0.4518	0.1714
RDP_5	0.0303	0.2450	0.1909	0.2083	0.0682	0.0315	0.0692	0.0289
RDP_6	0.0117	0.1726	0.1332	0.0892	0.1765	0.0448	0.0992	0.0675
RDP_7	0.0021	0.0215	0.0140	0.0147	1.0000	0.3588	0.9443	0.4100
RDP_8	0.0021	0.0201	0.0154	0.0070	1.0000	0.3845	0.8554	0.8573
RDP_9	0.0537	0.4832	0.4122	0.4533	0.0385	0.0160	0.0321	0.0133
RDP_{10}	1.0000	0.2594	0.2614	0.3131	0.0021	0.0298	0.0506	0.0192
RDP_{11}	0.2815	0.0618	0.0656	0.0942	0.0073	0.1251	0.2014	0.0638
RDP_{12}	0.0461	0.6233	0.6289	0.1945	0.0448	0.0124	0.0210	0.0309
RDP_{13}	0.0034	0.0346	0.0333	0.0166	0.6000	0.2232	0.3966	0.3621
RDP_{14}	0.0158	0.0118	0.0132	0.0193	0.1304	0.6569	1.0000	0.3113
RDP_{15}	0.0461	0.2461	0.2131	0.2629	0.0448	0.0314	0.0620	0.0229
RDP_{16}	0.0502	0.2878	0.2959	0.2253	0.0411	0.0269	0.0447	0.0267
RDP_{17}	0.0124	0.0077	0.0146	0.0060	0.1667	1.0000	0.9048	1.0000

$$\vartheta_{11} = \frac{127}{1453} = 0.0874 \qquad \vartheta'_{11} = \frac{3}{127} = 0.0236$$

Weighting of the normalized data and calculation of deviations from the criterion weights (δ_i *and* δ'_i) are implemented in an integrated manner through Equation (10) and Equation (11). Consequently, "value of RAWEC method" ϱ_i is calculated by means of Equation (12). The overall results obtained through these equations and ordered alternatives are presented in Table 9.

An exemplary calculation for δ_1, δ'_1 and ϱ_1 values are as follows;

$$\delta_1 = 0.2058 * (1 - 0.0874) + 0.2642 * (1 - 0.7049) + 0.2783 * (1 - 0.6840) + 0.2517 * (1 - 0.4983) = 0.4800$$

$$\delta'_1 = 0.2058 * (1 - 0.0236) + 0.2642 * (1 - 0.0110) + 0.2783 * (1 - 0.0193) + 0.2517 * (1 - 0.0121) = 0.9838$$

$$\varrho_1 = \frac{0.9838 - 0.4800}{0.9838 + 0.4800} = 0.3442$$

The calculations are directly performed with MS Excel and insignificant differences may arise since after a certain decimal value is not taken into consideration in the text.

The results obtained from the ordering problem handled in this study reveal that the "Red Meat Producing Agricultural Enterprises" alternative occupies the first position. On the other hand, the remaining rural development programmes ranked in the top six are "Milk Producing Agricultural Enterprises", "Diversification of Crop Production, Processing and Packaging of Crop Products", "Rural Tourism and Recreation Activities", "Processing and Marketing of Fruit and Vegetable Products" and "Craftsmanship and Value Added Products".

4.3 Sensitivity analysis

In order to confirm the reliability of the proposed RAWEC method, the weight of the most important criterion ω_3, determined by DIBR method is reduced by 1% in the first step and by 2% in the following steps. According to this sensitivity analysis conducted over 20 different scenarios, the variations observed in the criteria weights are visualized in Figure 3.

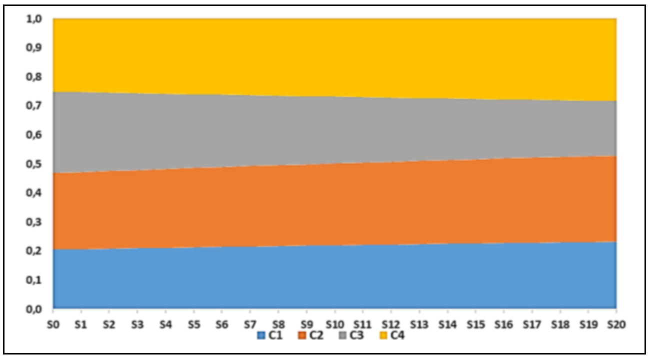

Figure 3. Variations observed in criterion weights.

The impact of these variations observed in the criterion weights on the order of 17 IPARD-II programs is illustrated in Figure 4.

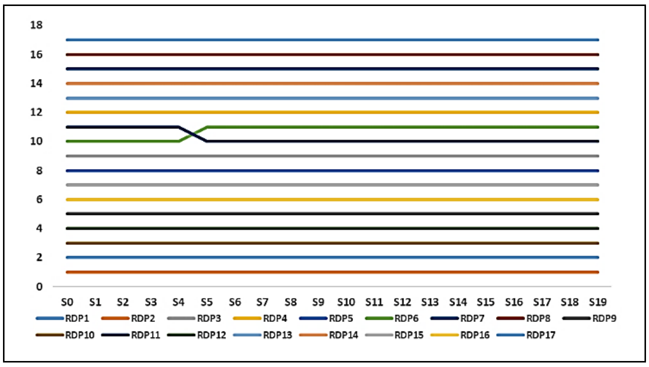

Figure 4. Order of rural development programs under different criterion weights.

This sensitivity analysis reveals that the order of 17 IPARD-II programmes exhibits a robust resilience against variations in criterion weights. Therefore, it can be deducted that the RAWEC method implemented enables a consistent assessment.

In addition to the RAWEC method, the ordering of financial support programmes was also conducted with the ARAS [43], EDAS [44], MABAC [45], MAIRCA [46], MAUT [47], and ROV [48] methods and the results are illustrated in Figure 5.

Table 9. δ_i, δ'_i, ϱ_i values and orders of rural development programs.

RDP	δ_i	δ'_i	ϱ_i	$Order$
RDP_1	0.4800	0.9838	0.3442	2
RDP_2	0.1713	0.9902	0.7051	1
RDP_3	0.8868	0.9326	0.0252	9
RDP_4	0.9754	0.6489	-0.2010	12
RDP_5	0.8235	0.9511	0.0719	8
RDP_6	0.8925	0.9073	0.0082	10
RDP_7	0.9863	0.3334	-0.4947	15
RDP_8	0.9882	0.2388	-0.6108	16
RDP_9	0.6325	0.9756	0.2134	5
RDP_{10}	0.5741	0.9728	0.2578	3
RDP_{11}	0.8838	0.8933	0.0054	11
RDP_{12}	0.6019	0.9739	0.2361	4
RDP_{13}	0.9767	0.6160	-0.2264	13
RDP_{14}	0.9851	0.4430	-0.3796	14
RDP_{15}	0.8000	0.9595	0.0906	7
RDP_{16}	0.7746	0.9653	0.1096	6
RDP_{17}	0.9898	0.1980	-0.6666	17

The results in Figure 5 indicate that the orders obtained by different methods do not display a significant discrepancy. That situation is explicitly demonstrated by the Pearson correlation coefficients between different methods as presented in Table 10.

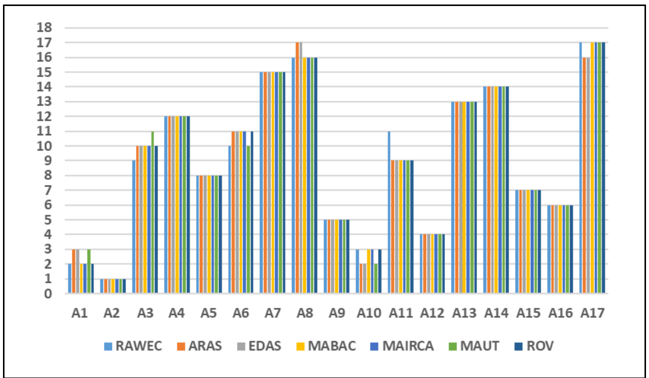

Figure 5. Comparison with different MCDM methods.

Table 10. Pearson correlation coefficients of MCDM methods.

	RAWEC	ARAS	EDAS	MABAC	MAIRCA	MAUT
ARAS	0.988					
EDAS	0.988	1.000				
MABAC	0.993	0.995	0.995			
MAIRCA	0.993	0.995	0.995	1.000		
MAUT	0.988	0.995	0.995	0.995	0.995	
ROV	0.993	0.995	0.995	1.000	1.000	0.995

5 Results and discussion

Rural development programs, which are implemented beyond agricultural supports, are activities that contribute to the economic welfare of individuals living in rural areas. The concept of rural development, which has a wide range of applications including issues such as gross national product per capita, education, communication, health, human rights, civil society organization, entrepreneurship culture and social entrepreneurship, has become more widely accepted by governments in recent years. Based on these justifications, this study aimed to ascertain the overall effectiveness of the Rural Support Programmes implemented during the IPARD-II period.

The performance of these seventeen programmes is evaluated based on four distinct criteria. In order to determine the weights of the criteria, DIBR method is employed with participation of five different experts and the order of significance for these criteria is determined as Total Financial Support Value (₺), Total Investment Value (₺), Paid Grant Value (₺) and Number of Funded Projects sequentially. The DIBR method enabled a methodical and unbiased approach to establishing the criteria weights based on expert opinions. By engaging five distinct experts in the procedure, a wide array of perspectives could be taken into consideration. Ultimately, the utilization of the DIBR method in conjunction with the participation of these experts contributed to ensuring the weights of the criteria in a robust manner in the decision-making process.

In the analysis to assess the success order of seventeen rural development programmes, the RAWEC method is employed and it is determined that “Red Meat Producing Agricultural Enterprises”, “Milk Producing Agricultural Enterprises”, “Diversification of Crop Production, Processing and Packaging of Crop Products”, “Rural Tourism and Recreation Activities”, “Processing and Marketing of Fruit and Vegetable Products” and “Craftsmanship and Value Added Products” are ranked in the first six order.

In the last stage, a sensitivity analysis was conducted to determine whether there is consistency in the results obtained from the RAWEC method used to determine the performance ranking of rural development programmes. In addition, the results obtained from the RAWEC method were also compared with some traditional MCDM methods. It should be noted that this study is limited to the IPARD-II supports offered by ARDSI as mentioned in the previous sections.

It is explicit that, rural development is a prominent policy area within the realm of regional development policies globally. The primary objective of rural development policies is to ensure a more equitable distribution of welfare across the country and to optimize the contribution of every region towards national development. It is noteworthy that "Rural Tourism and Recreation Activities" and "Craftsmanship and Value Added Products" programmes are among the most demanded rural development supports. These findings prove that rural development does not only comprise agricultural and/or livestock activities, but also the contribution of rural tourism and craftsmanship activities is of great importance for the economic welfare of rural communities. Therefore, it indicates that rural development programmes based solely on food supply will not be sufficient in the long run. This aspect should be duly considered during the preparation of quadrennial development plans put in force by the government in Türkiye. The results can also be a reference for the long-term policies of institutions such as the Ministry of Agriculture and Forestry, the Ministry of Industry and Technology, and the Ministry of Family and Social Policies towards individuals living in rural areas. In addition, a decision-making mechanism in line with the European Union acquis will be ensured in the policy planning stages of each institution in our country.

6 Conclusion

Demand for food, which follows a course parallel to the increase in the world population, is an issue that must be meticulously focused on in order to sustain the life of human beings. Agricultural activities, which are one of the most indispensable economic components of countries, have a vital function not only in terms of food supply of its citizens, but also in terms of ensuring food security and economic development of that particular nation. Therefore, the adoption of agricultural activities as a critical state policy will be an important approach for countries to ensure their own independence. However, it is an overly simplistic approach to limit the scope of rural development exclusively to measures related to food supply.

ARDSI, which was founded within the framework of the negotiations conducted prior to accession of Türkiye to the EU, has been structured as a pioneering institution that supports rural development programs within the framework of its duties and responsibilities. Within the scope IPARD-I and IPARD-II schemes, which were completed as of 2024, millions of Euros of grants were transferred to investors under different programs and significant contributions were provided to rural development.

In addition to the IPARD-II programme discussed in this study, it will be an important approach to examine the results of the completed IPARD-I programme, and the IPARD-III programme, which will start in 2024, with the rigour of data mining. The analyses conducted in this manner are expected to guide contemporary and objective rural development policies in the following periods.

It is also expected that the methods employed in the study can also be used as a performance measurement tool for the project calls of funding organisations such as TÜBİTAK, KOSGEB, Development Agencies, Development Administrations.

7 Author contribution statement

In this study, Sinan Dündar contributed to the determination of the subject of the article, design, literature review, evaluation of the results and proofreading.

8 Approval by the ethics committee and declaration of conflict of interest

“There is no need to obtain permission from the ethics committee for the article prepared”.

“There is no conflict of interest with any person / institution in the article prepared”.

9 References

[1] Moseley MJ. *Rural Development: Principles and Practice*. 1st ed. London, UK, Sage Publications, 2003.

[2] Kearney B, Boyle, G, Walsh J. *EU LEADER I Initiative in Ireland: Evaluation and Recommendations*. 1st ed. Dublin, Ireland, Stationery Office, 1995.

[3] De Janvry A, Sadoulet E, Murgai R. *Rural Development and Rural Policy.* Editors: Gardner BL, Rausser GC. Handbook of Agricultural Economics, 1593-1658, North Holland, Elsevier, 2002.

[4] Organisation for Economic Co-operation and Development. “Unlocking Rural Innovation”. OECD Publishing, Paris, OECD Rural Studies, 2022.

[5] Tarım ve Kırsal Kalkınmayı Destekleme Kurumu. “Tarım ve Kırsal Kalkınmayı Destekleme Kurumu 2019-2023 Stratejik Planı”. https://www.tkdk.gov.tr/Content/File/2019-2023%20Stratejik%20Plan%C4%B1.pdf (01.06.2024).

[6] Özkul G, Bozkurt AA. “Kırsal kalkınmada TKDK’nın rolü: IPARD I programına ilişkin Isparta ilinde bir inceleme”. *Süleyman Demirel Üniversitesi Vizyoner Dergisi*, 10(25), 536-554, 2019.

[7] Acar ZM, Çağlar N. “Kırsal alanda kadın girişimciliği: batı akdeniz bölgesinde TKDK’dan hibe alan kadınlar üzerinde bir araştırma”. *Mehmet Akif Ersoy Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 11(30), 902-920, 2019.

[8] Gülçubuk B, Köksal Ö, Ataseven Y, Gül U, Kan M. “Kırsal kalkınma desteklerinin ulusal düzeyde etkileri: Tarım ve Kırsal Kalkınmayı Destekleme Kurumu (TKDK) projelerinin incelenmesi”. *Tarım Ekonomisi Araştırmaları Dergisi*, 2(1), 32-41, 2016.

[9] Bahtiyar K. “Kırsal kalkınma uygulamaları üzerine bir değerlendirme: TKDK (Tarım ve Kırsal Kalkınmayı Destekleme Kurumu) örneği”. *Sosyal Ekonomik Araştırmalar Dergisi*, 14(28), 306-324, 2014.

[10] Božanić D, Epler I, Puška A, Biswa, S, Marinkovic D, Koprivica S. “Application of the DIBR II -rough MABAC decision-making model for ranking methods and techniques of lean organization systems management in the process of technical maintenance”. *Facta Universitatis Series Mechanical Engineering*, 22(1), 101-123, 2024.

[11] Tešić D, Božanić D, Radovanović M, Petrovski A. “Optimising assault boat selection for military operations: an application of the DIBR II-BM-CoCoSo MCDM model”. *Journal of Intelligent Management Decision*, 2(4), 160-171, 2023.

[12] Radovanović M, Božanić D, Tešić D, Puška A, Hezam IM, Jana, C. “Application of hybrid DIBR-FUCOM-LMAW-Bonferroni-Grey-EDAS model in multicriteria decision-making”. *Facta Universitatis, Series: Mechanical Engineering*, 21(3), 387-403, 2023.

[13] Tešić D, Marinković D. “Application of fermatean fuzzy weight operators and MCDM model DIBR-DIBR II-NWBM-BM for efficiency-based selection of a complex combat system”. *Journal of Decision Analytics and Intelligent Computing*, 3(1), 243-256, 2023.

[14] Pamucar D, Simic V, Lazarević D, Dobrodolac M, Deveci M. “Prioritization of sustainable mobility sharing systems using integrated fuzzy DIBR and fuzzy-rough EDAS model”. *Sustainable Cities and Society*, 82, 103910, 2022.

[15] Žnidaršič V, Dojić KV, Milić LN. “Selection of landing site for infantry river crossing using aluminum boat M70: Application of DIBR and Topsis Method”. *International Conference Knowledge-Based Organization*, 30(1), 1-8, 2024.

[16] Kara K, Yalçın GC, Simic V, Yıldırım AT, Pamucar D, Siarry P. “A spherical fuzzy-based DIBR II-AROMAN model for sustainability performance benchmarking of wind energy power plants”. *Expert Systems with Applications*, 253, 124300, 2024.

[17] Puška A, Štilić A, Pamučar D, Božanić D, Nedeljković M. "Introducing a novel multi-criteria Ranking of Alternatives with Weights of Criterion (RAWEC) model". *MethodsX*, 12, 102628, 2024.
[18] Petrović N, Jovanovic V, Marković S, Marinkovic D, Petrović M. "Multicriteria sustainability assessment of transport modes: A European Union case study for 2020". *Journal of Green Economy and Low-Carbon Development*, 3(1), 36-44, 2024.
[19] Gök Kısa AC. "TR83 bölgesinde yenilenebilir enerji kaynaklarının CRITIC tabanlı gri ilişkisel analiz yaklaşımı ile değerlendirilmesi". *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 27(4), 542-548, 2021.
[20] Uyan M. "Güneş enerjisi santrali kurulabilecek alanların AHP yöntemi kullanılarak CBS destekli haritalanması". *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 23(4), 343-351, 2017.
[21] Saaty T. "Decision making-the Analytic Hierarchy and Network Processes (AHP/ANP)". *Journal of Systems and Systems Engineering*, 13(1), 1-35, 2004.
[22] Rezaei J. "Best-Worst multi-criteria decision-making method". *Omega*, 53, 49-57, 2015.
[23] Pamučar D, Stević Ž, Sremac S. "A new model for determining weight coefficients of criteria in MCDM models: Full Consistency Method (FUCOM)". *Symmetry*, 10(9), 1-22, 2018.
[24] Pamucar D, Deveci M, Gokasar I, Işık M, Zizovic M. "Circular economy concepts in urban mobility alternatives using integrated DIBR method and fuzzy Dombi CoCoSo model". *Journal of Cleaner Production*, 323, 129096, 2021.
[25] Puška A, Štilić A, Pamučar D, Božanić D, Nedeljković M. "Introducing a novel multi-criteria Ranking of Alternatives with Weights of Criterion (RAWEC) model". *MethodsX*, 12, 102628, 2024.
[26] Badi I, Pamučar D, Stević Ž, Muhammad LJ. "Wind farm site selection using BWM-AHP-MARCOS method: A case study of Libya". *Scientific African*, 19, e01511, 2023.
[27] Bouraima MB, Tengecha NA, Stević Ž, Simić V, Qiu Y. "An integrated fuzzy MCDM model for prioritizing strategies for successful implementation and operation of the bus rapid transit system". *Annals of Operations Research*, 342, 141-172, 2023.
[28] Puška A, Božanić D, Nedeljković M, Janošević M. "Green supplier selection in an uncertain environment in agriculture using a hybrid MCDM model: z-numbers-fuzzy LMAW-fuzzy CRADIS Model". *Axioms*, 11(9), 1-17, 2022.
[29] Mešić A, Miškić S, Stević Ž, Mastilo Z. "Hybrid MCDM solutions for evaluation of the logistics performance index of the western Balkan countries". *Economics*, 10(1), 13-34, 2022.
[30] Matić B, Marinković M, Jovanović S, Sremac S, Stević Ž. "Intelligent novel IMF D-SWARA-Rough MARCOS algorithm for selection construction machinery for sustainable construction of road infrastructure". *Buildings*, 12(7), 1-26, 2022.
[31] Kahraman, Y. R. Robust Sensitivity Analysis for Multi-Attribute Deterministic Hierarchical Value Models. Phd Theses, Air University, Ohio, USA, 2002.
[32] Stević Ž, Das DK, Kopić M. "A novel multiphase model for traffic safety evaluation: a case study of South Africa". *Mathematical Problems in Engineering*, 2021, 1-22, 2021.
[33] Qahtan S, Alsattar HA, Zaidan AA, Deveci M, Pamucar D, Delen D, Pedrycz W. "Evaluation of agriculture-food 4.0 supply chain approaches using fermatean probabilistic hesitant-fuzzy sets based decision making model". *Applied Soft Computing*, 138, 110170, 2023.
[34] Yazdani M, Chatterjee P, Pamucar D, Doval M. "A risk-based integrated decision-making model for green supplier selection: a case study of a construction company in Spain". *Kybernetes*, 49(4), 1229-1252, 2019.
[35] Kumar S, Maity SR, Patnaik L. "A novel BWM integrated MABAC decision-making approach to optimize the wear parameter of CrN/TiAlSiN coating". *Journal of Industrial and Management Optimization*, 19(4), 2676-2703, 2023.
[36] Bonab SR, Ghoushchi SJ, Deveci M, Haseli G. "Logistic autonomous vehicles assessment using decision support model under spherical fuzzy set integrated Choquet Integral approach". *Expert Systems with Applications*, 214, 119205, 2023.
[37] Wei Q, Zhou C. "A multi-criteria decision-making framework for electric vehicle supplier selection of government agencies and public bodies in China". *Environmental Science and Pollution Research*, 30(4), 10540-10559, 2023.
[38] Blagojević A, Kasalica S, Stević Ž, Tričković G, Pavelkić V. "Evaluation of safety degree at railway crossings in order to achieve sustainable traffic management: a novel integrated fuzzy MCDM model". *Sustainability*, 13(2), 2021.
[39] Bošković S, Švadlenka L, Jovčić S, Dobrodolac M, Simić V, Bacanin N. "An Alternative Ranking Order Method Accounting for two-step Normalization (AROMAN)-a case study of the electric vehicle selection problem". *IEEE Access*, 11, 39496-39507, 2023.
[40] Ecer F, Pamucar D. "A novel LOPCOW-DOBI multi-criteria sustainability performance assessment methodology: An application in developing country banking sector". *Omega*, 112, 102690, 2022.
[41] Biswas T, Chatterjee P, Choudhuri B. "Selection of commercially available alternative passenger vehicle in automotive environment". *Operational Research in Engineering Sciences: Theory and Applications*, 3, 2620-1747, 2020.
[42] Pamucar D, Zizovic M, Biswas S, Božanić D. "A New Logarithm Methodology of Additive Weights (LMAW) for multi-criteria decision-making: application in logistics". *Facta Universitatis Series Mechanical Engineering*, 19(3), 361-380, 2021.
[43] Zavadskas EK, Zanonas T. "A new Additive Ratio Assessment (ARAS) method in multicriteria decision-making". *Technological and Economic Development of Economy* 16(2), 159-72, 2010.
[44] Ghorabaee MK, Edmundas KZ, Laya O, Zenonas T. "Multi-criteria inventory classification using a new method of Evaluation Based on Distance from Average Solution (EDAS)". *Informatica,* 26(3), 435-51, 2015.
[45] Pamucar D, Goran Ć. "the selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation Area Comparison (MABAC)". *Expert Systems with Applications,* 42(6), 3016-28,2015.

[46] Pamucar D, Ljubislav V, Vesko L. "Selection of railway level crossings for investing in security equipment using hybrid DEMATEL-MARICA model: application of a new method of multi-criteria decision-making". *XVI International Scientific-expert Conference on Railways,* Belgrade, 09-10 October 2014.

[47] Keeney R, Howard R, David R. "Decisions with multiple objectives: preferences and value trade-offs". *Systems, Man and Cybernetics, IEEE Transactions* On, 9(7), 403-403, 1979.

[48] Yakowitz DS, Lane LJ, Szidarovszky F. "Multi-attribute decision making: dominance with respect to an importance order of the attributes". *Applied Mathematics and Computation,* 54(2), 167-81, 1993.