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Regional Analysis of Organic Agriculture, Husbandry, and Beekeeping Efficiency in Türkiye

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ABSTRACT
Organic production enhances soil fertility, preserves biodiversity, and reduces pollution by avoiding from chemical pesticides and genetically modified organisms. Moreover, the increasing consumer demand for organic foods has encouraged producers to prioritize soil health and sustainable agricultural practices. The objective of this study is to analyze the development of organic agriculture, husbandry, and beekeeping, which contribute to biodiversity and ecosystem preservation through pollination, in Türkiye. Additionally, the study aims to offer insights for policy makers to establish a well-balanced production network. In this study, Türkiye's provinces were classified according to The Nomenclature of Territorial Units for Statistics (NUTS)-Level 1 (12 regions) and evaluated with Data Envelopment Analysis (DEA). Organic agriculture was evaluated Super Efficiency (SE) model while organic husbandry-beekeping was evaluated Lee and Zu model which is taken into account zero data. Moreover, to derive a final ranking of organic agriculture and organic husbandry-beekeping, the Copeland method, based on superiority comparison and not requiring normalization, was used. This study is noteworthy as the first of its kind to comprehensively consider organic agriculture, animal husbandry, and beekeeping collectively.

Keywords: Organic agriculture, Organic husbandry, Organic beekeping, Sustainability, Data Envelopment Analysis

1. Introduction

Chemical fertilizers, pesticides, and fungicides are widely used to meet the growing global food demand, aiming to boost crop yields in agriculture. However, their excessive application leads to soil pollution and poses risks to biodiversity, potentially threatening various species. Additionally, they have detrimental effects on the health of both producers and consumers, causing chronic illnesses and, in severe cases, fatalities (Durán-Lara et al.2020). Organic agriculture emerges as a prominent alternative to conventional farming, seeking to address the adverse impacts of traditional agricultural practices on the environment and human health. Unlike conventional methods, organic agriculture avoids synthetic fertilizers, pesticides, and genetically modified organisms to enhance crop yields. Instead, it relies on biofertilizers, natural pathogens, and pest control mechanisms to maintain soil fertility, promote biodiversity, and manage pests. Consequently, organic agriculture supports biodiversity, yields healthier products, and reduces water, soil, and air pollution (Zor et al. 2023). Over the long term, it significantly contributes to enhancing the sustainability of food systems (Sapbamrer & Thammachai, 2021). In recent years, interest in organic production has surged, driven by increasing consumer demand for organic foods and producers' efforts to safeguard soil health and promote sustainable agricultural practices (Sink et al. 2017; Aghasafari et al. 2020).

The transition from conventional agriculture to organic agriculture is mirrored in traditional animal husbandry practices. In recent years, significant advancements have been made in enhancing farm animal performance and reducing production costs in husbandry. However, concerns regarding animal health, welfare, and environmentally sustainable practices have been overshadowed by heightened production demands (Sundrum, 2001). In response to this case, organic husbandry has emerged, prioritizing animal welfare, reduced number of animals per unit area, limited use of pesticides and pharmaceuticals, and environmentally sustainable production methods. Organic husbandry is grounded in principles ensuring that animals can express natural behaviours, are not subjected to undue stress, are fed organic feed, and possess enhanced resilience to infections compared to conventionally raised animals (Åkerfeldt et al.2021).

Türkiye has considerable potential in terms of animal population, yet its utilization of this potential for organic animal production remains inadequate. Regions with vast meadow and pasture areas, devoid of industrial pollution, offer great potential for organic beekeeping, as well as the husbandry of both large and small ruminants, such as sheep and cattle. However, for various reasons, this potential has not been fully realized. For instance, animal breeders in these regions often operate as small family businesses, and organic farming and animal husbandry are subject to certification systems, with many breeders lacking sufficient knowledge and training in these areas. Additionally, the lack of consumer awareness and low purchasing power in the domestic market hinder the development of organic animal husbandry, despite significant increases in the number of organic animals, as well as milk, meat, and particularly egg production over the past decade. Moreover, the proportion of organic animal products in total animal production remains low and inadequate despite the rise in organic animal husbandry (Ak, 2017).

The potential for a country or region/regions to be self-sufficient in terms of both agricultural and animal production has become a necessity in today's world. In this context, the necessity of both ensuring economic development and minimizing logistics needs (increasing oil prices, transportation problems due to epidemics such as COVID-19, global threats, etc.) has emerged. Türkiye is a country that is diverse in terms of its climate, soil and water wealth and socio-economic characteristics due to its geographical location. For this reason, instead of considering Türkiye as a whole, the study preferred The Nomenclature of Territorial Units for Statistics (NUTS)-Level 1 (12 regions) classification based on population, geography, regional development plans, basic statistical indicators, and socio-economic development ranking.

The aim of this study is to analyse the development and current situation of organic agriculture, husbandry and beekeeping in Türkiye on a regional basis and to give ideas to policy makers in order to provide a regionally balanced production network. In addition to organic agriculture and husbandry, beekeeping, which contributes to biodiversity and the ecosystem through pollination and supports the maintenance of rural employment, has also been taken into consideration. A review of the literature reveals that this study is the first to evaluate organic agriculture, husbandry, and beekeeping collectively. The work proceeds as follows. In Chapter 2, a very detailed literature analysis is presented on studies evaluating the efficiency of organic agriculture, husbandry and beekeeping with Data Envelopment Analysis (DEA). The study also stands out in this respect. In Chapter 3, the methodology consisting of DEA, one of the most preferred methods in relative efficiency, and Copeland, which is based on superiority and offers full ranking without normalization, is presented. Finally, Chapter 4 contains Results and Analysis, and Chapter 5 contains Conclusion.

2. Literature Review

In this part of the study, we first evaluated papers on the efficiency of organic agriculture using DEA. These papers are grouped into the following categories: (i) Comparisons of institutions and organizations involved in both traditional and organic agriculture, (ii) evaluations of the efficiency of enterprises in organic agriculture, and (iii) assessments of the performance of organic agriculture in various regions and countries. Additionally, we examined papers on organic husbandry using DEA, but found that these studies are quite limited. Furthermore, no papers on organic beekeeping were found. Therefore, we also evaluated papers on DEA in traditional husbandry and beekeeping.

In the previous section, the reasons for the transition from traditional agriculture to organic agriculture, as well as the process itself, were explained. When examining the papers on organic agriculture in the literature, we identify a group of studies that compare traditional and organic agriculture, which we refer to as the first group. Table 1 includes the input and output variables, as well as the models used in papers comparing traditional and organic agriculture. Kuosmanen et al. (2021) evaluated the efficiency of organic farms from 2010 to 2017 to analyse the changes and progress of organic agriculture in Finland over the years. The study found that, although there is a significant performance difference between organic and conventional agriculture, the difference in production performance between farms has decreased over the years.

Table 1- Papers comparing traditional agriculture and organic agriculture

	DMUs	*Inputs*	*Outputs*	*Model*
Koner & Laha 2024	- organic and conventional farms	- average marketing costs	- average farm gate price	- VRS
Kuosmanen et al. 2021	- 2010-2017 years	- labor - the farm capital - the utilized agricultural area - energy	- total output of crops and crop products and livestock and livestock products	- DEA
Charyulu & Biswas 2010	- organic and conventional cotton farm - organic and conventional sugarcane farm - organic and conventional paddy farm - organic and conventional wheat farm	- per acre cost on seeds -fertilizers -pesticides -inter culture/weeding	-gross value of production per acre	- Super Efficiency
Uzundumlu et al. 2021	- organic and conventional wheat farms	- land amount - fixed costs - variable costs - fertilizer	- wheat production	- Input-Oriented Two-Stage Bootstrapped DEA
Riar et al. 2020	- organic and conventional cotton farms	- seed rate - irrigation - nutrient inputs	- cotton yield	- CCR
Poudel et al. 2015	- organic and conventional coffee farms	- farm size - labor - fertilizer - capital - coffee tree - labor cost - plant protection	- production product market value	- Constant Return to Scale (CRS) - Decreasing Return to Scale (DRS) - Increasing Return to Scale (IRS)
Basavalingaiah et al. 2022	- conventional, integrated and organic coffee-pepper farms	- labour - machinery - diesel - farmyard manure - greenleaf manure - nitrogen - phosphorus - potassium - micronutrient - herbicides - fungicides - pesticides - lime	- coffee	- DEA and Life cycle Assessment (LCA)
Zhen et al. 2023	- conventional, organic conversion and organic tea farm	- nitrogen (N) fertilizer - phosphorus (P2O5) - potassium (K2O) - labor - fuel - pesticide cost	- net income	- Super Efficiency
Artukoglu et al. 2010	- organic and conventional olive farms	- land - fertilizer costs - organic control costs for disease and pests - pesticide costs for disease and pests - fuel oil costs - labour costs - other costs	- conventional olive gross production value - organic olive gross production value	- CRS and Variable Returns to Scale (VRS)
Kashiwagi & Kamiyama 2023	- organic and conventional olive farms	- labor - paid cost - tree	- olive production	- Metafrontier DEA
Sintori et al. 2023	- organic, conservation, low-input, and standard olive farms	- variable capital - capital - labour - land	- revenues	- DEA

Charyulu & Biswas (2010) evaluated the efficiency of conventional and organic farms producing cotton, sugarcane, rice, and wheat in four states of India. They concluded that organic agriculture is more efficient on farms producing cotton and sugarcane, while conventional agriculture is more efficient on farms producing rice and wheat. Uzundumlu et al. (2021) assessed the efficiency of companies producing organic and conventional wheat in Erzurum province, Türkiye, and found that enterprises with medium-sized land are more efficient than those with small and large land. However, they also concluded that although organic production enterprises are more efficient, their variable costs are higher. Riar et al. (2020) evaluated organic and conventional cotton farms according to their size.

Poudel et al. (2015) evaluated the efficiency of organic and conventional coffee farms in Nepal and determined changes in efficiency using Tobit regression. They found that efficiency was associated with education, farm experience, and access to credit. Basavalingaiah et al. (2022) assessed the efficiency of conventional, integrated, and organic coffee-pepper farms using DEA and Life Cycle Assessment (LCA) methodology. Zhen et al. (2023) evaluated the environmental, economic, and technical efficiency of conventional, organic-conversion, and organic tea farms. They concluded that while there were no significant differences in the technical efficiency of the farm types, the environmental efficiency of organic-conversion and organic tea farms was significantly higher than that of conventional tea farms.

Kashiwagi & Kamiyama (2023) analysed the transition process of olive farms in the West Bank region of Palestine to organic agriculture using a meta frontier with directional distance function approach, taking into account the heterogeneity in agricultural technology. They concluded that organic farming is not cost-efficient, but empirical evidence also showed that the performance gap decreases over time. Artukoğlu et al. (2010) found that the technical efficiency of organic farms is higher than that of conventional farms, although the efficiency values are generally low. Raimondo et al. (2021) examined the efficiency of organic and conventional olive farms using Stochastic Frontier Analysis (SFA). Sintori et al. (2023) classified olive farms as organic, conservation, low-input, and standard.

Table 2- Papers evaluating farms or companies in organic agriculture

	DMUs	Inputs	Outputs	Model
Casolani et al. 2021	- organic conversion and organic farm that are subsidized from european union	- agriculture area - fixed cost, - variable cost	- total farm revenue	- CCR
Nastis et al. 2019	- organic farms that are subsidized from european union	- capital - land - labor - variable inputs	- profit	- Fuzzy CRS model of (Saati & Memariani, 2005)
Ersoy et al. 2021	first model: - 2009-2018 years second model: - organic tea farms	first model: - farms - tea area - fresh tea second model: - fresh tea - production cost	first model: - organic dry black tea - share of organic tea in dried tea second model: - organic dry black tea	- Super Efficiency
Melo 2021	- organic rice farms	- land area - seed preparation - seeds - labor - organic fertilizer	- total yield	- SFA and SBM

In the second group, we viewed the efficiency of farms or companies in organic agriculture as shown in Table 2. Some of these papers were conducted to analyse the contribution of support programs for the transition to organic agriculture (Nastis et al. 2019; Casolani et al.2021). Additionally, we assessed the efficiency of businesses producing organic tea (Ersoy et al.2021), organic rice farms (Melo 2021), and export-oriented organic rice farms. Koner & Laha (2024) examined the marketing efficiency of organic farms in three regions of India, revealing that marketing efficiency is influenced by factors such as the economic situation, education level, farming experience, land size of the farmer household, and type of marketing arrangement.

In the final part of organic agriculture, we viewed the efficiency of organic agriculture in regions, states, or countries as shown in Table 3. Manta et al. (2023) evaluated 27 countries of the European Union using data from 2000 to 2017 to investigate the connection between national culture and organic agriculture efficiency. Menten et al. (2023) analysed the change in organic agriculture efficiency of 32 OECD countries between 2011 and 2020. They clustered countries according to their efficiency levels on a yearly basis using context-dependent DEA. Efficiency changes between periods were examined with the Malmquist total factor productivity index. Yadava & Komaraiah (2021) and Yadava (2024) evaluated the organic farming performance of 21 and 22 states in India, respectively.

Table 3- Papers on the efficiency of organic agriculture in regions, states, or countries

	DMUs	Inputs	Outputs	Model
Yadava & Komaraiah 2021	- 21 Indian States	first model: - organic land - farmers - biofertilizers - manure second model: - organic land - farmers - biofertilizers - manure - land in conversion period	first model: - pure organic production second model: - pure organic production - production in the conversion period	- DEA and Bootstrap DEA
Manta et al. 2023	- 27 countries of the European union	- area of organic cultivation - number of producers of organic products	- total amount of sales	- DEA
Menten et al. 2023	- 32 countries of the OECD	- land - farmers	- organic product sales	- CRS, VRS and Context- Dependent and Malmquist

In this section, we reviewed papers using DEA on organic husbandry, an area of increasing interest (Manuelian et al., 2020). However, we found that the number of papers on this topic was quite limited. Therefore, we also analyzed traditional husbandry. Table 4 presents traditional husbandry with DEA, including input and output variables, and models.

Table 4- Papers on traditional husbandry

	DMUs	Inputs	Outputs	Model
Kuhna et al. 2020	- 371 Chinese hog farms	- Labor - Feed - Other cost	- Weight gain Undesirable/Bad Output - COD - Ammonia	- Slack-based DEA model (SBM)
Pandey & Singh 2021	- European farms	Agriculture Input - Forage land - Agricultural land - Fertilizer Animal farming Input - Forage - Grassland - Dairy Cow - Cattle feed	Agriculture Output - Cereal - Protein crops - Potato - SugerBeet - Oil-seed - Industrial crops - Vegetables - Forage Animal farming Output - Meat - Milk	- Network DEA
He et al.2022	- Counties of Tongliao	- Capital - Labor - Land - Public - Infrastructure	- Output value of grass-based livestock husbandry	-Malmquist index
Gomes et al.2015	- 21 beef cattle production systems	Economic Model Input - labor - area of pasture - spending on buying animals - other expenses Socio-environmental Model Input - area of pasture - spending on buying animals	Economic Model Output - area for native forest - livestock gross revenue Socio-environmental Model Output - labor - area for native forest - livestock gross revenue	-BCC

Considering animal husbandry, undesirable outputs such as greenhouse gases, chemical oxygen demand (COD), nitrogen, phosphorus, and ammonia are generated. Kuhn et al. (2020) categorized pig farms into large, medium, and small and identified COD and ammonia as undesirable outputs for evaluating environmental efficiency. They concluded that medium-sized farms, particularly those in transition, face challenges of low environmental efficiency and high pollution abatement costs due to limited waste disposal options. It is recommended to enhance waste management through projects for biogas production. Yan & Zhang (2023) accounted for carbon emissions from husbandry, a significant source of greenhouse gases. Pandey & Singh (2021) assessed the technical and environmental efficiency of European farms concerning both plant and animal production. Gomes et al. (2015) constrained the weighting of output variables in their study to evaluate whether capital costs yield economic, environmental, and social benefits.

Table 5- Papers on traditional beekeeping

	DMUs	*Inputs*	*Outputs*	*Model*
Makri et al. 2015	- beekeeping farms in Greece	- Fixed capital - Variable capital - Labour wages	- Gross return	- CRS and VRS
Aydın et al.2020	-beekeeping farms in Çanakkale	- labor - variable costs - fixed costs - number of frame	- Total income	- CRS and VRS
Dogan & Adanacioglu 2021	-beekeeping farms in Gümüşhane	- Number of bee hives - Feed costs - Medication costs - Labour costs - Other variable costs	- Gross Product Value	- CRS and VRS
Aşkan 2023	-beekeeping farms in Erzincan and Van	- Labor - Fixed costs - Variable costs - Number of hives	- Total honey production amount	- CRS and VRS
Angón et al2021	-beekeeping farms in La Pampa	- Investment - Feed costs - Labour costs - Number of hives	- Honey production	- CRS

In this section, no papers on organic beekeeping with DEA were found; therefore, traditional beekeeping studies were reviewed, as presented in Table 5. Particularly noteworthy is that most of the studies were conducted in Türkiye and its provinces. Aydin et al. (2020) divided beekeeping farms into three groups based on the number of hives and found that the efficiency values of the group with a higher number of hives were significantly higher than those of the other groups. Ceyhan et al. (2017) assessed the efficiency of beekeepers' unions and honey producers' unions in Türkiye. Additionally, Dogan & Adanacioglu (2021) evaluated the efficiency of beekeeping farms in Gümüşhane. Aşkan (2023) conducted a similar study in Erzincan and Van provinces, which are important representatives of local and gastronomy tourism. In Greece, Makri et al. (2015) investigated beekeeping farm efficiency, while Ferenczi et al.(2023) evaluated the efficiency of beekeeping farms in Hungary. Angón et al. (2021) evaluated beekeeping farms in Argentina and concluded that factors such as marital status, educational level, primary family income, source information usage, planning, and health area positively affected efficiency.

Upon examining the literature, it becomes apparent that there is a greater abundance of papers focusing on the efficiency of both traditional and organic agriculture at a product level. Furthermore, studies evaluating countries to analyse the impact of support programs for transitioning to organic agriculture are also prevalent. However, when reviewing the literature on organic husbandry and beekeeping, it is noted that studies in these areas are limited, with a preference for examining traditional husbandry and beekeeping instead. Many studies on traditional husbandry tend to focus on farms specific to certain animal species (such as beef, sheep, or poultry). Similarly, provincial analyses are predominant in traditional beekeeping studies. Moreover, Pandey & Singh (2021) conducted an evaluation of organic agriculture and husbandry together. Nevertheless, no study has been identified that evaluates organic agriculture, husbandry, and beekeeping collectively. Incorporating beekeeping alongside organic agriculture and husbandry in our study introduces a novel perspective compared to existing literature, offering a more comprehensive understanding of these practices.

3. Materials and Method

3.1. Data Gathering

The data in our study was obtained from the organic agriculture statistics section of the website of the Ministry of Agriculture of the Republic of Türkiye and was taken as basis for 2022, which contains the most up-to-date (TR Ministry of Agriculture & Forestry, 2024). In organic agriculture, products (number), farmer (number) and area (da) are determined as inputs, and the production (tons) is determined as output. Organic husbandry and beekeeping were evaluated together and poultry (number), small cattle (number), cattle (number), hive (number), and farmer (number) were selected as inputs. Outputs are meat (tons), milk (tons), egg (number) and honey (tons).

3.2. Methodology

In our study, Türkiye 's provinces were classified according to NUTS-Level 1 and each region evaluated as a Decision Making Unit (DMU). While the SE model was used for the organic agriculture of the regions, the Lee and Zu model, where zero data was taken into account, was used for organic husbandry and beekeeping. A noteworthy observation from the literature in Chapter 2 is the absence of models that account for zero data. Therefore, introducing a methodology that considers zero data for assessing the efficiency of farms, businesses, states, or countries has contributed a novel approach to the literature. Furthermore, to generate a unified ranking of efficiency for organic agriculture and organic husbandry-beekeeping, the Copeland method, which relies on superiority comparison and does not necessitate normalization, was adopted (Saari & Merlin , 1996). The proposed methodology is illustrated in Figure 1.

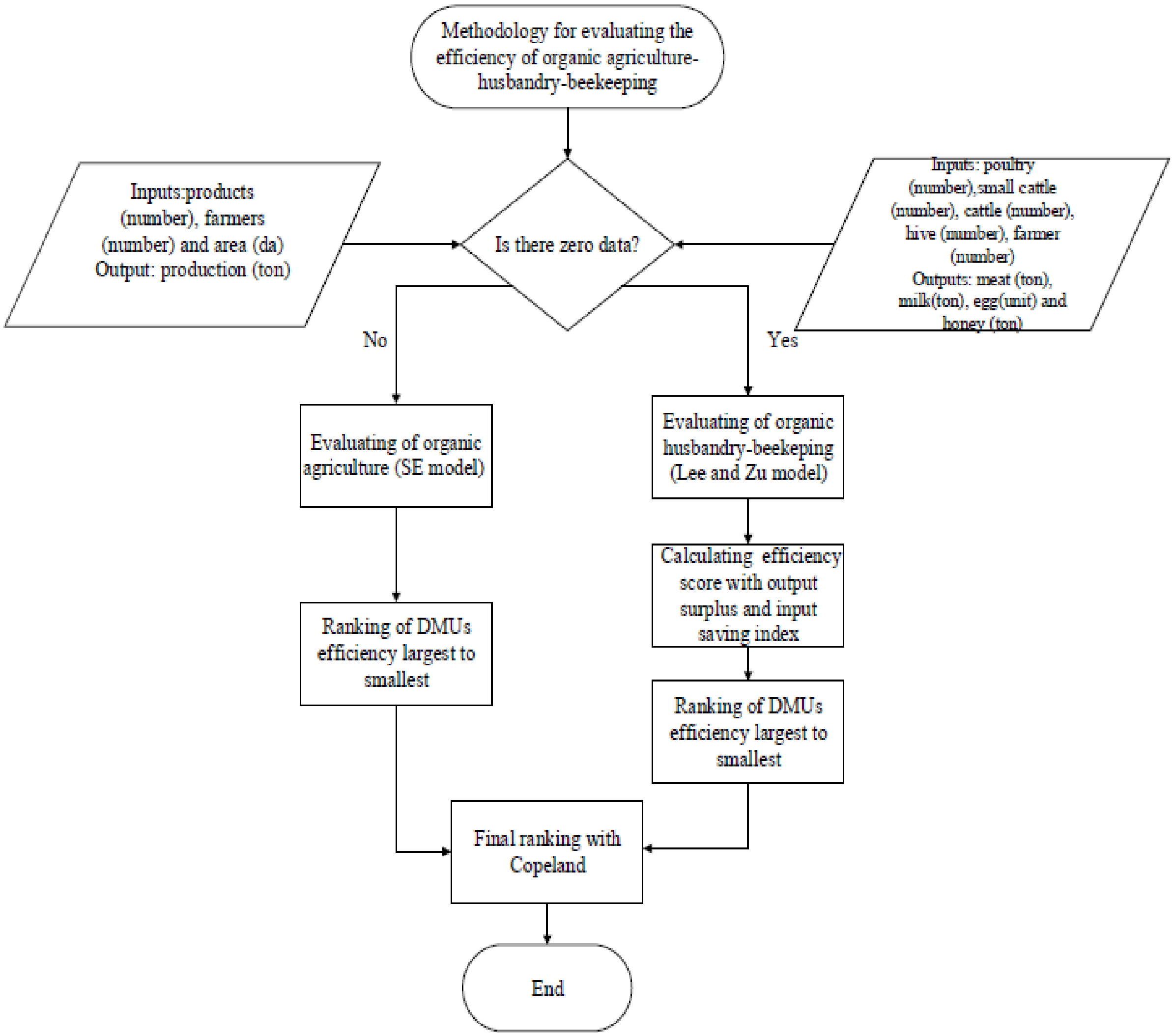

Figure 1- Steps for recommended methodology

3.2.1. Data Envelopment Analysis

DEA, a method based on linear programming and non-parametric assumptions, serves to evaluate the relative efficiencies of units producing similar outputs using similar inputs. The pioneering DEA model, the CCR was introduced by Charnes, Cooper, and Rhodes, enables the differentiation between efficient and inefficient DMUs, with efficient DMUs delineating the efficiency frontier and providing a preference ranking for inefficient ones (Charnes et al. 1978). However, the classical DEA models, the CCR model under the assumption of CRS and the BCC model under the assumption of VRS as proposed by Banker et al.(1984), fail to rank efficient DMUs. Consequently, numerous methodologies have been proposed to enhance DEA's discriminatory power, such as the Super-Efficiency (SE) model proposed by Andersen & Petersen (1993).

Initially, the parameters and decision variables for the SE model are delineated below, followed by the exposition of the input-oriented SE model (Andersen & Petersen, 1993). The primary objective of this model is to ascertain the efficiency score of DMU_0, which denotes the DMUS under assessment. In this context, θ_k symbolizes the efficiency score, with k representing the total number of DMUs.

Parameters:

N cluster of DMU
M cluster of input
S cluster of output
x_{ik} *i*-th input value of DMU *k*
y_{rk} *r*-th output value of DMU *k*
Decision Variables:
θ_k Efficiency score of DMU *k*
λ_k Matrix containing the weights of inputs and outputs for DMU *k*

(SE Model)

$$\text{Min } \theta_0 \tag{1}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k x_{ik} \leq \theta_0 \, x_{i0} \qquad \forall\, i \in M \tag{2}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k y_{rk} \geq y_{r0} \qquad \forall\, r \in S \tag{3}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k = 1 \tag{4}$$

$$\lambda_k \geq 0 \qquad \forall\, k \in N \tag{5}$$

In the SE model, DMUs are omitted from the dataset, thereby disrupting the existing efficient frontier and establishing a new one. The DMU under evaluation for efficiency is positioned beyond this newly established efficient frontier, yielding an efficiency score equal to or greater than 1. A higher efficiency score for an efficient DMU is indicative of greater desirability. In contrast, inefficient DMUs are unable to lie on the efficient frontier, resulting in their efficiency score as same as the classical models.

In the VRS assumption, the SE model may face infeasibility issues when evaluating certain efficient DMUs. Seiford & Zhu (1999) outline the necessary and sufficient conditions for the infeasibility of SE models, demonstrating that infeasibility is inevitable in the context of the VRS assumption in SE model. Various studies have attempted to address the challenge of infeasibility associated with the VRS assumption in SE model (Lovell & Rouse, 2003; Chen, 2005; Cook et al. 2009). Lee et al. (2011) propose a two-stage process to mitigate the issue of VRS infeasibility, producing a score that encompasses in both inputs and outputs. Additionally, Chen & Liang (2011) establish that the two-stage process can be resolved through a single linear program. Lee et al. (2011) illustrate that infeasibility arises in the input-oriented (output-oriented) model when there is any output surplus (input saving). In such cases, this novel approach identifies radial efficiency and output surplus (input saving) concurrently, yielding a SE score that encompasses both radial efficiency and output surplus (input saving) if present. However, these new SE model may still face infeasibility when dealing with positive data. In an extension of the research by Lee et al. (2011), Lee & Zu (2012) refine the model to ensure feasibility even in the presence of zero data in inputs. They assert that zero output data does not lead to infeasibility in the output-oriented SE models proposed in previous studies by Lee et al. (2011), Chen & Liang (2011), and Cook et al. (2009). The reason behind this is that the constraints on the output side can always be satisfied. Lee & Zu model is presented below (Lee & Zhu 2012):

(*Lee &Zu model)*

$$Min\, \tau + M\left(\sum_r \beta_r + \sum_i t_i\right) \tag{6}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k x_{ik} - t_i x_{imax} \leq (1+\tau)\, x_{i0} \qquad \forall\, i \in M \tag{7}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k y_{rk} \geq (1-\beta_r)\, y_{r0} \qquad \forall\, r \in S \tag{8}$$

$$\sum_{k \in N\text{-}\{0\}} \lambda_k = 1 \tag{9}$$

$$\lambda_k \geq 0,\ \beta_r \geq 0,\ t_i \geq 0,\ \tau \text{ is unlimited} \tag{10}$$

Where; $x_{imax} = max_{k=1}^{1}\{x_{ik}\}$, t_i is input saving and β_r output surplus, input saving index and output surplus index are calculated as follows with $I = \{i|\ t_i^* > 0\}$ and $R = \{r|\ \beta_r^* > 0\}$.

$$\hat{\iota} = \begin{Bmatrix} 0 & if\ I = \emptyset \\ \frac{\sum_{i\in I}\left(\frac{1+t_i^*}{1}\right)}{|I|} & if\ I \neq \emptyset \end{Bmatrix} \qquad o = \begin{Bmatrix} 0 & if\ R = \emptyset \\ \frac{\sum_{r\in R}\left(\frac{1}{1-\beta_r^*}\right)}{|R|} & if\ R \neq \emptyset \end{Bmatrix}$$

Then, the SE with zero data can be defined as $\breve{\theta} = 1 + \tau^* + o + \hat{\iota}$.

Consider a simple numerical example in Table 6 includes with 5 DMUs, two inputs (x_1 , x_2) and a single output (y_1). Here, $x_{1max} = max_{k=1}^{1}\{x_{1k}\} = 3$ and $x_{2max} = max_{k=1}^{1}\{x_{2k}\} = 4$. Table 7 shows the optimal values ($\tau^*, t_1^*, t_2^*, \beta_1^*$) from the Lee and Zhu model and input saving index ($\hat{\iota}$), output surplus index (o), SE with zero data ($\breve{\theta}$) from the formulas.

Table 6- Sample data set

DMUs	***Inputs***		***Output***
	x_1	x_2	y_1
1	2	1	1
2	1	2	1
3	1	4	2
4	2	3	1
5	3	0	1

Table 7- Lee and Zu model results of the sample data set in Table 6

DMUs	1+τ^*	t_1^*	t_2^*	β_1^*	t_1^{*}* x_{1max}	t_2^{*}* x_{2max}	β_1^* *y_{1k}	Input saving index ($\hat{\iota}$)	Output surplus index (o)	SE with zero data score ($\breve{\theta}$)
1	1	0	0	0	0	0	0	0	0	1
2	1.4	0	0	0	0	0	0	0	0	1.4
3	1	0	0	0.5	0	0	1	0	2	3
4	0.6	0	0	0	0	0	0	0	0	0.6
5	0.67	0	0.25	0	0	1	0	1.25	0	1.92

3.2.2. Copeland

The results from multi-criteria decision-making techniques can differ based on the evaluation methods utilized. This variance poses challenges for decision-makers, leaving them unsure when selecting the method and determining the best alternative. To resolve this issue, presenting alternative rankings obtained through multi-criteria decision-making methods using an integrative approach aids decision-making. Hence, the Copeland method serves as an integrative tool for this purpose (Saari & Merlin, 1996).

Step 1: The comparative superiorities are calculated according to Equation (11), where *i* represents the rank value of an alternative in the row, *j* represents the rank value of an alternative in the column, $f_k(i, j)$ denotes the superiority of alternative *i* over alternative *j*, and $r_k(A_i)$ signifies the rank value of alternative *i* with respect to method *k*.

$$f_k(i,j) = \begin{cases} r_k(A_i) < r_k(A_j) \wedge\ i \neq j \Longrightarrow 1 \\ r_k(A_i) > r_k(A_j) \wedge\ i \neq j\ \Longrightarrow 0 \\ r_k(A_i) = r_k(A_j) \vee\ i \neq j\ \Longrightarrow 0 \end{cases} \tag{11}$$

Step 2: The total comparative superiorities are computed using Equation (12), where *S(i, j)* represents the overall superiority of alternative *i* to alternative *j*, *k* denotes the rank value according to the MCDM method, and *m* signifies the total number of MCDM methods.

$$S(i,j) = \sum_{k=1}^{m} f_k\,(i,j), \quad i \neq j \tag{12}$$

Step 3: The conditions for winning, tying, and losing are provided sequentially in Equation (13).

$$G(i,j) = \begin{cases} S(i,j) > S(j,i) \wedge\ i \neq j \Rightarrow 1 \\ S(i,j) = S(j,i) \wedge\ i \neq j \Rightarrow 1/2 \\ S(i,j) < S(j,i) \wedge\ i \neq j \Rightarrow -1 \end{cases} \quad (13)$$

Step 4: Where GP_i represents the winnig score of alternative i, BP_i represents the tying score of alternative i, and YP_i represents the losing score of alternative i, the Copeland score CP_i is calculated using Equation (14).

$$\begin{aligned} GP_i &= \sum_{i=1}^{n} G(i,j)\ , G(i,j) > 0,\ n \\ BP_i &= \sum_{i=1}^{n} G(i,j)\ , G(i,j) = 1/2,\ n \\ YP_i &= \sum_{i=1}^{n} G(i,j)\ , G(i,j) < 0,\ n \\ CP_i &= GP_i + BP_i - YP_i \end{aligned} \quad (14)$$

3. Results and Analysis

In this study, to assess the efficiency of organic agriculture and organic husbandry-beekeeping, Türkiye's provinces were categorized according to NUTS-Level 1, with each region being treated as a DMU. Figure 2 illustrates the division of the 81 provinces into 12 groups on the map of Türkiye. Data pertaining to organic agriculture for these 12 groups were sourced from the website of the Ministry of Agriculture of the Republic of Türkiye and are presented in Table 8. Similarly, data concerning organic husbandry-beekeeping are provided in Table 9 (TR Ministry of Agriculture & Forestry, 2024). Figure 3 presents density maps for the selected outputs and inputs in our evaluation of organic agriculture and husbandry and beekeeping. Panel (a) shows the density of organic crop production (tons), one of the outputs in our analysis of organic agriculture. Panel (b) illustrates the total number of poultry, sheep, and cattle, which represent the inputs used in the evaluation of organic husbandry. Finally, panel (c) displays organic honey production (tons), representing the output of organic beekeeping.

Figure 2- The Nomenclature of Territorial Units for Statistics (NUTS)-Level 1 classification

Table 8- Organic agriculture data of the regions

DMUs	*Level 1 Zone Name*	*Inputs* *Products (number)*	*Farmer (number)*	*Area (da)*	*Output* *Production (ton)*
1	Istanbul	105	14	605.29	431.41
2	West Marmara	259	436	42,943.94	12,444.86
3	Aegean	505	11,060	697,436.73	389,127.34
4	East Marmara	480	808	28,483.95	23,793.90
5	West Anatolia	222	553	59,941.72	41,351.56
6	Mediterrenian	319	452	155,184.36	55,962.33
7	Central Anatolia	311	724	155,093.64	190,318.48
8	West Blacksea	260	2,434	149,715.22	36,778.42
9	East Blacksea	50	15,472	118,044.17	62,034.75
10	Northeast Anatolia	87	1,936	403,189.93	149,383.18
11	Central East Anatolia	128	1,639	145,919.50	88,822.95
12	Southeast Anatolia	90	903	184,457.90	102,711.94

Table 9- Organic husbandry-beekeeping data of the regions

Level 1 Zone Name			*Inputs*					*Outputs*	
	Poultry (number)	***Small cattle (number)***	***Cattle (number)***	***Hive (number)***	***farmer (number)***	***Meat (ton)***	***Milk (ton)***	***Egg (number)***	***Honey (ton)***
Istanbul	0	0	0	35	1	0	0	0	0.71
West Marmara	17,814	1,172	2,844	1,287	62	27.54	2,572.5	2,155,630	10.85
Aegean	352,662	22	2,762	664	28	78.00	16,054	41,117,289	13.15
East Marmara	139,044	0	232	289	17	0.99	959.50	27,407,376	4.96
West Anatolia	420	1,651	116	438	6	0	0	54,000	8.71
Mediterranean	17,000	2,485	60	12,477	42	0	264.00	3,517,867	481.53
Central Anatolia	0	0	1,206	4,709	60	0	6,910.8	0	88.20
West Black sea	0	0	0	74	1	0	0	0	0.74
East Black sea	113,500	0	0	12,143	100	0	0	2,000	132.11
Northeast Anatolia	0	0	0	11,310	34	0	0	0	183.49
Central East Anatolia	43,968	0	0	24,478	88	0	0	13,190,400	386.89
Southeast Anatolia	0	0	0	5,033	22	0	0	0	40.85

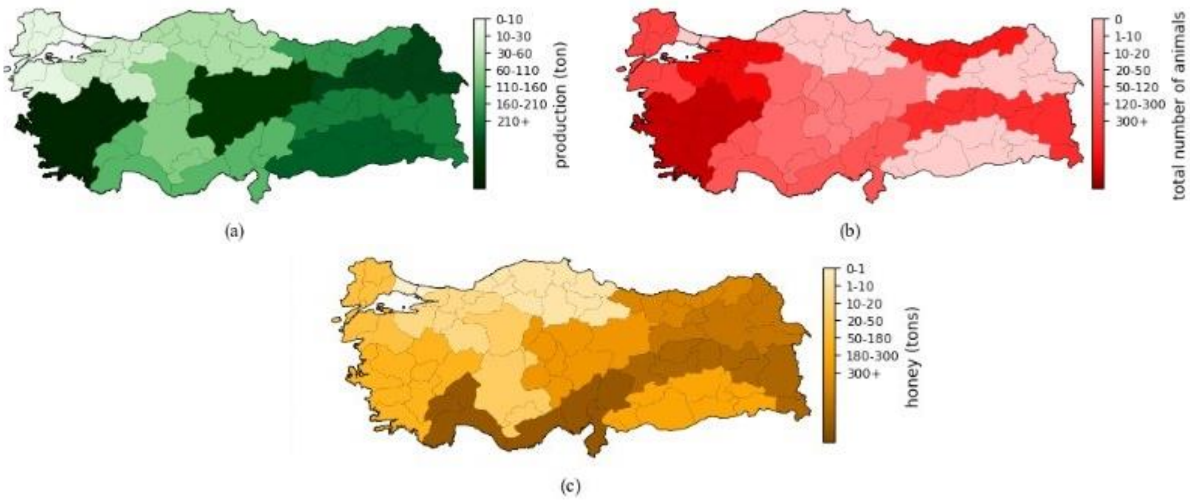

Figure 3- By region (a) organic agricultural production (b) number of poultry, sheep, and cattle (c) organic honey production

According to Figure 3 map (a), Istanbul exhibits the lowest agricultural production. However, as depicted in Figure 4, Istanbul possesses 14% of the authorized organizations with organic production certificates, trailing behind Izmir (TR. Ministry of Agriculture & Forestry, 2024). Moreover, the quantity of organic agricultural production is notably low in the Marmara Region (encompassing Istanbul, Western Marmara, and East Marmara), despite its significant population and high demand for organic products based on socio-economic characteristics. Conversely, the Aegean region, home to Izmir, boasts the highest agricultural production. Examining the number of organic animals illustrated in map (b), similar trends are evident for Istanbul and the Aegean region. Furthermore, while East Marmara, primarily focused on the poultry sector, stands out, Northeast and Southeast Anatolia, prominent in organic animal feed production, fall behind. Lastly, concerning map (c), the Mediterranean and Central East Anatolia regions lead in honey production.

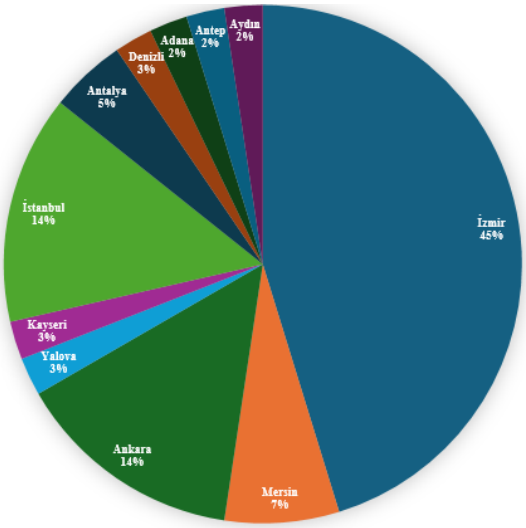

Figure 4- Authorized organizations for organic agriculture and husbandry

Table 10- Efficiency scores and final rankings

		Organic Crop		*Organic Husbandry-Beekeeping*		*Final Ranking*	
DMUs	***Level 1 Zone Name***	***Super efficiency score***	***Ranking***	***Super efficiency with zero data***	***Ranking***	***Borda count***	***Copeland***
1	Istanbul	2.1	3	2.11	8	5	6
2	West Marmara	0.42	11	6.99	3	7	7
3	Aegean	2.77	2	40.61	1	1	1
4	East Marmara	0.69	8	8.67	2	3	3
5	West Anatolia	0.64	9	0.61	11	11	11
6	Mediterranean	0.51	10	4.15	5	8	9
7	Central Anatolia	4.83	1	2.55	7	2	2
8	West Black Sea	0.4	12	1.01	9	12	12
9	East Black Sea	1.79	5	0.67	10	8	8
10	Northeast Anatolia	1.81	4	2.55	6	3	3
11	Central East Anatolia	0.93	7	6.56	4	5	5
12	Southeast Anatolia	1.29	6	0.50	12	10	10

In our study, we evaluated the efficiency of organic agriculture using the SE model and the efficiency of organic husbandry-beekeeping using Lee and Zu's model, which accounts for zero data. According to the organic crop efficiency scores derived from the SE model, Central Anatolia ranks first, with the Aegean Region in second place. Although the Aegean Region has the highest output, its second-place ranking is attributed to its significantly higher inputs compared to Central Anatolia. Additionally, despite having the lowest output, the Istanbul region ranks third due to its relatively low inputs. Finally, the West Black Sea Region, while not having a particularly low output, ranks last because of the high number of farmers considered as an input. According to the organic husbandry and beekeeping efficiency scores obtained from the Lee and Zhu model, the Aegean, East Marmara, and West Marmara regions rank in the top three, respectively. These regions engage in all activities (poultry, cattle, sheep, and beekeeping) and their outputs are higher than those of other regions. Additionally, despite having the highest output in honey production, the Mediterranean Region ranks fifth due to having zero data for meat production.

According to Table 10, the Aegean Region ranks second in organic crop and first in organic husbandry and beekeeping, indicating that it has a balanced production network. Although Central Anatolia ranks first in organic crop, it only ranks seventh in organic husbandry and beekeeping, primarily due to the zero data on poultry and small cattle in this region. As mentioned earlier, Istanbul has a favourable ranking in organic crop due to its low input and output, yet it ranks eighth in organic husbandry and beekeeping. Considering its population, Istanbul needs to further enhance its organic production capabilities. Northeast Anatolia ranks fourth and sixth, respectively. In this region, where the geographical features are known to be suitable, support for husbandry should be prioritized. Similar observations can be made for other regions as well. In conclusion, to establish a balanced production network across all regions, existing farms should be integrated into the certification system, or organic agriculture should be promoted through grant support.

Since the efficiency scores from these models can vary greatly, summing them may lead to misleading results. Additionally, due to extreme values in the efficiency scores from Lee and Zu's model, normalizing the scores does not effectively differentiate between DMUs with low efficiency scores. To obtain a single final ranking from these two sets of rankings, we employed the Borda count method, widely used in the literature, and the Copeland method, which is based on superiority comparison and does not require normalization. As shown in Table 10, the rankings are similar in both methods. The Aegean region, which ranks first in organic husbandry-beekeeping and second in organic agriculture, ranked first overall. According to Figure 3 (a, b, c), Central Anatolia, which has average values, ranks first in organic agriculture efficiency score based on the weighted input and output ratio. However, since it ranks seventh in organic husbandry-beekeeping, it comes in second in the final rankings.

East Marmara and North Anatolia are ranked third according to the Borda count method. Istanbul, which were last in terms of organic agriculture production, number of animals, and honey production, and Central East Anatolia ranked fifth. Istanbul is in the middle ranks due to its low inputs as well as outputs. In the Copeland method, Central East Anatolia ranked fifth, while Istanbul ranked sixth, thus resolving the tie. Finally, West Anatolia and West Black Sea ranked in the bottom two according to both methods.

4. Conclusions

Türkiye, with approximately half of its total land area being agricultural, is a significant producer and exporter of agricultural products. It is the largest producer and one of the leading exporters of various grain products, oilseeds, hazelnuts, raisins, figs, and tea. Thanks to its favourable geography, fertile soil, abundant water resources, and suitable climatic conditions, a wide variety of products such as fruits, vegetables, and grains are cultivated. These features make Türkiye naturally conducive to organic agriculture. However, organic product production and consumption rates remain low, comprising only 0.1% of the global organic agriculture market. To address this, many projects have been initiated to popularize organic agriculture, support the production of organic products accessible to all income groups, establish traceability, implement an effective control and certification system, and increase consumer awareness about organic products. As a result, the number of organic farming enterprises and the total organic farming land area have significantly increased over the last decade. However, certain challenges negatively impact organic agriculture in Türkiye. For instance, farms in the country are generally fragmented and small-scale family businesses. Approximately 65% of farms in Türkiye cover only 0-5 hectares, while lands under 10 hectares constitute about 83% of the total agricultural land. In our study, we handled the number of farmers as an input; however, due to the lack of scaling for the size of the farming, could not include in the evaluation. Therefore, if the ministry or policymakers scale these enterprises according to their size and share the data accordingly, more accurate analyses can be conducted, and can be assessed more effectively.

Türkiye has significant potential in terms of animal numbers, and although its potential for organic animal production is very high, it is not fully utilized. Regions with extensive meadow and pasture areas and no industrial pollution have great potential for organic sheep and cattle breeding and beekeeping. However, animal breeders in these regions are mostly small family businesses. Despite the need for a certification system to follow organic husbandry and beekeeping, some regions, such as the East and the Black Sea, lack certification bodies. Additionally, animal breeders' knowledge and training regarding both the certification system and organic husbandry are inadequate. For these reasons, this potential has not been fully realized. Furthermore, although the number of organic animals, and the production of milk, meat, and especially eggs, have increased considerably in the last decade, the lack of sufficient consumer awareness and low purchasing power in the domestic market negatively impact the development of organic husbandry. In this context, policymakers can create organizations to support organic production, particularly in regions with low performance. This includes providing farmers with necessary training, developing grant-based support programs, and expanding institutions that offer organic production certification systems in other regions as well as the Aegean Region. In the Eastern Anatolia and Black Sea Region, where husbandry and beekeeping are intensively practiced, farms can be encouraged to join the certification system. Furthermore, the marketing and promotion network for organic products can be enhanced, leading to greater branding and distribution of registered local products across various regions of Türkiye. Thus, interest in organic production can increase in alignment with the rising demand in both domestic and international markets.

In conclusion, Türkiye has regions that vary significantly in terms of natural, climatic, and socio-economic conditions. Therefore, analysing the development of organic agriculture, husbandry, and beekeeping on a regional basis in our study can provide a better understanding of the current situation and guide policy makers in formulating the necessary strategies.

References

Aghasafari H, Karbasi A, Mohammadi H & Calisti R (2020). Determination of the best strategies for development of organic farming: A SWOT–Fuzzy Analytic Network Process approach. *Journal of Cleaner Production* 277: 124039. doi:https://doi.org/10.1016/j.jclepro.2020.124039

Ak İ (2017). Organic Livestock in Turkey. *Proceeding of The Eurasian Agriculture and Natural Sciences Congress,*, (pp. 190-192). Bishkek, Kyrgzstan

Åkerfeldt M P, Gunnarsson S, Bernes G & Blanco-Penedo I (2021). Health and welfare in organic livestock production systems—a systematic mapping of current knowledge. *Organic Agriculture* 11(1): 105-132

Andersen P & Petersen N C (1993). A procedure for ranking efficient units in Data Envelopment Analysis. *Management Science* 39: 1261-1264

Angón E, Bragulat T, García A, Giorgis A & Perea J (2021). Key factors affecting the technical efficiency of bee farms in the province of La Pampa (Argentina): A two-stage DEA approach. *Revista de la Facultad De Ciencias Agrarias UNCuyo* 55(1): 150-163

Artukoglu M M, Olgun A & Adanacioglu H (2010). The efficiency analysis of organic and conventional olive farms: Case of Turkey. *Agricultural Economics* 56(2): 89 - 96

Aşkan E (2023). Increasing Honey Production Effectiveness in Erzincan and Van Provinces. *Sustainability* 15(9): 7524

Aydın B, Aktürk D & Arsoy D (2020). Economic and efficiency analysis of beekeeping activity in Turkey: Case of Çanakkale Province. *Ankara Üniv Vet Fak Derg* 67: 23-32

Banker R, Charnes A & Cooper W (1984). Some models for estimating techical and scale inefficiencies in Data Envelopment Analysis. *Management Science* 30: 1078-1092

Basavalingaiah K, Paramesh V, Parajuli R, Girisha H, Shivaprasad M, Vidyashree G & Rajanna G (2022). Energy flow and life cycle impact assessment of coffee-pepper production systems: An evaluation of conventional, integrated and organic farms in India. *Environmental Impact Assessment Review 92*(January): 106687

Casolani N, Nissi E, Giampaolo A & Liberato L (2021). Evaluating the effects of European support measures for Italian organic farms. *Land use policy* 102: 105225

Ceyhan V, Canan S, Yıldırım Ç & Türkten H. (2017). Economic Structure and Services Efficiency of Turkish Beekeepers' Association. *European Journal of Sustainable Development* 6(4): 53-64

Charnes A, Cooper W & Rhodes E. (1978). Measuring the efficiency of decision-making units. *European Journal of Operational Research* 2: 429-444

Charyulu D K & Biswas S (2010). Economics and efficiency of organic farming vis-à-vis conventional farming in India. Ahmedabad, India: Indian Institute of Management

Chen Y (2005). Measuring super-efficiency in DEA in the presence of infeasibility. *European Journal of Operational Research* 161(2): 545-551

Chen Y & Liang L (2011). Super-efficiency DEA in the presence of infeasibility: One model approach. *European Journal of Operational Research* 213(1): 359-360

Cook W, Liang L, Zha Y & Zhu J (2009). A modified super-efficiency DEA model for infeasibility. *Journal of the Operational Research Society* 60(2): 276-281

Dogan N & Adanacioglu H (2021). Performance Evaluation of Beekeeping Farms: A Case Study from Gümüşhane, Turkey. *Pakistan J. Zool* 53(5): 1837-1846

Durán-Lara E F, Valderrama A & Marican A (2020). Natural organic compounds for application in organic farming. *Agriculture* 10(2): 41. doi:https://doi.org/10.3390/agriculture10020041

Ersoy Y, Tehci A & Yıldız S (2021). Efficiency measurement in businesses producing organic products within the scope of ecological marketing: The example of a tea business. *Akademia Journal of Nature and Human Sciences* 7(1): 19-31, (In Turkish).

Ferenczi A, Szucs I & Gáthy A (2023). Economic Sustainability Assessment of a Beekeeping Farm in Hungary. *Agriculture* 13(6): 1262

Gomes E, Abreu U, Mello J, Carvalho T & Zen S (2015). Economic and socio-environmental performance assessment of beef cattle production systems: a data envelopment analysis (DEA) approach with weight restrictions. *Revista Brasileira de Zootecnia* 44(6): 219-225

He D, Deng X, Jin G, Wang X, Zhang Y, Sun Z & Zhao Z (2022). Ecological efficiency of grass-based livestock husbandry under the background of rural revitalization: An empirical study of agro-pastoral ecotone. *Frontiers in Environmental Science* 10(848134): 1-12

Kashiwagi K & Kamiyama H (2023). Effect of adoption of organic farming on technical efficiency of olive-growing farms: empirical evidence from West Bank of Palestine. *Agricultural and Food Economics* 11(26): 1-28

Koner N & Laha A (2024). Estimating Marketing Efficiency of Organic Farmers: Evidence from Districts of West Bengal India. *International Journal of Rural Management* 20(3): 335-352. https://doi.org/10.1177/09730052241229685

Kuhna L, Balezentis T, Hou L & Wang D (2020). Technical and environmental efficiency of livestock farms in China: A slacks-based DEA approach. *China Economic Review* 62: 101213

Kuosmanen N, Yli-Heikkilä M, Väre M & Kuosmanen T (2021). Productive performance of organic crop farms in Finland 2010–2017. *Organic Agriculture* 11: 1-14

Lee H S, & Zhu J (2012). Super-efficiency infeasibility and zero data in DEA. *European Journal of Operational Research* 216(2): 429-433

Lee H S, Chu CW & Zhu J (2011). Super-efficiency DEA in the presence of infeasibility. *European Journal of Operational Research* 212(1): 141-147

Lovell C & Rouse A (2003). Equivalent standard DEA models to provide super-efficiency scores. *Journal of the Operational Research Society* 54: 101–108

Makri P, Papanagiotou P & Papanagiotou E (2015). Efficiency and economic Analysis of Greek Beekeeping Farms. *Bulgarian Journal of Agricultural Science* 21(3): 479-484

Manta F, Morrone D, Toma P & Campobasso F (2023). Determining paths of innovation: The role of culture on the adoption on organic farming management. *Business Strategy and the Environment* 32(1): 96-109

Manuelian C, Penasa M, Costa L, Burbi S, Righi F & Marchi M (2020). Organic Livestock Production: A Bibliometric Review. *Animals* 10(4): 618

Melo M (2021). Organic Rice Production and Consumption to Sustain Food Security in Oriental Mindoro, Philippines. *Review of Integrative Business and Economics Research* 10(3): 338-354

Menten C, Çekiç B & Özal Saraç N. (2023). Evaluation of Organic Agriculture Production Efficiency in OECD Countries within the Framework of Sustainable Development Goals. *Hacettepe University Journal of Faculty of Economics and Administrative Sciences* 41(Special issue on Agriculture): 77-97. (In Turkish)

Nastis S A, Bournaris T & Karpouzos D (2019). Fuzzy data envelopment analysis of organic farms. *Operational Research* 19: 571-584

Pandey U & Singh S (2021). Environmental performance evaluation of European farms by assessing polluting factors in joint production. *Journal of Cleaner Production* 328: 129457

Poudel K L, Johnson T G, Yamamoto N, Gautam S & Mishra B (2015). Comparing technical efficiency of organic and conventional coffee farms in rural hill region of Nepal using data envelopment analysis (DEA) approach. *Organic Agriculture* 5: 263-275

Raimondo M, Caracciolo F, Nazzaro C & Marotta G (2021). Organic Farming Increases the Technical Efficiency of Olive Farms in Italy. *Agriculture* 11(3): 209

Riar A, Mandloi L, Sendhil R, Poswal R, Messmer M & Bhullar G (2020). Technical efficiencies and yield variability are comparable across organic and conventional farms. *Sustainability* 12(10): 4271

Saari D. & Merlin V (1996). The Copeland method. *Economic Theory 8*: 51-76. doi:https://doi.org/10.1007/BF01212012

Saati S & Memariani A (2005). Reducing weight flexibility in fuzzy dea. *Appl Math Comput* 161(2): 611–622

Sapbamrer R & Thammachai A (2021). A systematic review of factors influencing farmers' adoption of organic farming. *Sustainability* 13(7): 3842. doi:https://doi.org/10.3390/su13073842

Seiford L & Zhu J (1999). Infeasibility Of Super-Efficiency Data Envelopment Analysis Models. *INFOR: Information Systems and Operational Research* 37(2): 174-187

Sink N, Petkovsek M M, Veberic R & Marsic N K (2017). Chemical composition and morphometric traits and yield ofcarrots grown in organic and integrated farming systems. *Turkish Journal of Agriculture and Forestry 41*(6): 452-462. doi:https://doi.org/10.3906/tar-1705-8

Sintori A, Konstantidelli V, Gouta P & Tzouramani I (2023). Profitability, Productivity, and Technical Efficiency of Cretan Olive Groves across Alternative Ecological Farm Types. *Agriculture* 13(12): 2194

Sundrum A (2001). Organic livestock farming: a critical review. *Livestock Production Science* 67(3): 207-215. doi:https://doi.org/10.1016/S0301-6226(00)00188-3

T.R. Ministry of Agriculture and Forestry. (2024, May 16). Retrieved from T.R. Ministry of Agriculture and Forestry: https://www.tarimorman.gov.tr/Konular/Bitkisel-Uretim/Organik-Tarim/Yetkili-Kuruluslar-KSK

TR Ministry of Agriculture and Forestry. (2024, May 9). Retrieved from 2022 Organic Agriculture Statistics: https://www.tarimorman.gov.tr/Konular/Bitkisel-Uretim/Organik-Tarim/Istatistikler

Uzundumlu A S, Tamşen M & Bilgiç A (2021). Comparison of organic and conventional wheat in terms of efficiency and cost in Turkey: a case study of Erzurum Province. *Custos e@ gronegócio online* 17: 217-238

Yadava A K (2024). Macroeconomic determinants of organic farming efficiency: Double bootstrap DEA estimates from the Indian states. *Regional Science Policy & Practice Regional Science Policy & Practice* 16(6): 100036

Yadava A K & Komaraiah J B (2021). Benchmarking the performance of organic farming in India. *Journal of Public Affairs* 21(2): e2208

Yan J & Zhang Y (2023). Quantitative assessment, spatial and temporal characteristics, and dynamic evolution of carbon emissions from animal husbandry in China: 2001–2020. *Environmental Science and Pollution Research* 30: 116186–116201

Zhen H, Qiao Y, Ju X, Hashemi F & Knudsen M T (2023). Organic conversion tea farms can have comparable economic benefits and less environmental impacts than conventional ones—A case study in China. *Science of The Total Environment* 877: 162698

Zor M, Özüpek B, Pekacar S & Deliorman D (2023). Antioxidants, enzyme inhibitory activities, and phytochemical profiles of seven medicinal plants grown with organic farming techniques. *Journal of Agriculture and Forestry* 47(6): 918-930. doi:https://doi.org/10.55730/1300-011X.3137