Sustainable Site Selection for a Cooperative Dairy Factory in NW Türkiye

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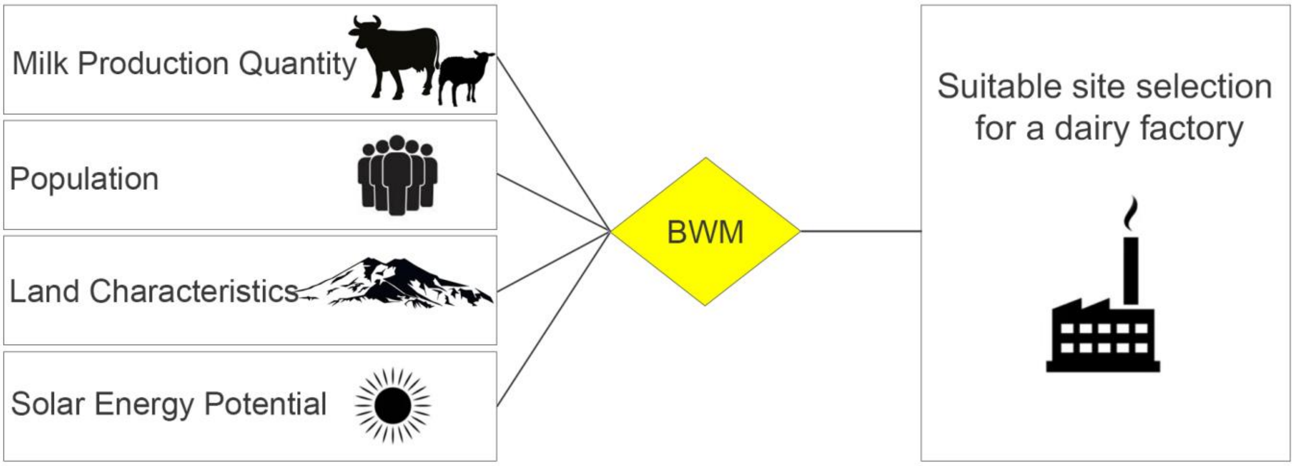
Graphical Abstract



Abstract

The world population is increasing, and agricultural products are strategically crucial for feeding the growing world population. In developed countries, cooperatives serve as an essential tool to ensure the sustainability of agricultural production and reduce costs. In Türkiye, cooperatives play a limited role in controlling the agricultural product market. There are many dairy cooperatives in Türkiye, but they are often ineffective in processing and marketing milk effectively. This study was conducted in Çanakkale, NW Türkiye. In this study, an approach was proposed to enable dairy cooperatives to select suitable sites for establishing a dairy factory. With this proposed approach, milk production quantity, population, land characteristics (land use capability classification (LUCC), and environmental conditions (solar energy potential) were used as main criteria. The Best Worst Method (BWM), a newly developed multi-criteria decision-making method (MCDM), was employed to determine the weights of the selected criteria. A geographical information system (GIS) was used to produce the final suitability map. Based on the BWM calculations, milk production quantity was identified as the most effective factor (46.55%), followed by population (25.86%), land use capability classification (17.24%), and photovoltaic potential (10.35%). The suitability analysis revealed that the Biga district was the most suitable location for establishing a dairy processing plant. The significance of the Biga district lies in its high milk production, large population, and well-established infrastructure that supports milk processing and marketing activities. The novel approach of this study is the integration of milk production, population, land use, and renewable energy potential through a Multi-Criteria Decision-Making (MCDM) method within a GIS environment, providing a guideline for the sustainable milk processing capacities of agricultural cooperatives. By considering photovoltaic potential and the utilization of marginal lands, the study emphasizes the importance of renewable energy and land conservation in dairy processing, thereby ensuring long-term environmental and economic benefits. Prioritizing sustainable and cooperative-oriented development contributes to Türkiye's efforts to strengthen its agricultural sector. The data produced by this study can be utilized by politicians, decision-makers, cooperative members, farmers, and other relevant stakeholders.

Keywords: Land suitability, Sustainable development, environmental protection, marginal land utilization, solar-based site selection.

1. Introduction

The role of cooperatives in achieving development in all sectors in the world is very valuable. Numerous academic studies on cooperatives, cooperative policies implemented around the world, and the stories of successful cooperatives prove this fact to us. In many countries, including Türkiye, different types of cooperatives work to develop not only individuals but also society. Cooperatives, which are particularly effective in ending poverty and benefiting disadvantaged individuals and small businesses, are the driving force of development. Cooperatives provide economic, technical, social, and cultural benefits to individuals and society and focus on the Turkish instance rather than focusing on European cooperatives. Agricultural cooperatives are the most essential tool of economic empowerment for farmers (Lee and Van Cayseele, 2022). The primary reason farmers establish cooperatives is to undertake processing and marketing activities (Bijman and Hendrikse, 2003; Van Cayseele, 2018). According to the United Nations Department of Economic and Social Affairs' 72. In the General Assembly resolution on cooperatives in 2017, cooperatives play a key role in achieving the Sustainable Development Goals and leave no one behind. The General Assembly report also states that the importance of cooperatives for development is undisputed (United Nations, 2023). It is well known that developed countries have achieved their development through cooperatives. Different studies support this idea (Song, et al., 2014; Sathapatyanon et a., 2018; Candemir et al., 2021; Imami et al., 2021). In developed countries, cooperatives are recognized as a third sector due to their significant contributions to the economy and development.

In addition, the United Nations has declared 2025 as the 'International Year of Cooperatives' in recognition of the role of co-operatives in achieving sustainable development goals and financing development. The theme of the 2025 International Year of Cooperatives is "Cooperatives Building a Better World". Thus, throughout the year, it is expected that cooperatives, governments, and other international organizations will raise awareness of the cooperative business model and its role in achieving the UN Sustainable Development Goals. However, in Türkiye, cooperatives have not yet reached the desired level of contribution to economic growth and development. For example, in Türkiye, dairy and dairy product exports increased by 16.26 percent compared to the previous year, reaching 510 million dollars and 170 million kg. However, there is no cooperative brand among the exporting brands. (Türkiye Exporters Assembly, 2024).

The types of agricultural cooperatives in Türkiye are agricultural development, irrigation, aquaculture, beet growers, agricultural credit, agricultural sales, tobacco production and marketing, and fresh fruit and vegetable marketing cooperatives. The number of these cooperatives in Türkiye is 11788, and the number of farmers who are members of these cooperatives is 3587206 (Republic of Türkiye Ministry of Agriculture and Forestry, 2023). As seen, Türkiye has many agricultural cooperatives. However, these cooperatives hold no significant share of the world market. Among these cooperatives operating in various sectors, this study specifically focuses on the dairy subsector. Dairy farmers in Türkiye are mostly members of agricultural development cooperatives. One of the primary goals of development and agricultural policies in Türkiye is to increase organization in agricultural production. However, cooperative awareness, culture and strong cooperative organization have not yet been established. It is worth noting that the share of cooperatives in the dairy and dairy products sector, one of the most significant sub-sectors of agriculture, remains remarkably low (Koç and Uzmay, 2018).

In the Netherlands, where successful cooperatives are prevalent, dairy cooperatives have been in existence for over 130 years. These cooperatives have had a market share of more than 80% since the 1950s. This indicates that cooperatives are resilient organizations within the Dutch dairy industry (Bijman, 2018). The market shares of Dutch agricultural cooperatives are also relatively high in other products. For example, the market share of cooperatives is 100% in sugar, 86% in milk, 95% in fruit and vegetables, and 95% in flower production. In addition, although these cooperatives are few, they are strong and effective in determining the market. (Bijman, 2016).

The rise of dairy cooperatives in Europe is explained by both technological and institutional innovations (Van Zanden, 1994; Henriksen, 1999; Fernández, 2014). The most significant institutional innovation is the existence of cooperative legislation, which enables dairy factories to become cooperative. Cooperative legislation was first introduced in England in 1852, followed by Germany and France in 1867, Belgium and Austria in 1873, and the Netherlands in 1876 (Rommes, 2014). However, the support provided by dairy technology and cooperative legislation is not sufficient for the establishment and continuity of cooperative dairy enterprises. Why don't farmers sell their milk to private factories? Because cooperatives reduce transaction costs and strengthen marketing power (Van Zanden, 1994; Henriksen, 1999; Fernández, 2014; Rommes, 2014). Selling raw materials to factories makes buyers opportunistic, which increases costs. Additionally, the dairy factory's monopoly led to low marketing power for farmers. Therefore, farmers have to own the factory (Bijman, 2018). The successful cooperative model in Europe is not limited to the Netherlands. In 2015, 64% of all cow's milk produced in Europe was from farmer cooperatives. The share of cooperatives in the milk market is 67% in Germany, 54% in France, 27% in the UK, 75% in Poland, and 68% in Italy (European Commission, 2024).

According to the Agricultural Estimates Report published in 2019 by the Organization for Economic Cooperation and Development (OECD) and the Food and Agriculture Organization (FAO), consumption of dairy and dairy products will show a steady increase. Long-term consumption estimates in the report predict a 24% increase in worldwide consumption of dairy and dairy products between 2015 and 2028 (European Commission, 2024). In a market where cooperatives are not involved in the processing and marketing processes in the dairy sector, prices are disadvantageous for both farmers and consumers. Therefore, Türkiye urgently needs cooperatives, which are farmer organizations that produce, process, and market milk.

The dairy sector differs from other sectors due to the perishability of the product, seasonality, demand fluctuations and small-scale production characteristics. Therefore, strategies related to the dairy industry are essential to meet the needs of the market, ensure food safety and competitive environment (Mor et al., 2018). Investments in milk production, perishability of milk, and dependence on a single buyer have led many dairy farmers to establish their businesses. Since such a business requires the milk of many farmers and the financing of a dairy factory, cooperation is an effective model.

The primary motivation of this study is based on the question, 'If a simulation were made in Çanakkale , which has 2.73% of the milk produced in Türkiye, where would small-scale dairy cooperatives combine their forces/production and establish a dairy factory?' In this context, this study investigated the answer to the question, 'If the dairy cooperatives in Çanakkale province were to establish a dairy factory, which region would they choose for location?'

The selection of a facility location among alternatives is a multi-criteria decision-making problem that involves both quantitative and qualitative criteria (Mokhtarian and Hadi-Vencheh, 2012). The advantages of GIS in industrial site selection for stimulating the economy and protecting the environment are enormous (Nuhu et al., 2021). The determination of production site selection is a fundamental element of competitive business strategy and is of vital importance. Site selection for production is essential for all sectors. Once a factory unit is established in a specific location, it cannot be moved in the short term (Sharma et al., 2010).

Although Türkiye has a significant number of dairy cooperatives, there is a considerable gap in milk processing by these cooperatives. Dairy cooperatives in Türkiye lack the capacity to add value to milk. It is essential for cooperatives to urgently develop milk processing capacities to enhance the value of their production. Thus, this study has the potential to serve as a guide to reveal the sustainable milk processing capacities of agricultural cooperatives in Çanakkale. The study's primary objective is to enhance dairy cooperatives' milk processing and marketing capabilities, increase their productivity and profitability, and contribute to achieving the Sustainable Development Goals. In this context, socioeconomic data (milk production quantity, population), land characteristics (land use capability classification (LUCC)), and environmental conditions (solar energy potential) were evaluated using a multi-criterion decision-making method (BWM), Çanakkale NW, Türkiye, and a suitable site selection was performed for the dairy factory.

2. Factor set

This study confidently presents a factor set consisting of four criteria: Milk production quantity (MPQ), land use capability classification (LUCC), population (P), and photovoltaic potential (PP), which can assist dairy cooperatives in selecting dairy plant sites (Fig. 1).

A comprehensive literature review forms the factor set and required literature information is given in (Table 1) for the evaluation criteria. Accordingly, when selecting an optimal location for a factory establishment, proximity to raw material sources is a critical factor for evaluation. This criterion considers the distribution of annual milk production in Çanakkale province by district. The second criterion for selecting a site for a cooperative dairy factory was the population of the districts. Population is crucial in providing the necessary labor force for the establishment of a factory. As the third criterion, LUCC, was considered, the land use capability classes of the districts in Çanakkale. This criterion aims to protect productive agricultural lands from land degradation during the establishment of the factory. The lands in classes VI, VII and VIII are not suitable for cultivation due to slope and soil shallowness limitation (Everest et. al, 2021; FAO, 1989). So, these lands can be preferred for establishing a dairy factory. In the study, the focus was on providing the energy needs of the enterprise from sustainable and clean sources. Photovoltaic potential is the final criterion considered for selecting the site of the cooperative dairy factory. The photovoltaic potential of the study area was considered to assess the feasibility of establishing a dairy factory that utilizes clean energy. This criterion is crucial for reducing costs, protecting the environment, and utilizing resources sustainably.

3. Materials and methods

3.1 Study area

This study was carried out in the province of Çanakkale in NW Türkiye. Çanakkale is located on both sides of the Aegean Sea and the Sea of Marmara. It covers an area of 993,318 hectares between 25° 40′- 27° 30′ east longitude and 39° 27′- 40° 45′ north latitude. Çanakkale is surrounded by Edirne, Tekirdağ, and Balıkesir (Ministry of Agriculture and Forestry, 2023). This study covers all districts of Çanakkale Province, except for Eceabat, Gelibolu, Bozcaada, and Gökçeada islands. The distribution of agricultural development cooperatives by district is shown below (Fig. 2). There is a total of 358 agricultural development cooperatives in Çanakkale province, excluding the islands. Çanakkale province has the advantage of supplying the raw materials required for the establishment of a cooperative dairy factory. Raw milk production in Türkiye in 2022 was 21,563,492 tonnes (TURKSTAT, 2023). In 2022, Çanakkale province met 2.73% of the 21,563,492 tons of milk produced in Türkiye (TURKSTAT, 2023; Ministry of Agriculture and Forestry, 2023).

Çanakkale is one of the essential milk-producing provinces. This importance is related to the quality of milk, rather than its quantity. In Çanakkale, an average of 750 tons of milk is collected daily in 615 milk cooling tanks by cooperatives and sent to milk factories. The milk is processed as drinking milk by the factories due to its high quality. The recognizability of Ezine Cheese, which is produced by processing the mixture of sheep, goat, and cow milk produced in the Ezine and Bayramiç regions, has exceeded the borders of Türkiye.

The presence of genetically superior livestock in dairy cattle and goat farming is one of the province's key advantages. In the study area, 85% of the existing dairy cattle are purebred cattle. Approximately 63% of the goat population in the province consists of Turkish Saanen goats, which are known for their high milk yield. 80% of the livestock farms in the province have 5-20 cattle. This situation increases the costs of milk production. Çanakkale province has the organizational capacity and awareness necessary for establishing a cooperative dairy processing facility. While the rate of village-based cooperatives in Türkiye is 37%, this rate is 61% in Çanakkale province. However, despite this rate of cooperation, farmer cooperatives are not effective in the marketing and price formation of agricultural products. Çanakkale has a market opportunity for the establishment of a cooperative dairy factory. The geographical location of Çanakkale is advantageous for both domestic and international marketing of agricultural products. It is located in the Marmara Region, which has the highest population density in Türkiye. Çanakkale is close to three border gates. Therefore, it has easy access to European countries.

3.2. Evaluated parameters

Site selection is one of the decisions in the establishment, expansion, or relocation process of any business. Site selection is critical for the success or failure of the industrial system. One of the main objectives in industrial site selection is to find a suitable location with the desired conditions defined by the selection criteria. Most of the data used by managers and decision makers in industrial site selection is geographical. This means that the industrial location process is a spatial decision (Rikalovic et al., 2014). Four criteria were evaluated in the study. These parameters were determined as MPQ, P, LUCC and PP. Detailed knowledge about the parameters is presented below.

3.2.1 Milk Production Quantity

It is preferred where the amount of raw material is high for factory site selection. The annual milk production amounts in the districts were analyzed. Accordingly, the highest annual milk production amount was realized in Biga (29%), Yenice (26%), and Çan (13%) districts, respectively. 12.562 farmers in the study area produce mainly cow milk, but also sheep and goat milk (Table 2).

The map showing the total quantity of milk produced annually in the districts in the study area is given below (Fig 3).

3.2.2. Population

Within the scope of the study, the population criterion was considered to ensure the labor needs of the dairy factory. The population of the Çanakkale districts is 490,434 (TURKSTAT, 2022). The districts with the highest population are the Merkez and Biga districts (Table 3). The map of the study region's population by district is presented below (Fig. 4).

3.2.3. Land Use Capability Classification

With the increasing population, people have begun to utilize land more extensively for their basic needs. Therefore, agricultural, pasture, and forest lands are continuously degraded (Everest et al., 2021). Consequently, a dairy factory must be established outside of productive agricultural lands. LUCC has eight classes from I to VIII. The first four classes are suitable for producing regionally adapted plants. The last four classes are not suitable for agricultural practices. The number of cultivated plants and the suitability of land characteristics decreased from class I to class VIII. While the lands in classes I and II are suitable for the cultivation of almost all kinds of cultivated plants, the suitability for the cultivation of cultivated plants decreases from class III. Lands in class V are not suitable for agriculture in their current condition. Lands in classes VI, VII, and VIII are not suitable for agriculture due to slope and soil shallowness problems. Lands in class VI should be used for pasture and forest purposes, and lands in class VII should be under forest cover (FAO 1989; Everest et al., 2011). Land resources and their distribution in the study area are given in (Table 4). Land use capability classification of the study area was given in (Table 5).

LUCC presents the suitability of the land for agricultural usage (Everest, 2021). For-non-agricultural practices, especially class VII and VIII lands, should be preferred. These areas are remarkably shallow and sloping, with low productivity compared to other lands. Since this study aims to identify a suitable area for a dairy factory, class VII and VIII lands that are proposed to be used for non-agricultural applications were prioritized. Information on VII and VIII class lands in the study area is presented in (Fig. 5).

3.2.4. Photovoltaic Potential (PP)

Energy consumption is one of the most critical cost elements of an enterprise. The use of fossil resources for energy needs not only increases costs but also increases global warming (Everest, 2021). Solar energy plays an important role in the direct generation of electricity through photovoltaic potential (PP). Solar energy is one of the simplest technologies to design and implement. However, it is still an expensive renewable technology. On the other hand, solar energy is always environmentally friendly and is a non-polluting, low-maintenance energy source (El Chaar and El Zein, 2011). Therefore, it is essential to prefer renewable resources in energy use. In this study, utilizing a clean and environmentally friendly energy source is considered a crucial factor. The approach proposed by the study is to utilize solar energy in the energy use of a dairy factory. The solar energy potential in the study region is presented below (Fig. 6). The photovoltaic potential of the study area was obtained from the website of the General Directorate of Meteorology (General Directorate of Meteorology, 2023).

3.3 Best-Worst Multi Criteria Decision Analysis

In this study, BWM was preferred as a multi-criteria decision-making method. BWM is an MCDM method based on pairwise comparisons, which was introduced to the literature by Rezaei in 2015 (Everest et al., 2024). In this method, the decision maker first determines the best and worst parameters (Table 6). After this step, the other criteria are compared with the criterion determined as the best and worst (Fig.7). According to the literature, five steps should be followed for BWM calculations (Rezaei, 2015).

1. In the first step, a set of decision criteria is formed;

2. In the second step, the best and worst evaluated parameters are determined

3. In the third step, the best criterion is compared with the other criteria $(A_B = (a_{B1}, a_{B2}, \ldots, a_{Bn})\ and\ a_{BB} = 1)$.

4. In the fourth step, the worst criterion is compared with the other criteria $(A_W = (a_{1W}, a_{2W}, \ldots, a_{nW})\ and\ a_{WW} = 1)$.

5. In the fifth step, weight values are obtained.

For each pairwise comparison, the best criterion and others must be satisfied between $(\frac{W_B}{W_j})$ and the worst criterion and others $\frac{W_j}{W_W}$. For this $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_W} - a_{jW}\right|$ must be minimized for all j.

In the methodology, the consistency rate is controlled by the following formula:

$$\text{Consistency ratio (CR)} = \frac{\xi^*}{\text{Consistency index (CI)}}$$

Here ξ^* is the optimal value of the method (Rezaei, 2015; 2016). Consistency ratio values close to 0 indicate more consistency, while values close to 1 indicate less consistency (Rezaei,.2016).

The BWM calculations were performed using Microsoft Excel. Expert opinions were utilized in determining the study's focus and prioritizing evaluation criteria. In this context, the insights of the Provincial Director of Agriculture and Forestry, the President of the Central Union of Agricultural Cooperatives, an academic specialized in agricultural cooperatives, and another expert in land-use planning played a key role in guiding the research.

3.4. Cartographic materials and datasets

Milk production quantity data were obtained from statistical data from the briefing report of the Çanakkale Provincial Directorate of Agriculture. Land use capability classification was obtained from a 1:100,000 scale soil map produced by the General Directorate of Rural Services (KHGM, 1999). Photovoltaic potential data were obtained from long-term average global solar radiation data for Türkiye, provided by the General Directorate of Meteorology. The population data were obtained from the Turkish Statistical Institute.

3.5. Land evaluation by GIS

GIS is an essential tool used in the generation of decision-support models that utilize geographical data. Land suitability mapping, utilizing GIS, plays a crucial role in the planning and management of natural resources (Malczewski, 2006; Romano et al., 2015; Everest et al., 2022). In this study, ArcGIS 10.4 was used for land evaluation. Milk production and population statistics available in Excel were transferred into the GIS. Then, milk production quantities and population are thematically mapped in a vector database in GIS. Land use capability classification data were derived from a 1:100,000 scale digital soil map. The analog photovoltaic potential map was digitized in GIS. The spatial elements on the map were converted to vector data format using a digitization tool. To generate a suitability map, an overlay analysis was conducted using the Model Builder tool in ArcGIS. Weighted values calculated with BWM were transferred to GIS, and overlay analyses were performed.

4. Results

In Çanakkale, dairy cooperatives are limited to milk collection activities and cannot process, package, brand, and market dairy products. These cooperatives sell the milk they collect to national brands. In other words, cooperative milk is not marketed under the cooperative brand, but under local brands. However, the primary task expected of cooperatives is to process the milk collected from their members and sell it to the market under the cooperative brand. With the presented model, only cooperatives will exist between the farmer and the consumer. Thus, the farmer will benefit from the raw milk sales price, and the consumer will benefit from the prices paid for milk and dairy products. According to a study conducted by Everest in Çanakkale in 2009, dairy cooperatives in Çanakkale are not successful in milk marketing (Everest, 2009). Therefore, the dairy cooperatives in Çanakkale province require a milk processing facility. In this study, the BWM MCDM method was employed to determine the weighted values of the evaluated criteria. As a result of the calculations, milk production quantity (46.55%) was the most significant factor, followed by population (25.86%) and land use capability classification (17.24%), which were assessed as the second and third most significant factors, respectively. The lowest weighted value was calculated for the photovoltaic potential (10.35%) criterion (Table 7). The consistency ratio was calculated as 0.0312, and this information allows us to conclude that the values of the consistency ratio are satisfactory.

Figure 8 presents the land suitability map obtained by the BWM calculations. Biga district was determined as the most suitable location for the proposed model for milk processing in Çanakkale.

5. Discussions

Biga has the highest milk production in Çanakkale. Annual milk production is 114058 tons. This accounts for 29% of Çanakkale's yearly total milk production. In addition, Biga district hosts the highest number of dairy farmers in the province, with a total of 3530 registered producers. This represents approximately 28% of the total number of milk producers in Çanakkale. In studies focusing particularly on milk and dairy products, careful planning regarding raw material is essential (Guan and Philpott, 2011; Jachimczyk and Myhan, 2022). Facility location is often determined by proximity to raw materials, depending on the nature of the product (Park et al., 2018). Accordingly, location decisions can be evaluated in terms of supply reliability, as a stable and continuous supply of raw materials is essential for efficient and sustainable production (Maas et al., 2016; Herrera-Cáceres et al., 2017; Park et al., 2018). Due to the nature and characteristics of the product, it is rational to locate the facility in regions with high production density. In this context, the districts of Çan and Yenice are also in close proximity to Biga via road connections. Thus, the selected location lies at the intersection of the areas with the highest levels of milk production. In the literature, the importance of raw materials in facility location decisions has been emphasized in various studies (Yao et al., 2018; Park et al., 2018; Ferro and Bonollo, 2019; Jachimczyk and Myhan, 2022; Akbari et al., 2023). Accordingly, it is deemed appropriate and consistent to assign the highest weight to the milk production quantity within the evaluation framework.

On the other hand, Biga district has the highest population after the central district of Çanakkale. The total population of Biga is 91537. The labor force is a crucial component of the production process. In a small and vulnerable rural economy, the long-term sustainability of the dairy sector largely relies on its human resources (Callister and Tipples, 2010). Labor productivity is a key factor for a company (Naglova et al. 2017). A skilled and adequately supported labor force is the basis of efficiency, product quality, and long-term sustainability in the dairy industry. Human capital has been a topic of significant debate among policymakers and decision-makers. The industry sector considers the importance of human capital for attaining a competitive advantage and sustaining their performance. Additionally, human capital is a valuable, rare, non-substitutable, and non-inimitable resource in the industry (Mubarik et al. 2017). Sharma et al (2010) investigated the factors influencing the location strategy of dairy plants in India. Accordingly, demographic factors, such as population density, employment, and literacy, are important in determining site selection. Similarly, Victers (1977) discussed the factors affecting the selection of a site for the production of high-quality dairy products and emphasized that the labor force is a crucial variable. According to Florida (2002), people have become the most significant resource in today's knowledge-based society. Similarly, Nuhu et al. (2021) evaluated human capital, eco-friendliness, accessibility, and economic conditions in their study, highlighting the importance of human resources in their economic evaluation of industrial site selection.

Due to its topographical and geomorphological characteristics, a significant portion of Çanakkale’s land is classified as marginal land. In this context, there are VI and VII class lands in the Biga district, as in the whole

Çanakkale. The large number of lands, which are limited in agricultural production, pointed to suitable areas for site selection. Furthermore, in determining suitable sites, lands with low agricultural capability were selected to minimize the risk of land degradation. Given the widespread presence of marginal lands in the study area, the process of land selection becomes more manageable. Therefore, it is justifiable to rank this factor as having the third highest importance in the analysis. Locating industrial facilities on land with poor biophysical conditions and low agricultural potential, rather than on fertile and productive farmland, is strongly recommended to ensure the optimal use of natural resources. In line with this, the literature suggests that, in site selection studies for industrial facilities, marginal lands with low agricultural potential should be prioritized for development (Wang and Shi, 2015). Apart from this, it is more appropriate to use marginal lands for non-agricultural activities. Especially according to LUCC, VI and VII class lands are more suitable for non-agricultural activities due to their limitations, such as slope, depth, and stoniness. Zucca et al. (2008) reported that agricultural areas should be protected in site selection studies.

The lowest weighted value was assigned for the photovoltaic potential in the study (Table 7). Biga district has a lower photovoltaic potential compared to the southern and western districts bordering the Aegean Sea (Figure 6). Due to this anticipated condition, the lowest weight was assigned to this parameter. However, aligning our study with the United Nations Sustainable Development Goal of "Affordable and Clean Energy" was among our primary objectives. Therefore, despite Biga's relatively lower potential, its photovoltaic capacity was still evaluated within this framework. Nuhu et al. (2021) noted that most researchers did not consider renewable energy sources in site selection studies, which they considered a critical deficiency. Solar energy is commonly emphasized in the literature, particularly in studies related to the site selection of energy facilities (Çolak et al., 2020; Jahangiri et al., 2016; Al Garni and Awasthi, 2017; Merrouni et al., 2018). One of the differences of this study is that renewable energy was also taken into consideration for dairy plant site selection.

While evaluating all selected parameters, the strategic roadmap of Çanakkale was also taken into consideration, and assessments regarding transportation opportunities were conducted. By interpreting this map, it is evident that milk produced in the Çan and Yenice districts, where milk production is high, can be transported via the nearest existing highways from the shortest distance. This situation was also taken into consideration during the evaluation. Furthermore, the fact that most small, medium, and large-scale industrial facilities in Çanakkale Province are in the Biga district lends support to our study.

Land-use planning studies are a necessary tool for enhancing the sustainability of agricultural development, balancing economic competitiveness, social equity, and environmental health (Barral and Oscar, 2012). Therefore, the environmental and social impacts of planning efforts, particularly before the implementation of large-scale projects, should be thoroughly assessed. This study has the potential to serve as a guide for more effective cooperative planning and for promoting social development. If any projects are to be developed based on the guidance of this study, a comprehensive environmental impact assessment of the region must be conducted. In this context, land use types, sensitive and protected areas, groundwater potential, biodiversity, flora and fauna, and other ecosystem services should be examined in detail and aligned with the planning framework proposed in this study.

This model could shape the investment decisions of the Ministry of Agriculture and Forestry and development agencies on how to incorporate planning for agricultural organizations and dairy processing. The reason for this is that the present study represents the first comprehensive planning effort in the region to compile diverse and detailed data addressing the processing needs of non-organized dairy enterprises and integrate these findings with expert opinions. Because all dairy cooperatives, milk production quantities, and population data in Çanakkale were thematically mapped using GIS. Additionally, land resources were evaluated in detail, and recommendations for clean energy sources were provided to develop a model that aims to reduce carbon emissions. Moreover, during the evaluation process, the parameters were prioritized through expert opinions using the Best-Worst Method (BWM), a recognized and reliable multi-criteria decision-making technique.

In this context, regarding the site selection for dairy cooperatives, it is recommended that cooperatives and policymakers establish a cooperative dairy processing facility in the Biga district. This recommendation is expected to result in the most effective site selection and contribute to local development. The selection of Biga as the most suitable location is also highly valuable due to its developed transportation infrastructure, the presence of other industrial facilities, and its proximity to Istanbul via the Çanakkale bridge. Moreover, the findings of this study align well with actual, on-the-ground data, further validating the results (Figure 9).

5. Conclusions

This study enables the selection of a suitable site for a dairy factory based on milk production quantity, population, land use capability class, and photovoltaic potential. The criteria's weighted coefficients were determined with (BWM) MCDM, which was recently added to the literature. As a result, the Biga district of

Çanakkale was defined as the best location for cooperatives to establish a dairy plant. This study's most significant contribution to the literature is its ability to offer a different perspective on dysfunctional cooperatives. The potential application of the BWM in determining suitable sites is presented in this study. BWM was also found to be more practical, as fewer comparisons were used in the calculation processes. It is recommended that the BWM, with its feasibility and practical value, be used in planning studies. This is considered a second output of the study. This model can be effectively utilized by policymakers, especially in developing countries, to restructure cooperative development strategies. The model produced in this study is a guide for producers, cooperative managers, decision-makers, farmers, policymakers, other institutions, and organizations supporting the agricultural sector for more effective use of co-operatives in similar geographies and areas with similar human characteristics. Suggesting suitable sites for the establishment of factories can provide decision-makers with sustainable conditions for selecting the final option, thereby avoiding the degradation associated with the improper establishment of these facilities. This study presents a model that is aligned with several Sustainable Development Goals, specifically 1 – No poverty, 2 – Zero hunger, 7 – Affordable and clean energy, 8 – Decent work and economic growth, 9 – Industry, innovation and infrastructure, 11 – Sustainable cities and communities, 12 – Responsible consumption and production, 13 – Climate action, and 15 – Life on land, highlighting its potential to contribute to both rural development and environmental sustainability. The limitation of the study was the availability of data. Detailed statistics on cooperatives are not available, so further details were not provided in the study. In future planned studies, different studies may be added to the literature using different MCDMs (AHP, FUCOM, and FUZZY systems, etc.).

Abbreviations

Milk production quantity (MPQ)

Best Worst Method (BWM)

Multi-criteria decision-making method (MCDM)

Land use capability classification (LUCC)

Geographical Information System (GIS)

Organization for Economic Cooperation and Development (OECD)

Food and Agriculture Organization (FAO)

Population (P)

Photovoltaic Potential (PP)

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FIGURES

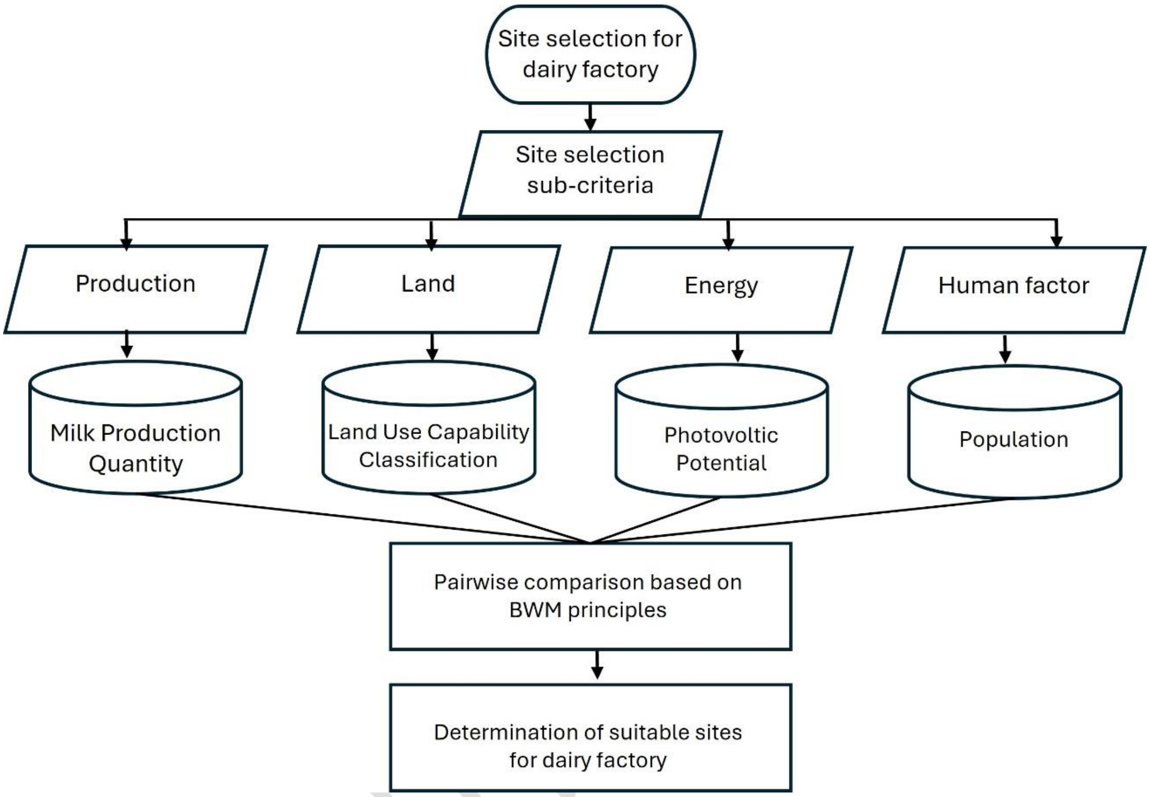

Fig. 1 Flow diagram of the study

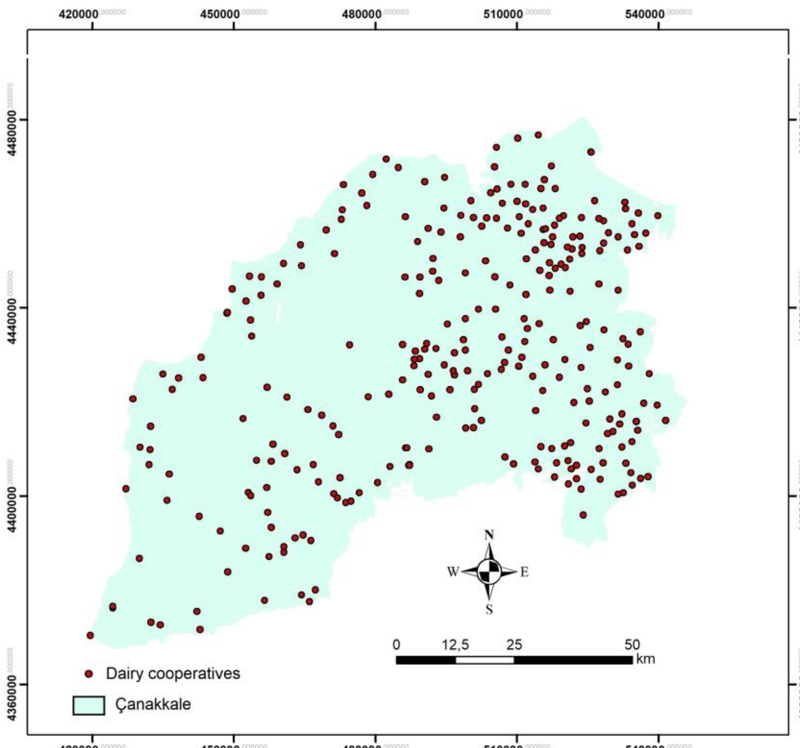

Fig 2. Map of Dairy Cooperatives in the Study Area

Source: Ministry of Agriculture and Forestry (2023)

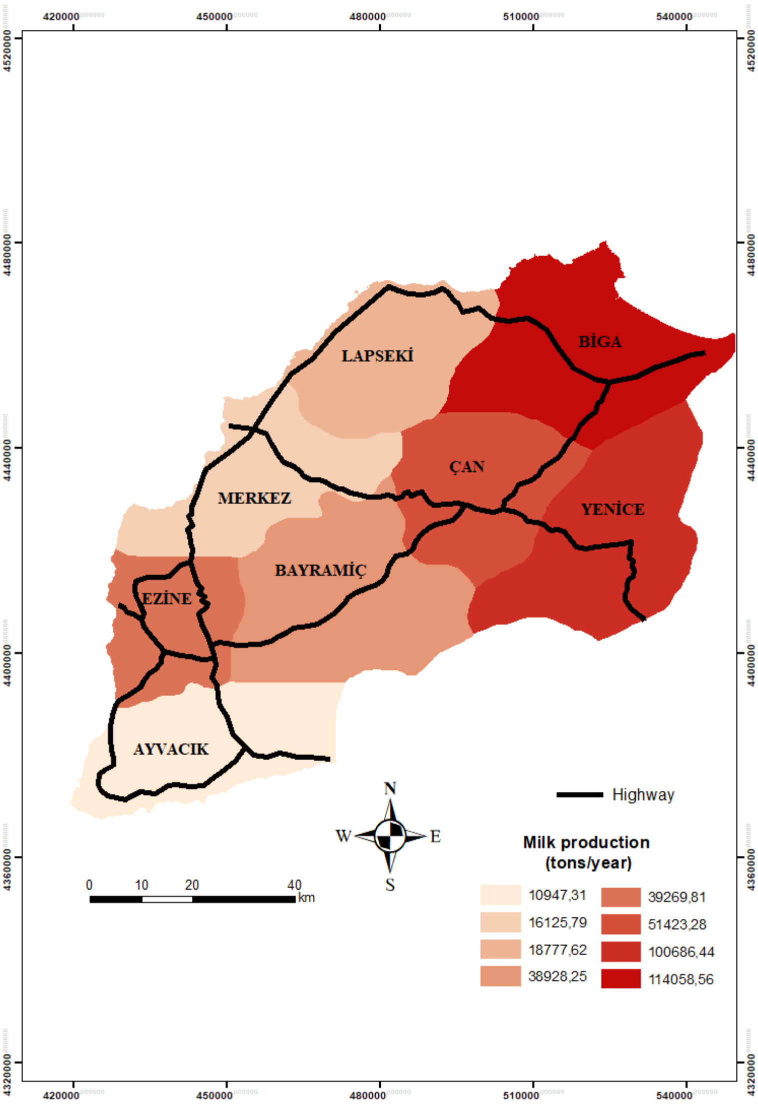

Fig. 3. Milk Production Quantity Map of the Study Area

Source: Ministry of Agriculture and Forestry (2023)

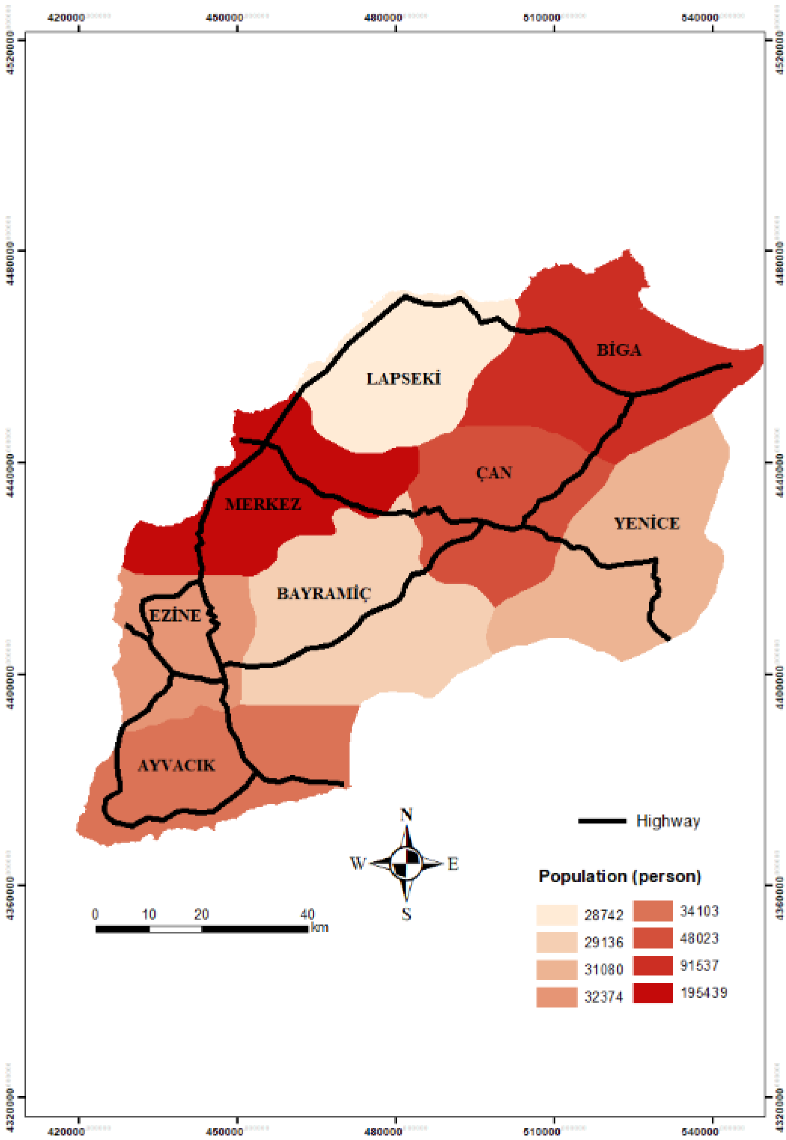

Fig 4. Population Map

Source: TURKSTAT (2022)

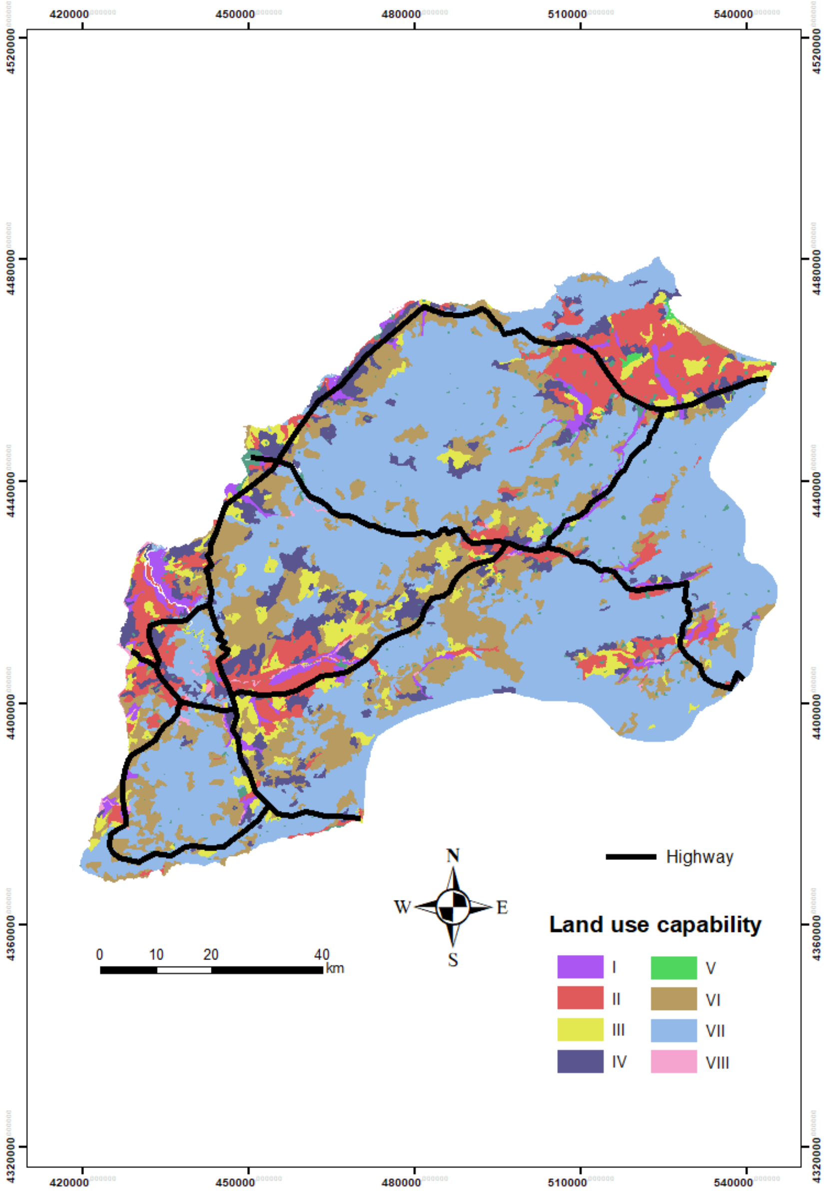

Fig. 5. LUCC in the study area

Source: KHGM (1999)

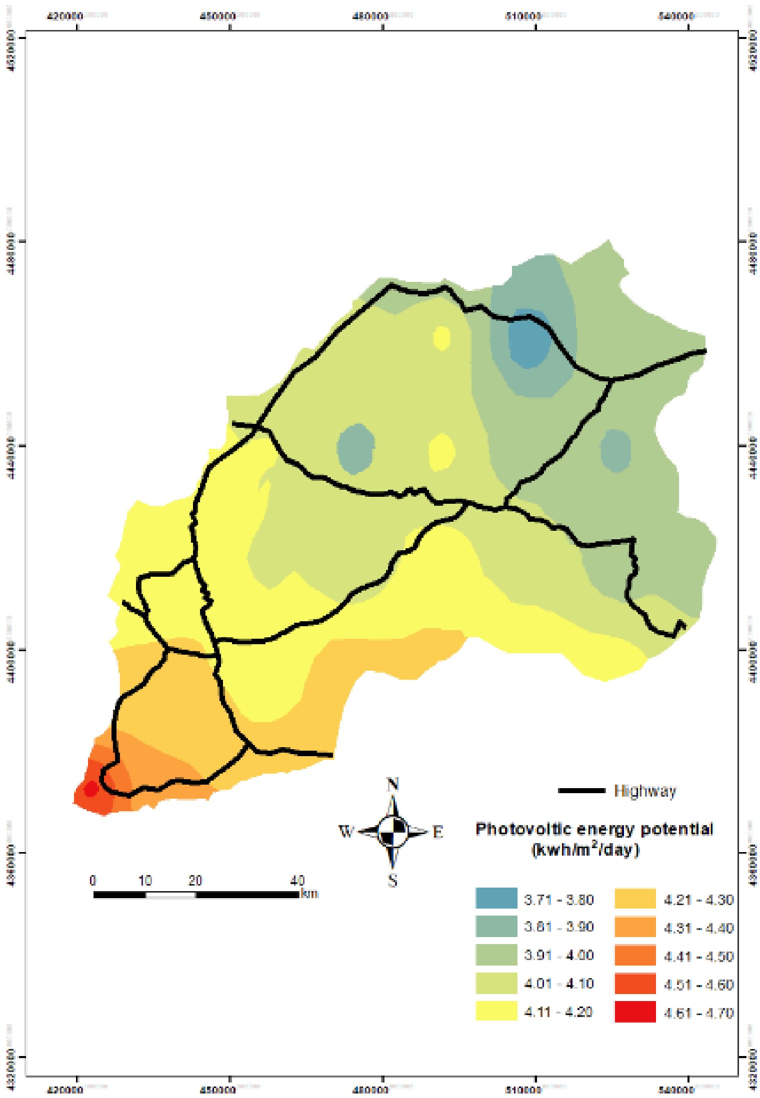

Fig. 6. Photovoltaic Potential of the Study Area

Source: General Directorate of Meteorology (2023)

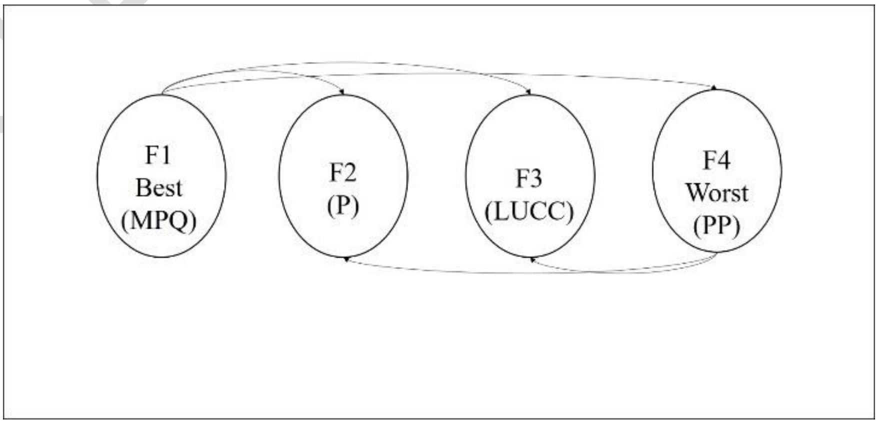

Fig. 7. Pairwise comparisons according to BWM

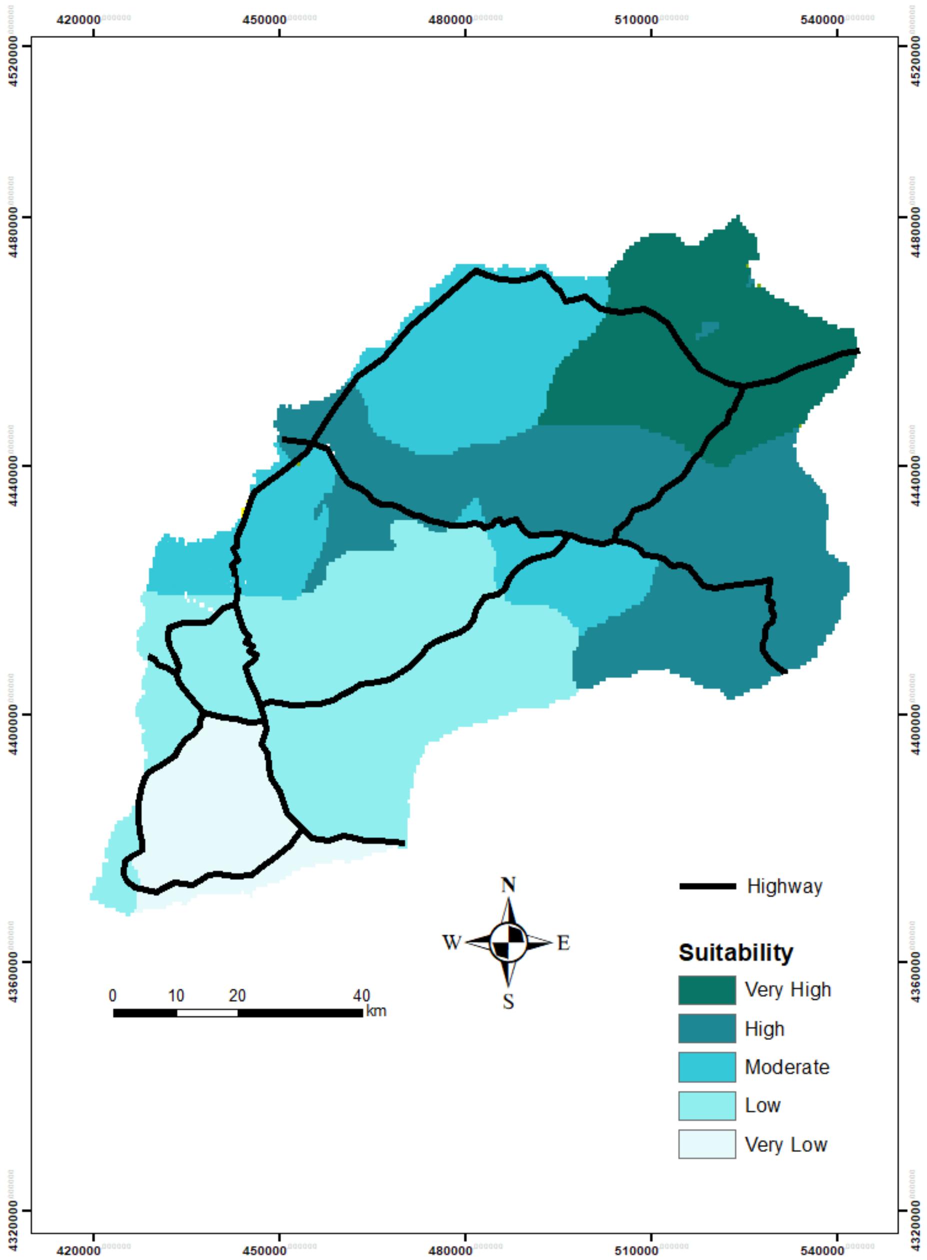

Fig 8. Final suitability map

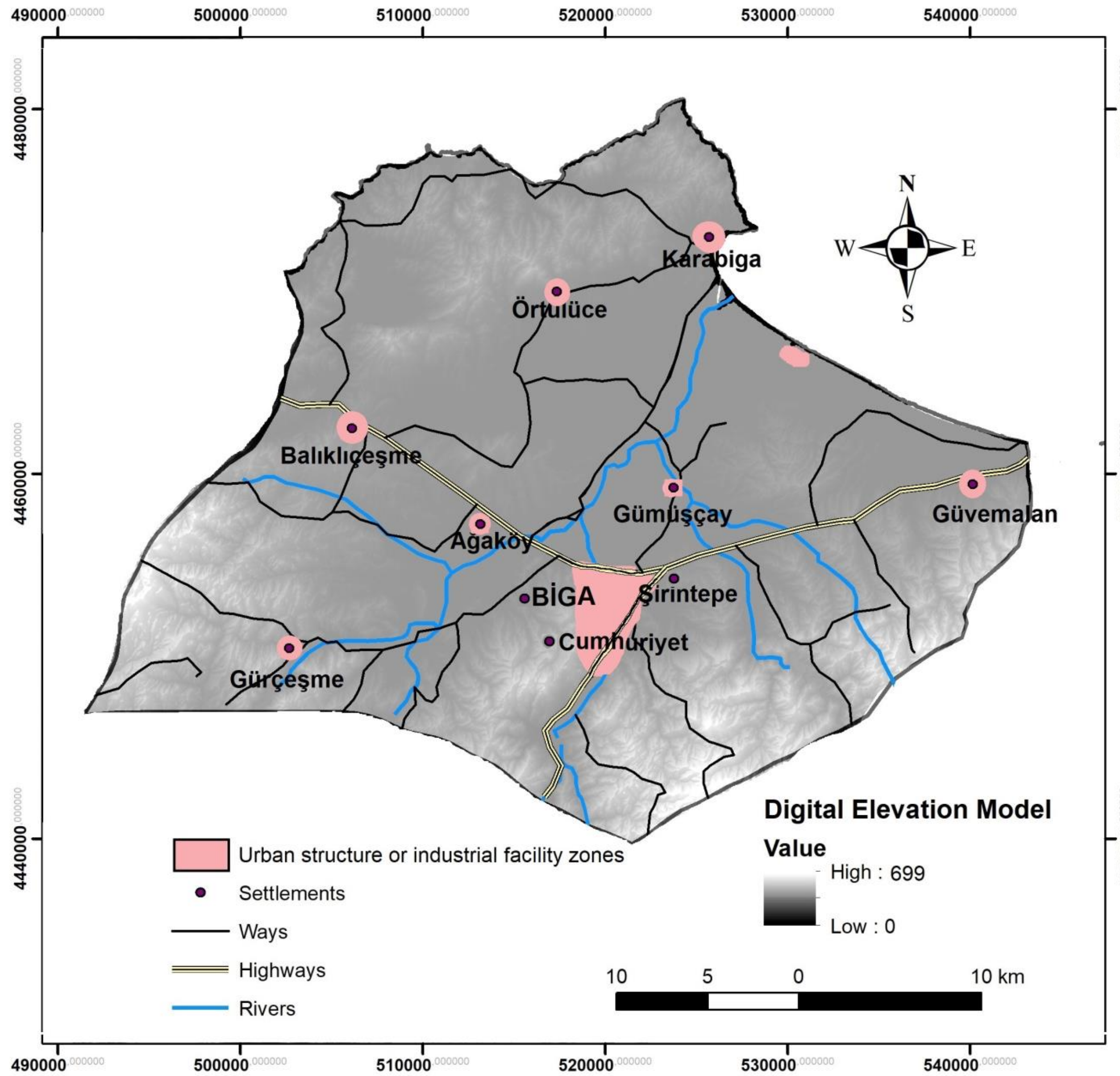

Figure 9. Infrastructure map of Biga

TABLES

Table 1. Descriptions of factor categories related to cooperative milk factory site selection criteria

Criteria	Criteria Description	References
Milk Production Quantity (MPQ)	This criterion pertains to the quantity of raw materials necessary for the factory.	Akbari et al. 2023; Victers, 1977; Yao et al. 2018
Land Use Capability Classification (LUCC)	Marginal lands with too many limiting factors for agricultural production should be preferred for non-agricultural activities.	Everest et. al. 2021; FAO, 1989; Zucca et al. 2008
Population (P)	This criterion pertains to the labor force needed by the factory.	Florida, 2002; Sharma et al., 2010, Victers, 1977
Photovoltaic Potential (PP)	This criterion pertains to the factory's ability to operate using renewable energy.	Al Garni and Awasthi, 2017; Çolak et al. 2020, Jahangiri et al. 2016; Merrouni et al. 2018; Nuhu et al. 2021

Table 2. Milk Production Amount in the Study Area (Tons/year), Ministry of Agriculture and Forestry (2023)

Districts	Number of Farmers	Cow Milk Quantity	Sheep Milk Quantity	Goat Milk Quantity	Total Milk Quantity	Ratio of Total Milk Quantity by Districts (%)
Ayvacık	746	8.795	829	1.325	10.948	3
Bayramiç	1.367	30.938	1.415	6.574	38.927	10
Biga	3.530	113.150	69	840	114.058	29
Çan	1.715	50.039	334	1.050	51.423	13
Ezine	902	34.188	1.865	3.219	39.271	10
Lapseki	795	17.045	226	1.506	18.777	5
Merkez	481	12.330	292	3.503	16.125	4
Yenice	3.026	100.353	170	165	100.687	26
Total	12.562	366.838	5.198	18.180	390.215	100

Table 3. Study Area Population, TURKSTAT (2022)

Districts	Total Population
Merkez	195.439
Ayvacık	34.103
Bayramiç	29.136
Biga	91.537
Çan	48.023
Ezine	32.374
Lapseki	28.742
Yenice	31.080
Total	490.434

Table 4. Land Resources and Distribution of the Study Area (ha), KHGM (1999)

District	Area (ha)	Ratio (%)	Cultivated Land		Forest Land		Meadow and Pastureland		Other Land (Settlement etc.)	
			Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)	Area (ha)	Ratio (%)
Merkez	92.900	11,16	24.551	9,16	62.159	14,29	662	3,17	5.528	5,08
Ayvacık	89.384	10,73	33.256	12,41	33.299	7,65	8.246	39,46	14.584	13,40
Bayramiç	129.122	15,50	31.780	11,86	63.100	14,50	529	2,53	33.713	30,97
Biga	137.601	16,52	60.422	22,55	51.935	11,94	8.932	42,74	16.312	14,98
Çan	91.082	10,94	26.572	9,92	47.580	10,94	604	2,89	16.326	15,00
Ezine	71.185	8,55	26.894	10,04	28.672	6,59	1.578	7,55	14.040	12,90
Lapseki	89.105	10,70	36.190	13,51	49.130	11,29	154	0,74	3.631	3,34
Yenice	132.415	15,90	28.303	10,56	99.192	22,80	194	0,93	4.727	4,34
Total	832.794	100,00	267.968	100,00	435.067	100,00	20.899	100,00	108.861	100,00

ha: hectare

Table 5. Land Use Capability Classes of the Study Area, KHGM (1999)

Class	Area (ha)	Ratio (%)
I	39.164	4,02
II	107.006	10,99
III	63.976	6,57
IV	78.687	8,08
V	818	0,09
VI	190.318	19,55
VII	483.582	49,66
VIII	10.139	1,04
Total	973.690	100,00

Table 6. Binary comparisons based on BWM

Best to others	Milk Production Quantity	Population	LUCC	Photovoltaic Potential
Milk Production Quantity	1	2	3	4

Others to worst	Photovoltaic
Milk Production Quantity	4
Population	3
LUCC	2
Photovoltaic Potential	1

BWM: The Best Worst Method, LUCC: Land Use Capability Classification

Table 7. Weighted values based on BWM

Criteria (n=9)	Criteria	Weight (%)
Cr 1*	***Milk Production Quantity***	46.55
Cr 2	Population	25.86
Cr 3	LUCC	17.24
Cr 4**	***Photovoltaic Potential***	10.35

**** Best criterion, ** worst criterion***

n = 4, CI (consistency index) = 1.63, ξ = 0.051, CR (consistency ratio) = 0.0312

BWM: The Best Worst Method, LUCC: Land Use Capability Classification, Cr: Criterion