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Projecting Agricultural Land Abandonment and Expansion in Turkiye Using the Subspace KNN Algorithm (2030)

Türkiye'de Tarımsal Arazilerin Terk Edilmesi ve Genişlemesinin Subspace KNN Algoritmasıyla Projeksiyonu (2030)

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ABSTRACT
One of the most important changes in agricultural land worldwide is the problem of land abandonment in underdeveloped and developing countries and in regions with low resilience to climate change. This problem is also an ongoing debate in Turkiye. This study first evaluates the process of abandonment and expansion of agricultural land in Turkiye based on the literature before presenting maps of the probability of abandonment and recovery of agricultural land. In this context, the abandonment and expansion of agricultural land due to changes in Coordination of Information on the Environment (CORINE) data for 2006-2018 are used as the dependent variables. Probability maps were constructed using the subspace KNN model with 13 independent variables. The immediate surroundings of cities are seen to come first as the places with a high probability of abandonment. For rural areas, this appears as the areas close to roads and places with forced natural environmental conditions. A very low recovery situation has emerged in terms of places that can be reclaimed. The areas that stand out among these are where hazelnut and tea plantations have expanded in the Black Sea region, as well as the areas with relatively favorable topography in the interior of the Western and Central Taurus Mountains in the Mediterranean region.
Keywords: Abandonment of agricultural land, Expansion of agricultural land, Subspace KNN, projection, Turkiye

ÖZ
Küresel çapta tarım arazilerinde gözlemlenen önemli değişikliklerden biri, az gelişmiş ve gelişmekte olan ülkelerde ve iklim değişikliğine karşı dirençliliğin düşük olduğu bölgelerde görülen, tarımsal arazilerin terk edilmesi problemidir. Bu problem Türkiye genelinde de tartışmaların devam ettiği bir süreci yaşamaktadır. Çalışmada ilk olarak Türkiye'de tarım arazilerinin terk edilmesi ve genişlemesi süreci literatüre dayalı olarak değerlendirilmekte; ikinci olarak tarımsal arazilerde terk edilme ve geri kazanma olasılığına yönelik haritalar sunulmaktadır. Bu kapsamda CORINE verilerindeki (2006-2018) değişikliğe bağlı olarak terk edilen ve genişleyen tarımsal araziler bağımlı değişken olarak kullanılmıştır. Subspace KNN modeli ile 13 bağımsız değişken kullanılarak olasılık haritaları oluşturulmuştur. Terk edilme olasılığı yüksek yerler arasında öncelikle kentlerin yakın çevresi görülmektedir. Kırsal alanlarda ise yollara yakın alanlar ile doğal ortam koşullarının zorladığı yerler belirmektedir. Yeniden kullanılabilecek yerler açısından ise oldukça düşük bir geri kazanma durumu ortaya çıkmıştır. Bu yerler arasında, Karadeniz Bölgesinde fındık ve çay arazilerinin genişlediği alanlar ile Akdeniz Bölgesinde, Batı ve Orta Torosların iç kesimlerindeki topografyanın nispeten elverişli olduğu alanlar dikkati çekmektedir.
Anahtar kelimeler: Terk Edilmiş Tarımsal Araziler, Tarım arazilerinin genişlemesi, Subspace KNN, Projeksiyon, Türkiye

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INTRODUCTION

Agriculture has been one of the most significant changes in human history. Various fields have developed as a result of the cultivation of plants and raising of animals. The agriculture sector remains the most critical economic activity, within which significant transformations have occurred since the Industrial Revolution. Rural areas play a crucial role in utilizing and preserving agricultural potential when viewed from a sustainability perspective (Food and Agriculture Organization 2006, p. 12).

Rural areas are also being reshaped and transformed in terms of demographics, economics, and society with the widespread acceleration of urbanization around the world (Dahms 1995; Montgomery et al. 2013). The most prominent effect of this transformation on rural areas is the gradual loss of their vitality accompanied by a decrease in population (Hart et al. 1968; Dahms 1995; Peters et al. 2018). Recently, the abandonment of agricultural land in rural areas has become one of the most significant trends in land-use change and one of the main indicators of rural decline (Benayas et al. 2007; Díaz et al. 2011; Güreşci 2014; Canpolat and Hayli 2018; Tao et al. 2021).

Agricultural land is the most important element defining rural areas and rurality. The abandonment of this type of economic activity identified with rural areas actually indicates a loss of rurality. Abandoned land as a term refers to land that had previously been used for agricultural activities but now human intervention and use has ceased for various reasons (Bielsa et al. 2005). The abandonment of agricultural land has led to many negative effects such as disappearing villages, abandoned settlements, declining rural economic benefits, and the inability to preserve cultural landscapes and heritage. However, these areas are also the most important resources for rural renewal and revitalization. By using these unused agricultural areas, the functions of rural areas can be recovered through support and regulation. In this way, rural landscapes can be transformed and rural economies revitalized (McManus et al. 2012; Naldi et al. 2015; Zhou et al. 2020b).

Research on agricultural land expansion is less common and has focused mainly on studying forest loss-related degradation (Ngoma et al. 2021), land rehabilitation (Shabanov 2009), land use changes and their influencing factors (Wang et al. 2022), and the relationships among climate change, water resources, and land expansion (Liu et al. 2021).

The abandonment of agricultural land is widespread throughout the world both in developed and developing countries and requires more attention due to agricultural land abandonment being closely related to food security and ecological security (Du et al. 2019). Research on the abandonment of agricultural lands is increasingly being conducted on a global scale (Huang et al. 2020), with studies on idle agricultural lands having examined and evaluated the problem from many angles. In fact, bibliometric and synthesis studies are found to have covered research on the subject (Huang et al. 2020; Qianru and Hualin 2021), focusing on the processes that contribute to the abandonment of agricultural land (Prishchepov et al. 2013; Levers et al. 2018; Zhou et al. 2020a), the impacts and consequences of the problem (MacDonald et al. 2000; Benayas et al. 2007; Filho et al. 2017; Deng et al. 2020), policies for solutions (Renwick et al. 2013; Deng et al. 2020), and the mapping of abandoned agricultural land (Yin et al. 2018; Levers et al. 2018).

Since the 19th century, a gradual decline has been occurring for agricultural land in Europe, which has seen one of the most significant land-use changes, especially in mountainous and semi-arid areas (Lasanta et al. 2017, p. 810). This decline is often attributed to the modernization and intensification of agriculture, which allows for increased agricultural productivity while reducing the amount of land and labor devoted to farming (Hatna and Bakker 2011, p. 720). Another study has attributed the continuing loss of agricultural assets leading to land abandonment to a lack of continuity, either due to a lack of direct descendants in families or to inheritance-related issues (Bernués et al. 2005; Bryden and Bruce 1995; Riedel et al. 2007). Garcia-Martínez et al. (2008) found the number of agricultural holdings in the Central Pyrenees of Spain to have fallen by 30% between 1990-2004. Of these farms, 40% ceased to exist due to the owner retiring and 56.6% due to the cessation of livestock farming. In addition, 42% of the farms remaining in 2004 had no guarantee of continuity because their children or grandchildren preferred to work in the industrial or service sector rather than to continue farming (Azima and Ismail 2011). However, the abandonment of agricultural land is a much more complex phenomenon. Indeed, different studies on the subject have shown the causes of the phenomenon to arise from the interaction of numerous variables related to social, demographic, economic, legal, administrative, and physical environmental characteristics (**Figure 1**).

A study conducted by the European Union (EU) on the abandonment of agricultural land highlighted three possible scenarios for the continent (Andronic et al. 2020). The first is that climate change will lead to an increase in disasters and the

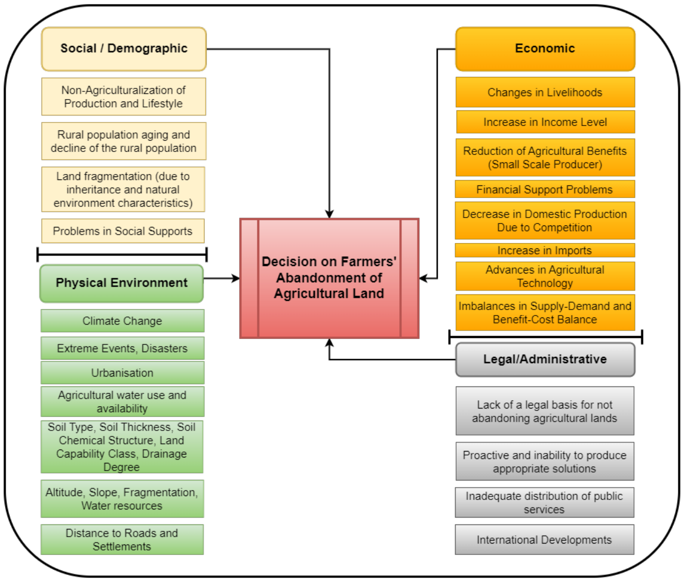

Figure 1: Factors influencing farmers' decisions to abandon agricultural land.

abandonment of agricultural land in mountainous and coastal areas due to changes in sea levels. The scenario regarding the globalization of markets predicts that small- and medium-sized enterprises will not be able to compete, leading to the abandonment of agricultural land in remote regions. Finally, the scenario of a major health crisis expressed before the outbreak of the pandemic that a migration would occur from urban centers to rural areas that would lead to an increase in the value of agricultural land and that land abandonment would no longer be a problem. These three potential scenarios can be observed to be intertwined synthetically for Türkiye. On the one hand, pandemics and disasters (especially earthquakes, apart from climate change) are shifting the population to rural areas and agricultural land is being reclaimed; on the other hand, agricultural land is being left to fallow in different regions due to small-scale producers' yield, credit, and market conditions.

In decreasing order of importance, the negative impacts of idle agricultural land are loss of biodiversity, increased frequency and intensity of fires, soil erosion and desertification, loss of cultural and/or aesthetic values, reduced landscape diversity, and reduced water supply (Benayas et al. 2007). Abandoned agricultural land is generally converted to sparse vegetation, tall grasses, shrubs, or forest ecosystems, depending on climate and soil conditions (Alcantara et al. 2012, p. 335). In Türkiye, however, a significant portion of such land is concentrated on the periphery of settlements and is therefore converted into functional land use areas for construction or settlement.

Türkiye has made announcements in recent years about the sanctions and support the government will apply to abandoned farmlands. This is because the trend in production value has increased the concerns about food security, both in terms of exports and for meeting needs internally. The decline in the rural population and the consequent reduction in the number of people working in agriculture may even bring radical regulations to the agenda as a solution to the problem. According to the Ministry of Agriculture and Forestry, Türkiye has about 3 million hectares of unused agricultural land. However, no qualified classification statistics are found on how much of this land is fallow, state land, or truly unused land.

Before the Tanzimat Decree of 1839, farmers who had left their land uncultivated (i.e., did not produce anything) were subject to a double tax called the *çift bozan*, and a farmer who left their land uncultivated for three years would have it taken away. This was the government's way of controlling production and ensuring continuity. The Land Law of 1858 divided the country's land into five parts and introduced the principle of individual ownership. The aim was to distribute the land to peasants through small farms. A farmer could use the land as they wished, grow any crop they wanted, rent it out, or sell it to anyone (Sumaytaoğlu 2012). As a result, the pressure on landowners to use their property rights was greatly reduced.

Currently, the preservation, development, classification, determination of minimum agricultural land sizes, and prevention of the division of agricultural lands, as well as the determination of principles and procedures for the planned use of agricultural lands, are regulated by the Law No. 5403 on the Protection of Agricultural Lands and the Utilization of Land. This law has no concrete provision regarding the abandonment or disuse of agricultural lands, which can be evaluated as a result of the global axiom (Pejovich 1990) that people cannot be pressured on how they use their property. However, in terms of today's changing conditions, re-evaluating this axiom has become mandatory, because in the post-capitalist society, value is created through the productivity and innovation of knowledge workers. Therefore, the correct, efficient, and sustainable use of property is more important than ever (Drucker 1993). The establishment of a legal framework to ensure the continuity of agricultural activities through legislation should therefore be reconsidered both as a means of encouraging and ensuring accountability.

DATA AND METHOD

Similar to other regions of the world, rural areas in Türkiye are undergoing a problematic metamorphosis demographic and structural changes. This article focuses on the geographical analysis of the status of vacant land and the reuse of agricultural land for the sustainability and permanence of agricultural function, which is a characteristic feature of rural areas.

Figure 2: Map of the study area.

Türkiye is a country at the crossroads of Europe and Asia between Southeast Europe and West Asia. It is surrounded by the Black Sea to the north, the Aegean Sea to the west, the Mediterranean Sea to the south and the Southeast Anatolian region to the east. Türkiye is located in the eastern part of the European continent, and the western part of the Asian continent and the Middle East. Türkiye has a total area of 783,356 square kilometers and average altitude of 1,141 meters. The Anatolian Peninsula has a rugged terrain due to the Pontic, Taurus, and other mountain ranges in the Alpine-Himalayan belt, with depressions and plateaus forming the main plains in this rugged topography (**Figure 2**).

Türkiye has 77.9 million hectares of land, of which 23.20 million are cultivated agricultural land (Kurugöllü and Ünel 2021). According to the results of the General Agricultural Census (Topçu 2012), the amount of unused land suitable for agriculture was identified as 4.995 million hectares in 1980, 2.161 million hectares in 1991, and 1.898 million hectares in 2001. Of the cultivated agricultural land, 31.36% is irrigable and 68.64% is non-irrigable (Turkish Statistical Institute 2016). Furthermore, between 2001-2018, the total agricultural area had decreased by 8% from 40.97 million hectares in 2001 to 37.82 million hectares in 2018. This decrease is larger than the area of 87 countries in the world. In addition, the production area for grains and other crops (cultivated and fallow land) had decreased by 17%, while the area for growing vegetables had decreased by 13.75%. The reasons for this include the land having fragmented, scattered, small, shared, and/or sloping structures (Kurugöllü and Ünel 2021).

Abandoned agricultural land has been classified into three categories: idle land (never used), semi-idle land (used very infrequently), and compulsory idle land (not used due to land reform or restructuring;(Keenleyside and Tucker 2010). No accurate monitoring methods are currently found for active, fallow, and abandoned agricultural land (Estel et al. 2015, p. 313). Therefore, data generated on the basis of land use change can be used as a data source to identify abandoned and newly utilized land. This study uses Coordination of Information on the Environment (CORINE) data (European Union 2018) to identify land use changes across the country. Although these data were first produced in 1990, the data for Türkiye cannot be said to have been produced accurately until 2006. Therefore, the dependent variables (abandoned land and expanding land) for land change scenarios were created based on the changes between 2006-2018. However, this short period has also shortened the projection time and eliminated the possibility of detecting changes over longer periods.

The study groups the CORINE land use/cover categories into three categories: arable land, non-arable land, and other land use types. The non-arable land category represents landcover types that emerge after abandonment (e.g., natural grassland, scrub, and wetlands). Conversions from arable to non-arable land between 2006-2018 were used to represent abandonment cases, while conversions from non-arable to arable land between 2006-2018 (i.e., arable land expansion cases) were used to represent gains. A total of 305,334 pixels were used for abandoned agricultural land and 310,491 pixels for gained agricultural land, of which 50% were randomly sampled. The results of both models were applied to 12,531,446 pixels nationally, and an attempt was made to model the land that would be abandoned and expanded by 2030. The study aims to use the obtained results as follows:

- To determine the process of agricultural land change based on CORINE data between 2006-2018,
- To identify the factors influencing the abandonment and recultivation of agricultural land,
- To evaluate the potential agricultural land use change based on the land change scenario.

The abandonment of agricultural land in Europe has occurred mainly in warm regions with high population density and accessibility (close to roads and/or cities). In eastern and southern Europe, farmland abandonment has been more common in areas with shallow soils, low water retention capacity, and/or relatively rocky and hilly terrain, while in western Europe it has occurred mainly on sloping or shallow soils. In Southern Europe, agricultural land abandonment has been more common in arid regions. In terms of expansion, it occurred in Western Europe in accessible areas near cities with high water retention capacity, while it occurred in Eastern Europe in rainy areas and near cities. In Southern Europe, it occurred mostly in dry areas close to roads but away from cities (Hatna and Bakker 2011, p. 725). In Türkiye, similar factors have affected the abandonment of agricultural land, so models have been developed using other parameters that may be suitable and effective for this observation.

Spatial Variables

Thirteen independent spatial variables were used in the models, which were created at a resolution of 250 meters, with resampling ensured by overlapping pixels (**Figure 3**). Real data, normalized data (min/max), and standardized data (deviation from mean) were used separately to build the models. Although no significant difference was found among them, the study has preferred the standardized data because these are commonly used when dealing with data in different units. Therefore, the models were built using standardized data. The subspace KNN algorithm, a type of ensemble learning model, was used to predict abandoned (lost) and reclaimed lands. The variables used in the models were selected and prepared under the following headings.

Elevation

Due to the significant global problem of abandonment of agricultural land being based on natural environmental conditions, studies have occurred on the management and development of unused agricultural land resources (Azima and Ismail 2011). Resultantly, variables indicative of natural environmental conditions are primarily used in relation to the probability of abandonment. The first of these variables is elevation, and data on this were obtained from the Shuttle Radar Topography Mission (SRTM) digital elevation model. Elevation is one of the most important variables due to its effects on soil depth, soil integrity, erosion, access, and climate in agricultural areas. The current physiography of Türkiye has a structure where elevation changes significantly over short distances. Therefore, both ruggedness and elevation changes are important variables that directly affect agricultural land.

Slope

This is an important factor that directly affects the productivity and integrity of the land, as well as its accessibility and cultivability. The compactness of the land, which determines the size of the plots and hence the yield, depends on the slope and terrain (Rehman et al. 2015). Similarly, slope is one of the factors with a high contribution to the model as it affects drainage, soil depth, and suitability for the use of agricultural machinery and transport.

Topographic Roughness Index (TPI)

The abandonment of agricultural land has been a widespread trend in rural mountain areas around the world since the 1940s. Technological development and the commercialization of agriculture as a result of industrialization and urbanization in accessible lowland areas have motivated many mountain farmers to migrate temporarily or permanently (Khanal and Watanabe 2006). Difficulties in working areas with agricultural machinery are one of the main agroecological factors for abandonment, as manual techniques make products uncompetitive in a free market economy. Therefore, steep slopes, small plots, and areas with poor accessibility are no longer cultivated. Many terraced slope areas in the Mediterranean mountains have been abandoned due to poor conditions for mechanization rather than due to soil fertility (Lasanta et al. 2017, p. 818). TPI actually complements the slope parameter (Gallant and Wilson 2000) and is calculated by comparing the height of each pixel with its neighbors. Elevation, slope, aspect, and curvature are combined to determine how the topography as a whole has changed, as well as the effect this change has on land abandonment using a numerical elevation model and the SAGAGIS software.

Topographic Wetness Index (TWI)

TWI describes the tendency of a cell to accumulate water using digital elevation models. The basic variables used in the index are catchment area and slope (Mattivi et al. 2019). One of the most important variables in the use or abandonment of agricultural land is water demand. TWI is actually the primary variable used to determine this requirement, which indicates the size of surface runoff and water collection basins. This index can also be used to determine the current water potential of agricultural areas and their proximity to potential water sources. The index was developed using the SAGAGIS software.

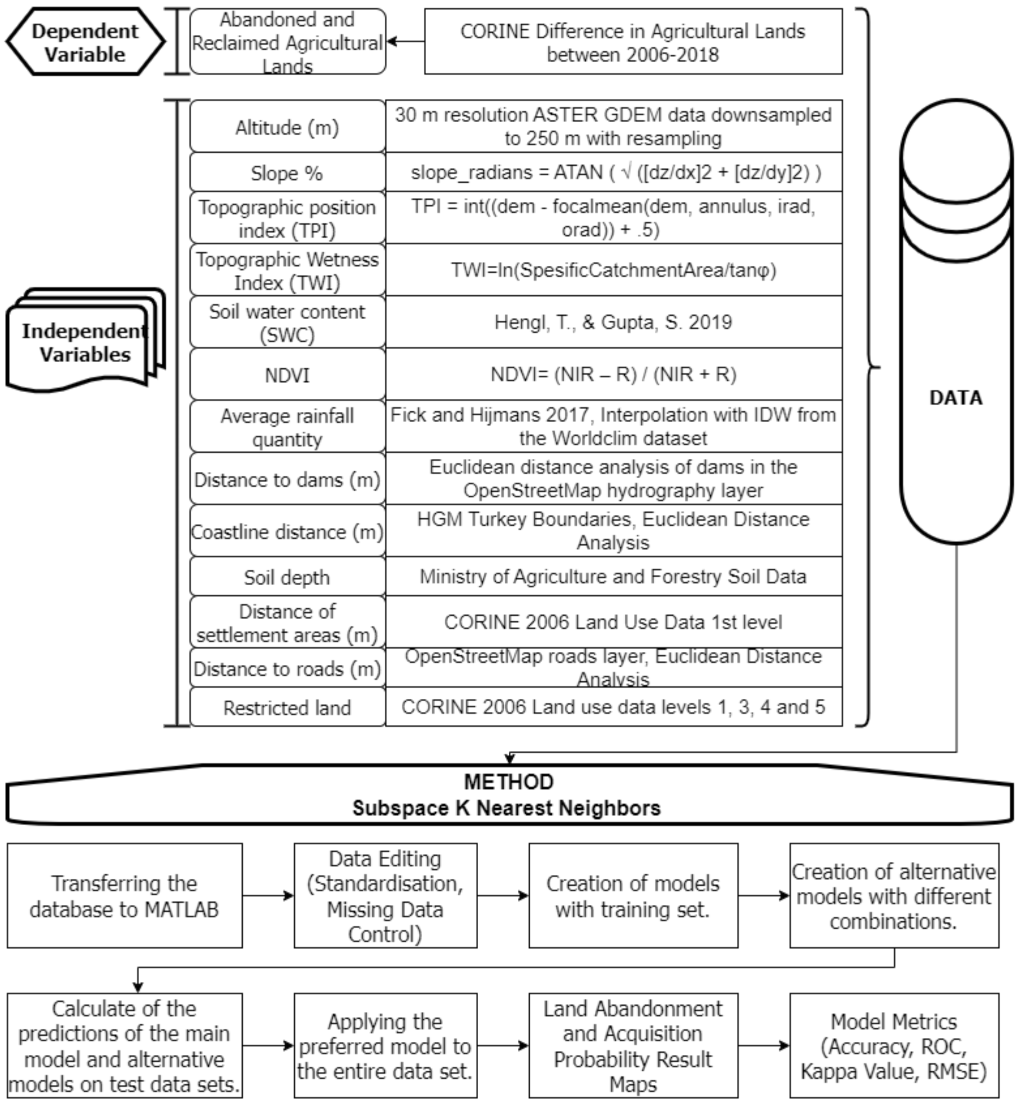

Figure 3: Methodology of this study.

Soil Water Content (SWC)

This datum type shows the volumetric SWC as a percentage at six standard depths (0, 10, 30, 60, 100, and 200 cm) estimated at a resolution of 250 m based on a global compilation of soil profiles from 1957-2017 (Gupta and Hengl 2019). The open-access six-banded data were reduced to a single band by averaging and used as a variable for SWC across Türkiye. It has been included as an important factor in models to detect abandoned agricultural land due to climate change and drought.

Normalized Difference Vegetation Index (NDVI)

NDVI data are an important parameter used as a variable or indicator in land use change studies. The main reason is that data produced by remote sensing provide spatially continuous/ numerical data and time series information, from which changes, trends, variations, and relationships can be derived (Yengoh et al. 2015). As a variable with the potential to provide data on drought, planted area in different agricultural use types, and moisture, NDVI has been included in the models by resampling the average of Sentinel 2 satellite imagery taken at 10 m resolution between 2016-2022 and then down-sampled to 250 m resolution.

Average Rainfall

One of the most important parameters for the productivity and continuity of agricultural land is the amount of precipitation that falls on a field. In a country with a highly heterogeneous distribution of rainfall values, in order to understand the possibility of abandonment of agricultural land, nationwide data and interpolation are needed to include this factor in the model. For this purpose, the WorlClim 2 database, an open-access climate database, was used (Fick and Hijmans 2017). The 900 m resolution raster dataset was converted to point data, and the sum of monthly mean precipitation values was calculated to produce the distribution of precipitation values across the country at 250 m resolution using the inverse distance weighted (IDW) interpolation method.

Distance to Dams

As dams are an important factor in the irrigation of agricultural land, the distance to dam lakes was added to the models to show their impact on the abandonment or acquisition of agricultural land. For this purpose, dams were selected in the hydrography layer of the OpenStreetMap data, and a distance variable to dams was created using Euclidean distance analysis (OpenStreetMap 2022b).

Distance to the Coastline

Distance to the coast was used as the last parameter for the water demand of agricultural land. This parameter was added to the model to test and verify the impact of the abundance of rainfall values in coastal regions, as well as the degradation and transformation processes of the land on its abandonment or reuse. Coastline distances were obtained from the Turkey administrative boundaries (General Directorate of Mapping 2022) country boundary data, and the distance was calculated using the Euclidean distance tool.

Soil Depth

One of the factors that directly affects the productivity and sustainability of agricultural activities is soil depth, which is obtained by digitizing the provincial land asset maps (Ministry of Agriculture and Forestry 1987). The deepest soils are classified in the data with a 1 and the shallowest with a 9, creating a hierarchical classification from 1 to 9. As deeper soils tend to be more productive, these are less likely to be abandoned. The data have been entered into the models as continuous variables, despite not containing intermediate values.

Distance to Settlement Area

One of the factors that have been shown to have the greatest impact on the abandonment of agricultural land is the growth of settlement areas (Andronic et al. 2020). Due to the rapid urbanization in Türkiye, agricultural land in the vicinity of cities has been transformed by remaining within the building zones, with the surrounding land being converted and developed. Therefore, as with other distance-related variables, the settlement areas obtained from the CORINE land use data have been transformed into a continuous numerical variable using the Euclidean Distance tool and then included in the models.

Distance to the Road

One of the most important changes in rural areas throughout Türkiye is the increased dispersion of rural dwellings. This dispersal is related to the construction of new houses on agricultural land close to roads rather than in village centers. As a result, some of these agricultural lands have lost their function, while others are beginning to be reused. Therefore, the probability of abandonment of agricultural land close to a road is low, and if it becomes unused, the probability of reuse is high. To create the variable, the road network obtained from OpenStreetMap data was converted into a numerical variable using the Euclidean Distance tool (OpenStreetMap 2022a).

Restricted Areas

Intuitive models apply a weighted overlay analysis in the final stage of creating the result maps. In this stage, constraints can be imposed by selecting classes that will not be included in the map creation process for each variable. However, this cannot be applied to statistical methods because the model equation evaluates all the data to arrive at a result. To overcome this limitation, the variable of restricted areas was added to the model. A variable consisting of two categories was obtained by classifying settlement areas, bare rocks, lakes, and swamps as areas that have no possibility of being converted into agricultural land as 0, with agricultural areas and areas of natural vegetation being coded as 1 in the land use data for 2006 in CORINE. The aim here is to increase the probability of excluding these areas in the event of abandonment or recovery.

In order to determine the probability of abandonment and reuse of agricultural land throughout Türkiye, dependent and independent variables were created before entering the stage of selecting the correct algorithm. This phase next phase trains and tests different models on the data within the Classification Learner in MATLAB and also performs accuracy analyses. To achieve accurate results from a highly heterogeneous dataset, ensemble learning models were prioritized that are commonly used for this purpose. Among these, the KNN subspace, random forest, support vector machine, and artificial neural network algorithms produced better results in terms of time and accuracy compared to the other models. Therefore, a projection of agricultural land to be abandoned was made by predicting the abandonment and acquisition of agricultural land for the year 2030 and then synthesizing the results.

Subspace k-Nearest Neighbors Algorithm

Assuming non-parametric data, the k-nearest neighbors (KNN) model is a simple and basic classification/regression algorithm that searches for vectors similar to the query vector based on the score provided by the similarity function equation. However, the traditional KNN algorithm does not sufficiently take into account the spatial distribution of the training examples, resulting in low accuracy when processing high-dimensional data sets. In addition, the creation of K-nearest neighbours requires the involvement of distance calculations for all known examples, which leads to a high time overhead. To solve these problems, a subspace-based KNN algorithm model has been developed, as subspace KNN is a widely used community machine learning model that is simple in concept, mature in theory, and easy to implement (Ma et al. 2021, p. 225). This algorithm is similar to the KNN algorithm, but subspace KNN performs feature selection to reduce the number of dimensions in the data set. This means the algorithm selects the most effective features by measuring the impact each feature has on classification in the dataset. This increases classification accuracy and reduces the risk of overfitting.

Typically, multi-classifier or community-based techniques are preferred over their single-classifier counterparts because they reduce the likelihood of weak selection. Ensemble learning combines different models to improve prediction performance and has different approaches such as selecting a random subset of features (selected subspace) before running the learning algorithm, making the learning algorithm random, and then combining the outputs of the models using majority voting. Subspace KNN is based on a simple majority voting rule (Ashour et al. 2018). Simple majority voting rule equation is as follows:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \quad (1)$$

The KNN algorithm has three stages. The first stage finds k points with similar features. The similarity (proximity) is determined using a distance metric (Euclidean, Manhattan, or Minkowski) that measures how far apart two data sets (x_1, x_2, ..., x_i) and (y_1, y_2, ..., y_i) are. Then, for classification, the majority class of similar data is found, and the k-point is assigned to that class. Finally, the average distance between the k-points is calculated to predict the class for the new data (Bruce et al. 2020, p. 238). The equation that explains this process is as follows:

$$Class(a) = \underset{c_i \in dom(y)}{\arg\max} \left(\sum_v h(y_v(a), c_i) \right) \quad (2)$$

To apply subspace KNN, c-class random T subsets are selected after KNN classification, and ct classifiers are created. Then, a random subspace ensemble model is built. Finally, the ct classifiers are combined and class assignments are made using majority voting (Ashour et al. 2018).

RESULTS AND DISCUSSION

A correlation analysis was carried out to check for the presence of positive or negative relationships among the variables in the model. The correlation matrix was observed to have a moderate negative correlation (-0.48) between slope and the topographic moisture index. The lowest correlation values were found between distance to dams and soil depth with regard to the other variables. Slope and altitude were the parameters having the highest correlations with other variables. These were followed by distance to settlements and precipitation. The variables having the highest correlations with distance to settlements were slope, distance to roads, and elevation. The VIF (variance inflation factor), which measures collinearity between variables, was used, and its value is generally expected to be less than 10, which indicates no variables with multicollinearity problems to be present in the model (**Table 1**).

The kappa value is a non-linear statistical measure used to evaluate the accuracy of a classification model. It is expressed not as a percentage but as a value that varies between 0 and 1. While the general accuracy value represents the percentage of correctly classified examples in the classification, the kappa value takes into account both correct and incorrect predictions, thus indicating the probability that the classifier will randomly make incorrect predictions while attempting to make correct predictions. In this way, it is a more objective evaluation metric. The overall accuracy of the model is approximately 86% for both the training and test data. The kappa value was measured to be around 0.7 for both datasets, indicating good discrimination. Finally, when looking at Figure 4, which shows the accuracy of the decisions made at different thresholds through the area under the curve (AUC), the obtained value of 0.94 for the test data set indicates the model to have good performance (**Table 2**).

Table 1: Correlation Matrix of the Variables Used in the Models.

Correlation	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	x12	x13	*VIF*
x1	1.00	0.00	0.03	0.15	-0.04	0.15	-0.02	-0.03	0.02	0.01	-0.01	0.11	0.18	*1.06*
x2	0.00	1.00	-0.14	-0.11	0.14	-0.02	0.07	0.10	0.01	-0.01	-0.03	-0.08	-0.08	*1.07*
x3	0.03	-0.14	1.00	0.10	-0.32	-0.12	0.29	0.22	0.02	-0.48	0.29	0.39	0.26	*1.82*
x4	0.15	-0.11	0.10	1.00	-0.26	0.17	-0.16	-0.18	0.09	-0.06	-0.05	0.27	0.33	*1.25*
x5	-0.04	0.14	-0.32	-0.26	1.00	-0.03	-0.08	0.03	-0.13	0.22	-0.11	-0.27	-0.24	*1.24*
x6	0.15	-0.02	-0.12	0.17	-0.03	1.00	-0.44	-0.32	0.03	0.00	-0.33	0.05	0.44	*1.56*
x7	-0.02	0.07	0.29	-0.16	-0.08	-0.44	1.00	0.35	-0.01	-0.17	0.37	0.10	-0.20	*1.48*
x8	-0.03	0.10	0.22	-0.18	0.03	-0.32	0.35	1.00	-0.04	-0.09	0.36	0.05	-0.19	*1.31*
x9	0.02	0.01	0.02	0.09	-0.13	0.03	-0.01	-0.04	1.00	-0.35	-0.01	-0.01	0.11	*1.19*
x10	0.01	-0.01	-0.48	-0.06	0.22	0.00	-0.17	-0.09	-0.35	1.00	-0.09	-0.22	-0.29	*1.60*
x11	-0.01	-0.03	0.29	-0.05	-0.11	-0.33	0.37	0.36	-0.01	-0.09	1.00	0.17	-0.23	*1.42*
x12	0.11	-0.08	0.39	0.27	-0.27	0.05	0.10	0.05	-0.01	-0.22	0.17	1.00	0.37	*1.40*
x13	0.18	-0.08	0.26	0.33	-0.24	0.44	-0.20	-0.19	0.11	-0.29	-0.23	0.37	1.00	*1.83*

x1 = Distance to Dam x2 = Depth x3 = Slope x4 = Distance to Roads x5 = Restricted Area x6 = Distance to Coastal x7 = NDVI (Normalized Difference Vegetation Index) x8 = SWC (Soil Water Content) x9 = TPI (Topographic Position Index) x10 = TWI (Topographic Wetness Index) x11 = Precipitation x12 = Distance to Settlements x13 = Elevation

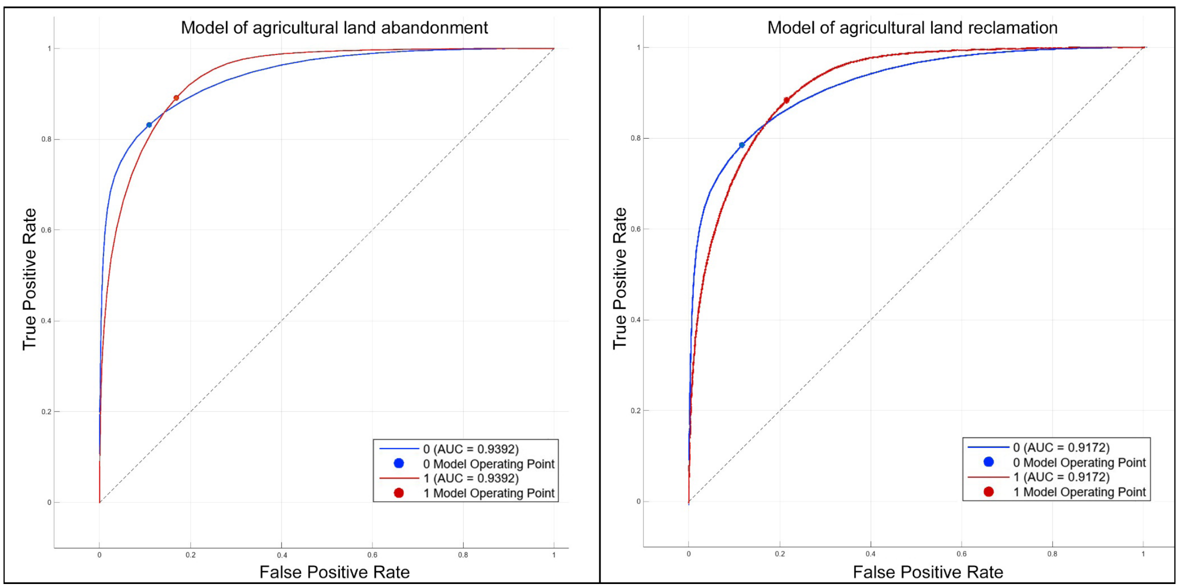

Figure 4: ROC curve and AUC values of models for the probability of abandonment and reclamation of agricultural land in Türkiye.

Table 2: *Accuracy Analysis Results of the Subspace KNN Model for the Probability of Abandoned Agricultural Land in Türkiye*

Type of data	Class Type	0	1	Classification Error	Overall Accuracy	Kappa Value
Training data	0 (Excluding Abandoned Agricultural Land)	116505	23634	16.9	86%	0.72
	1 (Abandoned Agricultural Land)	14607	119578	10.9		
Test data	0 (Excluding Abandoned Agricultural Land)	12982	2589	16.6	87%	0.73
	1 (Abandoned Agricultural Land)	1467	13442	9.8		

Table 3: *Distribution of Probability of Abandonment of Agricultural Land by Class in Türkiye*

Model Interval Values	Abandonment probability classes	Area (ha)	Percentage %
0.001 - 0.23	Very low abandonment probability	459.410	7.4
0.23 - 0.4	Low abandonment probability	1.301.330	20.8
0.40 - 0.57	Likely abandonment probability	2.401.829	38.4
0.57-0.73	High abandonment probability	1.287.234	20.6
0.73-1	Very high abandonment probability	800.198	12.8
Total		6.250.001	100

According to the projection made for the probability of abandonment of agricultural land, approximately 800,000 hectares have a high probability of abandonment throughout the country. When including the areas with a high and probable probability of abandonment, this figure rises to around 4 million hectares. In this case, agricultural land, which was 38 million hectares in 2018, will most likely reach between 36 and 34 million hectares by 2030 (**Table 3**).

The projection map obtained from the subspace KNN model shows proximity to roads and to settlements to be an important determinant for agricultural land with a high probability of abandonment. Therefore, when analyzing the probability of abandonment, the areas where human activities and changes are most concentrated are those close to roads and settlements.

In Türkiye, the main areas with a high probability of abandonment are agricultural land within settlements and the agricultural land surrounding settlements and vary based on the size of the city. Bringing the 2006-2018 data into the present allows one to directly confirm the change. In fact, if one looks at the map projecting the process until 2030, the agricultural areas in and around the cities can be seen to be made up of areas that have been developed or subdivided into urban plots ready for development. This is a change that can be directly observed in all cities. In addition to the growth of cities inward and toward their immediate surroundings, leapfrogging also extends the impact area of the probability of abandonment. Because the first stage of construction leading to land abandonment is the provision of roads and infrastructure, proximity to roads becomes a more decisive factor in the model in terms of its effect on land abandonment (**Figure 5**).

The number and distribution of areas with a high risk of abandonment vary according to the size and primary functions of the nearby city. For example, even in small cities on the Mediterranean coast, the areas with a high risk of abandonment in their immediate vicinity are quite numerous due to the influence of tourism. In Çukurova, the areas where settlements are expanding are effective, as well as settlements with other functional areas. The situation in the Ergene basin is more complex. Despite the presence of fertile plains, industrialization and the pollution of soil and water as a result of industrialization, rapid urbanization, and flooding have increased the probability of the abandonment of agricultural land.

Proximity to roads continues to be the most important parameter for rural land abandonment. The urbanization process that began in Türkiye in the 1950s continued with increasing momentum and eventually developed into a structure where the rural population had decreased significantly. Today, due to the deterioration of old dwellings or new housing construction based mainly on the demand for second homes, rural dwellings are mainly located on agricultural land close to roads. As a result, while the probability of using some of these areas has increased, the probability of abandoning others due to functional changes has also increased. This situation can be observed in the agricultural land in the southern part of Uşak province and in the land near rural settlements that extend in a crescent along the Kızılırmak River in Central Anatolia and is visible throughout the country.

The second most important factor influencing the model is the normalized difference vegetation index. This factor is identified as both a causal and summative parameter. In the Black Sea region, which has the highest forest coverage in the country, the concentration of high-risk abandonment areas inland

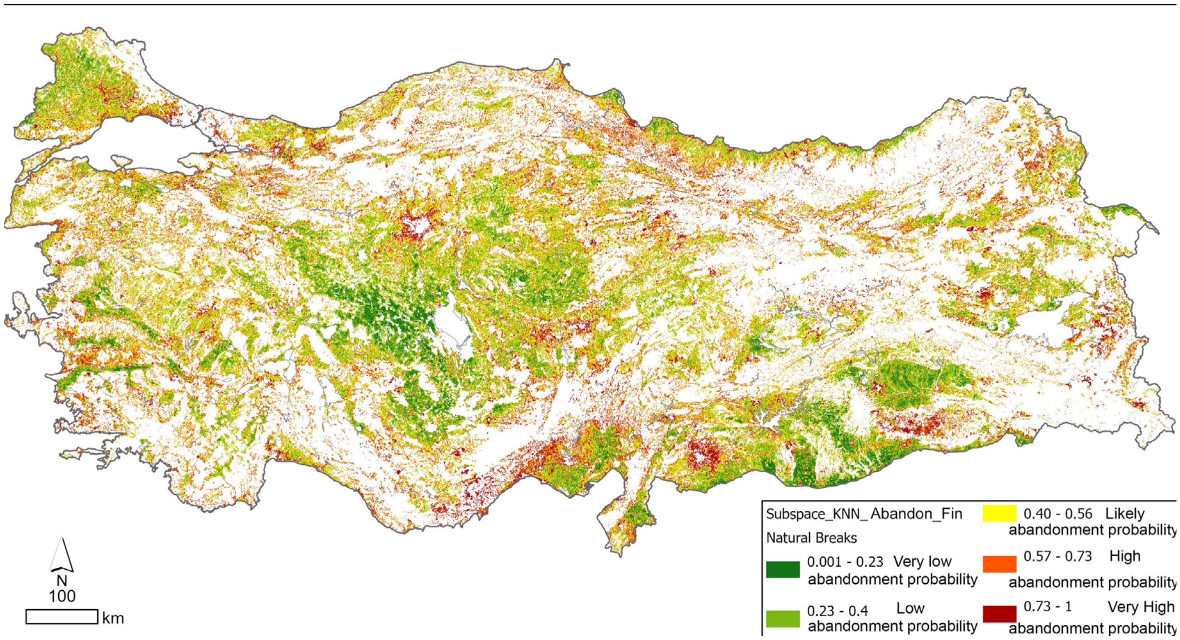

Figure 5: Türkiye-wide map of probability of agricultural land abandonment results.

is due to both forest cover and topographic structure. The topographic roughness index is ranked third after the NDVI in terms of effectiveness. Both forest cover and land topography increase the number of restricted areas for human activities and accelerate the conversion of forests and agricultural land into settlements and other functional areas. The high-risk abandonment areas observed along the Black Sea Mountains show how widespread the conversion and degradation of not only agricultural land but also forest land is. As a result, all agricultural lands in the immediate vicinity of rural or urban settlements in the region are found to have a high probability of abandonment. The same situation is observed in the vicinity of forest areas in the Mediterranean and Aegean regions.

Another important factor in land abandonment is the degree of fragmentation and resultant negative conditions such as erosion. This can be observed in many areas of the country, particularly in regions where narrow valleys are common due to dendritic drainage, such as hillsides. For example, a significant proportion of the land surrounding the Atatürk Dam reservoir consists of this type of area.

According to the model, mountainous areas are the second most likely to be abandoned. Despite their rural character, the mountainous areas of the Taurus Mountains, the Black Sea Mountains, and Western Anatolia stand out as areas at high risk of abandonment. This is related to natural factors such as slope, fragmentation, and soil depth, as well as factors such as low efficiency due to distance from cities and small-scale enterprises. Although rural-urban migration in Türkiye has decreased in recent years, it is still ongoing. This suggests that rural areas are running out of young people or people with the skills to farm. Therefore, the problem of fallow land in potential agricultural areas has become increasingly important. Meanwhile, Tables 4 and 5 show the distribution of agricultural land with a high probability of reclamation.

Table 4: *Accuracy Analysis Results of Subspace KNN Model for Land Reclamation Probability of Türkiye's Total Area*

Type of data	Class Type	0	1	Classification Error	Overall Accuracy	Kappa Value
Training data	0 (Excluding agricultural land reclaimed)	108560	29756	21.5	83%	0.67
	1 (Agricultural land reclaimed)	16376	124297	11.6		
Test data	0 (Excluding agricultural land reclaimed)	12193	3175	20.7	84%	0.69
	1 (Agricultural land reclamation)	1682	13948	10.8		

The overall accuracy of the land reclamation probability model was around 83% for both the training and test datasets. The kappa value was around 0.67 for both datasets, indicating good discriminative power (**Table 4**). Finally, the AUC value of 0.91 obtained by applying the model to the test data indicates the model to have quite good performance (**Figure 4**).

Table 5: *Distribution of Probability of Recovery by Agricultural Land Class Excluding Land Unsuitable for Agriculture Across Türkiye*

Model Interval Values	Probability of Reclamation Classes	Area (ha)	Percentage %
0.001 - 0.23	Very Low Probability of Reclamation	961.556	15.4
0.23 - 0.4	Low Probability of Reclamation	2.090.450	33.4
0.40 - 0.57	Likely Probability of Reclamation	2.162.509	34.6
0.57-0.73	High Probability of Reclamation	742.678	11.9
0.73-1	Very High Probability of Reclamation	292.807	4.7
Total		6.250.001	100

The following results were obtained by projecting the probability of agricultural land reclamation and reuse using the same algorithm across the country and by excluding restricted areas (settlements, mountain areas, wetlands, and forests). According to the model, an estimation coefficient of 0.5 is assumed to indicated that no very likely or highly likely areas are found that can be reused or opened for use; however, when evaluating the results on the basis of natural breaks (i.e., if the classes are evaluated according to the structure of the data), approximately 100,000 hectares of agricultural land are seen to be present in these two classes throughout Türkiye. One can therefore assume that all the land that could be made available for agriculture throughout the country is already in use, with very few areas found that can be brought back into use from abandoned land (**Table 5**).

Different from the probability of abandonment, the parameters that are effective in the distribution of land with a high probability of recovery are mainly related to physical environmental conditions such as slope, distance to the highway, soil depth, precipitation, elevation, distance to dams, and the topographic roughness index. Therefore, potentially usable areas appear as criteria for agricultural suitability. In this case, currently unused agricultural land with relatively favorable topography and therefore better soil depth, high precipitation values, and proximity to dams and highways can be said to have a higher probability of being recultivated.

When looking at the distribution of agricultural areas with a high probability of recovery at the regional level, the areas

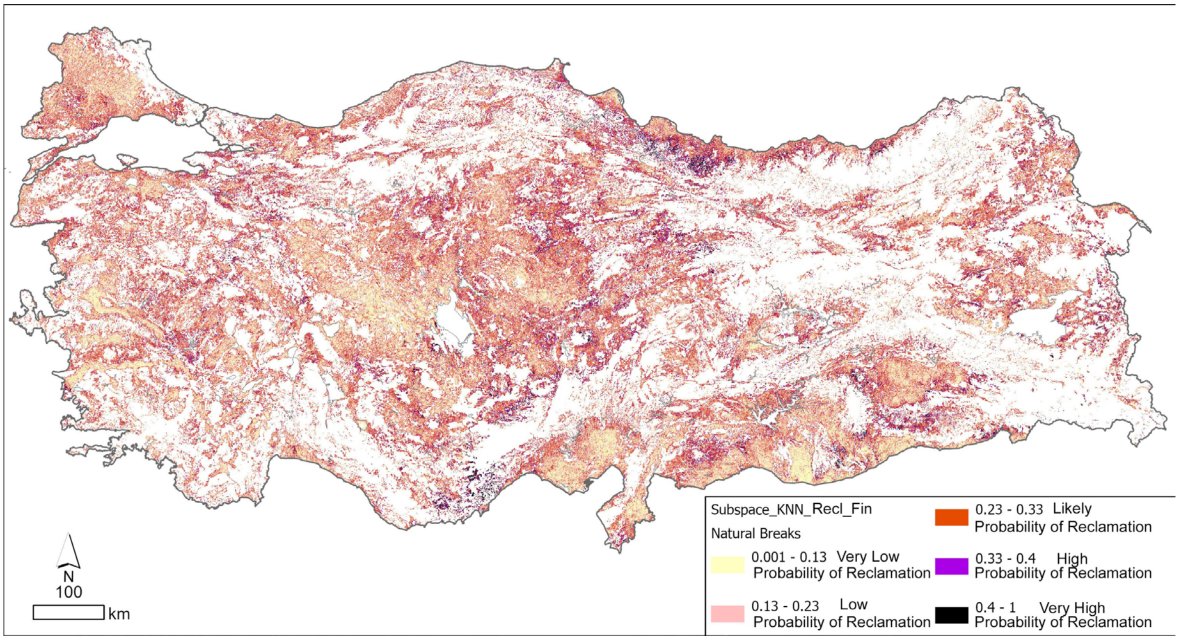

Figure 6: Reclamation probability result map for agricultural land in Türkiye.

around rural settlements in the Canik Mountains appear to be suitable for hazelnut cultivation. In addition, the possible tea growing areas in the Rize section of the Eastern Black Sea Mountains where the coastal effect can reach about 20 km inland and the mixed agricultural areas that are relatively suitable for cultivation on the plateau and slopes where the karst topography is relatively suitable in the Akçalı Mountains in the eastern part of the Western Taurus Mountains and immediately east of the Bolkar Mountains have a relatively higher probability of recovery (**Figure 6**).

In Türkiye as a whole, the same phenomenon is observed in areas near the upper limit of agriculture in different geographical units, as well as in areas near dams and water sources, which can be considered marginal agricultural areas.

In rural areas, a significant proportion of the areas estimated to have a high probability of recovery are located in mountainous areas where slopes and barriers have been relatively reduced. These areas also appear to require significant improvements in order to be converted into agricultural land.

According to the model, the areas identified as having a high, low, and very low likelihood of recovery in rural areas are mainly important agricultural areas where agricultural activity is currently taking place. However, when compared with the abandonment likelihood map, a significant degree of consistency is seen across all classes. Namely, areas with a low abandonment likelihood have also been identified as areas with a very low restoration likelihood on the restoration likelihood map. In fact, when comparing the abandonment and restoration likelihood maps, the *RMSE* value is found to be 0.3. In other words, as the data set ranges from 0 to 1, this *RMSE* indicates a 30% margin of error between the two maps.

In conclusion, assessing the probability of abandonment rather than the possibility of recovery for agricultural land throughout Türkiye and carrying out preventive and regulatory work accordingly would be more rational. As one of the earliest settlement areas in history, the study area has given people the time and opportunity to transform many of the places accessible to them. Some of these areas are not even very suitable for agricultural use. Some of the abandonment can be said to have occurred naturally and to be considered reasonable. However, the main problem has been the phenomena of transformation and loss due to construction in priority agricultural areas. Therefore, qualified and sustainable urbanization, as well as rational construction and transformation in rural areas, are vital issues that need to be prioritized in terms of spatial issues.

RESULTS

Recent years have shown a growing interest in scientific studies on farmland abandonment in different regions of the world. Although the scope, methodology, and content of these studies vary, they do also focus on some common issues, including economic improvement on different spatial scales related to agriculture, food security, and sustainable development, as well as land degradation related to urbanization and development. Of course, the transformation of agricultural land lies at the heart of these issues.

One of the most important issues regarding land change is the transformation of agricultural land. Supporting this change with predictive analysis alongside theoretical and field studies by looking at the spatial representation of the problem, is a prerequisite for accurately identifying the problem. Despite not covering all parameters, this way can take into account qualified information on the distribution of abandoned land when preparing environmental and regional development plans.

In the absence of qualitative data on the abandonment of agricultural land, this study has used CORINE land use data for 2006-2018 to identify the likely areas of agricultural abandonment. A total of 13 independent numerical variables have been used to identify the reasons these areas were abandoned. Subspace KNN provided a higher accuracy rate compared to the other models. In addition to land abandonment, land that could potentially be reclaimed or developed for new uses was projected using the CORINE dataset as the dependent variable. The study also produced abandonment and reclamation projection maps for the year 2030 using the same independent variables and model.

Türkiye has a geographical structure with rugged terrain that shows significant changes over short distances in the temperate zone. Therefore, predicting farmland abandonment with high accuracy in a heterogeneous space is both difficult and limited. Even with the highly successful subspace KNN algorithm, an accuracy of only about 85% could be achieved. By 2023, a significant part of the projected changes was also observed to have already had occurred.

The parameters that primarily influence the high probability of abandonment of agricultural land throughout the country are proximity to roads and settlements. Therefore, rural areas close to cities where human intervention is concentrated have been identified as priority areas at risk. However, rural areas where natural environmental conditions have reached a critical threshold in terms of suitability for agriculture (e.g., terrain, rainfall, soil depth) have also been identified as having a high probability of abandonment.

The Middle Black Sea region where hazelnut farming dominates, the Eastern Black Sea region where tea farming dominates, and various parts of the Central Taurus Mountains where mixed farming is practiced all have a high probability of recovering agricultural land. Furthermore, marginal agricultural areas that surround primary agricultural areas, areas near dams and water sources, and areas that can be improved by human intervention are also among the probable agricultural conversion areas.

Globally, sustainability, food supply, and green economy have become increasingly important, leading to more planning and projects aimed at achieving these. Additionally, as food trade becomes more of a negotiation between states, leaving agricultural land unused should be seen as a national security issue and evaluated accordingly. Non-marginal agricultural land should not only be encouraged for use, but so should a legal framework be established to hold landowners accountable for unused land.

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REFERENCES/KAYNAKÇA

Alcantara, C.,; Kuemmerle, T.; Prishchepov, A. V.; Radeloff, V. C. (2012): Mapping abandoned agriculture with multi-temporal MODIS satellite data. In *Remote Sensing of Environment* 124, pp. 334–347. DOI: 10.1016/j.rse.2012.05.019.

Andronic, C.; Derszniak, Noirjean; Gaupp, Berghausen M.; Hsiung, C.H.; Münch, A.; Schuh, B. et al. (2020): Research for AGRI Committee - The challenge of land abandonment after 2020 and options for mitigating measures. Brussels: European Parliament, Policy Department for Structural and Cohesion Policies.

Ashour, Amira S.; Guo, Yanhui; Hawas, Ahmed Refaat; Xu, Guan (2018): Ensemble of subspace discriminant classifiers for schistosomal liver fibrosis staging in mice microscopic images. In *Health information science and systems* 6 (1), p. 21. DOI: 10.1007/s13755-018-0059-8.

Azima, A. M.; Ismail, O. (2011): Idle Agriculture Land Resources Management and Development – An Institutional Causes: A Case Study in Malaysia. In *Interdisciplinary Journal of Research in Business* 1 (8), pp. 21–27.

Benayas, J. M.R.; Martins, A.; Nicolau, J. M.; Schulz, J. (2007): Abandonment of agricultural land: an overview of drivers and consequences. In *CAB Reviews* 2 (057), pp. 1–14. DOI: 10.1079/PAVSNNR20072057.

Bernués, A.; Riedel, J. L.; Asensio, M. A.; Blanco, M.; Sanz, A.; Revilla, R.; Casasús, I. (2005): An integrated approach to studying the role of grazing livestock systems in the conservation of rangelands in a protected natural park (Sierra de Guara, Spain). In *Livestock Production Science* 96 (1), pp. 75–85.

Bielsa, Isabel; Pons, Xavier; Bunce, Bob (2005): Agricultural Abandonment in the North Eastern Iberian Peninsula: The Use of Basic Landscape Metrics to Support Planning. In *Journal of Environmental Planning and Management* 48 (1), pp. 85–102. DOI: 10.1080/0964056042000308166.

Bruce, Peter; Bruce, Andrew; Gedeck, Peter (2020): Practical statistics for data scientists: 50+ essential concepts using R and Python: O'Reilly Media.

Bryden, John M.; Bruce, David (1995): Towards Sustainable Rural Communities: The Guelph Seminar Series. In *Canadian Geographer* 39 (3), p. 283.

Canpolat, F. A.; Hayli, S. (2018): Coğrafi göstergeler açısından Türkiye'de kırsal değişim (1980-2012 dönemi). In *Journal of Human Sciences* 15 (4), pp. 2229–2256.

Dahms, Fredric A. (1995): "Dying Villages', 'Counterurbanization' and the Urban Field -- a Canadian Perspective. In *Journal of Rural Studies* 11 (1), pp. 21–33. DOI: 10.1016/j.gloenvcha.2022.102551.

Deng, Xin; Zeng, Miao; Xu, Dingde; Qi, Yanbin (2020): Does Social Capital Help to Reduce Farmland Abandonment? Evidence from Big Survey Data in Rural China. In *Land* 9 (10), p. 360. DOI: 10.3390/land9100360.

Díaz, G. I.; Nahuelhual, L.; Echeverría, C.; Marín, S. (2011): Drivers of land abandonment in Southern Chile and implications for landscape planning. In *Landscape and Urban Planning* 99 (3-4), pp. 207–217. DOI: 10.1016/j.landurbplan.2010.11.005.

Drucker, P. F. (1993): Kapitalist Ötesi Toplum. İstanbuk: İnkılap Kitapevi.

Du, Jiang; Zeng, Miao; Xie, Zhengjuan; Wang, Shikun (2019): Power of Agricultural Credit in Farmland Abandonment: Evidence from Rural China. In *Land* 8 (12), p. 184. DOI: 10.3390/land8120184.

Estel, S.; Kuemmerle, T.; Alcántara, C.; Levers, C.; Prishchepov, A.; Hostert, P. (2015): Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series. In *Remote Sensing of Environment* 163, pp. 312–325. DOI: 10.1016/j.rse.2015.03.028.

European Union (2018): Copernicus Land Monitoring Service 2018, European Environment Agency (EEA). Corine Land Cover (CLC).

Fick, Stephen E.; Hijmans, Robert J. (2017): WorldClim 2: new 1-km spatial resolution climate surfaces for global land areas. In *Int. J. Climatol* 37 (12), pp. 4302–4315. DOI: 10.1002/joc.5086.

Filho, L. W.; Mandel, M.; Al-Amin, A. Q.; Feher, A.; Chiappetta J., C. J. (2017): An assessment of the causes and consequences of agricultural land abandonment in Europe. In *International Journal of Sustainable Development & World Ecology* 24 (6), pp. 554–560.

Food and Agriculture Organization (Ed.) (2006): The Role of Agriculture and Rural Development in Revitalizing Abandoned/Depopulated Areas. The 34th Session of the European Commission on Agriculture. Riga.

Gallant, J. C.; Wilson, P. J. (2000): Primary topographic attributes. In *Terrain analysis-principles and application*, pp. 51–86. Available online at https://cir.nii.ac.jp/crid/1573950400957839488.

García Martínez, A. (2008): Recent evolution of cattle farming systems in the Central Spanish Pyrenees and possibilities of adaptation to the socio-economic environment.

General Directorate of Mapping (2022): Türkiye Mülki İdari Sınırları. Available online at https://www.harita.gov.tr/urun/turkiye-mulki-idare-sinirlari/232, checked on 9/2/2022.

Gupta, S.; Hengl, T. (2019): Soil water content (volumetric%) for 33kPa and 1500kPa suctions predicted at 6 standard depths (0, 10, 30, 60, 100 and 200 cm) at 250 m resolution (Version … Available online at https://zenodo. org/, checked on 9/9/2022.

Güreşci, Ertuğrul (2014): Kırsal göç, tarım ve toplum üzerine köşede kalan yazılar: Semerci Yayınları.

Hart, J. F.; Salisbury, N. E.; Smith Jr, Everett G. (1968): The dying village and some notions about urban growth. In *Economic Geography* 44 (4), pp. 343–349.

Hatna, Erez; Bakker, Martha M. (2011): Abandonment and Expansion of Arable Land in Europe. In *Ecosystems* 14 (5), pp. 720–731. DOI: 10.1007/s10021-011-9441-y.

Huang, Yingqian; Li, Fengqin; Xie, Hualin (2020): A Scientometrics Review on Farmland Abandonment Research. In *Land* 9 (8), p. 263. DOI: 10.3390/land9080263.

Keenleyside, C.; Tucker, G.M. (2010): Farmland Abandonment in the EU: An Assessment of Trends and Prospects. With assistance of Tiffany Key, Hannah Lee and Andrew McConville. London: Institute for European Environmental Policy. Available online at https://www.researchgate.net/profile/clunie-keenleyside/publication/258375179_farmland_abandonment_in_the_eu_an_assessment_of_trends_and_prospects_report_prepared_for_wwf.

Khanal, Narendra Raj; Watanabe, Teiji (2006): Abandonment of agricultural land and its consequences. In *Mountain Research and Development* 26 (1), pp. 32–40. DOI: 10.1659/0276-4741(2006)026[0032:AOALAI]2.0.CO;2.

Kurugöllü, S.; Ünel, F. B. (2021): Ekonomik Katkısı Olmayan Tarım Arazilerinin Araştırılması ve Değerlendirilmesi. In *Türkiye Arazi Yönetimi Dergisi* 3 (2), pp. 58–65. DOI: 10.51765/tayod.906612.

Lasanta, T.; Arnáez, J.; Pascual, N.; Ruiz-Flaño, P.; Errea, M. P.; Lana-Renault, N. (2017): Space–time process and drivers of land abandonment in Europe. In *CATENA* 149 (4), pp. 810–823. DOI: 10.1016/j.catena.2016.02.024.

Levers, C.; Schneider, M.; Prishchepov, A. V.; Estel, S.; Kuemmerle, T. (2018): Spatial variation in determinants of agricultural land abandonment in Europe. In *Science of the total environment* 644, pp. 95–111.

Liu, Jinxiu; Shen, Weihao; He, Yaqian (2021): Effects of Cropland Expansion on Temperature Extremes in Western India from 1982 to 2015. In *Land* 10 (5), p. 489. DOI: 10.3390/land10050489.

Ma, Xiaoyu; Yang, Tao; Chen, Jiangchuan; Liu, Ziyu (Eds.) (2021): K-Nearest Neighbor Algorithm based on feature subspace. 2021 International Conference on Big Data Analysis and Computer Science (BDACS). Kunming, China, 25-27 June 2021. IEEE. Available online at https://ieeexplore.ieee.org/document/9516557, checked on 5/1/2023.

MacDonald, D.; Crabtree, J.R; Wiesinger, G.; Dax, T.; Stamou, N.; Fleury, P. et al. (2000): Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response. In *Journal of Environmental Management* 59 (1), pp. 47–69. DOI: 10.1006/jema.1999.0335.

Mattivi, Pietro; Franci, Francesca; Lambertini, Alessandro; Bitelli, Gabriele (2019): TWI computation: a comparison of different open source GISs. In *Open Geospatial Data, Software and Standards* 4 (1), pp. 1–12.

McManus, Phil; Walmsley, Jim; Argent, Neil; Baum, Scott; Bourke, Lisa; Martin, John et al. (2012): Rural Community and Rural Resilience: What is important to farmers in keeping their country towns alive? In *Journal of Rural Studies* 28 (1), pp. 20–29. DOI: 10.1016/j.jrurstud.2011.09.003.

Ministry of Agriculture and Forestry (1987): Türkiye Genel Toprak Amenajmanı Planlaması. Ankara.

Montgomery, M. R.; Stren, R.; Cohen, B.; Reed, H. E. (2013): Cities transformed: Demographic change and its implications in the developing world: Routledge.

Naldi, Lucia; Nilsson, Pia; Westlund, Hans; Wixe, Sofia (2015): What is smart rural development? In *Journal of Rural Studies* 40, pp. 90–101.

Ngoma, Hambulo; Pelletier, Johanne; Mulenga, Brian P.; Subakanya, Mitelo (2021): Climate-smart agriculture, cropland expansion and deforestation in Zambia: Linkages, processes and drivers. In *Land Use Policy* 107, p. 105482.

OpenStreetMap (2022a): Global Road Data. Available online at https://wiki.openstreetmap.org/wiki/Highways, checked on 10/9/2022.

OpenStreetMap (2022b): Global Water Data. Available online at https://wiki.openstreetmap.org/wiki/Key:natural, checked on 10/9/2022.

Pejovich, Svetozar (1990): The economics of property rights. Towards a theory of comparative systems. Dordrecht: Kluwer Academic (International studies in economics and econometrics, 22).

Peters, Paul; Carson, Dean; Porter, Robert; Vuin, Ana; Carson, Doris; Ensign, Prescott (2018): My village is dying? Integrating methods from the inside out. In *Canadian Review of Sociology/Revue canadienne de sociologie* 55 (3), pp. 451–475.

Prishchepov, Alexander V.; Müller, Daniel; Dubinin, Maxim; Baumann, Matthias; Radeloff, Volker C. (2013): Determinants of agricultural land abandonment in post-Soviet European Russia. In *Land Use Policy* 30 (1), pp. 873–884.

Qianru, Chen; Hualin, Xie (2021): Research progress and discoveries related to cultivated land abandonment. In *Journal of Resources and Ecology* 12 (2), pp. 165–174.

Rehman, Obaid Ur; Rashid, Muhammad; Kausar, Rahina; Alvi, Sarosh; Hussain, Riaz (2015): Slope Gradient and Vegetation Cover Effects on The Runoff and Sediment Yield in Hillslope Agriculture. In *Turkish JAF Sci.Tech.* 3 (6), p. 478. DOI: 10.24925/turjaf.v3i6.478-483.292.

Renwick, Alan; Jansson, Torbjorn; Verburg, Peter H.; Revoredo-Giha, Cesar; Britz, Wolfgang; Gocht, Alexander; McCracken, Davy (2013): Policy reform and agricultural land abandonment in the EU. In *Land Use Policy* 30 (1), pp. 446–457.

Riedel, J. L.; Casasús, I.; Bernués, A. (2007): Sheep farming intensification and utilization of natural resources in a Mediterranean pastoral agro-ecosystem. In *Livestock Science* 111 (1-2), pp. 153–163.

Shabanov, V.,V. (2009): Agricultural Land Improvement: Amelioration and Reclamation - Volume I. Edited by Boris Stepanovich Maslov: EOLSS Publications.

Sumaytaoğlu, E. C. (2012): Osmanlıda ve Türkiye'de tarımsal politikaların tarihsel gelişimi ve uygulaması. Master. Çankaya Üniversitesi, Ankara. Sosyal Bilimler Enstitüsü.

Tao, Zhou; Guanghui, Jiang; Wenqiu, Ma; Guangyong, Li; Yanbo, Qu; Yingying, Tian et al. (2021): Dying villages to prosperous villages: A perspective from revitalization of idle rural residential land (IRRL). In *Journal of Rural Studies* 84, pp. 45–54.

Topçu, Pınar (2012): Tarım arazilerinin korunması ve etkin kullanılmasına yönelik politikalar: uzmanlık tezi: Kalkınma Bakanlığı İktisadi Sektörler ve Koordinasyon Genel Müdürlüğü.

Turkish Statistical Institute (2016): Crop Production Statistics. Available online at https://biruni.tuik.gov.tr/medas/?locale=tr, checked on 9/2/2022.

Wang, Liye; Zhang, Siyu; Xiong, Qiangqiang; Liu, Yu; Liu, Yanfang; Liu, Yaolin (2022): Spatiotemporal dynamics of cropland expansion and its driving factors in the Yangtze River Economic Belt: A nuanced analysis at the county scale. In *Land Use Policy* 119, p. 106168. DOI: 10.1016/j.landusepol.2022.106168.

Yengoh, Genesis T.; Dent, David; Olsson, Lennart; Tengberg, Anna E.; Tucker, Compton J. (2015): Limits to the Use of NDVI in Land Degradation Assessment. In : Use of the Normalized Difference Vegetation Index (NDVI) to Assess Land Degradation at Multiple Scales: Springer, Cham, pp. 27–30. Available online at https://link.springer.com/chapter/10.1007/978-3-319-24112-8_4.

Yin, H.; Prishchepov, A. V.; Kuemmerle, T.; Bleyhl, B.; Buchner, J.; Radeloff, V., C. (2018): Mapping agricultural land abandonment from spatial and temporal segmentation of Landsat time series. In *Remote Sensing of Environment* 210, pp. 12–24. DOI: 10.1016/j.rse.2018.02.050.

Zhou, Ting; Koomen, Eric; Ke, Xinli (2020a): Determinants of farmland abandonment on the urban–rural fringe. In *Environmental Management* 65, pp. 369–384.

Zhou, Yang; Li, Yamei; Xu, Chenchen (2020b): Land consolidation and rural revitalization in China: Mechanisms and paths. In *Land Use Policy* 91, p. 104379.