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Real estate assessment of agricultural lands outside the zoning plan with artificial neural networks and multiple regression analysis methods: The case of Aksaray, Bahçesaray and Kırımlı rural districts

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Agricultural land
Land valuation
ANN
MRA
GIS

ABSTRACT

This study aims to determine the market value of the agricultural lands in the rural Bahçesaray and Kirimli districts, which are outside the zoning plan, where agricultural production continues in Aksaray Province, Central District, in Turkey, by mass valuation methods. It is also aims to provide value estimation and value map production with the help of geographic information systems (GIS). Using the sales data from 125 parcels in the study area, the market value of the real estates for which the value is unknown in the region, was estimated. The most frequently used criteria in the assessment of agricultural lands were determined, and the valuation was carried out with Multiple Regression Analysis (MRA) and Artificial Neural Networks (ANN). By means of the assessment and the valuation study, the performance of the valuation methods was compared, and it was determined that the best result according to the test data was the valuation with ANN. In the performance analysis conducted with ANN, the Coefficient of Determination (R^2)=0.87, Mean Absolute Percentage Error (MAPE)=0.192, Mean Absolute Error (MAE)=0.047 and Root Mean Square Error (RMSE)=0.059 was found. Moreover, according to the proportional standards guide determined by the International Association of Assessing Officers (IAAO), the performance measurement, the values derived for the Coefficient of Dispersion as (COD)=19.58 and Price-Related Differential as (PRD)=1.02 were also found to be within acceptable limits. Since the valuation of agricultural lands is a less studied subject, there are few articles in the literature. For this reason, it will be useful to increase such as article and evaluate the results applying it region by region. In this study, estimates were found with MRA and ANN methods and value maps were created

1. INTRODUCTION

Rural development studies are seen as a step towards becoming an influential renowned state at the global level, which is the fundamental long-term goal for Turkey. In rural development studies, the aim is to increase the contribution of the rural area to the country's economy and to reduce the development differences between the regions and the rural-urban by raising the living standard of the rural population (Karakayacı, 2011). Please rephrase this sentence like: Agricultural land prices have been risen in recent years not only in Turkey but also across the world. This situation can be regarded as positive as well as negative in terms of increasing the production cost for the farmers (Lehn and Bahrs, 2018). In addition, changing consumer preferences and the effort of agricultural production to meet the demand have also increased the need for agricultural land (Çınar et al., 2018). This situation makes it necessary for countries to have the potential to meet their self-sufficient nutritional needs amidst the Coranavirus pandemic. Today, the fact that food security has a strategic significance increases the importance of agricultural lands and makes it necessary to evaluate the agricultural lands for different purposes and to have knowledge about their value (Akın et al., 2020).

The value of real estates is used for taxation, insurance, and expropriation etc. in addition to

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transactions, it is also used for land management, planning, urban transformation, zoning applications, and real estate administration (Özdemir, 2019; Çoşar and Engindeniz, 2013; İban, 2021). Although it is simple and feasible to make valuations in such transactions with traditional methods such as comparison and income, the valuations to be made in such transactions can be applied simply and quickly by comparison, cost, income method, which is considered among the traditional methods. However, it does not give healthy results in comprehensive and large-scale studies. It is possible to reach healthy results in comprehensive studies with many criteria that affect the value of the real estate, with mass valuation (Garcia-Melon et al., 2008). The lack of an optimum number of criteria affecting land value that will serve as a base for mass valuation of real estates in Turkey and the lack of sufficient studies to establish a collective valuation system is a deficiency (Ünel, 2017). In this context, this study is important in terms of being an example for determining the values of real estates in rural areas according to objective criteria.

In this study, Multiple Regression Analysis (MRA) and Artificial Neural Networks (ANN) methods were used to evaluate the agricultural lands in the region, which is divided into two parts as Bahçesaray and Kırımlı Neighborhood, while Hamidiye-Alaca Village of Aksaray Province Central District still holds its rural characteristics. First of all, the criteria that are most frequently used in the studies on agricultural lands and that affect the value the most were determined. Necessary scoring and normalization processes regarding these criteria were performed. Prices are predicted was done with MRA and ANN methods, and a performance assessment was performed betweenmpredictions from these methods. Value maps were produced and drawn with ArcGIS 10.8, software.

2. MATERIALS AND METHODS

2.1. Real Estate Valuatıon Methods

Real estate valuation is a very complex process. The accuracy of the information obtained about the real estate depends on the knowledge and skills of the appraiser and the size of the errors caused by various factors in the valuation process (Choumert and Phélinas, 2015). For this reason, subjective factors affecting the valuation and some specific factors cause errors in the valuation, while valuations done with statistical and modern methods can give objective and correct results (Cupal, 2014). The valuation of agricultural lands requires for expropriation, insurance, crediting, and taxation, etc. and are done for different purposes. (Çoşar and Engindeniz, 2013). For this reason, the valuation results are important for the land owner, the appraiser, and the relevant institutions.

Valuation methods are generally divided into three: traditional, modern, and statistical. The most used of these are the traditional comparison, income, and cost methods (Kontrimas and Verikas, 2011). Artificial neural networks, fuzzy-logic, and spatial analysis methods are classified as modern methods. Nominal methods, multiple regression and hedonic methods are stated as statistical methods (Yalpır, 2007).

Within the scope of the study, MRA and ANN methods were being used in the valuation of the agricultural lands. For this reason, information will be given about MRA and ANN methods.

2.2. Multiple Regression Analysis Method

The MRA model consists of dependent and independent variables. A linear regression model is used to detect the properties and relationships between both dependent and independent variables. A basic linear regression model contains only one independent variable, while a multiple linear regression model contains many independent variables. Linear regression analysis generates the linear equation by determining the function for the plane closest to each data point in a scatter plot (Ge et al., 2021). The MRA model is represented by the formula (1);

$$Y = b_0 + b_1 X_1 + b_2 X_2 + \dots + b_n X_n + c \qquad (1)$$

Y: Dependent Variable (Real Estate Value)
X_i: Independent Variables (criteria affecting the value of the real estate)
b_i: Variable coefficients (coefficients/weights of independent variables)
b_0: Constant coefficient
c: Real error

2.3. Artificial Neural Networks Method

Artificial Neural Networks (ANN) can be defined as a modeling system to perform basic functions such as producing new data from the data collected by the brain by learning, remembering, and generalizing by imitating the learning path of the human brain (Yalpır, 2007; Öztürk and Şahin, 2018). ANN is used as a solid and effective tool particularly in the field of engineering in the aftermath of the advancements in computer technology. Artificial neural networks are modeled based on the biological nervous system. Many artificial neural networks formed in the model have been developed to realize various features of biological neural networks such as learning and responsiveness. ANN contains an input layer, one or more hidden layers, and an output layer (Bilgilioğlu, 2018).

Basic elements of artificial nerve cells are inputs, weights, addition function, activation function and outputs (Figure 1).

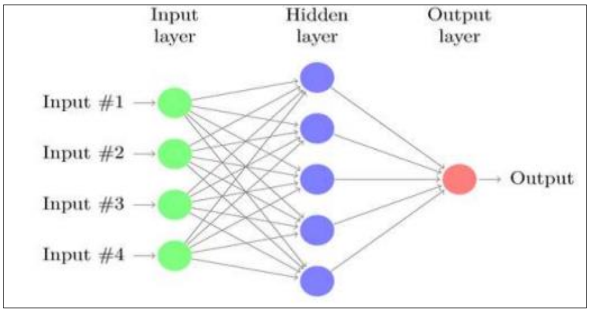

Figure 1. Artificial neural network cell (Soni and Sadiq, 2015).

Inputs is the information coming to the artificial neuron from the outside or from another neuron. Weights are coefficients that show the effect of the information coming to the artificial nerve cell on the cell. Each input is multiplied by the weight factor and then combined as a sum function. The addition function can be specified as a function that calculates the net input to a cell. The most common is the weighted sum. It is represented by the formula (2);

$$Net = \sum_{n=1}^{n}(W_i X_i + \mathrm{b}) \quad (2)$$

Here, X_i shows the inputs, W_i shows the weights, and n is the total number of inputs to a cell. (İlhan, 2019; Bilgilioğlu, 2018)

The characteristics of ANN can be listed as follows:

- It was developed with inspiration from biological neural networks. It mimics the human brain.
- It has non-linear characteristics.
- It can benefit from package programs.
- Learning is a method that can be adapted and generalized.
- It is necessary to work with healthy data. (Yalpir, 2007; Erdem, 2016).

2.4. Prediction performance analysis

An absolute error occurs in all operations performed with estimation methods. In order to compare the performances of the models made within the scope of the study, the accuracy of the estimated values is measured. The aim of all estimations is to create an estimation model with miniscule error values (Han, et al., 2022). The Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Coefficient of Determination (R^2) results were used in the analyzes when comparing the comparable values and real estate values calculated according to the criteria in all transactions (Ünel, 2017).

$$\mathrm{RMSE} = \sqrt{\frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}(\mathrm{yi} - \mathrm{yi'})^2} \quad (3)$$

$$\mathrm{MAPE} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}\frac{|\mathrm{yi}-\mathrm{yi'}|}{\mathrm{yi}} \quad (4)$$

$$\mathrm{MAE} = \frac{1}{\mathrm{n}}\sum_{\mathrm{i}=1}^{\mathrm{n}}|\mathrm{yi} - \mathrm{yi'}| \quad (5)$$

$$\mathrm{R}^2 = 1 - \frac{\sum_{\mathrm{i}=1}^{\mathrm{n}}(\mathrm{yi}-\mathrm{yi'})^2}{\sum_{\mathrm{i}=1}^{\mathrm{n}}(\mathrm{yi}-\bar{\mathrm{y}})^2} \quad (6)$$

yi: Precedent (market) value
yi': Estimated value
$\overline{y}$: Average value.

In addition, another performance measurement method accepted according to the proportional standards guide of the IAAO is the coefficient of dispersion (COD) and price-related differential (PRD). COD measures the average % rate at which individual rates differ from the average rate (assessed value/selling price). The PRD measures the inequality between high and low value properties in the same land group with respect to price (Url-1). The performance standard for the COD distribution coefficient should be 15% or less for residential properties, 20% or less for commercial properties and 25% or less for agricultural land. PRD values for all kinds of real estates are considered appropriate when they are between 0.98-1.03. (IAAO, 2013)

$$\mathrm{COD} = \frac{100}{n} * \frac{\sum_{\mathrm{i}=1}^{\mathrm{n}}\left|(\frac{T}{S} - (\overline{T}/\overline{S})\right|}{(\overline{T}/\overline{S})} \quad (7)$$

$$\mathrm{PRD} = \frac{\overline{T/S}}{\sum T / \sum S} \quad (8)$$

T: Estimated Value
S: Sale price
N: Number of samples

2.5. Study Area

The Aksaray Province is located at the intersection of east-west, north-south main road connections in the middle of Central Anatolia. (Url-2). The area of the Aksaray province is 7659 km² and the area of the Central district is 3540 km² (Url-3,). The study area covers the Bahçesaray and Kırımlı Neighborhoods in the Aksaray City Center (Figure 2). The province of Aksaray has a continental climate and generally wheat, silage corn, and sunflower are produced in their irrigated fields. On dry land, barley, and wheat are grown.

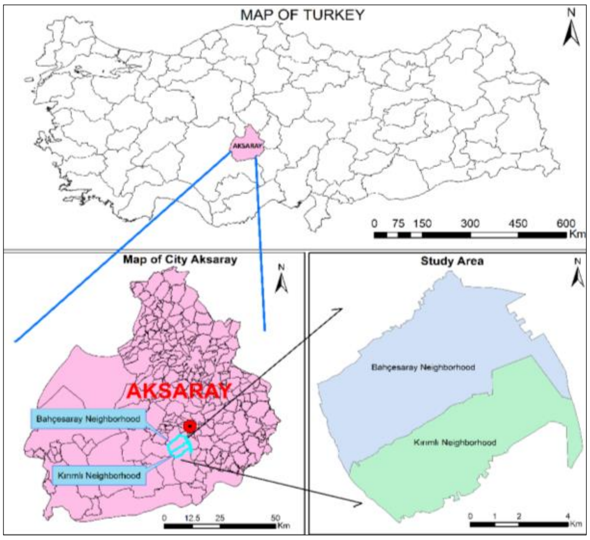

Figure 2. Study area.

2.6. Data Preparation

In the study, MRA and ANN methods were used for the collective valuation of agricultural lands. Before creating a model with these methods, the studies on valuation were examined and the most used criteria were determined (Table 1) (Ertaş, 2014; Koç, 2011; Karakayacı, 2011; Yiğit, 2019). The data set was prepared by scoring according to the importance of the sub-criteria used in the evaluation.

Table 1. Criteria used in the valuation of agricultural lands.

Criteria	Source/Author
Parcel Shape	Ertaş, 2014; Yiğit, 2019
Distance to city/district center	Ertaş, 2014; Koç, 2011; Karakayacı, 2011; Yiğit, 2019
Distance to neighborhood center	Ertaş, 2014; Karakayacı, 2011; Yiğit, 2019
Distance to main road	Ertaş, 2014; Koç, 2011; Karakayacı, 2011; Yiğit, 2019
Distance to pasturelands	Ertaş, 2014
Land Use Capability Class	Ertaş, 2014; Karakayacı, 2011; Yiğit, 2019
Possibility to generate new parcels	Ertaş, 2014; Koç, 2011
Parcel uniqueness	Ertaş, 2014
Irrigation	Ertaş, 2014; Koç, 2011; Karakayacı, 2011
Slope	Ertaş, 2014; Yiğit, 2019
Easement facility	

The price of agricultural land: The data regarding 125 parcels to be used in the valuation of the lands for which the market value will be determined consists of the values obtained from the sales works carried out by the Directorate of National property. The Bahçesaray and Kırımlı neighborhoods selected as the study area are outside the zoning plan and continue to be rural neighborhoods where agricultural production is made. However, due to the expectation that rural neighborhoods will be included in the development plan, the market value of the lands is constantly increasing (Figure 3). Therefore, since the sales values are estimated at different times, the value of the comparable properties was updated to September 2021, when the study was conducted, using the Wholesale Price Index (WPI) and Producer Price Index (PPI) rates published by the Turkish Statistical Institute (TUIK).

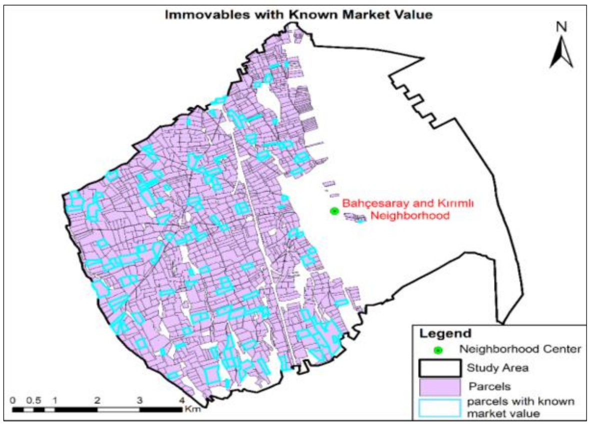

Figure 3. Precedent real estate.

Shape of the Land: There is a linear relationship between the shapes of the plots and the agricultural income. The uneven shape of the plots affects the net agricultural production area in the plot where direct cultivation is done. This situation causes losses in the net agricultural production area due to the maneuvering of agricultural tools used in agricultural activities such as planting, fertilizing, spraying and harvesting, resulting in a decrease in agricultural income. In addition, it directly affects the irrigation efficiency by negatively affecting the irrigation works of the parcel where agricultural production is made. In this case, more labor and materials will be required, independent of the irrigation method, to irrigate an irregularly shaped parcel. Planting-harvest operations and irrigation works will cause more uncultivated land to remain in amorphous agricultural lands and decrease irrigation efficiency. This will increase production costs and reduce revenues (Küsek, 2014). In this context, it would be appropriate to use the golden ratio, which is encountered in nature and in many areas, to determine the best geometric dimension of the parcel. In mathematics, the golden ratio is approximately equal to 1.618. The shape of the lands will be dealt with on a golden rectangle with a ratio of its long side to its short side of 1.618 (Ertaş, 2014; Selçuk et al., 2009). Between the rectangle and the edges of the land, a ratio was taken as approximately 1.60 (Ertaş, 2014).

$$\mathrm{K} = \frac{5.2\sqrt{\frac{f_p}{1.60}}}{C_p} \tag{9}$$

K: Golden ratio coefficient of the parcel
f_p: Area of the parcel

C_p: Perimeter of the parcel

According to the formula, as the result becomes closer to 1, it will provide the best parcel size according to the golden ratio. Accordingly, the golden ratio coefficient of the parcel is 0 provided that K ≤ 0.7 and K ≥ 1.3, 1in case the golden ratio coefficient is between 0.7-0.8 and 1.2-1.3, 2 in case the golden ratio coefficient is between 0.8-0.9 and 1.1-1.2, and finally the golden ratio coefficient is arranged as 3 points between 0.9-1.1.

Distance to City Center: The market situation and transportation to the city play an important role in delivering the products to the consumption areas of the districts (Odabaşı, 2020). When the products obtained from the agricultural production districts are evaluated in terms of reaching the market and transportation cost, the scoring was made according to each 8 km, 2 points were given between 0-8 km, and 1 point was given between 8-16 km.

Distance to highway: Scoring was done according to the Aksaray-Adana State Highway, which is one of the most important main roads in Turkey and Aksaray passing through the outer border of the study area. According to the distance to the highway, it was determined to be 4 points between 0-1 km, 3 points between 1-3 km, and 2 points between 3-5 km, and 1 point between 5-7 km (Figure 4).

Status of Easement Right in the Land: The right of easement is a limited real right that grants some or all of the powers related to use and exploitation on an item to the right owner or prohibits the use of some of the rights of the owner of the item for the benefit of the right-holder (Yalpır, 2007). The establishment of an easement right on a real estate may affect the owner's right of use, income, and value of the land. In the study area, the parcels that are in the projection of the energy transmission lines are given 0 points, while the ones that are not in the projection are given 1 point (Figure 4).

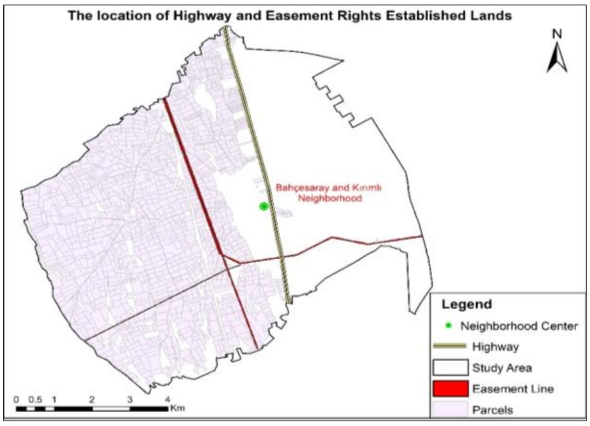

Figure 4. The location of the highway and Easement Rights Established Lands.

Distance to Neighborhood Center: The village of Hamidiye-Alaca, where agricultural production continues, it was divided into two: The Bahçesaray and Kırımlı Districts. Today, the neighborhoods maintain their rural characteristics and continue their agricultural production activities. Rural neighborhoods outside the zoning plan have a single center. For this reason, by scoring according to a single center, 4 points were given between 0-1 km, 3 points were given between 1-3 km, 2 points were given between 3-5 km, and 1 point was given between 5-7 km.

Irrigation Opportunity: Scoring was done according to the irrigation status of agricultural lands. Irrigable agricultural lands were given 1 point and non-irrigated agricultural lands were given 0 points (Figure 5).

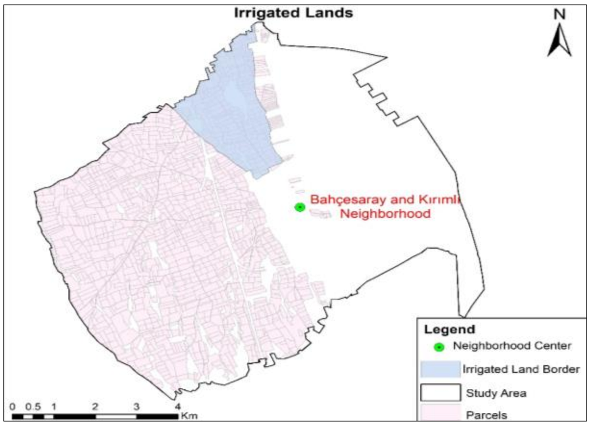

Figure 5. Irrigated lands.

Land Use Capability: Land Capability Classification (Land Use Capability Classes) is the physical determination of agricultural lands according to their suitability for tillage agricultural production, their characteristic features, and the number and type of problems limiting tillage agriculture (Doğrama, 2020). According to the technical instruction of soil and land classification standards, land use capability starts from the first (I) class suitable for agriculture and continues until the eighth (VIII) class, where no agricultural activity can be processed.

Starting from the first (I) class, the use of agricultural land decreases as the class rises. It is suitable for agricultural culture by cultivating the lands in the first, second, third and fourth classes, provided that good soil management and some soil protection measures are taken. Fifth, sixth, and seventh class lands, on the other hand, are not suitable for agricultural culture by cultivating the soil, but have the appropriate ability for meadow, pasture and tree cultivation. Some special types of fruit and vegetables can be grown in the fifth and sixth grades. VIII. On the other hand, no plant products can be obtained on the lands of the 2nd class (Bilal et al., 2022). In this context, according to the land use capability data obtained from Aksaray Provincial Directorate of Agriculture and Forestry, the first class where the is done best agriculture is given 8 points, the second class is given 7 points and the score of the eighth class is determined as 1. Since there was no eighth class land in the study area, scoring was made according to the seventh class land. (Figure 6).

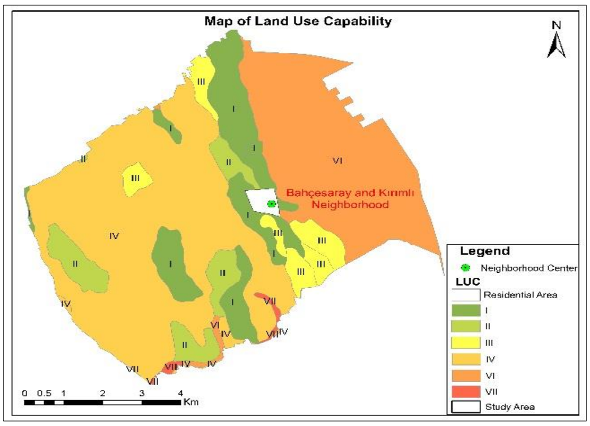

Figure 6. Land use capability.

Bordering the Pasture: In addition to agricultural activities, stock-breeding is also carried out on the lands in the study area. Pasture areas are important places for stock farming. In this context, the fact that agricultural lands are bordered by pasture, makes it easier to carry out stock-breeding activities together. (Ertaş, 2014). Within the scope of pasture information obtained from the Aksaray Cadastre Directorate, 1 point was given to the parcels bordering the pasture, while the score of the parcels not bordering the rangeland was determined as 0 (Figure 7).

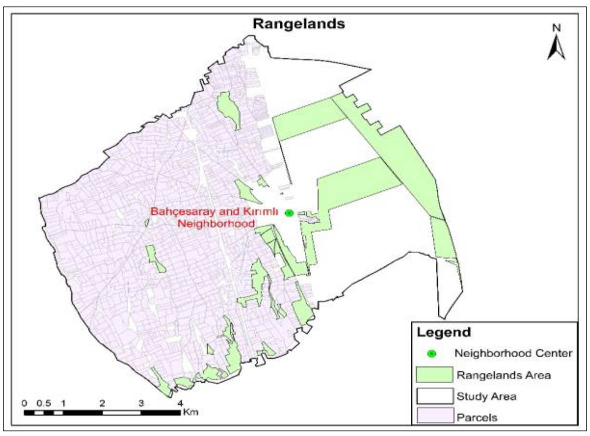

Figure 7. Rangelands in the study area.

Average Slope: The slope of the land is an important criterion for the cultivation of agricultural products. Since sloping lands are often exposed to erosion, it is a factor that makes it difficult to grow agricultural products. The slope map of the study area was created using the data obtained from the website of the United States Geological Survey (Url-4). The slopes of the land up to 6% are considered as flat or nearly flat. Since this slope will not hinder agricultural production, it is considered as a non-slope in the classification of sloping land. Generally, agricultural productivity decreases on lands with a slope of more than 6% (Başer, 2015). Accordingly, lands with a plot slope between 0% and 2% were given 3 points, those with a plot slope between 2% and 4%, were given 2 points, and 1 point was given for a plot slope between 4% and 6%+ (Figure 8).

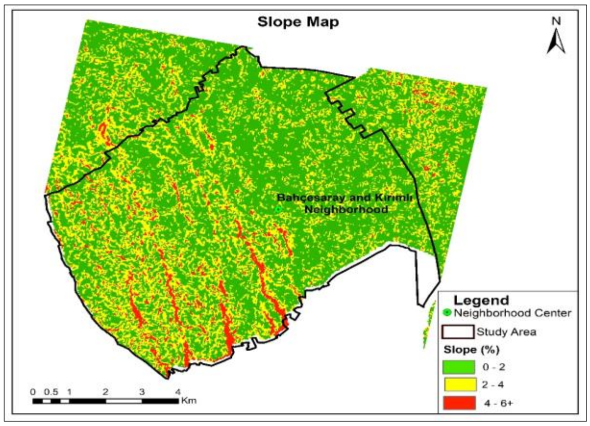

Figure 8. Slope map.

The Possibility of Being a Single Piece of Land and Generating New Parcels: The possibility of generating parcels is directly proportional to the size of the land. Since agriculture is a field of occupation made with the economic and physical contributions of family members, it is necessary for the owners of the lands to have the opportunity to generate large and new parcels (Ertaş, 2014).

According to the Soil Conservation and Land Use Law No. 5403, the criteria are that the minimum agricultural land size cannot be less than 2 hectares in absolute agricultural lands, marginal agricultural lands and special crop lands, 0.5 hectares in planted agricultural lands, and 0.3 hectares in greenhouse cultivation lands. exists. Furthermore, the size of agricultural land with sufficient income for the Central District of Aksaray Province, which is included in the Law No. 5403, is determined as 75 decares in irrigated land, 185 decares in dry land, 10 decares in planted land, and 3 decares in greenhouse land. While the minimum parcel size determined in this law and the parcels on subsistence land are 1, those below the specified criteria are given 0 points. 8 points are given for each divisible piece of eight or above that can be produced in multiples of the size as prescribed in the law numbered 5403, 7 points for seven pieces, 6 points for six pieces, and 1 point for one piece.

The boundary value scores of the criteria determined for the valuation of agricultural lands are shown in Table 2.

Table 2. Limit values and scores of the criteria used in the valuation.

Criteria	Limit Values and Scores
Irrigation Possibility	Available [1], N/A [0]
Land Use Capability	1st Class [8]
	2 st Class [7]
	3 st Class [6]
	4 st Class [5]
	5 st Class [4]
	6 st Class [3]
	7 st Class [2]
	8 st Class [1]
Distance to main road and Distance to village center	1 km [4]
	3 km [3]
	5 km [2]
	7 km [1]
Distance to city center	8 km [2]
	16 km [1]
Bordering pasture and forest areasland class	Available [1], N/A [0]
Right o easement facility on the land	Available [1], N/A [0]
Shape of the real property (Golden ratio rule)	0.1-0.7 [0]
	0.7-0.8 [1]
	0.8-0.9 [2]
	0.9-1.1 [3]
	1.1-1.2 [2]
	1.2-1.3 [1]
	1.3-2.0 [0]
One Piece of Land	Plot area > Subsistance Land Area [1] Plot area < Subsistance Land Area [0]
New Parcel Generation Opportunity (For each piece generated on subsistence land)	For 8 +piece of land [8]
	For 7 piece of land [7]
	For 6 piece of land [6]
	For 5 piece of land [5]
	For 4 piece of land [4]
	For 3 piece of land [3]
	For 2 piece of land [2]
	For 1 piece of land [1]
	For 0 piece of land [0]
Average Slope	0%-2% [3]
	2%-4% [2]
	4%-6+% [1]

2.7. Normalization of Data

In the analysis process to be performed with MRA and ANN, dependent and independent variables were normalized between 0.1 ≤ X ≤ 0.9 using Equation (10).

3. IMPLEMENTATION

3.1. Agricultural Land Value Estimation with Multiple Regression Analysis

To be used in the model, sales data of public institutions regarding 125 parcels with a known value in the study area were obtained. 70%(87) of this data was used as training data and 30% (38) was used as test data. MRA was performed with the help of the Statistical Package for The Social Sciences (SPSS) 26.0 program, and an R^2= 0.892 value was obtained as a result of the analysis. Since the R^2 value found is very close to 1, it was determined that the model is well explained by the independent variables. It was seen that the criteria that had the most positive effect on the value of the parcel and deemed as significant were the distance to the city center, the possibility of irrigation, the distance to the neighborhood center, and the main road (Tables 3, 4, 5 and 6).

Table 3. MRA R^2 and adjusted R^2 values.

Model	R	R Square	Adjusted R Square	Standart Error of the Estimate
1	0.952	0.906	0.892	0.05909

Table 4. MRA variant analysis (ANOVA) table.

Model	Sum of square	df	Mean Square	F	Sig.
Regression	2.513	11	0.228	65.425	,000^b
Residual	0.262	75	0.003		
TOTAL	2.775	86			

Table 5. MRA performance analysis.

Model	PERFORMANCE ANALYSIS				
		R^2	MAPE	MAE	RMSE
MRA	Training	0.91	0.195	0.044	0.055
	Testing	0.87	0.277	0.056	0.072

Xi: Represents the input value,
$Xmin$: Represents the smallest number in the input data,
$Xmax$: Represents the largest number in the input data (Han, et al., 2022).

$$\text{Normalization}=0,8*\frac{\text{Xi}-\text{Xmin}}{\text{Xmax}-\text{Xmin}}+0,1 \qquad (10)$$

Table 6. Table of MRA criteria coefficients.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Variance increase Factor
	B	Std. Error	β			VIF
Constant	-0.102	0.052		1.961	0.054	
Shape of the real property	0.051	0.026	0.072	1.933	0.057	1.113
Distance to city center	0.389	0.061	0.261	6.351	0.000	1.347
Distance to main road	0.147	0.059	0.192	2.498	0.015	4.690
Distance to neighborhood center	0.246	0.063	0.270	3.908	0.000	3.791
Irrigation possibility	0.292	0.030	0.481	9.813	0.000	1.907
Land Use Capability	-0.029	0.053	-0.022	-0.552	0.583	1.318
Proximity to do rangelands	0.039	0.025	0.067	1.567	0.121	1.445
Average Slope	0.071	0.035	0.089	2.037	0.045	1.526
Easement facility on the land	0.055	0.038	0.058	1.448	0.152	1.263
Land as one-piece	-0.024	0.020	-0.050	1.209	0.230	1.379
Possibility to generate new parcels	-0.097	0.066	-0.061	1.463	0.148	1.368

The F test value and R^2 value found from the model as a result of the analysis are among the important values that should be checked first. The F test is a test conducted with ANOVA to examine the significance of the regression model. The significance level corresponding to the F test value obtained as a result of the ANOVA test helps in the decision of the suitability of the created model. It was interpreted that the result of the F test is significant ($p<0.05$) and that the model makes a significant contribution to explaining the dependent variable. The R^2 value indicates that the % of the variance in the dependent variable is explained by the independent variable. The closer this value is to 1, the better the model is explained by the independent variables (Ünel, 2017).

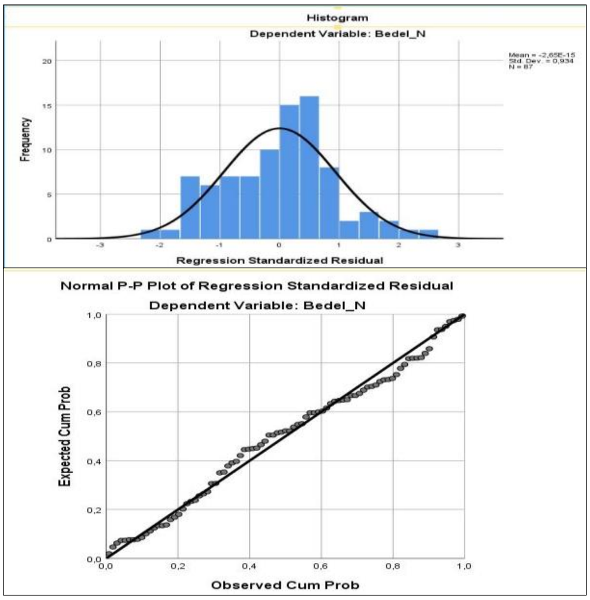

Figure 10. MRA results.

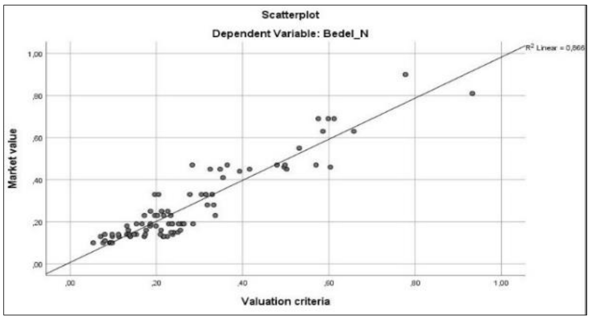

Figure 10. MRA results (continuation)

3.2. Agricultural Land Value Estimation with Artificial Neural Network Method

According to the data used in Multiple Regression analysis, ANN analysis was performed based on the Matrix Laboratory (MATLAB R2016b) program. 65% (81) of the sales data obtained from public institutions regarding 125 parcels in the study area were used as training data, 30% (38) were used as test data, and 5% (6) were used as validation data. Levenberg-Marquardt algorithm is selected as default in MATLAB R2016b program and ANN is used as backward feed. Whether the model is significant or not can be decided by looking at the R^2 value (Bilal et al., 2022). The training data has shown the model at the level of 95%, and the validation data confirms the model at the rate of 95%. In addition, the test data finds the model was significant at the rate of 87%. The significance and error rates of the created ANN model are shown in Table 7. According to these ratios, it can be interpreted that the performance of the ANN model is quite accurate and successful (Figure 11).

Table 7. ANN Performance analysis.

Model		PERFORMANCE ANALYSIS			
		R^2	MAPE	MAE	RMSE
ANN	Training	0.95	0.126	0.032	0.043
	Validation	0.95	0.120	0.020	0.027
	Testing	0.87	0.192	0.047	0.059

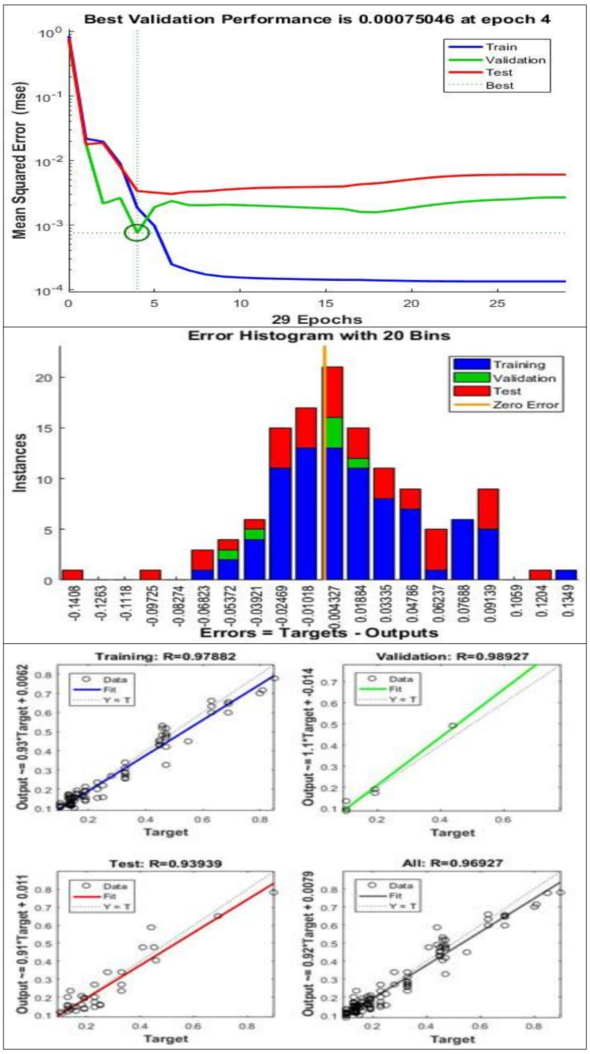

Figure 11. ANN results.

3.3. Comparison of MRA and ANN Application Results

R^2, MAPE, MAE, and RMSE are shown in Table 8 in the study to determine the value of agricultural lands with MRA and ANN. When these values are examined, it is understood that the most significant and the lowest error rate is according to the results obtained with the ANN method. In this case, it was concluded that the most successful model in the estimation of agricultural land was ANN properties

Table 8. ANN ve MRA performance analysis.

Model		PERFORMANCE ANALYSIS					
		R^2	MAPE	MAE	RMSE	COD	PRD
MRA	Training	0.91	0.195	0.044	0.055	19.49	1.04
	Testing	0.87	0.277	0.056	0.072	26.63	1.10
ANN	Training	0.95	0.126	0.032	0.043	12.77	1.02
	Validation	0.95	0.120	0.020	0.027	12.73	0.99
	Testing	0.87	0.192	0.047	0.059	19.58	1.02

One of the accepted performance measurement methods according to the proportional standards guide of IAAO is the coefficient of distribution (COD) and PRD value. The dispersion coefficient (COD) will give better results as it approaches 10 (ten). The performance standard for the COD distribution coefficient should be 15% or less for residential properties, 20% or less for commercial properties and 25% or less for agricultural land. (IAAO, 2013). PRD is an indicator of vertical equality. It is calculated by dividing the mean by the weighted average. The closer the value is to 1, the better the result will be. PRD values for all kinds of real estates are considered appropriate when they are between 0.98-1.03. (IAAO, 2013). If the PRD value is greater than 1, it indicates that parcels with higher values are undervalued and pull the weighted average lower. If the PRD value is less than 1, high value parcels will be proportionally more valuable. This indicates that the weighted average has been pulled higher (Url-1).

In this context, when comparing the ANN and MRA models according to the COD and PRD values, it was seen that the estimation results made with the ANN model were within acceptable limits according to the proportional standards guide of the IAAO.

The value estimation maps of the agricultural lands in the study area were drawn from the data obtained according to the model created by ANN and MRA methods (Figure 12). According to these maps, it was observed that the value of irrigated lands and the value of lands close to the main road is higher. In dry lands, it can be understood that there is a gradual decrease in the value of agricultural lands as they move away from the neighborhood center and the main road.

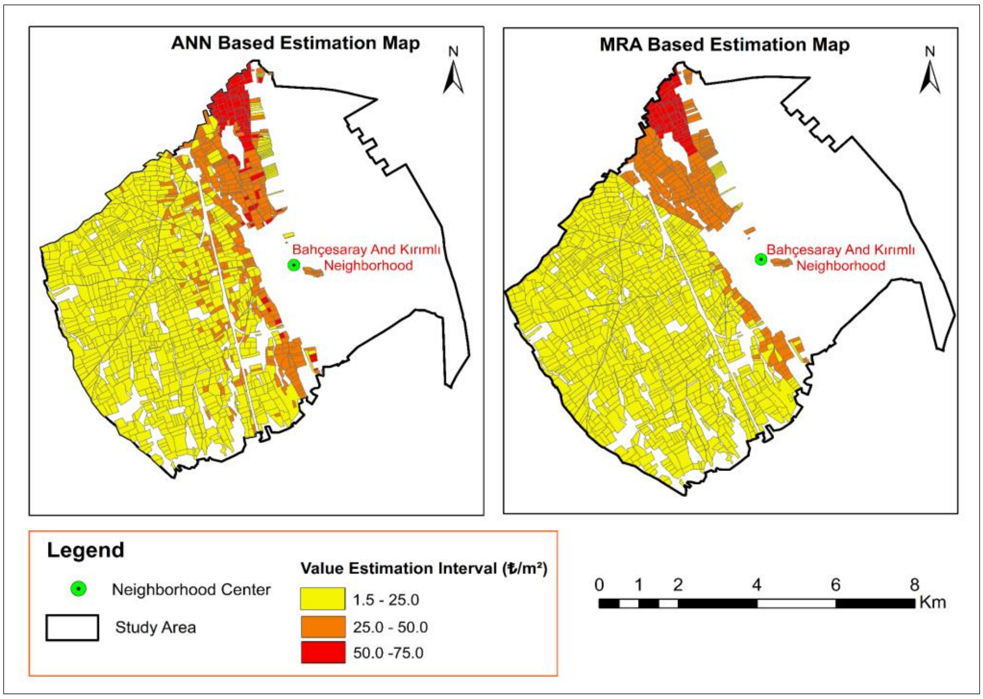

Figure 12. ANN and MRA based estimation maps.

4. CONCLUSİONS

While the Aksaray Province Merkez (Center) district was the Hamidiye-Alaca Village, it was divided into two to be Bahçesaray and Kırımlı Districts in 2014. However, the neighborhoods maintain their rural characteristics as a function and continue their agricultural production activities and are outside the scope of the zoning plan.

According to the sales data made by public institutions in the Central district of Aksaray province, the Bahçesaray and Kırımlı neighborhoods agricultural land valuation was carried out with ANN and MRA methods. A data set was created according to the sales values of 125 parcels obtained from public institutions. Using this data set, an algorithm for valuation was created with respect to the MRA model with the help of the SPSS program and the ANN model with the help of the MATLAB program. It was determined that the analysis with the most significant and least error yielding concerning the R^2, MAPE, MAE and RMSE results were derived by the algorithm as a consequence of the analysis with ANN. The COD and PRD values produced by the model algorithm created with the ANN were found to be within acceptable limits according to the proportional standards guide of the IAAO. Furthermore, it has been seen that the value maps drawn according to ANN give more accurate results and better reflect the value of the real estate.

Real estate valuation is carried out for various purposes such as expropriation, purchase and sale, crediting, taxation, and bank mortgaging. The valuation procedures for agricultural lands are generally carried out in the form of determining the capitalization value according to the income method. When a valuation is conducted according to the income method, the valuation process is carried out without considering the spatial criteria (distance to the main road, distance to the village center, and distance to the city center) and some of the productive criteria (the shape of the land, the easement on the real estate, etc.) where the agricultural land is located. Under these circumstances, this situation may not give accurate results in determining the values of agricultural lands. For this reason, it would be appropriate to use modern and statistical methods in valuation according to all criteria affecting the value of the real estate.

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Author Contributions

Hakan Karaduman: Conceptualization, Data curation, Methodology, Software, Writing-Original draft preparation. **Kamil Karatas**: Supervision, Methodology, Writing, Reviewing and Editing.

Conflicts of Interest

The authors declare no conflict of interest

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Petrographic and geochemical properties of the ignimbrites around Hatunsaray (Konya)

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ABSTRACT

The study area is located around the town of Hatunsaray, approximately 40 km away from the south-west of Konya. In this study, the petrological and geochemical characteristics of the Bulumya ignimbrite, Detse ignimbrite and Sadıklar ignimbrite observed in the region were revealed. The study area contains Upper Miocene - Lower Pliocene aged Güneydere formation and overlying Bulumya ignimbrite, Detse ignimbrite, Sadıklar ignimbrite and Quaternary alluviums. All these units were formed in the Upper Miocene - Lower Pliocene aged fluvial and lake environment and have a lateral vertical transition with carbonate, clastic units. The gray-colored Bulumya ignimbrite contains andesite-dacite rock fragments and large pumice grains. The Detse Ignimbrite is yellow in color and shows a well sorted lapilli tuff composition. The Sadıklar Ignimbrite, on the other hand, contains agglomeratic levels with yellow colored slightly fused lenses and wedge geometry. All ignimbrite samples have porphyric texture and were classified as "crystal-vitric tuff" and "crystal lithic-vitric tuff" in the glass-crystal-rock fragment classification. Petrographic investigations of ignimbrites show that major components are quartz, plagioclase, plagioclase microliths, biotite, amphibole, opaque minerals and rock fragments. Geochemical data shows that all ignimbrite samples are subalkaline, trachy-andesite, andesite-basaltic andesite and calc-alkaline in character. When the main oxide, trace and rare earth elements in ignimbrites are evaluated, fractional crystallization controlled by feldspar minerals is observed. In addition, the high K and Rb content in the spider diagrams indicate crustal contamination. The distribution of the ignimbrite samples in the Rb/Y-Nb/Y diagram suggests that the magma source forming the samples is enriched by subduction and/or crustal components.

1. INTRODUCTION

Extensive volcanic activity in Turkey developed as a result of the Arabian plate colliding with the Eurasian Plate before the Miocene. With this collision, which marked the beginning of the Neotectonic period, the formation of the East and North Anatolian faults began. The Anatolian block started moving westward along these two major faults, and widespread volcanic activity in the Neotectonic period occurred (McKenzie, 1972; Şengör et al., 1985; McKenzie and Yılmaz, 1991). Depending on these activities, volcanic rocks covered an area of approximately 85,000 km^2 in Eastern, Central and Western Anatolia. The predominantly calc-alkaline volcanic products located in the west of Konya covering large areas (Figure 1). Surrounded by the North Anatolian Fault in the north and the African-Anatolian convergence system in the south, this area is considered to have developed under transtensive and transpressive tectonic regimes that have been effective since the Late Miocene (Şengör et al., 1985; Kempler and Garfunkel, 1991) (Figure 1). According to Keller et al., (1977), volcanic activity in this area continued from the Late Miocene (11.9 Ma) to the Pliocene (3.35 Ma). A limited number of studies have been conducted on these volcanics around Konya (Ota and Dinçel, 1975; Keller et al., 1977; Ulu et al., 1994; Kurt et al., 2003; Koçak, 2012; Asan and Ertürk, 2013; Uyanık and Koçak, 2016; Koçak, 2017; Koçak, 2021). Petrological and geochemical data obtained from volcanic rocks provide information about the geodynamics of the study area. The aim of this study

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is to characterize the petrological and geochemical properties of ignimbritic rocks in the Konya (Hatunsaray) region and to interpret the origin of magmas. In the vicinity of the study area, the basement rocks form an ophiolitic complex with pre-Miocene schist, marble, quartzite, and dolomitic limestones (Eren, 1993; Koçak and Kaya, 2019). Volcanic, volcano-sedimentary units and lacustrine and fluvial sediments unconformably overlie these units (Keller et al., 1977; Ulu et al., 1994; Temel et al., 1995; Temel et al., 1998). Neo-autochthonous units follow a regional angular unconformity on the autochthonous and allochthonous paleotectonic formations in the region. These units belonging to the Late Miocene-Early Pliocene aged Dilekçi group formed in the neotectonic period begin with the Ulu Muhsine formation, which is composed of lacustrine limestones and marls at the bottom. The Küçük Muhsine formation, which includes tuff-tuffite-volcanic breccia and sandy-muddy clastics, is conformably observed in the Ulumuhsine formation. Erenlerdağı volcanics formed by lava flows of dacitic-andesitic composition overlie the Küçük Muhsine formation. On the other hand, the Plioquaternary aged, horizontally bedded, diagenetic conglomerate, sandstone, mudstone Topraklı formation overlies the lacustrine, volcano-sedimentary and volcanic faces units forming the Dilekçi group with an angular unconformity. All these units are covered by Quaternary alluvium, especially around Hatunsaray (Turan et al. 1997; Soğucaklı, 2006). The geology of the study area and its surroundings has been studied by Göğer and Kıral (1973), Özcan et al. (1990) and Ulu et al. (1994) and many researchers. Keller et al. (1977) and Temel et al. (1995) conducted studies on the geology, petrology and geochemistry and radiometric dating of the volcanics in the region. According to Keller et al. (1977), the age of the rocks was found to be 11.95-3.35 Ma by fossil content and radiometric dating method. In the study, ignimbrites cropping out in the region were examined under four different names: Kızılören ignimbrites, Erenkaya (Bulumya) ignimbrites, Detse (Kuzağıl) ignimbrites and Sadıklar ignimbrites. This study aims to approach the origin of ignimbrites by determining the petrographic and geochemical properties of Bulumya (Erenkaya) ignimbrites, Detse (Kuzağıl) ignimbrites and Sadıklar ignimbrites.

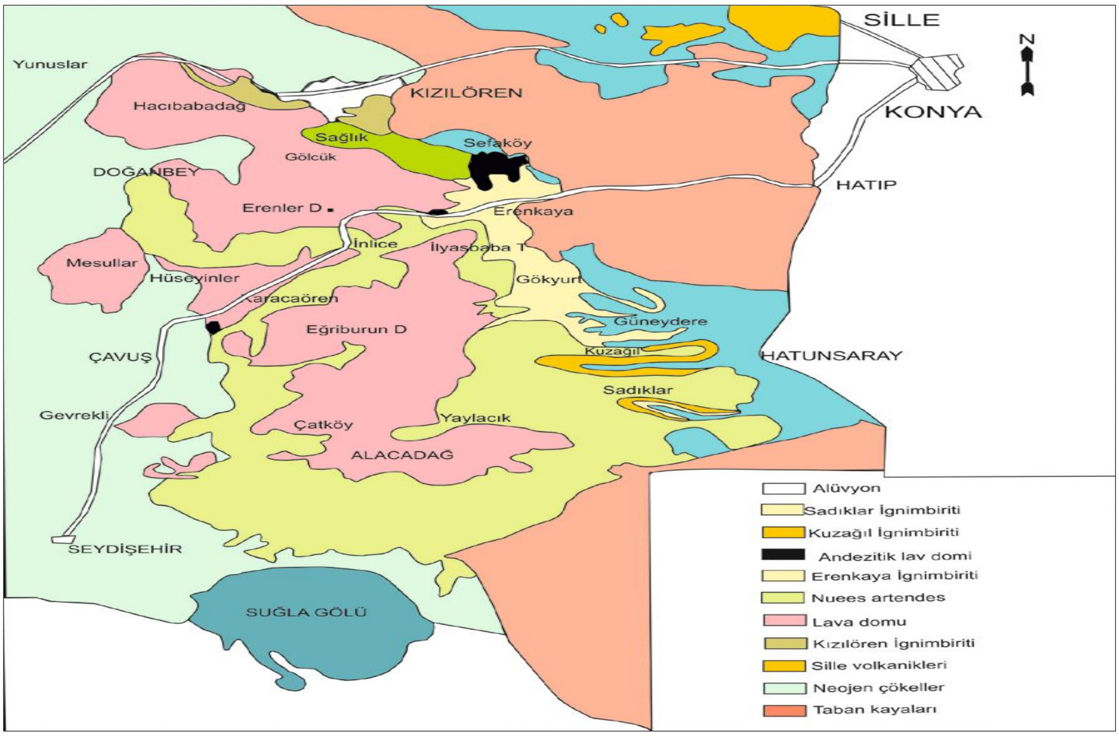

Figure 1. A regional geological map (Keller et al., 1977).

2. METHOD

Within the scope of the study, the stratigraphic relations of the units with each other were examined, and samples were taken for petrographic and geochemical investigations in the study area (Figure 2). Thin sections made for petrographic and mineralogical examinations were examined under polarizing microscope. These examinations were carried out in the Aksaray University Geological Engineering Optical microscope laboratory. The mineralogical, petrographic and textural properties of the rocks examined under the polarizing microscope were determined. According to petrographic examinations, main oxide, trace and rare earth element analyzes were made from the least altered samples. The samples were ground to approximately 200 mesh first in a jaw grinder and then in a ring grinder, were sent to ACME Analytical Laboratories for major oxide, trace and rare element analysis. Here, major oxide and trace elements were analyzed by X-Ray Diffractometry (XRD) and rare earth elements were analyzed by ICP-MS (Inductively coupled plasma-mass spectrometer).

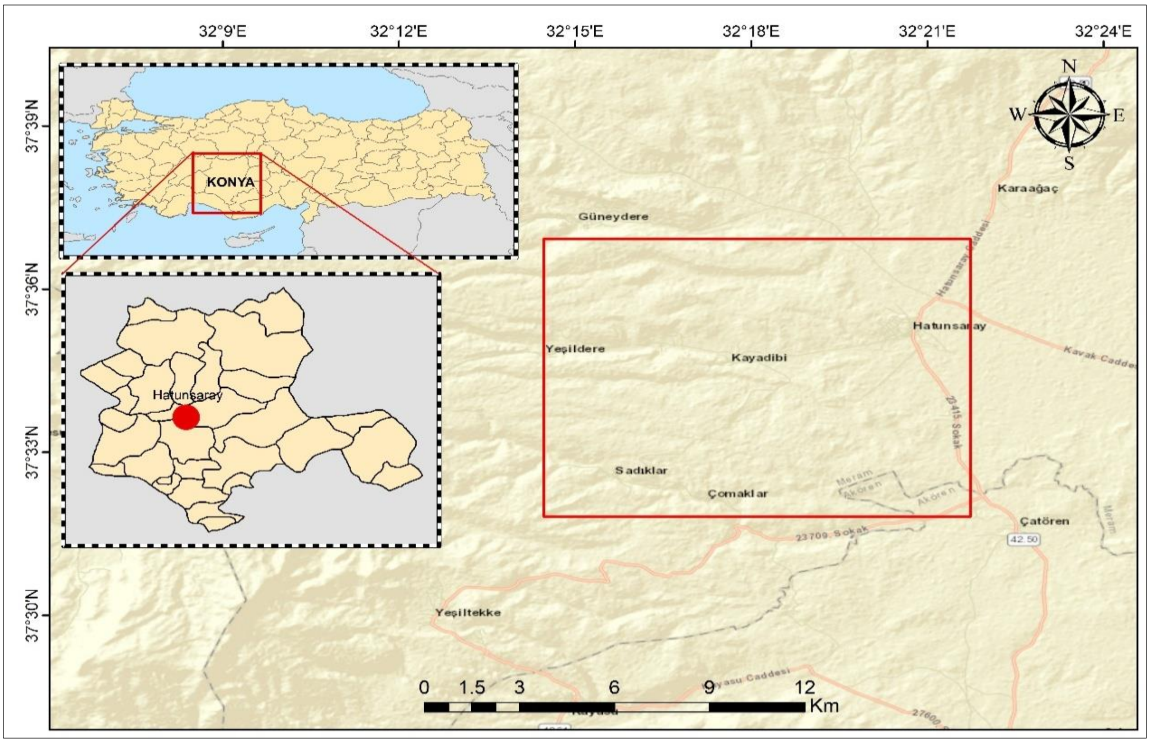

Figure 2. Study area.

3. RESULTS

3.1. General Geology

The Upper Miocene – Lower Pliocene aged Dilekçi group forms the basis of the units in the study area. The unit was named "Dilekçi formation" for the first time by Göğer and Kıral (1969). These units were later subdivided by Eren (1993) under the name of the Dilekçi group as Sille formation, Ulu Muhsine formation, and Küçük Muhsine formation. Since this study focuses on the petrographic and petrological characteristics of the ignimbrites in the region, no formation distinction was made in the clastics and carbonates in the Dilekçi group and they were examined as a single formation as the Güneydere formation. The Güneydere formation is Upper Miocene-Lower Pliocene aged and includes Bulumya ignimbrite, Detse ignimbrite, Sadıklar ignimbrite, Explosion breccia and nuée ardente (Glowing cloud) members from bottom to top. Alluviums consisting of loose sediments overlie these units unconformably.

3.1.1. Bulumya Ignimbrite

The Bulumya ignimbrite, named for the first time by Keller et al. (1977), consists of grey-coloured ignimbrites formed as two separate eruption phases. A nearly horizontal paleosol zone separated these two phases with an inclination of 0-5 degrees towards the south. In the lower levels of ignimbrite, massive, poorly sorted, thickness varying laterally according to topography, less fused, less crystalline, pumice-predominant andesite, basalt dacite rock fragments are observed in approximately 25 m thick. In the upper levels, it has a better fused, coarse and polycrystalline grain structure compared to the lower level. Both levels in the Bulumya ignimbrite have the same composition in terms of both chemical and mineral presence, and it has been determined that they are successive cooling units (Keller et al., 1977). Below the unit, pyroclastic surge deposits are located in lateral vertical transitions with clastic carbonate units, where these deposits are absent (Figure 3). Above it, Detse ignimbrite and Sadıklar ignimbrite overlain by eruption breccia and accompanying units where these units are not present. The age of the Bulumya ignimbrite was determined as 9-9.4 my in the age determination made by the K/Ar method by Keller et al. (1977).

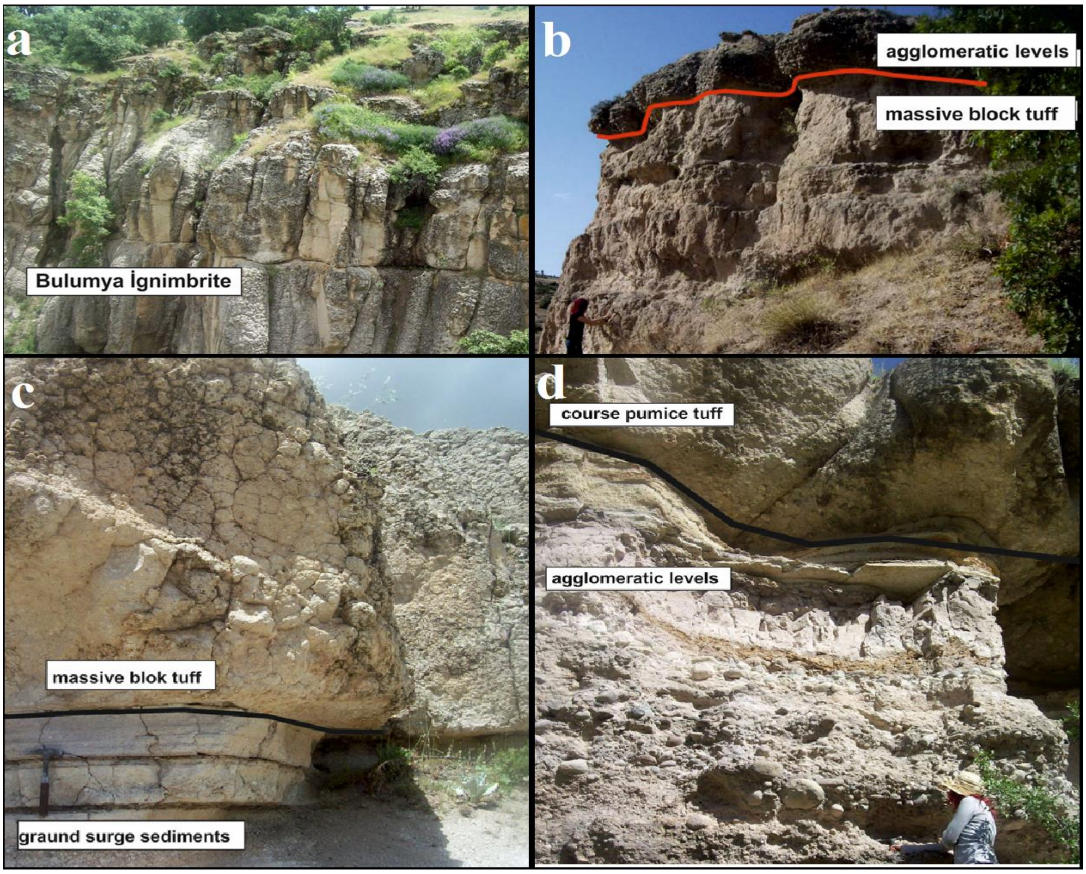

Figure 3. Bulumya Ignimbrite a) separation of the lower and upper levels by the paleosol level b) agglomeratic levels and tuff boundary view with massive blocks c) with massive block tuff and ground surge sediment d) course pumice tuff and agglomeratic levels.

3.1.2. Detse Ignimbrite

Detse ignimbrite is a yellow-colored lapilli tuff with well-sorted lower levels. This unit, which contains coarse pumice grains, andesite, dacite and basalt rock fragments towards the top, has a laterally variable thickness. It is thick, where the topography on which it flows is pits, and thin, where there are bumps. There are lens and wedge-shaped agglomeratic levels in places within the unit. In the lower levels of Detse ignimbrite, it has a massive, unbedded, tabular and occasionally irregular geometry. It contains andesite, dacite and basalt rock fragments in pumice and lapilli size. It is poorly sorted and the grains are supported by tuff matrix. In the upper parts, agglomeratic levels with lens and wedge geometry are dominant. It is a medium round, poorly sorted, consisting of andesite, dacite, basalt and pumice blocks (Figure 4). Bulumya ignimbrite is overlien by the Detse ignimbrite stratigraphically. Where Bulumya ignimbrite is not observed, it is laterally and vertically transitional with clastic and carbonate units. This unit is covered by the eruption and flow breccia and accompanying units.

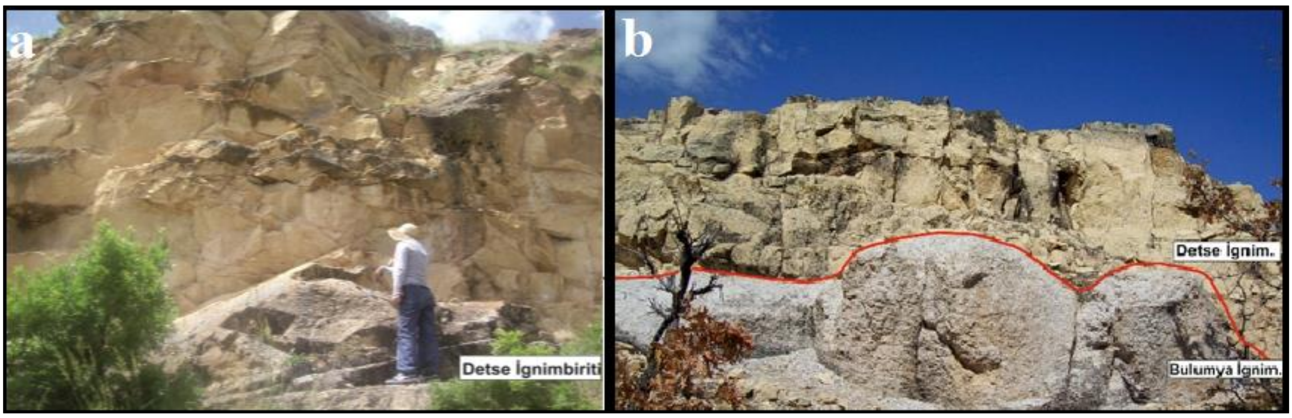

Figure 4. Detse Ignimbrite a) land view b) Bulumya ignimbrite border relation

3.1.3. Sadıklar Ignimbrite

Sadiklar ignimbrite generally contains yellow-colored, less fused, agglomeratic layers with lens and wedge geometry. In its upper levels, there are dust cloud surge deposits. Sadıklar ignimbrite is mostly homogeneous, fine-grained, sometimes ignimbritic tuff containing andesite pebbles. The approximate thickness of the unit is around 50 m. Sadıklar ignimbrite continues with a pink-colored fine-grained tuff level above the lapilli tuff levels containing agglomeratic levels at the bottom. Bulumya ignimbrite is located stratigraphically under the Sadıklar ignimbrite. Where the unit is not observed, it is laterally and vertically transitional with clastic and carbonate units. The lower level of the Sadiklar ignimbrite consists of lens-shaped, coarse-grained tuff layers. This level contains coarse tuff grains and fine lapilli with lens and wedge geometry and shows reverse gradation from place to place. Thick-bedded, poorly sorted, massive lapilli tuffs are observed over this unit (Figure 5).

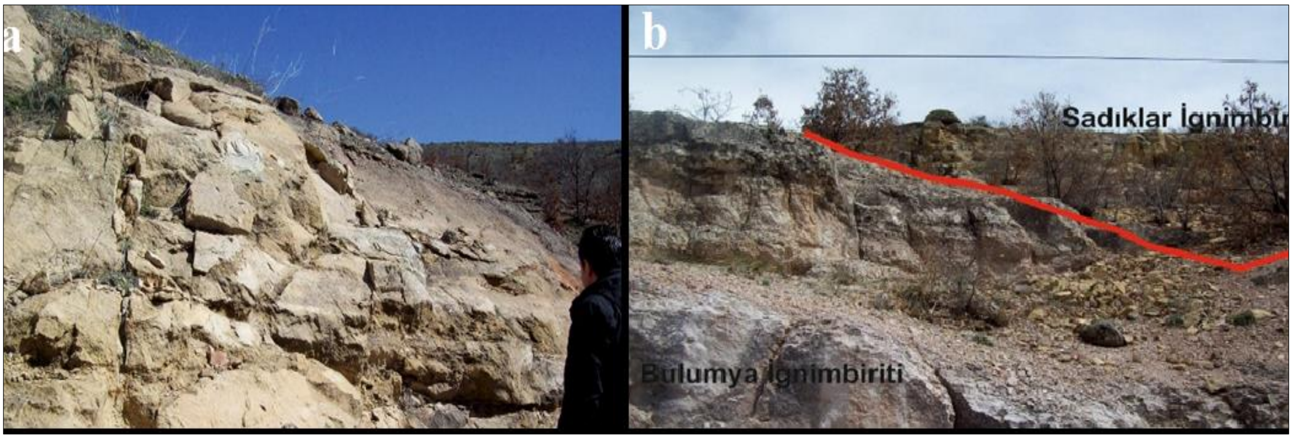

Figure 5. Sadıklar ignimbrite a) land view, b) Bulumya ignimbrite border relation.

3.1.4. Explosive breccia, nuée ardente and associated continental deposits

Named for the first time by Keller et al. (1977), this unit spreads over a very wide area in the study area and the region. This unit consists of agglomerate, red-brown colored tuff, conglomerate, sandstone, siltstone and lava alternation. The unit is approximately 50 m thick and laterally transitions to conglomerate, sandstone and sometimes lacustrine limestones (Ulu et al., 1994). In the age determination, it is stated that the age of the unit is 5.76 Ma. According to this data, the age of the unit is Upper Miocene – Lower Pliocene. The Detse ignimbrite and the Sadıklar ignimbrite are located under the unit. Alluvial deposits are unconformably overlying the unit.

3.2. Petrography

In the geological literature, the term ignimbrite was first used by Marshall (1935) to describe Taupo tuffs with acidic composition, which are widely spread and welded in some places. The definition of ignimbrite is made in different ways by different researchers. In these definitions, the term ignimbrite is sometimes used to describe a lithological unit corresponding to welded tuff. Sometimes it is used to mean a sediment formed as a result of pyroclastic flows. According to Sparks et al. (1973), ignimbrite is defined as "a special type of pyroclastic flow deposits containing abundant pumice, volcanic glass splinters, regardless of volume and degree of welding". McPhie et al. (1993) define it as "rocks formed by the combination of pumice fragments ranging in size from bomb to lapilli size and lesser lithic fragments by a matrix composed of vitric, crystal and lithic ash". Ignimbrites result from the collapse of an eruption column of a single explosion or a series of successive eruptions. As a result of the collapse of Plinian eruption columns, large volumes of pumice flows with abundant pumice occur. The pyroclastic material deposited from the Plinian eruption column flows along the surface due to gravity and is deposited in one place. Such flow deposits are defined as ignimbrite. Generally, the topography that fills the valley and depression areas shows controlled settlement (Cas and Wright, 1988).

The ignimbrites around Konya have been studied by many researchers (Göğer and Kıral, 1973; Özcan et al., 1990; Ulu et al., 1994; Keller et al., 1977; Temel et al., 1995). In these studies, ignimbrites cropping out in the region were studied under four different names: Kızılören ignimbrites, Erenkaya (Bulumya) ignimbrites, Detse (Kuzağıl) ignimbrites and Sadıklar ignimbrites. This study aims to approach the origin of ignimbrites by determining the petrographic and geochemical properties of Erenkaya (Bulumya) ignimbrites, Detse (Kuzağıl) ignimbrites and Sadıklar ignimbrites. The petrographic features of the Bulumya, Deste and Sadıklar Ignimbrites identified in the study area were revealed from the thin sections. In petrographical studies, the main mineralogical composition of ignimbrite samples was determined as quartz + plagioclase + plagioclase microliths +

biotite + amphibole + sericite + iron oxide + opaque mineral + volcanic glass + lithic component. Ignimbrites show a hypocrystalline porphyric texture. In petrographical studies, the main mineralogical composition of ignimbrite samples was determined as quartz + plagioclase + plagioclase microliths + biotite + amphibole + sericite + iron oxide + opaque mineral + volcanic glass + lithic component. Ignimbrites show hypocrystalline porphyritic texture according to the grain state (Table 1).

Table 1. Mineral compositions of ignimbrite samples detected in microscopic examinations.

Sample	Q	Plg	Plg Mic.	Bi	Ser.	Op	Fe	Volc. Glass	Lytic comp.	Name of the rock
B1	+	+	+	+	+	+	+	+	–	Crystal-vitric tuff
B2	+	+	+	+	+	+	±	+	–	Crystal-vitric tuff
B3	+	+	+	+	+	+	±	+	–	Crystal-vitric tuff
B4	+	+	+	+	+	+	±	+	–	Crystal-vitric tuff
B5	+	+	+	+	+	+	+	+	–	Crystal-vitric tuff
B6	+	+	+	+	+	+	+	+	+	crystal lithic vitric tuff
B7	+	+	+	+	+	+	+	+	+	crystal lithic vitric tuff
B8	+	+	+	+	+	+	±	+	–	Crystal-vitric tuff
D1	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
D2	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
D3	+	+	+		+	+	+	+	+	crystal lithic vitric tuff
D4	+	+	+	±	+	+	+	+	–	Crystal-vitric tuff
D5	+	+	+	–	+	–	–	+	–	Crystal-vitric tuff
D6	+	+	+	±	+	+	–	+	–	Crystal-vitric tuff
D7	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
D8	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
S1	+	+	+	–	+	+	±	+	–	Crystal-vitric tuff
S2	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
S3	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
S4	+	+	+	–	+	+	+	+	–	Crystal-vitric tuff
S5	+	+	+	–	+	+	±	+	–	Crystal-vitric tuff
S6	+	+	+	–	+	+	±	+	–	Crystal-vitric tuff
S7	+	+	+	–	+	+	+	+	+	crystal lithic vitric tuff
S8	+	+	+	–	+	+	+	+	+	crystal lithic vitric tuff

(Q; quartz, San; sanidine, Pl; plagioclase, Bi; biotite, Kal; Ser; serizite, Op; opaque mineral, Fe; iron oxide mineral)

In addition, vitrophyric texture, microcrystalline texture, poiklitic texture, glass splinters and pumice fragments were found in the ignimbrites. In the microscopic examination of the samples, sericitization, iron oxidation, opacitization, and chloritization type alterations are observed. Quartz in ignimbrites has been determined as different sizes and coarse-grained, and resorbing and fractures in quartz are noteworthy. Biotites are known as euhedral to subhedral, dark brown. In addition, there are bending, twisting and fractures in biotite. Alterations such as chloritization, iron oxidation and opacification have been observed in the biotites. Plagioclase minerals observed in different sizes, show polysynthetic and zonal extinction, and it has been calculated that they have oligoclase and andesine characteristics based on their extinction angle. Plagioclase minerals mostly show sericitization and argillization type weathering according to the matrix (Figure 6). The ignimbrite sampless were determined as “vitric tuff” in the classification of Schmid (1981) considering the glass-rock fragment-crystal components. In the classification made according to Carozzi (1993), the examined samples range from crystal vitreous tuff to crystalline lithic vitric tuff.

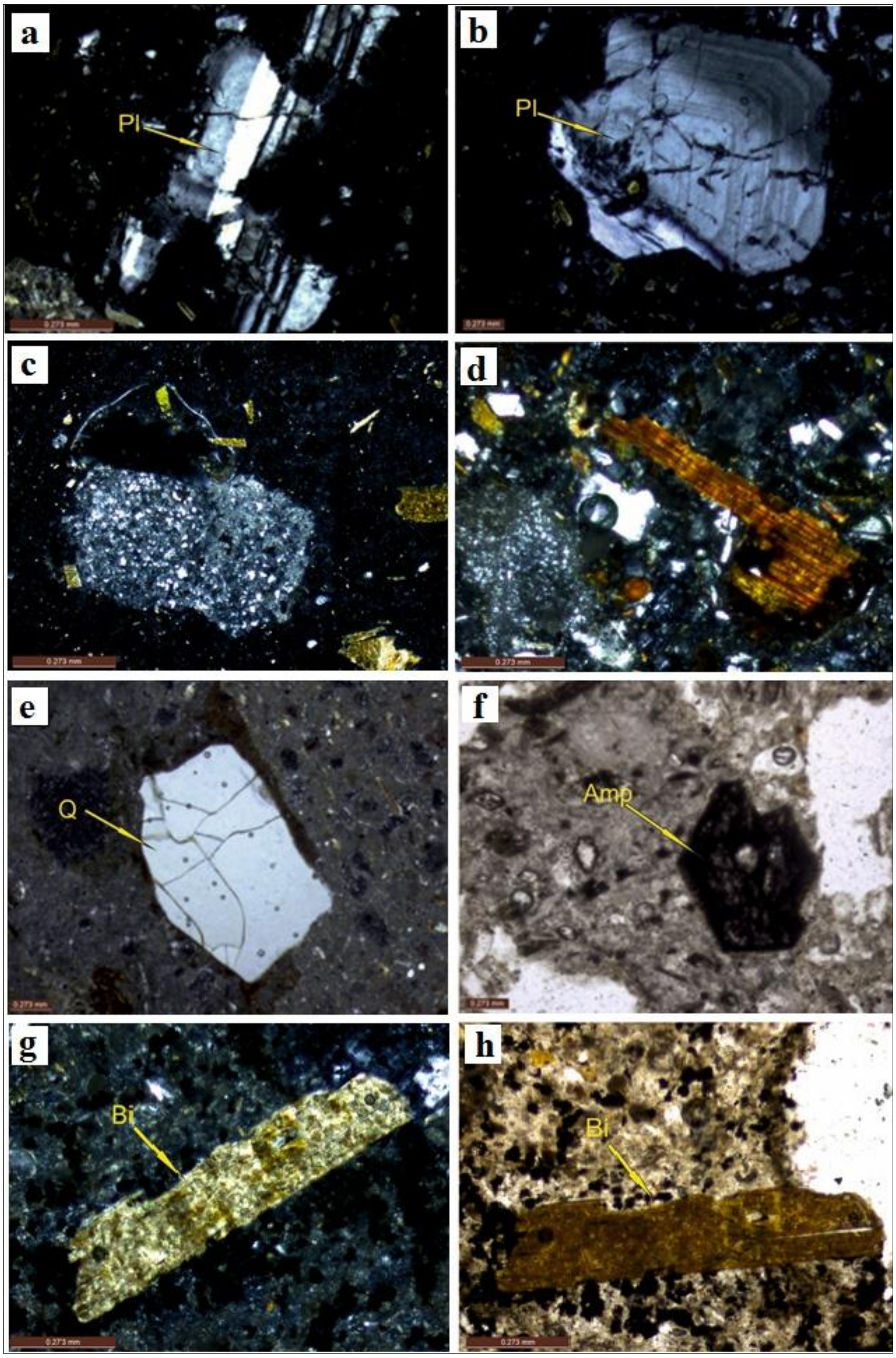

Figure 6. Ignimbrite samples a) Polysynthetic twinned plagioclase (double nicol) b) zoned plagioclase (single nicol) c) sericitization type alteration (cross nicol) d) resorbed edges biotite mineral (double nicol) e) significant fractures in the quartz mineral (double nicol) f) opacified amphibole g) biotite mineral (double nicol) h) biotite mineral (single nicol).

3.3. Geochemistry

3.3.1. Major and Trace Element Geochemistry

Major, trace and rare earth element analyses were carried out to determine the geochemical properties of the ignimbrite samples. The analysis results were interpreted using different diagrams, and the character and chemical properties of the magma forming the ignimbrites were constrained. In the samples, Al_2O_3 content varies between 5.31%-21.31%, SiO_2 53.16%-75.39%, MgO 0.01-1.09%, Fe_2O_3*, 0.01-5.55%, TiO_2 0.43-0.82%, CaO 0.08-2.6%, Na_2O content 0.03-1.63%, K_2O% It varies between 1.31-4.22, P_2O_5 0.08-0.86%, MnO 0.01-0.05% according to the matrix. The geochemical analysis of the ignimbrite samples is given in Table 1 and 2.

Table 2. Major oxide analyses of the ignimbrites.

Sample	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K2O %	P_2O_5 %	LOI %	TOTAL %
S5	73,99	0,67	8,42	0,01	0,01	0,01	0,08	0,03	1,66	0,3	15,9	101,08
S6	71,31	0,78	8,33	0,01	0.01	0,01	0,13	0,13	2,29	0,19	16,2	99,38
S7	57,68	0,66	21,19	0.02	0.02	0.01	0,16	0,09	4,22	0,86	17,01	101,86
S9	62,02	0,65	9,08	0,5	0,03	0,5	0,48	0,47	3,43	0,23	20,6	97,99
D2	73,1	0,74	6,86	0,1	0,01	0,1	0,27	0,32	2,17	0,35	15,7	99,72
D3	68,19	0,8	11,73	0,08	0,02	0,08	0,22	0,35	2,87	0,82	14,2	99,36
D5	75,39	0,82	5,31	0,37	0,02	0,37	0,48	0,16	1,31	0,22	15,8	100,25
D6	71,77	0,81	6,72	0,19	0,01	0,19	0,29	0,79	2,8	0,29	16,3	100,16
D8	72,37	0,55	7,56	0,15	0,03	0,15	0,63	0,45	2,11	0,85	14,3	99,15
B2	60,35	0,63	8,86	3,09	0,04	1,09	1,67	1,23	2,12	0,08	19,1	98,26
B3	60,49	0,56	6,02	4,81	0,05	0,81	0,98	0,71	1,9	0,68	20,2	98,21
B4	59,63	0,59	8,53	5,02	0,04	1,02	1,58	1,13	2,11	0,08	18,3	98,3
BI6	55,16	0,59	21,31	5,55	0,04	0,9	1,01	0,83	1,97	0,84	11,9	100,1
BI8	58,77	0,63	18,54	5,43	0,04	0,87	2,61	1,63	2,18	0,16	10,2	101,06

Table 3. Trace element results of ignimbrites.

Samp.	Sc ppm	Ba ppm	Cs ppm	Ga ppm	Hf ppm	Nb ppm	Rb ppm	Sr ppm	Ta ppm	Th ppm	U ppm	V ppm	W ppm	Zr ppm	Y ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	As ppm	Au ppm
S3	13	1211	12,4	62,9	6,6	18,6	42,5	1408,5	1,3	33,5	6,2	413	3,1	212,7	5	12,8	101,5	26	0,9	161,9	3,4
S5	3	969	3,2	40,6	3,8	13,8	8,5	272,7	1,1	17,8	5,1	231	3,8	129,9	2,1	2,5	244,7	17	0,5	73	1,1
S6	5	1014	9,3	22,7	5,7	13,5	37	234,2	1,2	11,1	2,2	143	2,8	201,1	1,5	3,7	159,1	15	0,5	47,1	2,2
S7	5	1347	1,7	25,2	5,1	12	19,3	969,3	1	34,2	2	186	1,9	178,8	1,9	2,7	1325,2	10	0,6	329,6	<0.5
S9	45	769	15,5	18,3	3	9,5	78,6	1162,5	0,5	18,1	4,4	365	2,4	137,1	3,8	15	18,3	83	5,8	14,8	<0.5
D2	10	923	4,7	10,4	5,5	12,3	43,4	800	0,8	29,5	4,5	78	1,8	196,5	6,6	4,4	142,1	14	0,9	36,3	3,6
D3	11	1262	4,7	27,2	5,5	13,3	38,7	1706,6	0,9	36,7	5,2	224	2,2	191,2	8,3	5,6	57,8	15	0,6	66,5	2,8
D5	7	718	8,2	23,6	6,9	16,7	40,7	604	1,6	19,3	5,4	168	3,5	256	6,3	12	22,2	40	4,6	8,5	3,1
D6	6	1281	3,5	8,1	5,1	13,6	48,1	404,4	0,8	28,8	5,1	91	2,1	200,8	6,1	3,2	30,4	6	0,3	37,7	1,6
D8	8	1785	5,6	21,1	3,4	9,1	59,3	2539,6	0,4	75,2	5	207	1,4	131,9	11	16,1	13,8	35	1,8	19	1,3
B2	16	684	13,4	15,3	5,4	10,1	109,4	474,9	0,7	15,3	6,7	118	1,7	190,9	14,1	25,3	16,9	54	4,7	1,5	7,6
B3	9	922	10,1	19,9	4	10,2	113	2307	0,7	19,8	6,6	137	0,6	159	15,6	14,8	9,5	46	2,5	1,3	1,2
B4	15	680	12,3	15,1	4,3	10,4	109	471	0,8	16,1	6,3	105	1	160	13,4	22,1	15,8	50	3,9	1,2	3,2
BI6	12	1191	12,6	17,3	5,8	11,8	109,8	2834,1	0,8	21,7	8,6	124	1,9	212,4	21,7	25,2	9,7	45	3,4	2,5	1,9
BI8	12	769	7,8	17,4	4,1	10	98,8	747,8	0,8	16,6	8,7	120	1,8	152,7	33,5	29,6	13,4	100	4,8	0,8	13,8

According to the analysis results of the ignimbrite samples, a total alkali (%Na_2O+ K_2O) - silica (%SiO_2) diagram was prepared to determine the character of the magma, and it was determined that the samples placed in this diagram fell into the subalkaline area (Figure 5a). The ignimbrite samples showing a subalkaline magma character were collected in the calc-alkaline area in the AFM diagram developed by Irvine and Baragar (1971) (Figure 5b). Examples are located in the high-K calc-alkaline series and Calc-alkaline series areas in the SiO_2 vs. K_2O diagram (Peccerillo and Taylor, 1976). It is known that the K calc-alkaline boundary of the K_2O–SiO_2 diagram is a feature that reflects the active continental margin and continental orogenic regions. In addition, samples with high calkali properties show high values in the orogenic series of large ion lithophile elements (e.g. K, Rb, Ba, Sr and Zr). Elements such as Zr, Nb, Y, TiO_2, which are known to be stable against chemical events such as alteration, metamorphism and metasomatism, are frequently used especially in nomenclature of the volcanic rocks, determining their petrological properties and tectonic formation environments. In the Nb/Y-Zr/TiO_2*0.0001 rock naming diagram (Pearce, 1996), created by using Nb, Y, Zr and TiO_2 elements, the samples are mostly found in trachy-andesite, andesite - basaltic andesite areas according to the matrix (Figure 7).

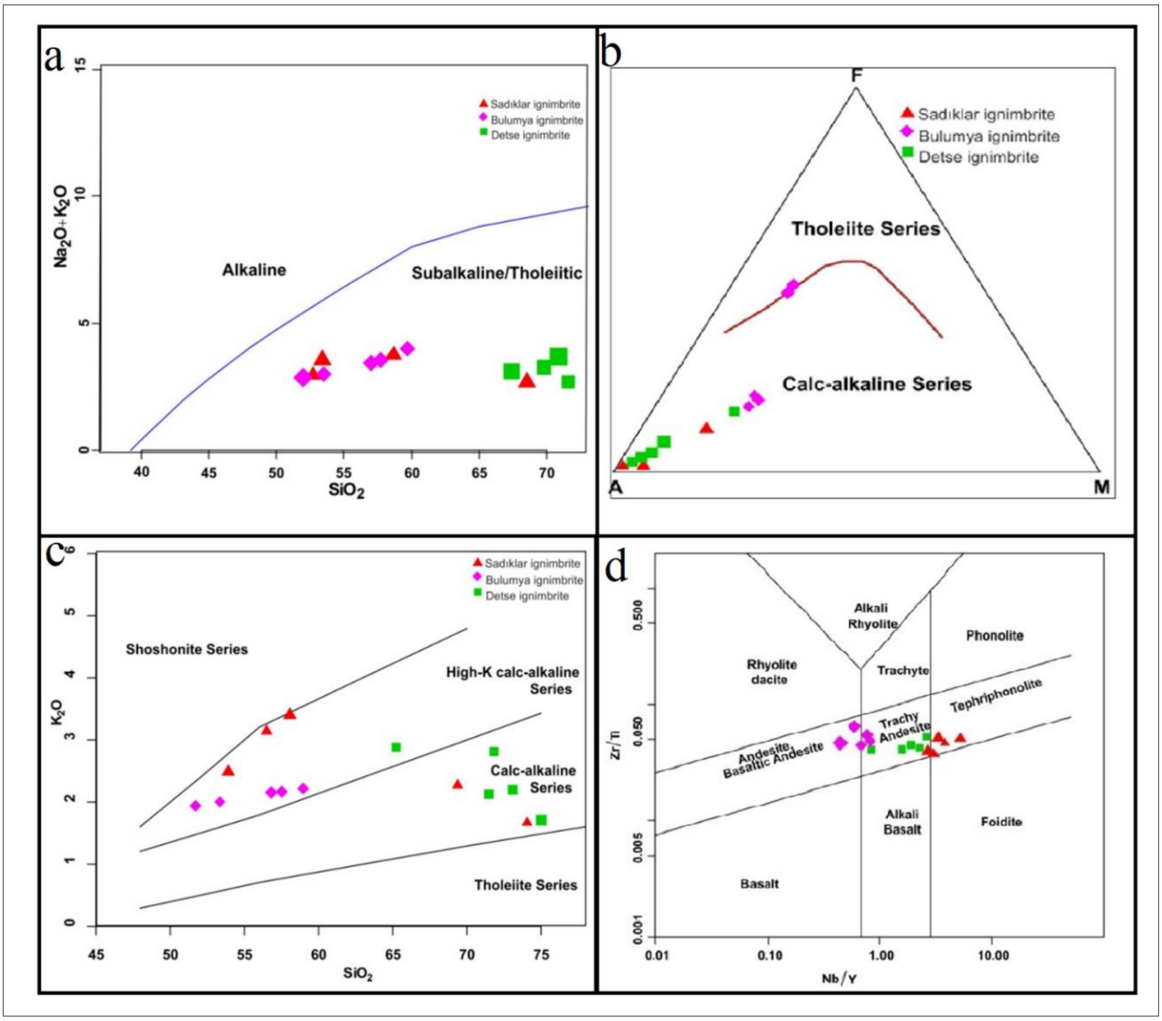

Figure 7. Nomenclature diagrams of the ignimbrite samples a) SiO_2(%)-Na_2O+K_2O (%) (Irvine and Baragar, 1971), b) AFM diagram (Irvine and Baragar 1971) c) SiO_2(%)-K_2O(%) diagram (Peccerillo and Taylor, 1976 (d) Nb/Y-Zr/TiO_2*0.0001 diagram (Pearce, 1996).

Harker diagrams were made to examine the behaviour of major and trace elements against SiO_2. No coherent variatıons were observed in the variation diagrams prepared by using the main oxide and trace element contents of the ignimbrite samples against SiO_2. In the main oxide element change diagrams of the samples, it is seen that MgO, Fe_2O_3, Al_2O_3 and CaO elements show a negative trend as SiO_2 amount increases. Also, in harker diagrams, the Bulumya samples differ from other samples and exhibit better correlations; SiO_2 contents increase with increasing CaO, Na_2O and K2O.This can be explained by the reduction of MgO, Fe_2O_3, Al_2O_3 and CaO elements by incorporating them into anorthite-rich plagioclase (Ca plagioclase), amphibole, biotite and opaque minerals (magnetite, titanomagnetite). The negative correlation with Al_2O_3 indicates the plagioclase fractionation in the development of ignimbrite samples. As the amount of SiO_2 increases, a positive increase is observed in the amount of Na_2O The observed positive increase in Na_2O can be explained by the incorporation of Na into the minerals formed later.In addition, against SiO2, MgO, CaO and. The decrease in Fe_2O_3 with the increase of SiO_2 indicates the fractionation of magnetite and titanomagnetite (Fe-Ti oxides). The reduction in MgO content probably associated with the clinopyroxene fractional while the reduction in Fe_2O_3 content be associated with the pyroxene and Fe-Ti oxide fractionation (Figure 8).

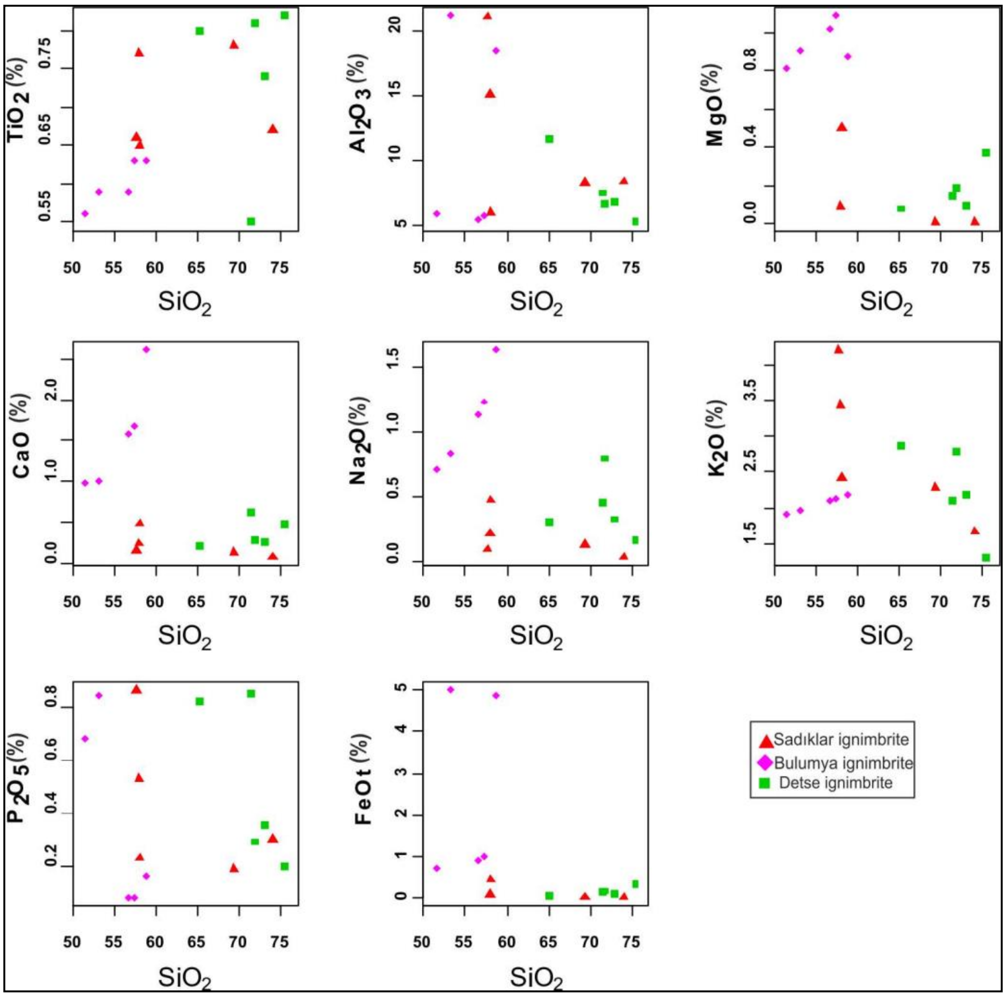

Figure 8. Main oxide element variation diagrams of ignimbrite samples versus SiO2.

It is seen that, in the trace element results of the ignimbrite samples examined in general, the large ion lithophile (LIL) element (K, Sr, Rb, Ba) amounts were higher than the high field strength (HFS) elements (Y, Hf, Zr, Ti, Nb). According to these diagrams, there is a negative relation between incompatible elements such as Rb and Ba and SiO_2, and a positive relation between compatible elements such as Sr and Nb. As the silica content increases, the incompatible element contents increase and the compatible element contents decrease, which is explained by fractional crystallization. It indicates that the rocks with these changes in the main oxide and trace elements may have been derived from the main magma by fractional crystallization. It is thought that the rocks with these changes in the main oxide and trace elements may have been derived from the main magma by fractional crystallization. However, the main magmatic event in the development of these rocks is not thought to be the effect of other magmatic events. (magma mixing, crustal contamination, etc.) The positive correlation of incompatible element K_2O against SiO_2 and increases in incompatible elements indicate that they are enriched probably due to crustal contamination and alteration. Since K-containing minerals (K-feldspar and biotite) are the last crystallized products in the magmatic melt, an increase is observed in the Rb element in parallel with the increase in SiO_2. The first increase and then decrease in Ba content against SiO_2 indicates the formation of sanidine in rhyolite-type tuffs (Rollinson, 1993). Since Hf and Zr elements have similar ion radii, they act together in the magmatic system. Zr is seen in large amounts in the last crystallized products during crystallization according to the matrix (Figure 9).

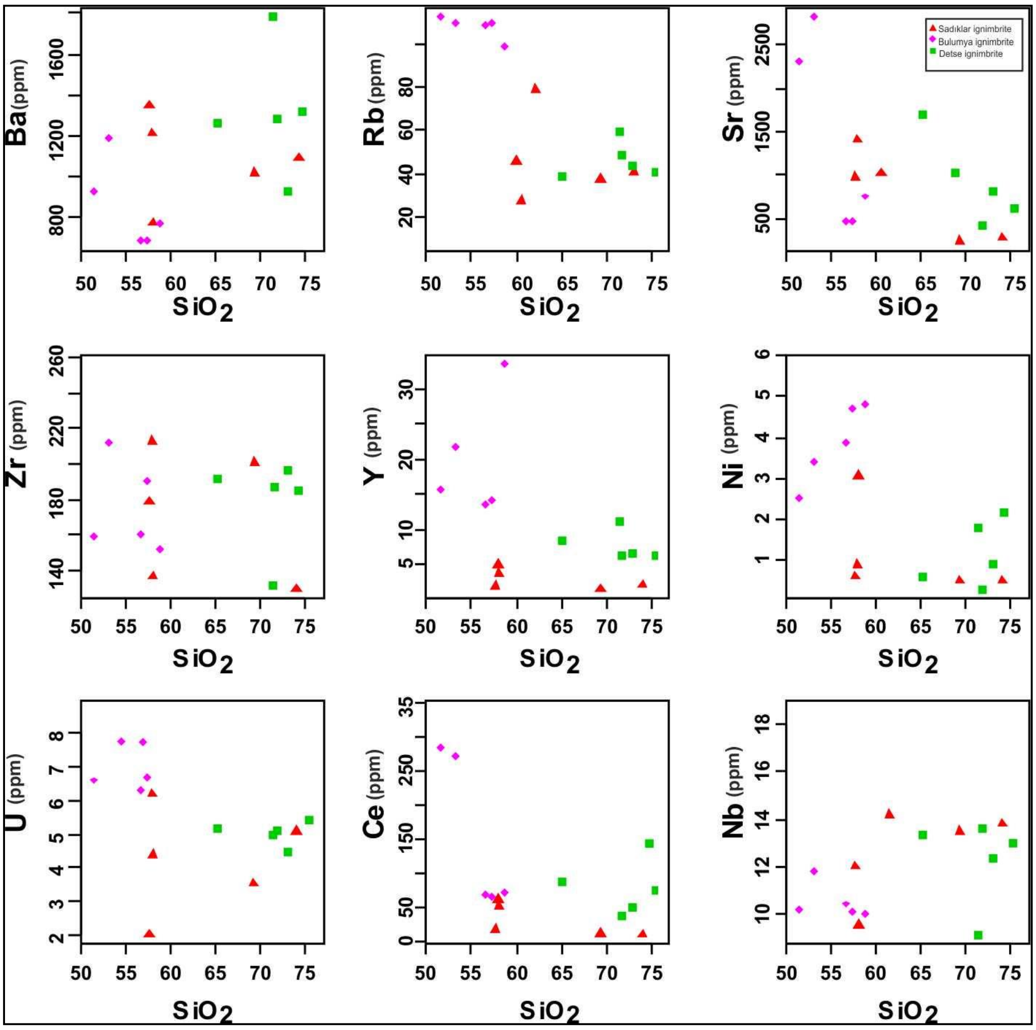

Figure 9. Trace element variation diagrams of ignimbrite samples versus SiO2.

The main magma was tried to be determined by drawing the trace element distributions of the samples normalized according to the primary mantle and chondrite. When looking at the spider diagrams normalized to the Primary Mantle, a significant lithophile element enrichment with a large ion radius and significant negative anomaly are observed in elements with high persistence. In the fractional crystallization process, the presence of positive anomalies in Sr and Ba elements shows the effect of feldspar minerals, and the presence of positive anomalies in Ti element (except for Bulumya samples) shows the effect of Fe-Ti oxide minerals. While the enrichment in K, Rb and Th elements may have resulted from crustal contamination, the presence of Nb anomaly indicates the effect of subduction and/or crustal components on the development of the main magma of the volcanic. When we look at the chondrite normalized spider diagrams, it is noteworthy that a lithophile element with a significantly large ion radius and elements with high enrichment and persistence, Pb, P and Ti are also consumed in REEs with significant negative anomalies. Lithophile element enrichment may result from continental crustal contamination. Excessive enrichment of rocks (especially K, Rb and Th) in terms of large ion lithophile elements (LILE) and depletion in terms of Nb and Ti are characteristic features observed in trace element distributions according to the matrix (Figure 10 and Figure 11).

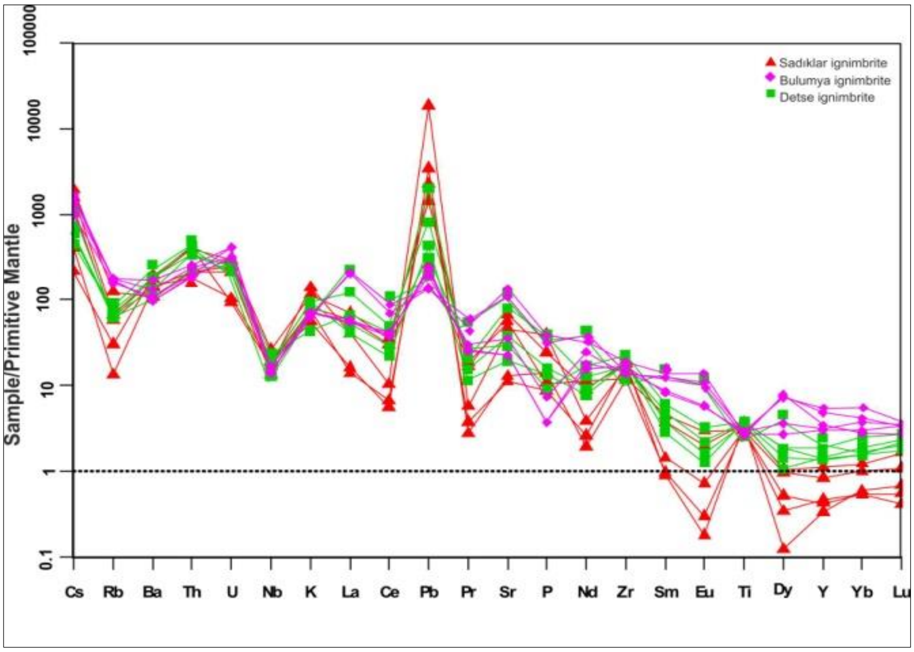

Figure 10. Examples of multi-element distributions normalized to the primary mantle (Normalization values, Sun and McDonough, 1989).

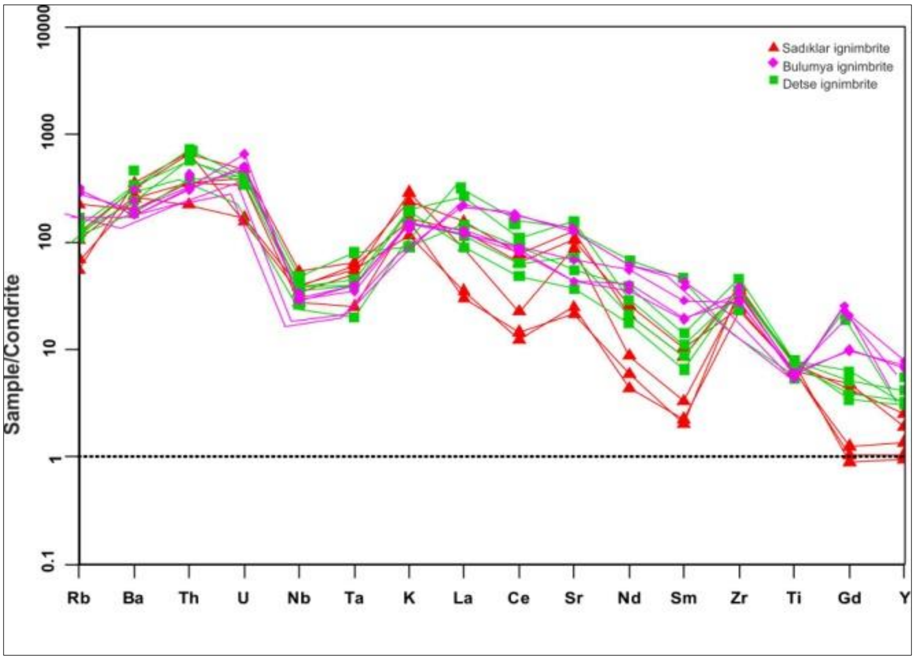

Figure 11. Examples of multi-element distributions normalized to the chondrite (Normalization values, Sun and McDonough, 1989).

Rare Earth Element Geochemistry

Values of rare earth elements of ignimbrite samples in the study area are given in Table 4. All sample distributions show parallelism with each other in the Rare Earth Element (REE) variation diagram normalized according to the chondrite of the examined samples. When the Rare Earth Element distributions were examined, it was seen that light rare earth elements (LREE) were more enriched by heavy rare earth elements (HREE). The high LREE/HREE ratios of the samples indicate an enriched mantle source. This suggests that the magma from which the ignimbrites are derived may have been influenced by the crust. This suggests that the magma from which the ignimbrites are derived may have been affected by the crust. More pronounced Negative Eu anomaly is observed in Sadıklar and Detse samples compared to Bulumya ignimbrite. Negative Eu anomaly in Sadıklar and Detse samples indicates that plagioclase fractionation plays an important role in the development of these rocks (Figure 12).

Table 4. Rare earth element contents (ppm) of ignimbrite samples.

Samp.	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
S3	48,8	62,3	4,54	12,3	1,66	0,33	1,18	0,21	0,77	0,2	0,65	0,09	0,6	0,12
S5	11,1	10	0,76	2,6	0,43	0,05	0,29	0,04	0,25	0,09	0,24	0,03	0,26	0,03
S6	9,5	11,8	1,04	3,5	0,39	0,03	0,25	0,03	0,09	0,03	0,11	0,03	0,29	0,05
S7	28	18,2	1,56	5,2	0,63	0,12	0,35	0,05	0,38	0,05	0,14	0,04	0,26	0,04
S9	40,5	52,8	5,21	15,3	1,99	0,49	1,34	0,18	0,7	0,13	0,51	0,07	0,49	0,08
D2	35,9	51,4	4,28	12,5	1,66	0,27	1,07	0,18	0,78	0,26	0,77	0,12	0,93	0,17
D3	84,4	88,7	5,71	17,2	2,12	0,37	1,42	0,22	1,35	0,36	0,98	0,16	1,25	0,2
D5	45,9	74,4	7,42	23,1	2,7	0,54	1,76	0,24	1,35	0,24	0,72	0,13	0,76	0,13
D6	28,1	39,2	3,17	10,5	1,25	0,21	0,95	0,15	1,04	0,21	0,78	0,11	0,76	0,16
D8	178,4	339,2	37,97	128,8	16,58	3,09	10,11	0,88	3,32	0,41	1,2	0,16	0,96	0,17
B2	38	66,1	6,84	21,2	3,64	0,95	2,72	0,46	2,64	0,5	1,52	0,24	1,82	0,26
B3	143	284	32,4	125	18,5	4,19	13,7	1,33	5,8	0,79	2,21	0,24	1,37	0,2
B4	40,6	70,2	7,1	24,2	3,79	0,99	2,83	0,46	1,98	0,47	1,45	0,22	1,46	0,25
BI6	137,7	272,8	30,86	120,5	17,52	3,74	12,37	1,39	5,49	0,89	2,25	0,33	2,04	0,25
BI8	37,5	73,4	8,2	33	5,49	1,79	5,77	0,99	5,31	1,2	3,31	0,55	3,49	0,55
P1	27,7	44,5	4,38	14,6	2,42	0,72	2,5	0,45	2,59	0,54	1,76	0,27	1,86	0,32
P2	27,2	45,5	3,97	12,3	1,73	0,39	1,25	0,22	1,15	0,26	0,83	0,13	1,07	0,14

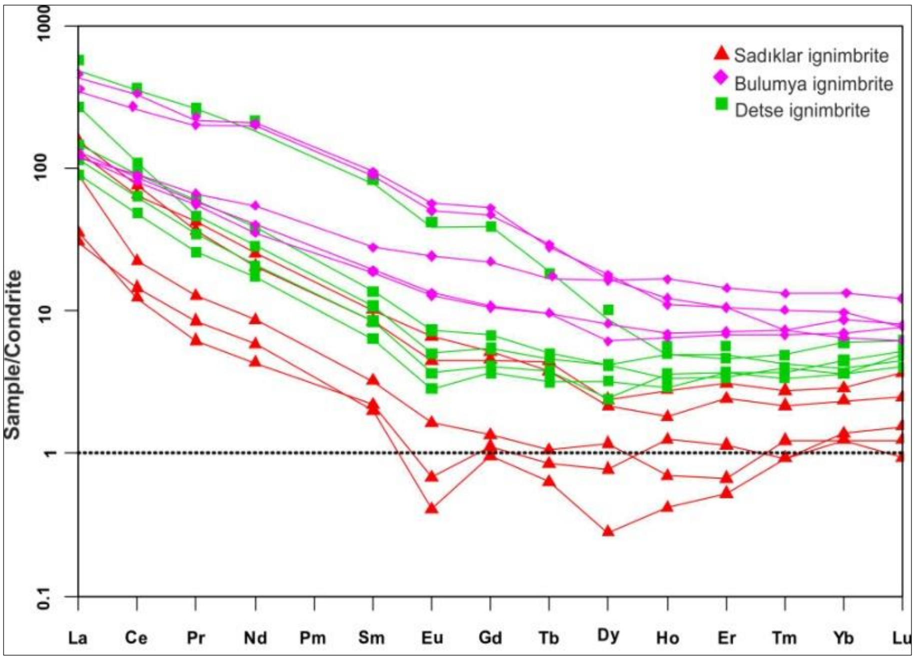

Figure 12. Rare earth element distribution plots of ignimbrite samples normalized to Chondrite (Normalization values are taken from Boynton, 1984).

Source Magma Features and Crustal Contamination

Various diagrams have been prepared in order to determine which minerals play an active role during the fractional crystallization process in the magma from which the ignimbrite samples are derived. In these diagrams, fractionation of plagioclase, olivine and apatite is observed in the samples with incompatible elements that are enriched in the melt during the fractional crystallization process. Their ratios to each other are known to remain constant. It is possible to determine which subplate enrichment and/or crustal contamination and in-plate enrichments are effective in developing igneous rocks with diagrams using trace element ratios such as Th/Y, Nb/Y and Rb/Y. The RbY-Nb/Y diagram was created to determine the origin of the main magma for the ignimbrite samples. In the Rb/Y-Nb/Y diagram, the

Rb/Nb=1 line shows intraplate enrichments, while the vertical variation shows subduction zone enrichments and/or crustal contamination (Edwards et al., 1991). The ignimbrite samples placed in this diagram show a vertical distribution (Figure 11b). This suggests that the magma source forming the ignimbrite samples is enriched by subduction and/or crustal components (Figure 13).

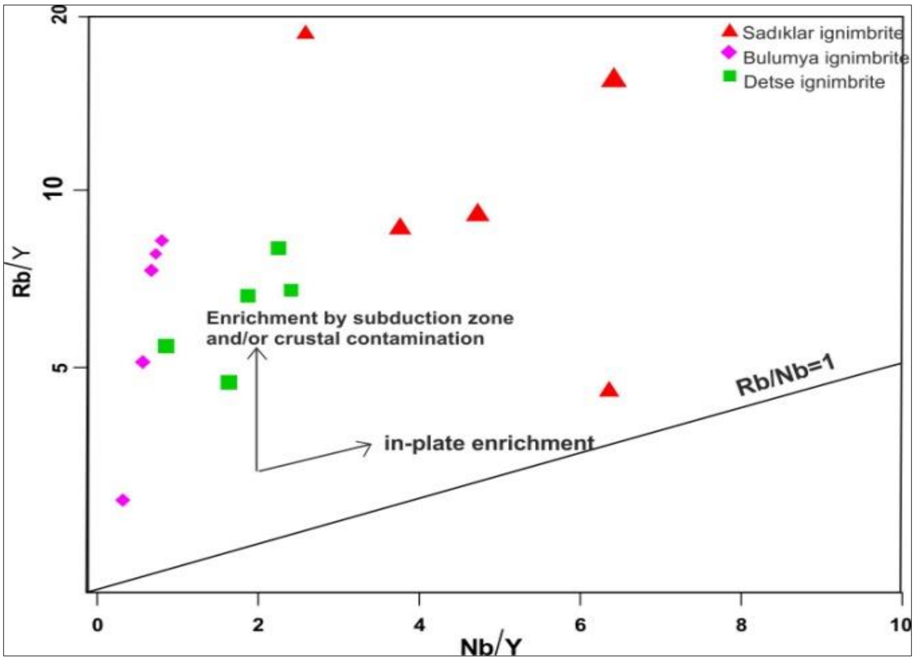

Figure 13. Nb/Y versus Rb/Y (Edwards et al., 1991) variation diagrams of ignimbrite specimens.

4. CONCLUSIONS

The study area is basically Upper Miocene - Lower Pliocene aged Güneydere formation and overlying Bulumya ignimbrite, Detse ignimbrite, Sadıklar ignimbrite and Quaternary alluviums. All these units were formed in the Upper Miocene - Lower Pliocene aged fluvial and lake environment and have a lateral vertical transition with carbonate and clastic units. The grey-colored Bulumya ignimbrite contains andesite-dacite rock fragments and large pumice grains. The Detse ignimbrite is yellow in colour and shows a well-sorted lapilli tuff composition. The Sadiklar ignimbrite contains agglomeratic levels with yellow-coloured, slightly fused lenses and wedge geometry. All ignimbrite samples have porphyritic texture and were classified as "crystal-vitric tuff" and "crystal lithic-vitric tuff" in the glass-crystal-rock fragment classification. In petrographic investigations of ignimbrites, general mineral paragenesis consists of quartz, plagioclase, plagioclase microliths, biotite, muscovite, amphibole, opaque minerals and rock fragments. When geochemical data are evaluated, it is observed that all ignimbrite samples are sub-alkaline, trachy-andesite, andesite-basaltic andesite and calc-alkaline in character. When the primary mantle and chondrite normalized spider diagrams are examined, a significant lithophile element enrichment with a large ion radius and significant negative anomaly in elements with high persistence and depletion in REEs are observed. When the Rare Earth Element distributions were examined, it was seen that light rare earth elements (LREE) were more enriched by heavy rare earth elements (HREE). The high LREE/HREE ratios of the samples indicate an enriched mantle source. In addition, the high K and Rb content in the spider diagrams indicate shell contamination. The Rb/Y-Nb/Y diagram suggests that the magma source constituting the ignimbrite samples is enriched by subduction and/or crustal components.

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Author Contributions

Hacer Bilgilioğlu: Methodology, Validation, Formal analysis, Writing-Original Draft, Writing- Reviewing and Editing, Visualization. **Halil Baş**: Conceptualization, Methodology.

Conflicts of Interest

The authors declare no conflict of interest.

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Comparison of classical-RTK and network-RTK surveying methods in coastal regions

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Classic-RTK
Network-RTK
Static

ABSTRACT

Since the beginning of human life, human beings have wanted to know their location, and have therefore tried to find out where they are and where they are going throughout their lives. Researches and inventions that have shaped this situation have followed one another. Throughout history, the methods used to obtain location information have improved day by day, and the possibilities of obtaining precise location information faster with more ergonomic devices have emerged. Recently, the Real Time Kinematics have attracted attention in this respect. In this study, "Comparison of Classical-RTK and Network-RTK surveying methods in Coastal Regions" was conducted in Coastal Regions. For this purpose, 12 point locations were determined by creating two separate study areas in two different regions with an approximate surface area of 3.078 km2 and 1.346 km2 in the coastal region. When a base was created between TUSAGA-Active points namely, N4, N5, N6, IN1, IN2, IN3 were located in the inside and N1, N2, N3, DN1, DN2, DN3 points were located in the outside part of the network structure. Static, Classical-RTK and Network-RTK measurement methods were used at 12 points in the study areas in both regions. First of all, static measurements were made at 12 points were taken into account as a reference values for the comparison of the measurements from both Classical-RTK and Network-RTK methods. The differences of the static measurement values and the measurement values obtained by Classical-RTK and Network-RTK measurement methods were taken respectively. These measurement differences were analyzed and compared in various aspects.

1. INTRODUCTION

When the paths followed to access location information since the past and the researches carried out for this purpose, the methods discovered and developed are examined, engineering applications and geodetic research have become more and more important day by day. One of the most significant developments in this regard has been the Global Positioning System (GPS). Its introduction to civilian use in the 1980s opened up avenues for research in cartography, surveying, geodetic applications, tracking changes in the Earth's crust, vehicle navigation systems, and engineering services (Telli et al., 2014).

Throughout history, the methods used to obtain location information have evolved with each passing day, and this development has tended to obtain faster and more precise location information with more ergonomic devices (Sickle, 2015). Some situations brought about by developing and changing conditions have paved the way for the discovery of new position determination methods and techniques, and the new position determination methods and techniques discovered have been included in Global Navigation Satellite Systems (GNSS) systems (Telli et al., 2014). Classical-RTK (Real Time Kinematic) measurement method is a GNSS measurement method, briefly defined as Classical-RTK, which allows the position information to be obtained in the field at the time of measurement by sending data from the fixed reference receiver in the field to the mobile receiver for measurements and enables precise results to be obtained in a short time (Lachapelle and Ryan, 2002). A limitation of the classical RTK surveying method is that the mobile receiver is dependent on a fixed reference station and there is a limit to the distance to this fixed station. In the light of these ideas, a new positioning method called Network-RTK or also known as CORS (Continuously Operating Reference Station) has been developed to

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overcome the existing limitations (Raquet, 1998; Landau et al., 2002). Network-RTK has assumed the role of an alternative measurement method by minimizing the limitations of the Classical-RTK measurement method to almost the minimum level (Mekik, 2004). To use this technique, also known as Network-RTK or CORS, many countries have established a network of fixed stations for continuous observation. For the use of this technique in our country, a system called TUSAGA-AKTIF (Turkey National Fixed GNSS Stations Network- Active) or CORS-TR, consisting of 158 fixed reference stations, has been established since 2009 to cover the entire country (Kalkan and Alkan, 2005).

The areas where location information is needed have expanded over time, and cartography activities have become increasingly widespread. Some situations brought about by evolving and changing conditions have initiated searches for new location determination methods and techniques. As a result, newly discovered location determination methods and techniques have been included in GNSS systems (Telli et al., 2014).

Coastal regions in the world can be preferred in many different areas such as tourism, transportation, industry and settlement. This situation is also preferred in our country in the same way and some damages occur at the same time (e.g. unplanned development, destruction of nature, etc.) (Aykut et al., 2005). As a result of changes in the earth's surface, the instantaneous position of any location can be affected by this change and the accuracy of the position can change accordingly.

The satellite-based positioning system, which was initially determined only by the GPS satellite system produced by the United States of America, was later expanded with different satellites accompanying GPS satellites, satellites developed by the leading countries of the world, America, Russia, the European Union, China, Japan and India, and a large GNSS network was created. The satellite systems, called GNSS for short, consist of GPS, GLONASS, GALILEO, COMPASS/BEIDOU, etc. (Cansız, 2013). A large system for location information has been created by developing different artificial satellites that can access location information. Although these developed systems are different, it is likely that they have used similar infrastructures in the same areas since they basically serve the same purpose (Kahveci and Yıldız, 2007). GNSS, in particular GPS, provides ellipsoidal height when used for position determination. Ellipsoidal height is a measure of height calculated relative to the reference ellipsoid. The relation between orthometric height and ellipsoidal height is H=h-N (Yurt, 2005).

There have been many research studies on GNSS measurement methods and techniques from past to present. Some of these are as follows:

1- "Performance of Single Base RTK GNSS Method versus Network RTK" in this study, the Performance of Single-Base RTK GNSS Method against Network RTK is investigated. The CORS-TR network RTK solution was used at the same points and the results were compared The performance tests of the YLDZ station were carried on in two stages.

In the first stage, the coordinates of YLDZ station were determined in the CORS-TR network by real-time measurements using the VRS method. As a result of this measurement, the precision of coordinates and standard deviations of the YLDZ point was calculated in the CORS-TR network system datum. In the second stage, test surveys were carried out in 5 pillar-constructed benchmarks with a 5 repeatability up to 50 kilometers from YLDZ single base station, in distances of 10, 15, 25, 40 and 50 kilometers respectively. As a result of the measurements carried with the CORS-TR network at the benchmark points, the differences between the known and measured coordinates are under 3-4 cm horizontally and vertically. The results of the measurements with 5 repeatability are close to each other at the same benchmark points. The standard deviations of these are near/under 1 cm horizontally and 3-4 cm vertically. The coordinate differences determined by the two RTK solutions were under 1.5 cm with 99% of measured epochs (Aykut et al., 2015).

2- In a different study, locations of the points in 10 regions with thirty points each determined in two different ways, using only GPS satellites and GPS, GLONASS satellites. Measurement results of 300 points located in different regions, comparison was made as a whole. The average errors were found to be between ±2.21 cm ±7.81 cm. The highest differences were observed in heights (Inal et al., 2015).

3- Another example of a study is the usability of GNSS mass market receivers for cadastral surveys, considering RTK and NRTK techniques. For this, 4 different areas were identified and 16 points two different techniques have been investigated: the RTK single-base positioning considering both master and rover L1 multi constellation receivers and the NRTK positioning using the VRS and NRT corrections. Considering the same points used for single-base positioning, the NRTK survey has been done using the VRS correction. 16 points have been considered in four different areas, along different boundaries of cadastral parcels, performing a single-base RTK survey. The mass-market master device has been placed on well-known point about 1, 3, 5, 8 and 10 km far from the rover site. It has been observed that if the distance between the main and roving receivers is less than 5 km, a single-base methodology can be exploited, while if the distance inter-station increases, it is better to use NRTK positioning if a CORS network is available (Dabove, 2019).

4- Statistical analysis of accuracy and precision of GNSS receivers used in network RTK, another example of a study called, accuracy and precision of GNSS receivers are tried to determine depending on different correction techniques. For this purpose, 12-h GNSS observations were performed at SLCK-Turkish National Fundamental GPS Network (SLCK-TNFGN) point. The observations were adjusted based on CORS-TR. N-RTK measurements were performed with different GNSS receivers, and accuracies of the receivers were investigated.

Measurements were performed by using four different GNSS receivers and three different correction techniques at the SLCK-TNFGN point located in Selçuk University Campus Area. In the measurements, the same survey team, the same atmospheric conditions and the same satellite configuration were used. A comparison was made in terms of accuracy and precision at the 2D position and the height of the receivers used. The 2D position accuracy and precision of the receivers were found to vary depending on the height correction techniques (Inal et al., 2018).

In geodetic studies, Classical-RTK and Network-RTK (CORS) measurement methods are almost exclusively used for ease and speed of processing. Investigations of the location accuracies obtained by these methods were carried out in the inner regions of the network of TUSAGA-Active points, but not in the edges. In this study, measurements were made at the edges of the network and the accuracy between Classical-RTK and Network-RTK was investigated.

2. REAL-TIME KINEMATIC MEASUREMENT METHOD (RTK)

Previously, the information obtained as a result of measurements made using Static and Real-Time Kinematic measurement methods could only be used by evaluating it in various software. This is not the case for every study, and some studies in particular required instantaneous location data at the moment of measurement in the field (Leick, 1995).

2.1. Classical-RTK

In the classical-RTK method, the fixed GNSS receiver at the reference station transmits the error corrections calculated at the fixed point to the roving receiver over radio frequency between the fixed GNSS receiver and the roving GNSS receiver. GNSS rover-receivers that receive the correction in this way can instantly display the coordinates of each point to be located on the GNSS receiver screen during the measurement (Sezer, 2008). In the classic-RTK surveying method, the distance between the reference station and the rover GNSS receiver varies up to 10-15 km in order to obtain precise measurement results (Kahveci, 2009; Mekik and Arslanoğlu, 2003).

2.2. Network-RTK

The constantly evolving and changing world of technology has positively affected and promoted the GNSS measurement methods. To this end, a large number of research have been conducted with the aim of removing the mandatory constraints of the previous methodology. One of these research was carried out to diminish the limitations of the Classical-RTK namely the Network-RTK or network supported real-time kinematic measurement method was introduced. Obvious the Network-RTK technique was developed based on the idea of creating a network of many fixed reference stations for this purpose (Raquet, 1998).

How the Network-RTK system works: quickly resolve phase ambiguity and calculate atmospheric corrections and coordinate corrections to rover receivers with appropriate data transmission methods. Receiving these corrections, the rover receiver determines the precise point locations (Kahveci, 2009).

3. TUSAGA-ACTIVE

Turkey National Basic GNSS Stations Network-Active (TUSAGA-AKTIF), also known as CORS-TR, is carried out as an R&D project supported by TÜBITAK in partnership with the General Directorate of Land Registry and Cadastre and the General Directorate of Maps (HGM), was initiated in 2006. Within the scope of this project, 158 fixed GNSS stations were established throughout Turkey and the Turkish Republic of Northern Cyprus. When communication facilities are available, location information is obtained within seconds at a random place and time (Url-1).

This project is specifically targeted at areas where location information will be needed to design and implement projects for the development of residential areas;

- Cadastral and cartography studies
- Infrastructure and superstructure services
- Execution and management of spatial projects
- Making meteorological forecasts
- Geographic Information Systems (GIS) studies
- Urban Information Systems studies etc.

It is expected that the TUSAGA-Active project, developed by using the possibilities of technology in cases where its use is mandatory in land and land-oriented studies in similar areas, will provide services for obtaining location information quickly and with high accuracy (Uzel and Eren, 2008).

4. METHOD

A research was conducted for "comparison of Classical-RTK and Network-RTK Surveying Methods in Coastal Regions". For this, two separate study areas were established in two different regions. These two areas of work are also divided into internal and external parts. The locations of

TUSAGA-AKTIF fixed stations were used to determine the point locations. Triangular closed areas were created from these fixed stations in two different regions. The closed areas created by utilizing the fixed CORS-TR stations AYD2-DIDI-MUG1 (Figure 1) and FETH-KAAS-FINI (Figure 2) were characterized as first study area and second study area, respectively. The first region has an area of approximately 3,078 km^2 and the second region has an area of approximately 1,346 km^2. A total of 12 points were located in both study areas, 3 points in the interior and 3 points in the exterior of the closed areas (Figure 3) and (Figure 4). While determining the locations of the points, it was taken into consideration that their distance from each other was approximately 1 km or more.

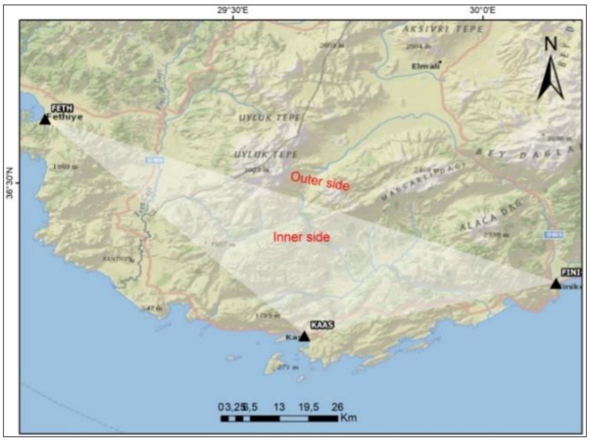

Figure 1. First study area.

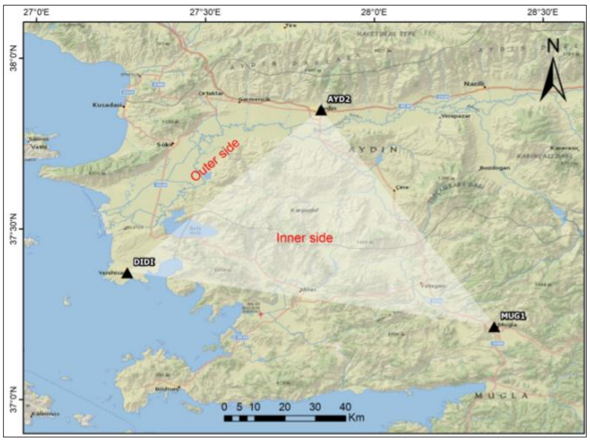

Figure 2. Second study area.

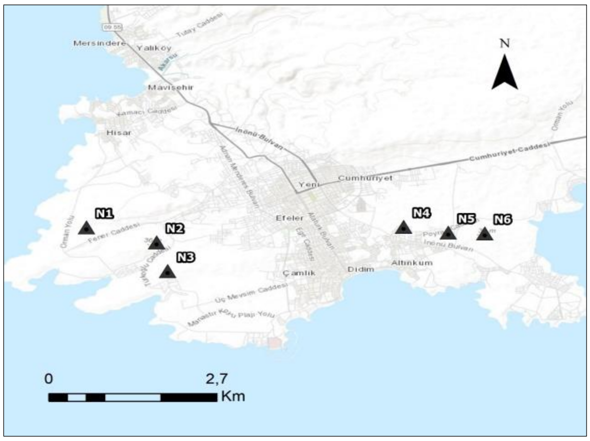

Figure 3. Six points in the first study area.

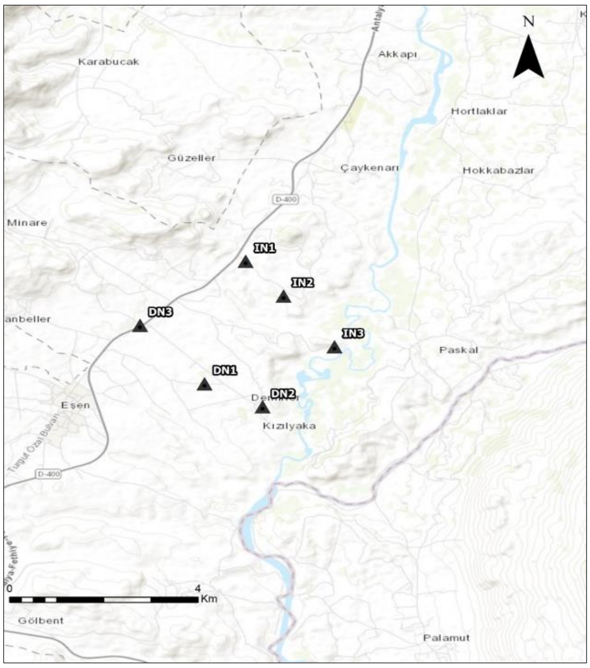

Figure 4. Six points in the second study area.

5.1. Static Measurement

In order to determine the precise position information of 12 points located in Aydın-Didim and Muğla-Fethiye regions, data were collected with two different Topcon GNSS receivers on October 29.2022 and September 11.2022 by first performing static measurement sessions at these points. Approximately 1.5 hours of static measurement was performed at each measurement point. The first static measurement session in this study area was carried out at point N4 between 11:31-13:28 hours (Figure 5).

Figure 5. An image from a static measurement.

5.2. Classical-RTK and Network-RTK Measurement Methods

Classical-RTK and Network-RTK surveying methods were used at 12 points in the study areas in both regions. The measurements made at 12 points with Classical-RTK and Network-RTK measurement techniques were completed with a data collection interval of 1 s and fifteen epochs. A fixed GNSS receiver was installed at 3 of the (N3, N4, DN1) 12 points whose precise coordinates were determined by static surveying method, and the fixed receiver was connected to the mobile receiver simultaneously and the Classical-RTK measurement was performed (Table1) and (Table2).

Table 1. Coordinate values of 6 points in the first study area obtained by the Classical-RTK measurement method.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
N1	519159.0590	4135831.9770	37.5080
N2	520607.0830	4135409.1170	36.7290
N3	520833.0480	4134594.3495	38.6980
N4	525678.6957	4135861.6737	54.2300
N5	526600.5310	4135701.4700	40.2340
N6	527349.1280	4135682.5350	35.7950

Table 2. Coordinate values of 6 points in the second study area obtained by the Classical-RTK measurement method.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
IN1	438846.1800	4039560.8040	124.2100
IN2	439488.5110	4038782.4410	124.4430
IN3	440346.8870	4037649.3410	100.5280
DN1	438121.3946	4036838.5625	111.2580
DN2	439111.4010	4036317.5700	107.8650
DN3	437030.8800	4038148.8340	133.1810

By connecting to the TUSAGA- AKTIF system, which has actively used in Turkey, Network-RTK measurements were made at 12 points in the study areas in the two regions on October 29, 2022 in the first study area (Table 3) and August 11, 2022 in the second study area (Table 4). With the Network-RTK measurement method, measurements were made at 12 points with a recording interval of 1 s, 15 epochs and an elevation angle of 10°.

Table 3. Network-RTK measurement values of 6 points in the first study area.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
N1	519158.9710	4135832.2130	37.720
N2	520606.8410	4135409.3760	36.940
N3	520832.9120	4134594.5530	38.874
N4	525678.5990	4135861.8960	54.451
N5	526600.4320	4135701.7410	40.434
N6	527348.9500	4135682.7240	36.005

Table 4. Network-RTK measurement values of 6 points in the second study area.

Point Id	Easting (Y)	Northing (X)	Ellip. Height (Z)
IN1	438845.9130	4039560.8810	124.399
IN2	439488.2840	4038782.5020	124.418
IN3	440346.7100	4037649.3980	100.537
DN1	438121.2000	4036838.6590	111.414
DN2	439111.2620	4036317.6980	107.488
DN3	437030.6890	4038148.8790	133.197

5.3. Processing of Static Measurement Data

The process of evaluating and adjusting the static measurement data consists of three stages. These are;

- Transferring the data collected by static measurement method to the computer,
- Data conversion to The Receiver Independent Exchange Format (RINEX) format and reorganization according to point names,
- Evaluation and stabilization in Leica Geo Office 7.0 software.

The GNSS measurement evaluation for the application in both regions was made in Leica Geo Office 7.0 software as 2 different projects for each study region. As a result of the process, the precise location coordinates of 12 points in the study areas in both regions were obtained.

5.4. Comparison of Classical-RTK and Network-RTK Measurement Methods

With the reference coordinate values determined as a result of adjustment of the static measurement values in the study areas in both regions the differences of the measurement results obtained by Classical-RTK and Network-RTK measurement methods were taken respectively. In this study, the difference (delta H) of the values obtained with Classical-RTK and Network-RTK with Static measurements was analyzed. As the N geoid heights of the points are the same in all three measures, there will be no effect when the differences are taken. Therefore, ellipsoidal heights were used in this study. The location information obtained at each point is indicated as position in Easting (Y), Northing (X) and Height (Z), and the measurement differences are indicated as Δy, Δx, Δz. The mathematical values of the measurement differences were accepted in absolute value and accordingly, the average of the determined measurement differences were taken and analyzed. Since N3, N4 and DN1 points were taken as fixed points in Classical-RTK measurements, they were not subjected to the comparisons made for Classical-RTK measurement method. Some analyzes were made as follows;

- With adjusted static measurement results of 6 points in the first study area the differences of measurement results obtained by classical-RTK measurement method (Table 5).

- With adjusted static measurement results of 6 points in the second study area the differences of measurement results obtained by Network-RTK measurement method (Table 6).

- With adjusted static measurement results of 6 points in the second first area differences of measurement results obtained by classical-RTK measurement method (Table 7).

- With adjusted static measurement results of 6 points in the second study area differences of measurement results obtained by Network-RTK measurement method (Table 8).

- Differences between the results of the adjusted static measurements of 6 points located in the inner part of both study areas and the results obtained by the Classical-RTK surveying method (Table 9).

- Differences between the results of the adjusted static measurements of 6 points located in the inner part of both study areas and the results obtained by the Network-RTK surveying method (Table 10).

Table 5. Static and Classical-RTK measurement differences of 6 points in the first study area.

Point Id	Δy	Δx	Δz
N1	0.0778	0.0987	0.1639
N2	-0.0768	-0.0059	0.0103
N3	0.0000	0.0000	0.0000
N4	0.0000	0.0000	0.0000
N5	0.0608	0.0195	0.0127
N6	-0.0668	-0.0177	0.1740

Table 6. Static and Network-RTK measurement differences of 6 points in the first study area.

Point Id	Δy	Δx	Δz
N1	0.1658	-0.1373	-0.0481
N2	0.1652	-0.2649	-0.2007
N3	0.1360	-0.2035	-0.1764
N4	0.0967	-0.2223	-0.2215
N5	0.1598	-0.2515	-0.1873
N6	0.1112	-0.2067	-0.0360

Table 7. Static and Classical-RTK measurement differences of 6 points in the second study area.

Point Id	Δy	Δx	Δz
IN1	-0.0395	-0.0305	-0.0074
IN2	-0.0388	-0.0356	-0.0156
IN3	0.0136	-0.0296	-0.0151
DN1	0.0000	0.0000	0.0000
DN2	0.0570	0.0463	-0.0293
DN3	-0.0086	-0.0598	-0.0179

Table 8. Static and Network-RTK measurement differences of 6 points in the second study area.

Point Id	Δy	Δx	Δz
IN1	0.2275	-0.1075	-0.1964
IN2	0.1882	-0.0966	0.0094
IN3	0.1906	-0.0866	-0.0241
DN1	0.1946	-0.0965	-0.1557
DN2	0.1960	-0.0817	0.3477
DN3	0.1824	-0.1048	-0.0339

Table 9. Static and Classical-RTK measurement differences of 6 points located in the interior of both study areas.

Point Id	Δy	Δx	Δz
N4	0.0000	0.0000	0.0000
N5	0.0608	0.0195	0.0127
N6	-0.0668	-0.0177	0.1740
IN1	-0.0395	-0.0305	-0.0074
IN2	-0.0388	-0.0356	-0.0156
IN3	0.0136	-0.0296	-0.0151

Table 10. Static and Network-RTK measurement differences of 6 points located in the interior of both study areas.

Point Id	Δy	Δx	Δz
N4	0.0967	-0.2223	-0.2215
N5	0.1598	-0.2515	-0.1873
N6	0.1112	-0.2067	-0.0360
IN1	0.2275	-0.1075	-0.1964
IN2	0.1882	-0.0966	0.0094
IN3	0.1906	-0.0866	-0.0241

When the network data consisting of CORS-TR points are balanced, the error ellipses at the points on the edges will be higher than the error ellipses at the points inside the network. In the classical-RTK method, the error will increase as you move away from the reference point. Considering this situation, the highest difference between the two measurements may be due to the fact that the measurements were made on the coasts where there is no TUSAGA-AKTIF point in the south and west directions.

6. CONCLUSIONS

In this study, the locations of the points were determined precisely depending on the geographical features and conditions in the coastal area, also paying attention to the distances of the points from each other. Static, Classical-RTK and Network-RTK measurements were carried out at 6 points in a study area of about 307 hectares in Didim district and at 6 points in a study area of 131 hectares between Fethiye and Kaş. Measurement points N3, N4 and DN1 were not subjected to comparison since they were taken as fixed points in Classical-RTK measurements.

When the coordinate differences of the N1, N2, DN2, DN3 measurement points located in the outer part of both study areas are examined, it is seen that the largest difference in the easting for Classical-RTK is 0.0778 m, the smallest difference is 0.0086 m, the average difference is 0.0123 m, the largest difference in the northing is 0.0987 m, the smallest difference is 0.0059 m, the average difference is 0.0198 m and the largest difference in the height is 0.1639 m, the smallest difference is 0.103 m, the average difference is 0.0318 m.

The coordinate differences of the points located in the outer part of both study areas, N1, N2, N3, DN1, DN2, DN3 measurement points for the Network-RTK, the largest difference in the easting is 0.1960 m, the smallest difference is 0.1360 m, the average difference is 0.1733 m, the largest difference in the northing is 0.2649 m, the smallest difference is 0.0965 m, the average difference is 0.1481 m and the largest difference in the height is 0.3477 m, the smallest difference is 0.0339 m, the average difference is 0.0445 m.

When the coordinate differences of N5, N6, IN1, IN2 and IN3 measurement points located in the inner part of both study areas are examined, it is seen that the largest difference in the easting is 0.0668 m, the smallest difference is 0.0136 m, the average difference is 0.0141 m, the largest difference in the northing is 0.0356, the smallest difference is 0.0177 m, the average difference is 0.0188 m and the largest difference in the height is 0.1740 m, the smallest difference is 0.0074 m, the average difference is 0.0297 m.

When the coordinates of the N5, N6, IN1, IN2 and IN3 measurement points located in the inner part of both study areas are analyzed, it is seen that the largest difference in the easting for the Network-RTK is 0.2275 m, the smallest difference is 0.0967 m, the average difference is 0.1623 m, the largest difference in the northing is 0.2515 m, the smallest difference is 0.0866 m, the average difference is 0.1619 m and the differences in the height are 0.2215 m, the smallest difference is 0.0094 m, the average difference is 0.1093 m.

According to these results, it is understood that the measurement values obtained with the Classical-RTK measurement method are mostly closer to the static measurement values and in general, the results obtained with the Classical-RTK measurement method are better than the results obtained with the Network-RTK measurement method.

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Author Contributions

Şeri Dilan Oğuz: Methodology, Software, Validation, Formal analysis, Writing-Original Draft, Visualization. **Kemal Yurt**: Supervision, Writing-Original Draft.

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Development of A Housing Information Management System for Tambari Estate, Bauchi Metropolis, Nigeria

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ABSTRACT

Economic activity and population growth Bauchi metropolis contributed to the emergence of the Tambari Estate to house the state's civil service's senior and junior staff. This has not only increased the need for land to accommodate the various land uses, but it has also posed challenges to proper and efficient layout management. Appropriate land administration is critical to any nation's socioeconomic development and long-term land information systems. In this period, information and new strategies for sustainable land administration are becoming increasingly important. However, the storage and management of land information have continued to remain analog, resulting in difficulties in land boundary litigation and economic losses. In this paper, a digital housing information management system for the Tambari estate in Bauchi Metropolis was developed. ArcGIS 10.7 was used to digitize and update the layout of the estate sourced from the Bauchi State Ministry of Housing while the attribute data like ownership information, plot details, plot type, number of rooms, status, land use, and other relevant information were gotten through fieldwork. The information of each house was entered into an attribute table to create a relational database. The relational database was used to develop the user interface created using Microsoft Visual Basic 6.0 software which then allowed for the development of the housing management system with an interactive interface with username and password. The development of a Housing Information Management System will provide accurate information to the government and stakeholders in a timely and efficient manner for proper planning and decision-making, as well as effective land-use management. The study recommended the implementation of housing information systems by all levels of government. The system will stimulate economic activity, social cohesion, and long-term development.

1. INTRODUCTION

After food, the second most valuable aspect of man's physical survival is housing (Tsemberis, 2010), which is built on land. Land management is essential to development at the individual, community, and national levels because it guarantees land resource use and development (FAO, 2002; Ojigi et al., 2011). Housing has a significant impact on man's health, welfare, quality of life, and efficiency (Abimbola and Pauline, 2015). According to Festus and Amos (2015), housing is essential to human survival. Traditional land administration methods are combined with corruption and poor land management on the part of customary landowners. Dale and McLaughlin (1988)

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define an information system as "a mixture of technical and human resources, along with a set of organizing methodologies that generates information in support of some supervisory requirement." Population growth in cities is not being matched by an adequate supply of land for housing, infrastructure, utilities, and services to maintain a reasonable standard of living. This lack of preparedness could manifest as a lack of knowledge about various types of land tenure, estate valuation and taxation, physical extension potentials, and so on (Billen, 2014; Osabuohien, 2013). This has also resulted in the spread of informal settlements, pollution of water bodies and air, and ramshackle housing (Williamson, 2004; Usman, 2010). Constituently, governments, urban planners, hydrologists, ecologists, and others must track and identify urban growth for proper planning and decision-making (Yusuf, 2022). Musa et al. (2016) in their study, stored details like ownership, location, plot size, plot status, use, and the worth of the building constructed on-site in a spatial database. If this information is effectively handled and the correct decision is made, adoption would greatly help with the issues related to landed properties.

The housing data in the study area are stored on paper forms that were easily torn and misplaced. Similarly, most agencies at both the national and state levels are not fully digitized, resulting in poor storage and retrieval of information on time, which can lead to conflict. The information is kept on paper, which is easily torn and misplaced. These datasets are difficult to manipulate, query, and even update, unlike the digital database which is easy to operate. Even though cadaster has been in place in the country since 1883, there has been a lack of collaboration and cooperation between agencies with technical expertise to use new technologies available for the development of an effective administration of land resources (Osabuohien et al., 2020).

Furthermore, urban growth greatly influences the local climate, notably because it raises the earth's temperature (Yusuf et al., 2023). Omosebi (2016) created a housing management system that is web-based. The system will handle senior staff housing and make it easier to apply for and update lodgings. Adobe Creative Suite 5 was used to develop the front end of the web-based system, while the graphics on the pages were designed using CorelDraw Version 15. The XAMMPServer version 5.3.5, which included PHP and MySQL applications, was used to make the site pages dynamic. PHP was used as middleware, and MySQL was used as the web portal backend. The new system demonstrated its necessity and essential features in the areas of information capture and processing, as well as database management.

Okae (2022) created a powerful online residential housing management system that can aid administrators in attending to students' housing issues. Using the University of Ghana as a case study, the system was designed to meet the accommodation demands of both continuing and freshmen students. The conclusions from subsequent data obtained from system users after its deployment proved that it decreased the timeframes for residential housing searches, changing halls or rooms, and paying fees to the bare minimum.

Zegeye (2019) developed a cadastral information system in a GIS interface to improve land management in Tepi Town, South Western Region, Ethiopia. The geographical and non-spatial data for the research area were compiled into a geodatabase using a thorough GIS-based methodology. Spatial data were added using Coordinate Geometry (COGO) in the GIS interface.

Mustapha and Hassan (2017) developed a functional database of the current situation of their research area in order to present virtual information and information such as land use, plot type, parcel information, ownership details, and so on. The researchers failed to include the images of each house will could have made their work more comprehensive.

However, Musa et al. (2016) in their research reveal the non-adoption and deployment of GIS methods in collecting and managing spatial information by Land and Survey ministries, agencies, and similar organizations. The authors advised the bodies concerned to continue the current trend in the use of geospatial technology.

AL-Hameedawi et al. (2017) used an old agricultural cadastral map from the 1930s as a hardcopy in their study in the Wassit province south-east of Baghdad, which was then digitized and upgraded utilizing control points and a recent satellite image for the same location. They improved the technique for updating Iraq's agricultural cadastral maps using Differential Global Positioning System (DGPS), Satellite Imagery, and Total Station, as well as the cadastral editor extension in ArcGIS software to create new agricultural maps.

Property records are critical since they serve as the foundation for the Government of Nigeria's proposed land reform programs (Ibimilua and Ibitoye, 2015). As a result, the purpose of this paper is to develop a housing information management system for the Tambari estate in Bauchi, Northern Nigeria. The Housing Information Management System (HIMS) will aid in guaranteeing title, legal security, quick services for users, complete coverage, comprehensive liable secured system that is computerized and will cater to the needs of current and future generations.

2. METHOD

In this section, data acquired and different methods adopted in this study are discussed.

2.1. Data Needed for the Study

To achieve the aim of this study, both spatial and non-spatial data for the Housing Database were gathered from various sources and using multiple techniques (Table 1). The data acquired for the research include the layout plan of the study area; attribute data such as parcel details, house number, area, ownership information, and land use; the photographs of the buildings on the parcels of the study area will be captured during fieldwork. A 2022 satellite image of the study area was acquired and geo-reference using 10 ground control points within the study area. The types of Pre-processing carried-out on the image include radiometric correction, geometric correction and geo-referencing using ERDAS Imagine 2014.

Table 1. Data needed for the study.

Data type	Source
Layout Plan	Bauchi State Ministry of Housing
High-Resolution Satellite Image	Google Image 2022
Parcel/Ownership Information	Fieldwork
Pictures	Fieldwork
Coordinates	Handheld GPS GARMIN 76 (Accuracy: ±3m)

The layout plan of the estate was obtained from the Bauchi State Ministry of Housing which was updated using satellite images and the attribute data obtained will be obtained from the field during data collection. The following are the types of information acquired from the site to develop the housing database.

Table 2. The information needed to create the database.

Category	Data needed
Ownership Details	Name, occupation, and Phone number
Parcel Information	Plot number, Date of allocation and Plot address
House Type	Number of rooms, Image

Table 2 shows the type of information needed to create the database.

2.2. The Database Creation

The steps below were followed to create the housing database for the estate.

2.2.1 Digitization of satellite image

The satellite image was sourced from Google Earth Pro and saved in the Tambari Project folder and imported into ArcGIS 10.7. The image was then georeferenced to UTM, WGS 84, Zone 32 using the coordinates captured on-site using Handheld GPS (GARMIN 76).

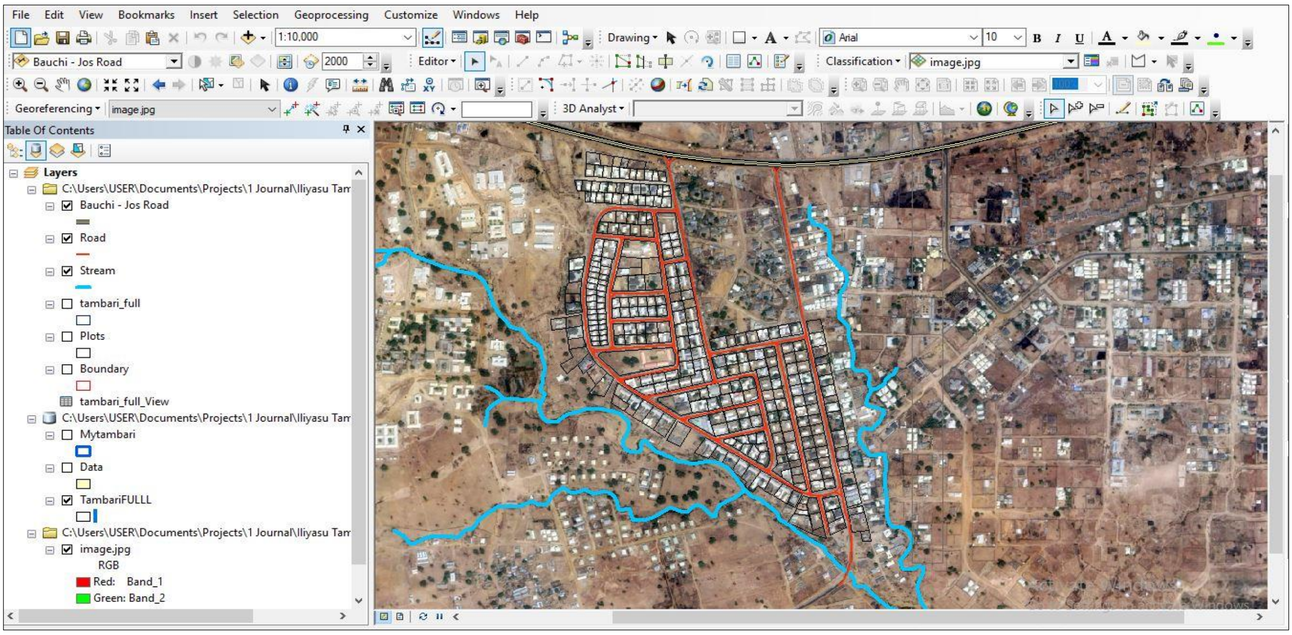
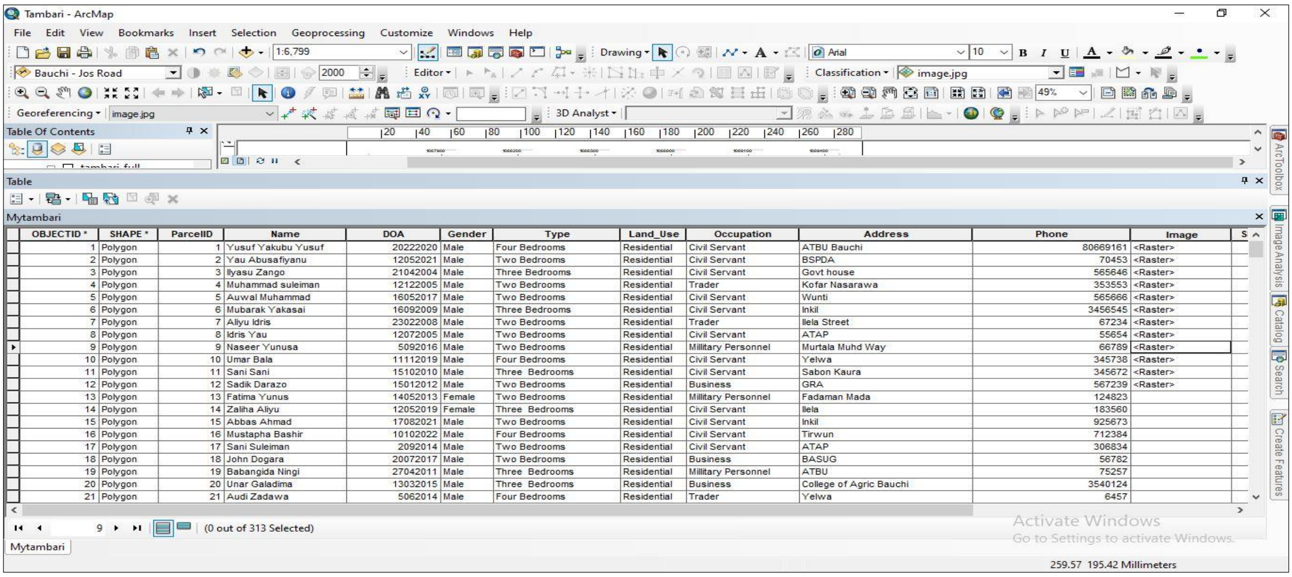


Figure 1. Digitization process.



OBJECTID *	SHAPE *	ParcelID	Name	DOA	Gender	Type	Land_Use	Occupation	Address	Phone	Image
1	Polygon	1	Yusuf Yakubu Yusuf	20222020	Male	Four Bedrooms	Residential	Civil Servant	ATBU Bauchi	80669161	<Raster>
2	Polygon	2	Yau Abusafiyanu	12052021	Male	Two Bedrooms	Residential	Civil Servant	BSPDA	70453	<Raster>
3	Polygon	3	Ilyasu Zango	21042004	Male	Three Bedrooms	Residential	Civil Servant	Govt house	565646	<Raster>
4	Polygon	4	Muhammad suleiman	12122005	Male	Two Bedrooms	Residential	Trader	Kofar Nasarawa	353553	<Raster>
5	Polygon	5	Auwal Muhammad	16052017	Male	Two Bedrooms	Residential	Civil Servant	Wunti	565666	<Raster>
6	Polygon	6	Mubarak Yakasai	16092009	Male	Three Bedrooms	Residential	Civil Servant	Inkil	3456545	<Raster>
7	Polygon	7	Aliyu Idris	23022008	Male	Two Bedrooms	Residential	Trader	Ilela Street	67234	<Raster>
8	Polygon	8	Idris Yau	12072005	Male	Two Bedrooms	Residential	Civil Servant	ATAP	55654	<Raster>
9	Polygon	9	Naseer Yunusa	5092016	Male	Two Bedrooms	Residential	Millitary Personnel	Murtala Muhd Way	66789	<Raster>
10	Polygon	10	Umar Bala	11112019	Male	Four Bedrooms	Residential	Civil Servant	Yelwa	345738	<Raster>
11	Polygon	11	Sani Sani	15102010	Male	Three Bedrooms	Residential	Civil Servant	Sabon Kaura	345672	<Raster>
12	Polygon	12	Sadik Darazo	15012012	Male	Two Bedrooms	Residential	Business	GRA	567239	<Raster>
13	Polygon	13	Fatima Yunus	14052013	Female	Two Bedrooms	Residential	Millitary Personnel	Fadaman Mada	124823	
14	Polygon	14	Zaliha Aliyu	12052019	Female	Three Bedrooms	Residential	Civil Servant	Ilela	183560	
15	Polygon	15	Abbas Ahmad	17082021	Male	Two Bedrooms	Residential	Civil Servant	Inkil	925673	
16	Polygon	16	Mustapha Bashir	10102022	Male	Four Bedrooms	Residential	Civil Servant	Tirwun	712384	
17	Polygon	17	Sani Suleiman	2092014	Male	Two Bedrooms	Residential	Civil Servant	ATAP	306834	
18	Polygon	18	John Dogara	20072017	Male	Two Bedrooms	Residential	Business	BASUG	56782	
19	Polygon	19	Babangida Ningi	27042011	Male	Three Bedrooms	Residential	Millitary Personnel	ATBU	75257	
20	Polygon	20	Unar Galadima	13032015	Male	Three Bedrooms	Residential	Business	College of Agric Bauchi	3540124	
21	Polygon	21	Audi Zadawa	5062014	Male	Four Bedrooms	Residential	Trader	Yelwa	6457	

Figure 2. Relational database**.**

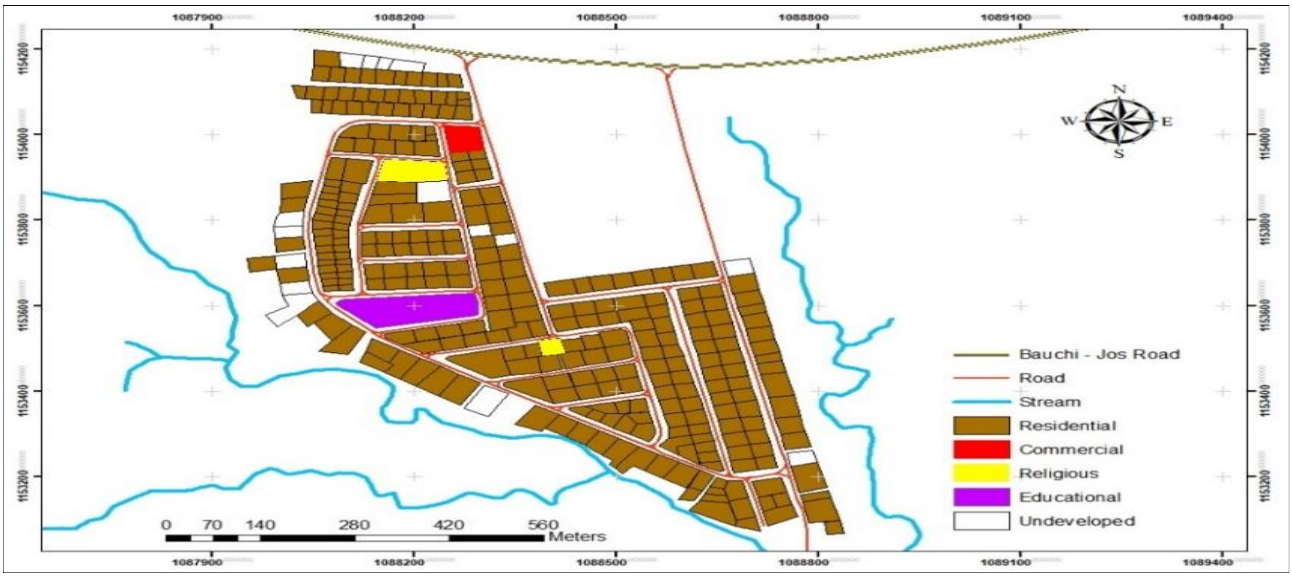


Figure 3. Land use map of the study area.

2.2.2 Adding shapefiles

In order to be able to work on ArcGIS, it is necessary to use folder connection using the connect folder function in ArcCatalog. The shapefiles created are; Plots, Roads Network, Stream, and Jos-Bauchi expressway. The shapefiles were created as independent layers to show the features that made up the estate and their relationship with each other (Figure 1).

2.2.3 Relational database

The attribute table was automatically created while digitizing the map features. Add field function was used to create additional Columns for Parcel ID, Name of the owner, Gender, Date of allocation, type of house, Address, land use occupation, and phone number added in the table. To create the database, the plots were assigned ID numbers and the data acquired from the field was stored against the respective plots (Figure 2).

2.2.4 Land use map

After successfully digitizing the plots, the various land uses were identified through fieldwork, and every plot was assigned its respective land use. To export the different land uses, a right click was done upon the plots layer in the table of the content panel to view the table of contents. Selection by attribute was done to select the land uses to export them and add them as an independent layer (Figure 3). The same process was performed for all the land uses to get the substantive and updated land use map of the estate. Residential land use is the largest in terms of area coverage followed by commercial, educational, and access roads while religion is the least. The buttons added are controlled behind the scenes by the codes written as shown below.

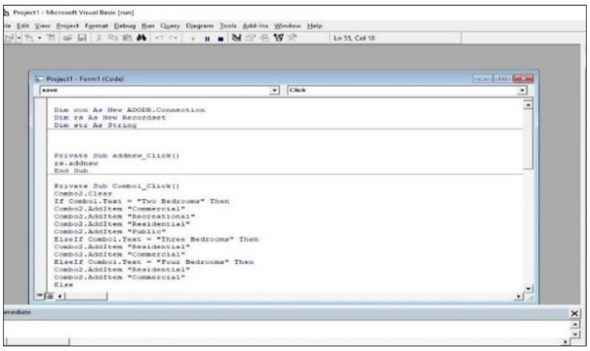


Figure 4. Visual Basic Code Editor for command buttons.

A login functionality was also added for added security to the interface. Access will only be granted if and only if the correct name and password are entered into their respective fields as depicted in Figure 5 and Figure 6.

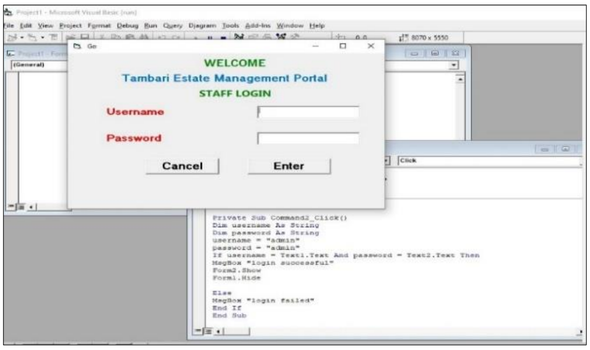


Figure 5. Visual Basic staff login interface.

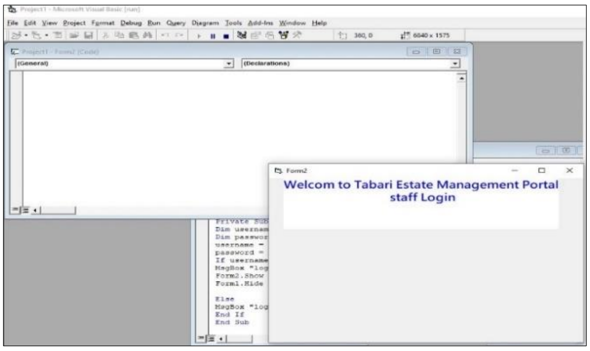


Figure 6. Visual Basic welcome staff login.

3. RESULTS

3.1 Tambari Housing Database

The database created has many functionalities and advantages that will aid in proper management. The system was designed to allow for storage, retrieval, and updating without any obstacles, unlike the traditional method (Figure 7 and 8).

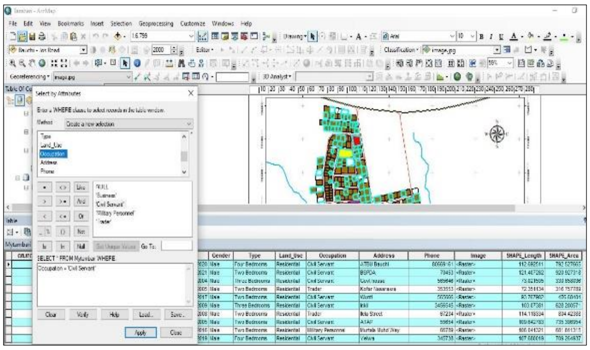


Figure 7. Database query showing houses owned by civil servants.

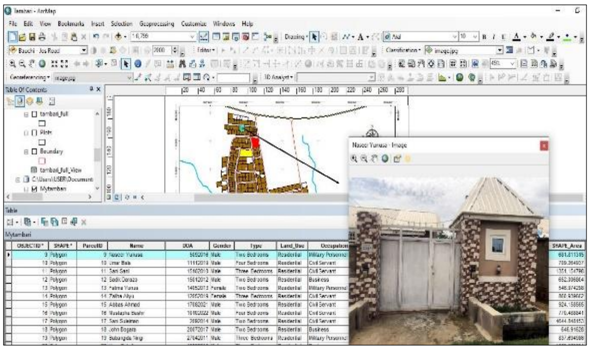


Figure 8. Database showing house information.

3.2 Virtual Login Interface

Microsoft Virtual basic software was used to create a user interface that will connect with the relational database for easy retrieval of the data when needed (Figure 9). A new form was created and fields like Parcel ID, Name of the owner, Gender, Date of allocation, type of house, Address, land use occupation, phone number, and pictures were added to the form. Fields, labels, commands, and textboxes were used in the creation of the form as shown in above in Figure 4.

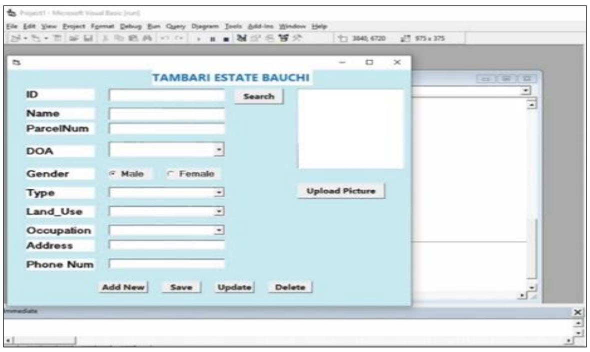


Figure 9: Visual Basic 6.0 user interface.

The interface is an added security to the database as it only allows authorized persons with access to the database. To gain access to the database, an Active Password and username must be entered and accepted before granting access.

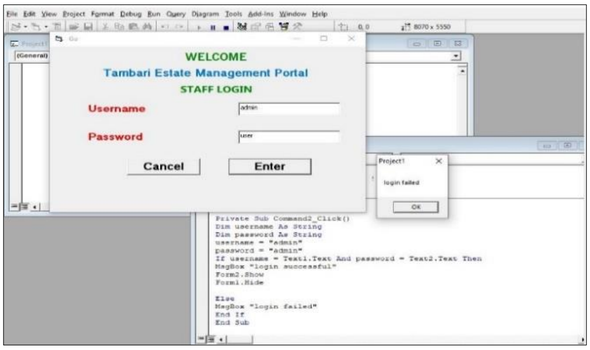


Figure 10. Failed login attempt.

Figure 10 shows a wrong password entered into the login page which denied access to the database.

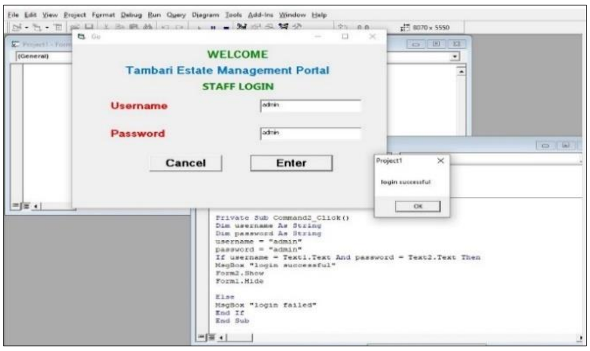


Figure 11. Successful login.

Entering a valid password will show login successful and allow the user access to the database as designed to protect the database from unauthorized personnel (Figure 11).

3.3. Database Management Form

The interface has all the functions needed for effective management of the housing estate. It allows for viewing, modifying, and adding new data to the table without any obstacles. It also allows for searching of certain data using the Parcel ID for easy retrieval of information.

Figure 12. User interface.

4. CONCLUSION

The study demonstrated that the use of GIS provides a sufficient solution to manage land and its resources due to their simple, intelligent automation and capacity to analyze a lot of data in a short length of time. The knowledge expressed in this study has a significant possibility of assisting the citizens of Bauchi state by providing vital information to decision-makers (land administrators) that will allow them to make choices that are favorable to sustainable development within the context of appropriate land management and administration. The globe is a global village, and the spirit of integration is the mother of harmony and growth, which is why GIS should be used at all levels of human activity (Dukiya and Morenikeji, 2017).

The Bauchı state government can utilize this system to ease effective land management in the state. The failure of Land and Survey ministries, authorities, and similar institutions to integrate GIS techniques to collect and handle spatial information leads to ineffectiveness. The platform will promote long-term development, social cohesiveness, and economic growth if implemented.

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Author Contributions

Yusuf Yakubu Yusuf: Collected the datasets and analyzed the data, Methodology, Validation and writing of the Visual Basics script. **Kuforijimi Olorunsola:** Reviewing and proofreading the manuscript before submission. **Ahmed Hafeez Auwal:** Methodology, reviewing and proofreading the manuscript before submission. **Yau Abu Safiyan:** Data collection in the field. **Abe Bashir Saidu:** Participated in GIS analyses. **Yakubu Hamza Adam:** Writing the manuscript, review and editing. **Muhammad Ilyasu:** Writing the manuscript, review and editing. **Mohammed Alhaji Abdullahi:** Writing the manuscript, review and editing.

Conflicts of Interest

The authors declare no conflict of interest.

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