DEVELOPMENT OF PLANT-BASED LAND SUITABILITY MODEL FOR WHEAT IN SEMI-ARID CONDITIONS AND VALIDATION WITH YIELD VALUES

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Abstract. In this study, a land suitability model was generated specifically for arid-semiarid climate conditions using the hybrid system approach with Analytic Hierarchy Process (AHP) and Geographic Information Systems (GIS) integration for wheat. The study was carried out in 11 soil series and 92 land units at the Konya-Konuklar Agricultural Enterprise, covering an area of 4060 ha and representing a continental climate. For the suitability model, 20 parameters affecting plant development were selected and grouped as: (i) land indicators – depth, slope, stoniness, and drainage; (ii) physical indicators – available water content (AW), bulk density, hydraulic conductivity, and texture; (iii) chemical indicators – electrical conductivity, pH, organic matter, and $CaCO_3$; and (iv) nutrient indicators – P, K, mineral nitrogen, Zn, Cu, Fe, Mn, and B. These were divided into factors according to their degree of effect. The success of the model was tested using long-term average yield values representing the soil series under dry conditions, and a 75% statistical correlation was determined. As a result of the study, a novel contribution was made to this field through a plant-based evaluation approach that can be applied by decision makers, and it was suggested that the developed model could be preferred for determining suitable lands for wheat cultivation in regions with similar climates. Additionally, the study evaluated that GIS-AHP integration can be used to determine the agricultural suitability of different crop varieties specific to the region.
Keywords: *AHP, hybrid approach, land evaluation, multi-criteria decision making, suitability model, wheat*

Introduction

Today, many developed and developing countries generate plant-based land evaluation models, especially for strategic plant species, as part of precision agriculture applications, and use them in the classification of agricultural soil suitability for selected products. In our country, it is important to conduct similar studies on a regional scale for the wheat plant, which has strategic significance. However, original land assessment models based on climate, soil, and topographic characteristics have not been developed for wheat grown in diverse regions. This situation leads to the selection of crops that are not suited to the potential of our soils, which are a scarce natural resource, and causes harm to both the grower and the country’s economy. Therefore, the research was designed by seeking an answer to the question of to what extent the soil of the Central Anatolia region can meet the demands of wheat plants grown under dry farming applications and what this criterion corresponds to the suitability classes to be categorized according to the research findings. The research question also provides the basis for modern plant-based land evaluation approaches. The study aims to determine the soil and land factors affecting the optimum development and yield of wheat plants in arid-semi arid climate conditions, to score these parameters according to their degree of change in regional lands and to weight them according to their degree of effect on vegetation development, to develop a wheat land suitability model and to produce a wheat land suitability distribution map in a Geographic Information Systems (GIS) environment as a result of model

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application. In this way, an innovative plant-based application was generated as an alternative to traditional land evaluation approaches. These approaches include the assessment of land suitability as the basis for sustainable crop development (Sathiyamurthi et al., 2024). At this stage, GIS capabilities are also used to provide a basis for planners. In fact, GIS enables experts to assess land suitability for different uses based on various factors such as soil and terrain properties. It helps in thematic mapping of areas in different suitability classes by spatially joining different data sets and attribute information. It is also gaining importance for countries with high population growth and migration potential, such as Turkey. In Turkey, bread wheat comes first with an annual production of 17.70 million tons and the largest cultivation area, FAOSTAT (2024). Bread wheat has an important place in human nutrition and is a strategic product (Mazid et al., 2009). The fact that it is one of the important sources of income for people living in rural areas and one of the basic raw materials of the food industry increases the importance of wheat. The average bread wheat yield in the country is 2.8 tone/ha and in the same year it was 3.54 tone/ha in the World, 5.76 tone/ha in the EU and 3.54 tone/ha in the FAOSTAT (2024). The specified values are behind both the world average and the averages of developed wheat growing countries. This situation is also a result of planting even in areas that are not suitable for wheat cultivation. Indeed, it has been reported that as a result of wheat cultivation on unsuitable soil and land characteristics, product yields have decreased to 1 tone/ha, and this situation has affected the surrounding farmers, triggering the use of more chemical fertilizers in the following period even if their own growing environment is suitable, and has caused economic damage in every area (Küçükçongar et al., 2014). In order to increase wheat production in our country and reach the world average, land use policies that will support sustainable rural development need to be developed. Therefore, plant-based land assessment studies should be carried out primarily in regions where intensive wheat farming is carried out in Turkey. Land evaluation is an absolutely necessary process for determining the potential capabilities of lands for different uses and sustainable soil fertility (Mueller et al., 2010; Almayyahi et al., 2024). Carrying out this process in the most efficient way requires a multi-faceted approach that requires the weighting of the influence degrees of many factors that affect each other and are unified in different ways, such as physical, chemical, morphological, topographic and climatic soil properties, also using expert opinion in terms of agricultural use (Mokarram and Mirsoleimani, 2018). For this reason, multi-criteria decision-making models developed in the 1960s to support decision makers offer a preferred approach in land evaluation and agricultural suitability classification today (Chavez et al., 2012; Kaya and Dengiz, 2024). In recent years, especially for strategically important plants, the Analytical Hierarchical Process (AHP), which is a Multi-Criteria Decision-Making method, has been preferred in the evaluation of land suitability by Saaty (1980) for the evaluation of multiple - heterogeneous factors (Malczewski, 2006; Mandere et al., 2010; Kaya and Dengiz, 2024). AHP is a decision-supported method that separates complex multi-factor problems into a hierarchical structure (Yang et al., 2008). This hierarchical structure provides the opportunity to present a parametric approach that includes expert opinion. In this way, a hybrid system can be developed, unlike standard AHP-GIS approaches, and a model that includes region-specific comments can be constructed. At the same time, the incorporation of analytical models into GIS has been reliably used by researchers to evaluate land suitability and allocation (Yalew et al., 2016). In fact, in China, suitability classification of tobacco plants was made using AHP/GIS depending on different climate, soil type, nutrient content and topography factors and it was stated

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that AHP model was the most effective method in determining the weights of the factors (Zhang et al., 2015; Makar et al., 2024). Similarly, in the model developed by Sarkar et al. (2014) to determine the areas suitable for wheat plants in India, precipitation data, soil depth, texture, drainage status, pH, organic matter content and slope factors were weighted using AHP model and suitability maps were produced with Weight Superimposition Analysis in GIS environment. Many studies have confirmed the capabilities and benefits of AHP/GIS techniques in the integration and visualization of spatial or non-spatial data obtained in crop-based land assessment studies, especially for strategically important plants such as wheat, beet, corn, sunflower and tobacco (Mendas and Delali, 2012; Zhang et al., 2015; Mokarram and Mirsoleimani, 2018; Nungula et al., 2024; Rangzan et al., 2024). However, a region-specific land assessment model has not been developed for wheat, which is of high importance in Turkey and the Central Anatolian region. As a result, the potential of our lands to meet wheat development demands is also unknown. It is necessary to investigate alternative land assessment methods that can be used successfully in Turkey. Based on this requirement, a unique land suitability model for continental (semi-arid) climate conditions was developed using the Hybrid Multi-Criteria Decision Support approach and AHP and GIS integration for the wheat plant, which has strategic importance for the country and the world, and the suitability assessment of the study area soils was carried out. At the same time, the 10-year average wheat yield of the study area was compared with the suitability class values of the soils, and its validation was provided, and its success was tested.

Materials and methods

Study area

The research was conducted in Konuklar Agricultural Enterprise is located between 38° 23′ 27″ - 38° 15′ 29″ North latitudes, 32° 22′ 14″ - 32° 20′ 27″ East longitudes in the Konya province of Central Anatolian, Turkey. The farm has an area of 4060 ha and the cultivated land size is 3.540 ha, wheat cultivation is carried out in dry conditions on 85% of these lands (3000 ha). Fodder crops and fruit growing activities are carried out on 15% of the farmlands (540 ha). Its altitude above sea level between 1010 m and 1055 m. The most important issue in selecting the farm is that detailed soil surveys have been conducted (Dinç et al., 2002). In this way, phase separations (depth, texture, slope, stony, drainage, etc.) of different soil series specified in detailed survey reports and distributions shown on the soil map were used and wheat suitability assessments were made at the mapping unit level. Since it was not possible to take samples from the same pedons representing the series specified in the soil survey report of the farmlands, new soil profiles were opened for morphogenetic definitions and 51 disturbed soil samples were taken based on genetic horizons to soil analyses. In addition, 33 undisturbed soil samples were taken from 0-20 cm in 11 series with 3 replications. The distribution of soil series and farm location presented in *Fig. 1*. According to the detailed soil map and report of the study area (Dinç et al., 2002), the soils of the region reflect the typical soil properties of the Central Anatolian region formed under the arid/semi-arid climate conditions, with high calcareous, low organic matter content, high pH, stony and physiographic units consisting of alluvial deposits in different slope groups. According to Soil Survey Staff (1999), the soils of the region are classified as Typic Xerorthent, Typic Haploxerept, Petrocalcic Calcixerept, Typic Calcixerept and Typic Haploxerert subgroups in 11 different series and 92 land units (LU).

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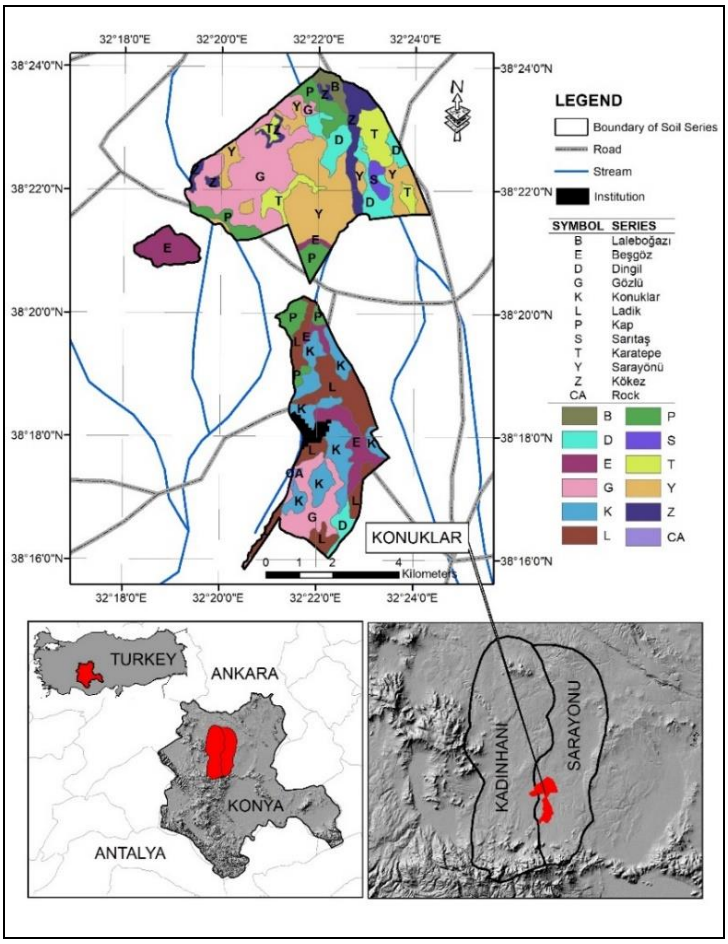

Figure 1. *Soil series and location map of the study area*

The study area has the same general climate criteria as Konya province. The climate is typical Central Anatolian continental climate. According to the long-term average of meteorological climate data in the study area, the average rainfall is 259 mm, the least precipitation with 48 mm occurred in May and the least precipitation with 8 mm occurred in September. The annual average temperature is 11.92°C, and the annual average relative humidity is 57.80%. The lowest relative humidity with 46.47% occurred in August and the highest relative humidity with 70.50% occurred in December.

Parameter selection, scoring and weighting of subgroups

In the wheat land suitability model, “Hybrid System” was used for the selection of parameters affecting plant development. This system refers to the composition of two types of models in the modern land assessment approach. One of these models simulates the qualitative reasoning function, while the other simulates the quantitative modeling section (De la Rosa and Van Diepen, 2002). In the study, Expert Knowledge and literature research were used as the qualitative reasoning function and the selection of the parameters taken into consideration and their scoring to sub-factors were made. In the wheat land suitability model, 20 parameters affecting plant development were determined. These are 1- Land indicators: Depth, slope, stony and drainage (De La Rosa et al., 1981; Huddleston et al., 1987; Dedeoglu and Dengiz, 2019), 2- Physical indicators:

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Useful water capacity (FS), bulk density (HA), hydraulic conductivity (Hİ), and texture (Arshad and Martin, 2002; Jahn et al., 2006; Mustafa et al., 2017), 3- Chemical indicators: Electrical conductivity (EC), pH, organic matter (OM), $CaCO_3$ (Barraclough, 1989; Soil Survey Staff, 1999; Zhan et al., 2016) and 4- Nutrient indicators: P, K, Mineral Nitrogen (NH4++ NO3- - N), Zn, Cu, Fe, Mn, and B (McVay et al., 1989; FAO, 1990; Rajaram et al., 1993; Pathak et al., 2003; Iojă et al., 2014; Aldababseh et al., 2018) were selected using a lot of literature according to the optimum vegetative development requirements of the wheat plant as evaluation parameters. In the study, land indicators were produced as digital layers in the GIS environment from the survey report and map of the regional soils. Other indicator values were obtained as a result of laboratory analyses. The laboratory analyses conducted in the study are presented in *Table 1*.

Table 1. *Physicochemical analyses and methods*

Parameters	Unit	Protocol	Reference
Bulk Density	gr cm^{-3}	Undisturbed soil sample	Blacke and Hartge (1986)
Hydraulic Conductivity	mm h^{-1}	Undisturbed soil sample, saturated, Darcy equation	Oosterbaan (1994)
Available Water	%	Ceramic table, pressure unit, Field capacity and wilting point difference (33 kPa -1500 kPa)	Klute (1986)
Organic Matter	%	Oxidation method with potassium dichromate ($K_2Cr_2O_7$) (Walkley-Black)	Nelson and Sommers 1982
Texture	%	Hydrometer method	Soil Survey Staff. 2011.
pH EC	1:2.5 dS m^{-1}	Soil – water suspension (w:v)	Soil Survey Staff. 2011.
$CaCO_3$	%	Scheibler calcimetry	Soil Survey Staff. 2011.
P	mg kg^{-1}	Olsen method	Olsen ve Sommers (1982)
Min N (NH_4+NO_3-N)	mg kg^{-1}	Kjeldahl method	Bremner and Mulvaney (1982)
1N CH3COONH4 K	mg kg^{-1}	1 N ammonium acetate, flame photometer	Kacar (2009)
DTPA–Zn, Fe, Mn, Cu	mg kg^{-1}	DTPA extract, AAS	Kacar (2009)
Boron	mg kg^{-1}	Karmine method, Spectrophotometer	Kacar (2009)

The selection of indicators to be used to determine the plant-based potential of soils is very important (Zhan et al., 2016). Because there are many features that affect product development in varying amounts and it is not possible to use all of them (Karlen et al., 2014). In this regard, Doran and Parkin (1996), suggested using as few parameters as possible in model approaches. Indeed, it is known that there is a high correlation between some physical, chemical and biological features (Andrews et al., 2014), and it is stated that using all of them as indicators at the same time is not practically possible and contrary to the basic principles of the land assessment measurement paradigm (Şeker et al., 2015). Another issue is that performing too many soil analyses makes the application of the method to be developed cumbersome (Askari and Holden, 2015). For this reason, the indicators to be used in the project study were selected according to expert opinion and literature knowledge, considering their quality of representing one or more of the soil

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features, and their activities are presented in *Table 2*, and the sub-factor scoring of the parameters is presented in *Appendix 1*. In addition, in the selection of field indicators, the phases specified in the detailed soil map and defined as plant growth restricting parameters were used, while nutrient element indicators were selected by evaluating both plant growth and environmental impact factors and scored into subgroups. In this respect, the study method completely covers the application of expert opinion and literature knowledge, which is used in plant-based land assessment models and is a stage of the Hybrid System approach (De la Rosa and Van Diepen, 2002; Yalew et al., 2016).

Table 2. *Selected parameters and their effectiveness in the wheat land suitability model*

Indicators	Parameters	Effectiveness	Reference
Land Indicators	Depth	Root development, water storage capacity	Sarkar et al., 2014
	Slope	Losses through surface runoff	FAO, 1977
	Stoniness	Plant growth, tillage, water retention	Miller et al., 1984; Sauer et al., 2010
	Drainage	Salinity, root development, loss of nutrients	Siegel et al., 1980
Physical Indicators	Texture	Infiltration rate, structure type, plant-water relations	Ahmed et al., 2016; Ashraf et al., 2010
	Bulk Density	Soil compaction, aeration, infiltration	Şeker and Işıldar, 2000; Pagliai et al., 2003
	Hydraulic Conductivity	Air filled porosity, drainage, surface runoff	Kessler and Oosterbaan, 1974
	Available Water	Reserve water amount, plant water consumption, drought resistance	Letey, 1958
Chemical Indicators	EC	Osmotic potential, ion toxicity	Miransari and Smith, 2007
	pH	Nutrient availability, microbial activity	Baridón et al., 2014
	Organic Matter	Soil quality, biological activity	Riley et al., 2008; Guo et al., 2015; Kurzatkowski, 2004
	$CaCO_3$	Nutrient element fixation, aggregation	Erdal et al., 2000
Nutrient Indicators	P K NH_4^++NO_3^--N Zn Cu Fe Mn B	Vegetative development, nutrient balance, plant metabolism, salinization, toxicity, yield	Lindsay and Norvell, 1978; FAO, 1990; Jiang et al., 2006; Laghari et al., 2010; Marschner et al., 1996; Gezgin and Hamurcu, 2006

In the study, field indicators selected based on expert opinion and literature knowledge for wheat suitability assessment consist of important parameters for wheat development, especially in arid conditions. Soil depth is important for root development, water and nutrient storage (Aldababseh et al., 2018), while slope has affected soil management, mechanization practices and the increased degree of slope brings along the risk of erosion and this leads to organic matter and nutrient loss, especially in the soil (Sauer et al., 2010). For these reasons, it has been considered as a limiting factor for land capability in the land evaluation approach for wheat. Stoniness is an important problem adversely

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affecting the moisture storage, infiltration of soil surface and lower horizons and limiting the land use (Miller et al., 1984). This situation causes disadvantages of wheat cultivation in the region and causes a loss of productivity. Drainage can cause root suffocation problems due to the rise of groundwater in the winter months, and salinity problems due to capillarity in the summer months (FAO, 1997), especially in the soils that developed on the old lake bottom, such as regional lands. Common soil physical indicators used also in this study include surface soil particle size, bulk density, hydraulic conductivity and available water content. These factors are very important in arid regions because they directly interact with soil water capacity, water movement in the root zone, and plant - water relations (Rahmanipour et al., 2014; Sanchez-Navarro et al., 2015). The chemical properties of the soil are essential in determining the amount of yield, plant health, fixation and biological activity (Gugino et al., 2009). In this study, the following soil properties: OM, EC, pH, and $CaCO_3$ were offered by many authors due to their effects on root development, availability nutrient elements, soil structure, and aggregate stability, etc. (Chen et al., 2013; Linlin et al., 2017; Nabiollahi et al., 2017). On the other hand, the indicators selected above reflect inherent soil and land properties. However, in regions where intensive agriculture is carried out, dynamic ones reflect soil conditions resulting from current agro-technology (Wienhold et al., 2004). In this current study, our approach established soil fertility indicators called macro and micronutrients enabling them to reflect main effects because of land management practices. To this end we used Soil Fertility Index (SFI) was used to better understand the effect of macro and micronutrient content and to unify them into common score values (Mandal et al., 2005). SFI calculates qualitative soil fertility classes with a parametric approach using NPK parameters for each profile point (Dengiz et al., 2014). The factors in the SFI calculation of nutrient content in the study were determined according to *Appendix 1*. The SFI formula used in the calculation of the rating value for each diagnostic factor is presented with *Equations 1*.

$$SFI = \left[R_{max}\, x \sqrt{\frac{A}{100}\, x\, \frac{B}{100}\, x\, \ldots}\right] x\ 100 \qquad \text{(Eq.1)}$$

where,
SFI = Soil fertility index,
R = Maximum ratio, ((A+B+⋯+P)/3),
A, B... = Rating value for each diagnostic factor.

SFI values determined for soil samples were assigned according to the classes specified in *Table 3* and categorized into sub-classes.

Table 3. *Soil fertility index classes and values (Dengiz et al., 2014)*

Classes	Range	Weight
High	> 80	4
Moderately	80-50	3
Marginal	50-20	2
Low	< 20	1

In the study, each indicator parameter was assigned a score between 1 and 4 according to the status of allowing wheat plant growth. The criterion classes are assigned a value of 4 if they allow optimum wheat plant growth, and a value of 1 if they do not allow wheat

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plant development. The value between these two values was evaluated according to the limiting factor and its degree. The quantitative modeling phase of the study was carried out Analytic Hierarchical Process (AHP) which is the multi-criteria decision-making algorithm (Saaty, 2008).

Determination of wheat land suitability values of land units

In order to classify the potential qualities of the study area soils and determine their agricultural suitability, the Linear Combination Technique (LCT), which is a parametric approach, was applied to 92 different land units (LU) prepared vectorially with the Geographic Information System program ArcGIS 9.3. The Linear Combination Technique is a practical and reliable mathematical equation used in many similar studies in the evaluation of the sub-factor scores and weight ratios of the parameters that are effective in land use in terms of agriculture (Dengiz and Sarıoğlu, 2013; Romano et al., 2015). The formula for the LCT approach is presented with *Equations 2*.

$$LCT = \sum_{i=1}^{n}(Wi\,.Xi) \qquad \text{(Eq.2)}$$

where,
LCT; is the land suitability score for wheat,
Wi; is the weight value of parameter i,
Xi; is the sub-criteria score of parameter i,
n; the total number of parameters considered.

Wheat land suitability scores calculated with LCT are categorized into suitability classes based on FAO (1976) *(Table 4)*. At the same time, in order to determine the value ranges that will represent the suitability classes in the farm land, Q1 (3.2050), Q3(3.6560), median (3.5140) and range (1.5190) values were extracted from the histogram graph *(Fig. 2)* of the suitability values of all LU's with LCT and the suitability classes were categorized according to the intervals of natural diffraction (Zhang et al., 2015).

Table 4. *Suitability classes are divided into four categories according to FAO (1976)*

Suitability	Class	LCT Index
High	S1	>3.3035
Moderately	S2	3.018-3.3035
Low	S3	2.8782-3.017
Not Suitable	N	<2.8782

Suitability classes are categorized as "Highly Suitable: S1" in cases where there are no restrictive factors for wheat cultivation and development, "Moderately Suitable: S2" in cases where there are some mild restrictive factors, "Low Suitable: S3" in cases where there are serious factors affecting cultivation, and "Not Suitable: N" in cases where cultivation is not suitable.

Model validation

The success of the wheat land suitability model was tested using the 10-year yield values recorded by a parcel basis between the years 2009 - 2018. For this purpose, the yield averages of the parcels in the LU's and the suitability scores determined as a result

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of the LCT calculation for each mapping unit were calculated with the Zonal Statistics tool in the Spatial Analysis add-on package of ArcGIS 9.3 software and compared with linear regression analysis. If a statistical relationship of 70% and above was determined as a result of the comparison of wheat yields and suitability class values, the model was accepted to be successful. Indeed, similar studies have also reported that the linear relationships determined between yield values and land suitability classes between 51% and 70% indicate that the developed model can be used for giving ideas, while it has been reported that it is reliable for regression relationships above 70% (Keshavarzi, 2010; Zhang et al., 2015).

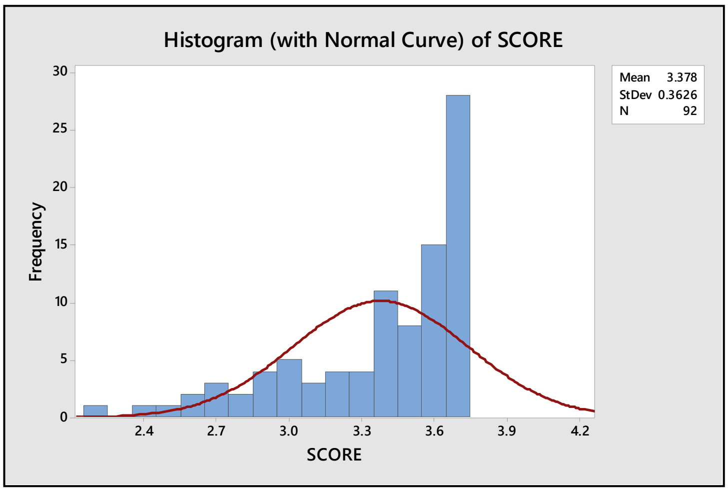

Figure 2. *Histogram graph of LCT scores (values)*

Results and discussions

Laboratory analysis results and descriptive statistics of samples representing previously determined soil series in farmlands are presented in *Table 5*. Most of the soils have a clay texture, and the clay content reaches 50% in some regions. The bulk density values of the regional soils vary between 1.06-1.45 cm^{-3}, and it has been determined that soil compaction, which is a major problem in soil tillage and management practices and is caused by heavy field traffic in some clay-textured irrigated agricultural areas, may occur. The usable water content values, which are of great importance for determining the irrigation time of plants, especially in irrigated agricultural areas, vary between 7% and 24%, and the average is determined as 15%. It is known that the usable water content values are directly related to the texture, pore size distribution and bulk density, and that the usable water content will decrease with the increase in bulk density and pore size. The determined values are generally within the expected ranges for soils with a clay texture and tend to decrease as the textural structure becomes coarser. When the pH and EC values of the regional soils are examined, according to Richards (1954), no salinity problem has been determined in the region. However, pH, which is directly related to the availability of macro and micronutrients, shows slightly alkaline properties. Similarly, the soil in the region contains high levels of lime. Organic matter content is at low-medium levels. When the available phosphorus (P) and potassium (K) contents of the soils in the region are evaluated for alkaline reaction soils according to (FAO, 1990), they show changes in the medium-high classes. Mineralizable nitrogen (N) contents are

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distributed in the low-medium classes in the region. When the micro element contents of the soil samples are examined according to Lindsay and Norvell (1978), manganese (Mn) is low and copper (Cu) is sufficient classes, ranging between 4.15-14.50 mg kg^{-1} and 0.41-1.94 mg kg^{-1}, respectively. Iron (Fe) content was found to be at low-high levels with values of 1.67-7.04 mg kg^{-1}. Zinc (Zn) content was determined between low and high classes with values of 0.12-7.91 mg kg^{-1}. Boron (B) contents of the regional soils are distributed between low and sufficient classes with values between 0.48 - 1.12 mg kg^{-1}.

Table 5. *Physicochemical characteristics of pedons*

Parameters	Min	Max	Mean	StDev	SE Mean	Variance
EC, dsm^{-1}	1.11	3.85	2.68	0.96	0.28	0.91
pH	7.24	8.05	7.50	0.27	0.08	0.07
$CaCO_3$, %	3.00	26.00	14.83	8.54	2.46	72.88
OM	1.32	3.63	2.23	0.73	0.21	0.53
P_2O_5, mg kg^{-1}	11.44	62.48	26.87	15.20	4.39	230.96
K_2O, mg kg^{-1}	4.99	27.28	11.73	6.64	1.92	44.03
Min N, mg kg-^{1}	46.88	81.72	57.38	11.71	3.38	137.02
Sand, %	16.50	53.70	29.26	10.29	2.97	105.95
Silt, %	24.40	36.40	30.48	3.53	1.02	12.47
Clay, %	21.90	51.30	40.27	8.67	2.50	75.10
Bulk Density gr cm^{-3}	1.06	1.45	1.28	0.06	0.02	0.02
Hydraulic Conductivity mm h^{-1}	1.13	6.18	3.77	1.55	0.45	2.39
Available Water g/g	0.07	0.24	0.15	0.05	0.01	0.02
Zn, mg kg-^{1}	0.19	0.95	0.40	0.27	0.08	0.07
Fe, mg kg-^{1}	1.67	7.04	2.88	1.43	0.41	2.04
Mn, mg kg-^{1}	4.15	14.50	9.28	3.06	0.88	9.35
Cu, mg kg-^{1}	0.41	1.94	1.33	0.48	0.14	0.23
Boron, mg kg-^{1}	0.48	1.12	0.80	0.23	0.07	0.05

According to the detailed soil survey report, the study area is located on 4 different physiography. These physiographic units are valley bottom fillings, old river terraces, old riverbeds and marl-limestone terraces. The soil depth shows a wide distribution between 11-200 cm. It was determined by using the digital soil map that there is a low (2-5%) and moderate (5-15%) 5-20 cm diameter stony problem in some regions of the operation lands and it is distributed in 28% of the total area. Cultivated plants are grown in all lands where stony problem is determined. The land size determined to have inadequate drainage conditions in the study area constitutes 6.32% of the total area. Areas where drainage problems were detected were defined in the plains formed on the old riverbed and in the lands around the valley bottom fillings. When the operating soils were examined in terms of slope groups, 61.1% of the total area was distributed in the flat-near flat, 38.15% in the slightly sloping classes, while 0.75% was in medium-steep topography. The weight values based on pairwise comparisons made to determine the suitability of 92 LU’s in the study area for wheat cultivation with the selected criteria are presented in *Appendix 2*.

Consistency Ratio of the weights determined as a result of pairwise comparisons; CR = 0.098. This value is less than 0.10 indicates that the method is valid (Saaty, 2008). In the pairwise comparison of the indicators and parameters evaluated; (1) the vegetation demands of the wheat plant, (2) the importance of the indicators and parameters relative

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to each other, (3) the elimination of the restrictive effects of the parameters on wheat development, and (4) the degree of change of the parameters in the regional soils were taken into account and the weight scores were determined. In fact, in studies conducted on a plant-based and regional scale, it is recommended that the weight value of region-specific characteristic features (e.g. high lime content, pH) and nutrient content whose restrictive effect can be easily eliminated should be low compared to other parameters, but the features that are not economical to improve or change in the field (e.g. slope, soil depth) should be weighted higher. However, it is known that the parameters that are not necessary for plant growth but have a beneficial effect on soil properties (e.g. organic matter) should also have a medium-level weight ratio, according to Riley et al. (2008). Thanks to all these evaluations, it is ensured that the model also represents the ecology of the region where it was developed (Aldababseh et al., 2018). Weighting of the parameters with the AHP method will be carried out with the following process steps (Saaty, 2008; Dengiz and Sarıoğlu, 2013). In the light of all these evaluations, as a result of the pairwise comparisons made by taking into account the ecology of the region, the degrees of the indicators used in measuring the suitability of farmlands for wheat cultivation were evaluated in 3 groups as high, medium and low. As a result of the AHP application, it was determined that the indicators of depth (11.9%), slope (10.9%), EC (11.1%) and texture (10.7%) had high weight coefficients. As a matter of fact, the effect degrees of these indicators also have high coefficients in the evaluation of lands in terms of plant cultivation (Dengiz et al., 2014). On the other hand, drainage (9.3%), stony (9.3%), texture (7.4%) and organic matter amount (6.0%) have taken the middle level weight value. This situation is also a finding that the remediable land conditions and the physical properties that can be improved with organic matter increasing applications can positively change the land quality index class. In fact, it has been stated that mechanization is facilitated, plant emergence and yield values increase with the improvement of stony and drainage conditions in agricultural lands (Miller et al., 1984; Sauer et al., 2010). In addition to these, the positive effects of organic matter on water retention, soil compaction, aeration and biological activity reduce the restrictive effect of texture and increase the suitability of the land for cultivation (Guo et al., 2015). With AHP application, available water content (5.8%), boron (5.6%), lime (5.5%) bulk density (5.5%), pH and EC (%4.7), macro (%4.3) and micro (%4.1) nutrients and hydraulic conductivity (%4.0) have established functions with low weight scores. It is known that plant growth, yield and nutrient uptake properties increase significantly depending on the suitable NPK and micro element content of the soil and that economic inputs due to fertilization decrease (Jiang et al., 2006). However, nutrient content can be increased with fertilizer applications made at different times. Therefore, the ratio of macro and micronutrient content at low weight values is an easy factor to improve. A similar situation was determined for Boron content, which is selected as an important parameter in wheat suitability assessment of farm soils. Indeed, boron requirement of wheat during vegetation is quite low. However, boron in growing medium can tolerate up to 2 mg kg^{-1} and is negatively affected by boron above this level (Gupta et al., 1985). For this reason, the regional soil was evaluated in terms of boron toxicity and since it was not determined above the threshold values for wheat, the weight value (5.6%) was kept low. The striking point here is the weight coefficient of the pH indicator, which is the subject of almost all land quality indices. Indeed, pH directly or indirectly affects many physical, chemical and biological events occurring in the soil (Baridón et al., 2014), and it has been stated that the mobility of phosphorus and trace elements in the soil decreases at high pH values, and

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the uptake of toxic elements by the plant increases in acidic soils (Leonard et al., 1976). However, the evaluation of pH with a low weight coefficient in the study is due to the fact that the study was conducted at a regional scale and the pH values of the regional lands did not show a striking change. A similar approach was applied for EC, lime and hydraulic conductivity, and the weight scores of the factors that depend on different parameters (e.g. groundwater, parent material origin, texture class) in the region were evaluated low. The wheat land suitability map of each mapping unit determined by LCT in the study is presented in *Fig. 3*, the suitability classes for each mapping unit are presented in *Appendix 3* and their areal sizes according to suitability classes are presented in *Table 6*.

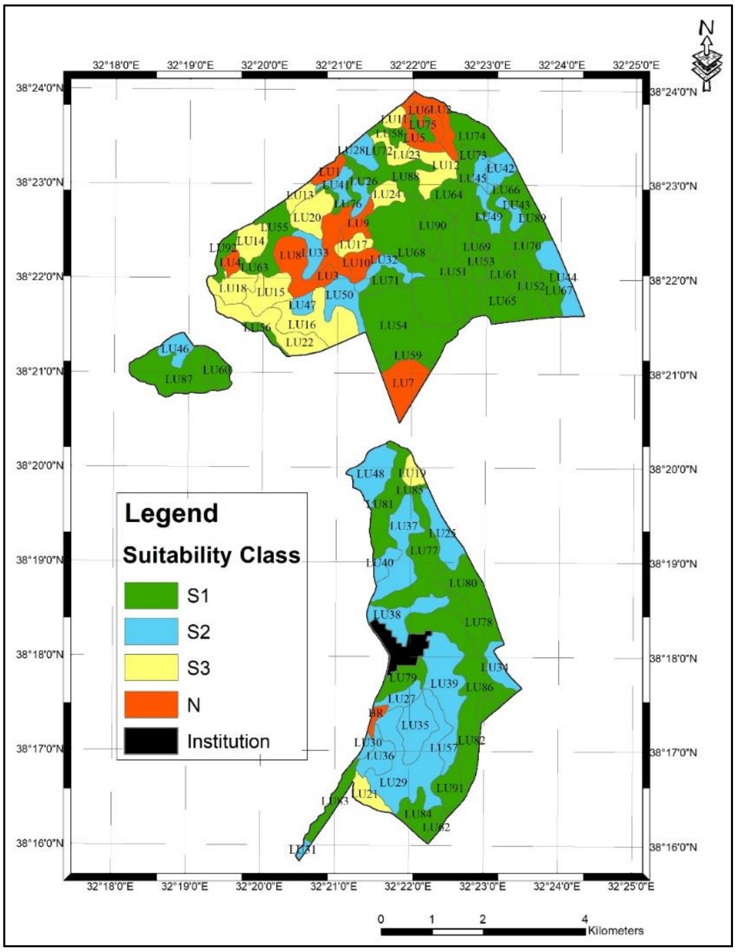

Figure 3. *Wheat land suitability map determined by LCT for each land unit*

Table 6. *Spatial distribution of suitability classes under the LCT categories*

Suitability	Class	Area (ha)	Distribution (%)
High	S1	2053.5	51.2
Moderately	S2	1052.3	26.3
Low	S3	532.7	13.3
Not Suitable	N	359.39	8.97

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As a result of the study, lands distributed in all suitability classes were determined in the farm. According to the wheat land suitability map, 2053.5 ha (51.2%) in the study area was classified as “highly suitable” as expected. The criteria evaluated for wheat cultivation in these areas do not have a restrictive effect. 1052.3 ha (26.3%) of the area in the region was defined as “moderately suitable”. These areas have a soil depth between 50-100 cm and are flat-close to flat slopes. However, heavy texture factors, low organic matter content and stony problems varying between 2-15% stand out as restrictive factors for agricultural production and reduce the LCT value. As a result of the index classification, 532.7 ha (13.3%) of the area was determined as “low suitable”. The combinations of the factors used in the suitability index in these areas with different degrees of effect were found to be remarkable. In fact, although some lands have flat slopes, high organic matter content and 25-50 cm soil depth, 5-15% stony problem together with drainage required these areas to be evaluated in low suitability classes. Similarly, areas with 2-5% stony, 5-15% $CaCO_3$ content, but soil depth of 0-25 cm and slope of 4-6% were also included in this class. It was determined that 532.7 ha (13.3%) of land in the study area was “not suitable” for wheat cultivation. At the same time, the unsuitable class shows the lowest areal distribution in the farmland. In these areas, 0-25 cm soil depth, 6% and above slope, 15-50% stony problem and insufficient drainage conditions are the restrictive factors for wheat cultivation and even the functioning of other factors with high weight values could not include these lands in suitable classes for wheat cultivation. Suitability class score values determined as a result of index calculation were compared with 10-year (2009 - 2018) average wheat yields (*Appendix 4*) representing the series and grown in dry conditions using linear regression analysis (*Fig. 4*) on a mapping unit basis. As a result of the evaluation of the data, it was determined that there was a relationship of r^2 = 0.75 between the yield and LCT values of the suitability classes. The validation numbers obtained showed that the Expert approach - AHP combination gives reliable results in the sub-factor weighting of the selected criteria for wheat suitability classification. In many studies conducted on plant-based land evaluation modeling, decision uncertainty has directed experts to the fuzzy logic theory approach and successful results have been obtained (Malczewski, 2006; Sharififar et al., 2016; Aldababseh et al., 2018; Almayyahi et al., 2024).

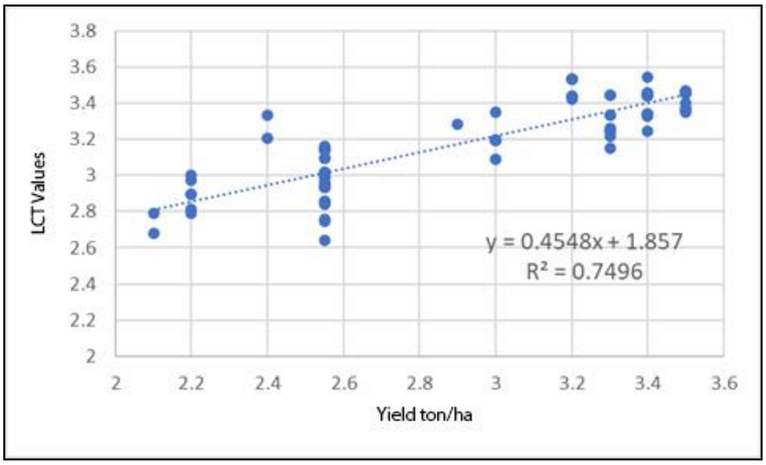

Figure 4. *Relationship between wheat yield and LCT values*

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Our study is also different in that the optimum conditions required for wheat cultivation are consistent with both expert opinion and literature knowledge. Indeed, AHP is essentially based on the subjective evaluation of the relative importance of the two factors, and while revealing the relationship between each factor, weightings that overlap with literature knowledge and expert opinion (Exper System) provide consistency (Saaty, 2008). In addition, the LCT model was found to be successful in calculating criteria in different units standardized according to the Hybird system and in its integration with GIS, like previous studies (Feizizadeh and Blaschke, 2013; Zabihi et al., 2015; Makar et al., 2024). In a study conducted to assess the suitability of dry farming in the region, it was stated that AHP supports decision making for sustainable agricultural production and offers the opportunity to improve agricultural planning by providing much-needed information for farmers and agricultural planners (Bozdağ et al., 2016). Similarly, Yaman and Mutlu (2025), developed the model for suitable wheat cultivation in Konya by using hybrid system with climate parameters, but the fact that the soil criterion was not considered is among the limitations of the study and it is recommended that this criterion be taken into account in future studies. In this respect, our study has both provided the contributions suggested in previous studies and presented a specific approach to planners for similar dry conditions by using yield values for model validation.

Conclusion

The study demonstrates the success of a practical plant-based land evaluation approach integrated with GIS developed in accordance with arid-semi arid climate conditions in the Central Anatolian Region to determine lands suitable for wheat cultivation. The developed model was tested with yield parameters, which are ground realities belonging to the farm, and it was determined that it classified land suitability for wheat with reliable accuracy. In addition, we recommend that GIS capabilities are appropriate for the analysis of research data and scientific definition and mapping of lands suitable for wheat cultivation. In the wheat land suitability model, the criteria weighted with AHP were evaluated under three main headings as physical, chemical and topographic, and the fact that wheat cultivation was highly affected by topographic and physical criteria provided a reliable index approach. While revealing the relationship between each factor with AHP, making common decisive weights that overlap with literature knowledge and expert opinion provides consistency. Especially the soil texture distribution, bulk density and available water parameters were evaluated as an indicator that the use of precision agricultural tools and equipment would be appropriate in the mechanization plans, soil processing and leveling works in the region. In this way, the protection of soil water and the nutrient-water balance with reduced soil processing should be targeted. The relevant parameters are also indicators that directly concern the parameters of soil compaction, plowing time, germination and plant water consumption in terms of agricultural cultivation. Therefore, the weight coefficients were found appropriate for the developed model. In fact, other physical indicators are highly correlated with soil texture and appropriate value ranges change in different textures. This situation is explained by the texture class being weighed higher than the bulk density and available water content. However, considering the changing climate conditions, the regional soils carry a permanent salinity risk in the future. For this reason, it is recommended that nutrient content and pH increases that may develop in the lower horizons (the beginning of sodicity) should be carefully monitored with EC values. Fertilization programs have to

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prepared by taking the relevant indicators as reference and OM increasing measures would be taken. The study also showed similarity with previous research findings that AHP has a high capacity for the integration of heterogeneous data. Therefore, we suggest that the wheat land suitability model can be used to determine scientifically defined suitable lands for wheat cultivation in different regions with similar climates in Turkey. In the study, wheat yields of soils under applications depending on operating habits were used. However, different cultural applications cause variable yields to be obtained in similar soils. Therefore, it is predicted that the model can be improved by using the applications and times applied in addition to the yield parameters of the region in future studies. However, in order for the wheat land suitability model to be used as a general-valid index, it should be tested and developed in similar climate conditions and different soil types. In this way, the effects of changes that may occur in different soil properties on score values and suitability class assignments will be better understood. Therefore, it is thought that taking the study one step further and using yield values obtained as a result of pessimistic-optimistic and traditional cultural applications (fertilization, hoeing, organic matter addition, etc.) in field conditions will increase the model success.

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APPENDIX

Appendix 1. *Sub-score values of the parameters to be used in the wheat land suitability model determined using expert opinion and literature knowledge*

Land Indicators

Depth (cm)		Slope %		Stoniness %		Drainage	
Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight
0-25	1	0-2	4	% 0-1	4	İyi	4
25-50	2	2-6	3	% 2 – 5	3	Orta	3
50-100	3	6-12	2	% 5 – 15	2	Yetersiz	2
100+	4	12-20	1	% 15 – 50	1	Fena	1

Physical Indicators

Texture		Bulk Density g/cm^3		Hydraulic Conductivity mm h^{-1}		Available Water g/g	
Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight
fS, LS, SL, cS and Si	1	< 1.50 - > 0.80	4	141.3 – 181.9	4	> 0.12	4
		1.50 – 1.55	3	95.8 – 141.2	3	0.10 - 0.12	3
		1.56 - 1.60	2	64.0 – 95.7	2	0.05 – 0.11	2
		>1.60- < 0.80	1	< 64.0	1	< 0.05	1
C->%45 -C, SC, SiC	2	< 1.25 - >0.80	4	10.4-14.0	4	>0.18	4
		1.25 -1.35	3	7.5-10.3	3	0.15 -0.18	3
C-<%45 - C, CL, SL, SC, SiCL	3	1.36-1.45	2	7.4 – 3.8	2	0.10 -0.14	2
		>1.45 - <0.80	1	<3.8	1	< 0.10	1
L, SiL and SCL	4	< 1.30 - > 0.80	4	28.40-43.80	4	> 0.15	4
		1.30 – 1.35	3	16.50-28.30	3	0.13 – 0.15	3
		1.36 – 1.50	2	10.90-16.40	2	0.11 – 0.14	2
		> 1.50 - < 0.80	1	< 10.90	1	< 0.11	1

Chemical Indicators

pH		EC (dS m^{-1})		$CaCO_3$ (%)		Organic Matter %	
Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight	Sub Factor	Weight
> 8.2 < 5.5	1	0-2	4	< 5	4	0-1	1
5.5 – 6.5	3	2-4	3	5-10	3	1-2	2
6.5-7.5	4	4-8	2	10-25	2	2-3	3
7.5-8.2	2	8-10	1	> 25	1	>3	4

Nutrient Indicators

	Unit		Weight			
			4	3	2	1
Olsen-P	mg kg^{-1}	Sub Factor	8-25	2.5-8	>25	<2,5
1N CH3COONH4 K	mg kg^{-1}		>130	130-72	33-72	<33
NH_4^++NO_3^--N	mg kg^{-1}		>60	60-40	40-20	<20
DTPA-Zn	mg kg^{-1}		0.7-2.4	0.7-0.2	>2,4	<0,2
DTPA-Cu	mg kg^{-1}		0.2-1	0.2-0.1	>1	<0,1
DTPA-Fe	mg kg^{-1}		>4.5	4.5-2.5	2.5-1	<1
DTPA-Mn	mg kg^{-1}		14-50	14-4	>50	<4
B	mg kg^{-1}		1-2.5	0.4-1.0	>2,5	<0.,4

Sub-factors are grouped according to the sources and expert opinion in Table 2.

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Appendix 2. *AHP technique calculations for determining the weight values of parameters*

Pairwise Comparison Matrix

Parameters	Depth	Slope	Stoniness	Drainage	OM	Texture	Macro	Micro	$CaCO_3$	HC	BD	B	pH	EC	AW
Depth	1	2	3	3	2	3	5	1	1	1	2	1	3	3	1
Slope	1/2	1	1/2	3	2	3	3	3	3	5	1	1	3	3	1
Stoniness	1/3	2	1	1/3	2	3	3	3	3	3	1	1	3	1	1
Drainage	1/3	1/3	3	1	3	3	3	3	3	3	1	1	1	1	1
OM	1/2	1/2	1/2	1/3	1	3	3	3	3	1	1	1	1	1	1
Texture	1/3	1/3	1/3	1/3	1/3	1	2	2	3	2	1	3	3	3	1
Macro	1/5	1/3	1/3	1/3	1/3	1/2	1	2	1/3	2	1	1	1	1	1
Micro	1	1/3	1/3	1/3	1/3	1/2	1/2	1	1/3	2	1	1	1	1	1
$CaCO_3$	1	1/3	1/3	1/3	1/3	1/3	3	3	1	2	1	1	1	1	1
HC	1	1/5	1/3	1/3	1	1/2	1/2	1/2	1/2	1	1	1	1/2	1	1
BD	1/2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
B	1	1	1	1	1	1/3	1	1	1	1	1	1	1	1	1
pH	1/3	1/3	1/3	1	1	1/3	1	1	1	2	1	1	1	1	1
EC	1/3	1/3	1	1	1	1/3	1	1	1	1	1	1	1	1	1
AW	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Total	9.37	11.03	14.00	14.33	17.33	20.83	29.00	26.50	23.17	28.00	16.00	17.00	22.50	21.00	15.00

Normalized pairwise comparisons matrix

Parameters	Depth	Slope	Stoniness	Drainage	OM	Texture	Macro	Micro	$CaCO_3$	HC	BD	B	pH	EC	AW
Depth	0.11	0.18	0.21	0.21	0.12	0.14	0.17	0.04	0.04	0.04	0.13	0.06	0.13	0.14	0.07
Slope	0.05	0.09	0.04	0.21	0.12	0.14	0.10	0.11	0.13	0.18	0.06	0.06	0.13	0.14	0.07
Stoniness	0.04	0.18	0.07	0.02	0.12	0.14	0.10	0.11	0.13	0.11	0.06	0.06	0.13	0.05	0.07
Drainage	0.04	0.03	0.21	0.07	0.17	0.14	0.10	0.11	0.13	0.11	0.06	0.06	0.04	0.05	0.07
OM	0.05	0.05	0.04	0.02	0.06	0.14	0.10	0.11	0.13	0.04	0.06	0.06	0.04	0.05	0.07
Texture	0.04	0.03	0.02	0.02	0.02	0.05	0.07	0.08	0.13	0.07	0.06	0.18	0.13	0.14	0.07
Macro	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.08	0.01	0.07	0.06	0.06	0.04	0.05	0.07
Micro	0.11	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.01	0.07	0.06	0.06	0.04	0.05	0.07
$CaCO_3$	0.11	0.03	0.02	0.02	0.02	0.02	0.10	0.11	0.04	0.07	0.06	0.06	0.04	0.05	0.07
HC	0.11	0.02	0.02	0.02	0.06	0.02	0.02	0.02	0.02	0.04	0.06	0.06	0.02	0.05	0.07
BD	0.05	0.09	0.07	0.07	0.06	0.05	0.03	0.04	0.04	0.04	0.06	0.06	0.04	0.05	0.07
B	0.11	0.09	0.07	0.07	0.06	0.02	0.03	0.04	0.04	0.04	0.06	0.06	0.04	0.05	0.07
pH	0.04	0.03	0.02	0.07	0.06	0.02	0.03	0.04	0.04	0.07	0.06	0.06	0.04	0.05	0.07
EC	0.04	0.03	0.07	0.07	0.06	0.02	0.03	0.04	0.04	0.04	0.06	0.06	0.04	0.05	0.07
AW	0.11	0.09	0.07	0.07	0.06	0.05	0.03	0.04	0.04	0.04	0.06	0.06	0.04	0.05	0.07

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Eigenvector

Parameters	**Normalized sum of rows**	**Normalized average rows**	**Eigenvector**
Depth	1.79	1.79/15	0.119
Slope	1.64	1.64/15	0.109
Stoniness	1.39	1.39/15	0.093
Drainage	1.40	1.40/15	0.093
OM	1.02	1.02/15	0.068
Texture	1.11	1.11/15	0.074
Macro	0.62	0.62/15	0.041
Micro	0.65	0.65/15	0.043
$CaCO_3$	0.83	0.83/15	0.055
HC	0.60	0.60/15	0.040
BD	0.82	0.82/15	0.055
B	0.84	0.84/15	0.056
pH	0.70	0.70/15	0.047
EC	0.71	0.71/15	0.047
AW	0.88	0.88/15	0.058
λ_{max} =17.182; CI = 0.155; CR = 0.098			

* HC: Hydraulic Conductivity, BD: Bulk Density, B: Boron, AW: Available Water, OM: Organic Matter, Macro: Macro Nutrients, Micronutrients, CI: Consistency Index, CR: Consistency Ratio

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Appendix 3. *Spatial distribution of suitability classes to land units*

Land Unit	Class	Area (ha)	Land Unit	Class	Area (ha)	Land Unit	Class	Area (ha)	Land Unit	Class	Area (ha)
LU1	N	17.54	LU25	S2	48.18	LU49	S2	19.30	LU73	S1	15.59
LU2	N	31.07	LU26	S2	15.51	LU50	S2	44.75	LU74	S1	132.07
LU3	N	10.76	LU27	S2	24.30	LU51	S1	58.69	LU75	S1	13.63
LU4	N	12.75	LU28	S2	25.74	LU52	S1	45.62	LU76	S1	21.22
LU5	N	22.87	LU29	S2	168.26	LU53	S1	11.40	LU77	S1	93.82
LU6	N	26.85	LU30	S2	7.87	LU54	S1	176.11	LU78	S1	59.79
LU7	N	61.75	LU31	S2	4.26	LU55	S1	50.25	LU79	S1	38.81
LU8	N	113.72	LU32	S2	29.19	LU56	S1	10.99	LU80	S1	57.05
LU9	N	23.21	LU33	S2	26.82	LU57	S1	0.00	LU81	S1	67.82
LU10	N	29.18	LU34	S2	26.59	LU58	S1	16.39	LU82	S1	47.11
LU11	S3	12.96	LU35	S2	62.68	LU59	S1	17.34	LU83	S1	29.34
LU12	S3	50.36	LU36	S2	38.40	LU60	S1	29.39	LU84	S1	45.30
LU13	S3	16.25	LU37	S2	85.21	LU61	S1	44.34	LU85	S1	30.71
LU14	S3	36.54	LU38	S2	55.45	LU62	S1	8.95	LU86	S1	149.13
LU15	S3	50.48	LU39	S2	119.72	LU63	S1	11.73	LU87	S1	98.71
LU16	S3	92.40	LU40	S2	18.79	LU64	S1	32.27	LU88	S1	33.69
LU17	S3	20.47	LU41	S2	21.24	LU65	S1	102.68	LU89	S1	34.76
LU18	S3	41.67	LU42	S2	26.07	LU66	S1	48.80	LU90	S1	43.80
LU19	S3	16.80	LU43	S2	15.96	LU67	S1	31.11	LU91	S1	43.34
LU20	S3	48.71	LU44	S2	47.36	LU68	S1	201.75	LU92	S1	18.38
LU21	S3	25.62	LU45	S2	18.47	LU69	S1	13.14			
LU22	S3	72.27	LU46	S2	26.40	LU70	S1	11.49			
LU23	S3	24.37	LU47	S2	14.81	LU71	S1	26.95			
LU24	S3	23.79	LU48	S2	60.99	LU72	S1	39.00			

Appendix 4. LCT values and suitability classes corresponding to yield values

Land Unit	LCT	Yield tone/ha	Land Unit	LCT	Yield tone/ha	Land Unit	LCT	Yield tone/ha	Land Unit	LCT	Yield tone/ha
LU2	2.79	2.10	LU70	3.46	3.50	LU26	3.15	2.55	LU14	2.99	2.55
LU6	2.68	2.10	LU52	3.46	3.50	LU49	3.15	2.55	LU17	2.99	2.55
LU5	2.76	2.55	LU63	3.46	3.50	LU43	3.15	2.55	LU18	2.95	2.55
LU1	2.86	2.55	LU53	3.35	3.00	LU33	3.16	2.55	LU15	2.94	2.55
LU9	2.86	2.55	LU71	3.40	3.50	LU44	3.20	3.00	LU16	2.90	2.20
LU8	2.84	2.55	LU67	3.44	3.30	LU32	3.20	3.00	LU22	2.90	2.20
LU10	2.75	2.55	LU54	3.44	3.30	LU50	3.20	3.00	LU19	3.00	2.20
LU4	2.64	2.55	LU56	3.45	3.40	LU47	3.20	3.00	LU21	2.98	2.20
LU3	2.82	2.20	LU60	3.45	3.40	LU48	3.20	3.00			
LU7	2.79	2.20	LU87	3.45	3.40	LU25	3.20	3.00			
LU74	3.53	3.20	LU59	3.45	3.40	LU37	3.09	3.00			
LU75	3.53	3.20	LU81	3.45	3.40	LU40	3.20	2.40			
LU58	3.53	3.20	LU85	3.34	3.40	LU38	3.33	2.40			
LU72	3.53	3.20	LU77	3.34	3.40	LU39	3.26	3.30			
LU73	3.44	3.20	LU80	3.34	3.40	LU34	3.34	3.30			
LU88	3.44	3.20	LU78	3.34	3.40	LU27	3.34	3.30			
LU76	3.42	3.20	LU86	3.34	3.40	LU29	3.22	3.30			
LU66	3.47	3.50	LU79	3.34	3.40	LU35	3.24	3.30			
LU64	3.47	3.50	LU82	3.45	3.40	LU36	3.15	3.30			
LU89	3.36	3.50	LU57	3.55	3.40	LU30	3.24	3.30			
LU68	3.47	3.50	LU91	3.45	3.40	LU31	3.33	3.40			
LU65	3.35	3.50	LU83	3.45	3.40	LU46	3.24	3.40			
LU90	3.37	3.50	LU84	3.45	3.40	LU11	3.02	2.55			
LU55	3.46	3.50	LU62	3.44	3.40	LU23	3.02	2.55			
LU51	3.46	3.50	LU28	3.28	2.90	LU12	2.96	2.55			
LU92	3.46	3.50	LU42	3.14	2.55	LU24	2.94	2.55			
LU69	3.46	3.50	LU45	3.10	2.55	LU13	2.94	2.55			
LU61	3.46	3.50	LU41	3.10	2.55	LU20	2.94	2.55			

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