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RESEARCH PAPER

Geospatial Evaluation of Soil and Land Suitability for Sustainable Maize Cultivation

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ABSTRACT

Tanzania's soil data is insufficient for local strategies on agricultural land use planning since it is extremely specialized to locations deemed to have great promise based on a small amount of data. The study used geographical informatics to understand soil suitability for maize crop production in Tungi Village agroecosystem, Morogoro District, Morogoro Region. This has implications for food security, poverty, and climate in the area. Three criteria were used in the suitability analysis to determine which areas would be best for growing maize: soil properties, topography, and climate. Each criterion was assigned a weight value using the Multi-Criteria Evaluation's Analytic Hierarchy Process (AHP) method. Through ArcGIS 10.8, cumulative weights for each criterion were employed to create the soil result maps. Results show potassium, cation exchange capacity, total nitrogen, and organic carbon were sufficient. The climate and topography were ideal for growing maize crops. S1 (vastly appropriate), S2 (fairly suitable), and S3 (minimally suitable) were determined by the land suitability results to be around 51% (2,555 acres), 34% (1,677.5 acres), and 15% (767.5 acres), respectively. It is therefore placed that the soil suitability map would be a tool for local agro-land use decision-making in Tanzania and beyond.

HIGHLIGHTS

- The study employed Geographic Information Systems (GIS) integrated with the Analytic Hierarchy Process (AHP) to evaluate land suitability for maize cultivation, enabling precise and data-driven decision-making.
- Study use three evaluated criteria soil, climate, and topography soil properties (e.g., pH, organic carbon, nitrogen, potassium, CEC) were found to have the highest impact on maize suitability.
- The analysis revealed that 51% of the land was highly suitable (S1) for maize production, while 34% was moderately suitable (S2), and only 15% minimally suitable (S3).
- General suitability, the study found low levels of available phosphorus and Cation Exchange Capacity (CEC) in some areas, signaling a need for targeted soil fertility management.
- Generated maize suitability maps offer valuable tools for local authorities, extension agents, and

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farmers to plan sustainable agricultural practices and improve productivity in the face of climate and land use challenges.

Keywords: GIS, Maize, land degradation, climate change, land suitability, AHP1

Land degradation affects smallholder farmers, rural communities, and 3.2 billion impoverished people worldwide (Alkharabsheh *et al.* 2023; Otieno *et al.* 2022; Nungula *et al.* 2024; Sairam *et al.* 2023, 2025). Accordingly, the demand for agricultural products is predicted to increase, and by 2050, the world's population is predicted to reach 9.7 billion people (FAO, 2017). According to Nungula *et al.* (2023), 80% of people live in rural areas and rely on land resources for their livelihood, especially in Tanzania. Human activity is thought to be responsible for the degradation of over 51% of rural land at the moment, primarily as a result of inadequate land management (Emmanuely *et al.* 2024; Nungula, 2024). Given the strong need for intensive, sustainable farming and the need to expand land holdings to accommodate the rapidly expanding population, this suggests food insecurity. One important answer for the future is the use of Geographic Information Systems (GIS) technology as a land management tool for sustainable land management (Mugo *et al.* 2021).

Through the use of diverse geographical data, GIS can enhance agricultural production by increasing productivity potentials and facilitating decision-making data access (El Baroudy, 2016; Massawe *et al.* 2024). For the purpose of mapping the suitability of the land, GIS was created to effectively collect, store, update, manipulate, and evaluate various types of spatially referenced data (Hamzeh *et al.* 2014; Nduwumuremyi *et al.* 2013). When combined with multiple-criteria decision-making tools, GIS provides land-use planners and land managers with numerous advantages in terms of integrating and controlling various elements when making decisions and mapping the land for a particular use (Torrieri and Batà, 2017; Mwendwa *et al.* 2019). A sustainable land-use management practice can be achieved with the help of these methods (Musakwa, 2018; Maitra *et al.* 2023).

Due to its effectiveness in making decisions using a variety of factors ranked according to expert judgment, the analytical hierarchy process (AHP) method is the most widely used multiple-criteria decision-making (MCDM) technique in GIS-based land evaluation assessment (Torrieri and Batà, 2017; Michelle, 2021; Otieno *et al.* 2023). It is used to select the best option among the alternatives identified for a particular land use and allows the evaluation of group decisions. The choice of appropriate and suitable sites for agricultural purposes is always made using a combination of GIS and AHP (Sanchez-Lozano *et al.* 2013). Kihoro *et al.* (2013) assert that utilizing a GIS-AHP is an effective method for gathering, analyzing, and evaluating data and results since it allows a researcher to make minor corrections more quickly and provide more accurate findings. Planning and maintaining agricultural land in both complex and dynamic agricultural systems can be done with knowledge thanks to GIS-AHP integration (Romeijn *et al.* 2016; Zephaline *et al.* 2024; Maitra *et al.* 2024).

Due to a lack of soil data regarding the suitability of maize in various places, Tanzania's abundance of arable land and favorable agroecological zones have not yet been fully utilized for agricultural production (Kimaro and Hieronimo, 2014). For nations like Tanzania that have a comparative advantage in the production of agricultural commodities, evaluation and assessment of land suitability may increase agricultural productivity and result in the self-sufficiency of food commodities (Chappa *et al.* 2023).

Tanzania having plenty of vast arable land and favourable agroecological zones, still, such opportunities have not been fully exploited for agricultural production due to the lack of soil information on the suitability of maize in different regions (Kimaro and Hieronimo, 2014). Literature suggests that land suitability evaluation and assessment could improve agricultural productivity and lead to food commodities' self-sufficiency for countries that have a comparative advantage in agriculture commodities' production like Tanzania (Chappa *et al.* 2023). In order to close this gap, this study used a computer-based land evaluation system called GIS-AHP to assess the Tungi Farm's feasibility for producing maize. Therefore, evaluating the appropriateness of maize is long overdue and could contribute to increasing production, thereby addressing the significant food insecurity challenge (Nungula, 2024).

METHODOLOGY

Study Area Description

The study was carried out on Tungi Farm, which is located in Tanzania's Morogoro District at latitude 6o 44′15″ and longitude 37o 42′07″ (Figure 1). The farm is 2000 hectares in size and is farmed by smallholder farmers, especially for maize. The region experiences 770 mm of rainfall on average each year, with an average temperature of 25.1 °C. The locations' predominant textures are sandy to loam. Maize is the main crop farmed in this region for agricultural production, which is the main socioeconomic activity.

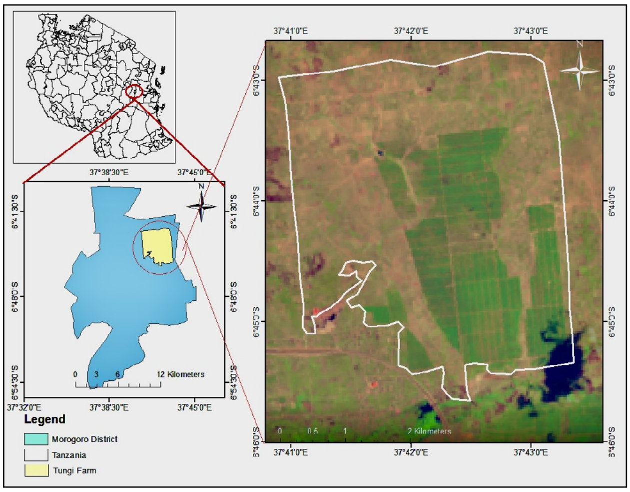

Fig. 1: Study area map

Soil survey and soil sampling

To determine the farm's location and general landform characteristics, a reconnaissance study was carried out. Important leads to farm boundaries and landmark feature locations were recorded using a GARMIN extrex 20 Global Positioning System (GPS) device. A Digital Elevation Model (DEM) with a 90 m spatial resolution that was taken from Google Earth Pro, processed in a GPS visualizer, and interpolated in ArcGIS 10.8 geostatistical software was used to create a base map (Figure 2). To distinguish the sampling units, observable land characteristics such as soil color, and land use type were noted, together with elevation and slope gradient. Areas exhibiting similar characteristics were combined to create sample units, and six sampling units were found (Figure 2). Composite samples were taken from each mapping unit using the zigzag method of soil sampling, labeled, and sealed in a ziplock bag and transported to Kenyatta University's soil laboratory for analysis. The following characteristics of the soil were examined: textural class, pH, OC, TN, K, Av. P and CEC. The sampling locations were marked with a handheld GPS.

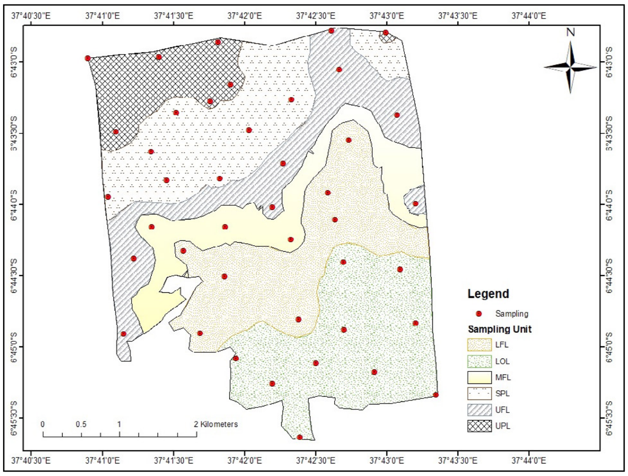

Fig. 2: Composite samples with their location

Laboratory analysis

The Hydrometer method was used to determine the soil's texture class (Kalala *et al.* 2017). Using a pH meter and a 1:2.5 soil/water ratio, the pH of the soil was measured (Ryan *et al.* 2001). Total nitrogen was determined using the Kjeldahl digestion method, and the Walkley-Black method was employed to analyze soil organic carbon (SOC) (Nelson & Sommers 1996; Chappa *et al.* 2023). Phosphorus was extracted using the Mehlich-3 technique with ICP-OES (Mehlich, 1978). Phosphorus availability was evaluated using a UV-vis spectrophotometer. Exchangeable potassium (REF) was measured using the Flame Photometry technique. The ammonium acetate method was used to determine Cation Exchange Capacity (CEC) (Chapman, 1965).

Ranking of identified criteria for growing maize

By using a pair-wise preference matrix to compare one criterion to another, as explained by Saaty (2014), the weights assigned to the various criteria were determined using AHP approach of the

Multi-Criteria Evaluation (MCE). The weight value indicates the degree of significance given to the selected criteria, suggesting the relative importance of one criterion to the other criteria being considered (Table 1); the criterion with the highest weight is therefore more significant than the others (Kumar *et al.* 2019; Girari *et al.* 2020).

Table 1: The Saaty's rating scale

Intensity of importance	Definition	Explanation
1	Equal significance	Two elements equally contribute to the goal
3	Little more significant	Experience and judgment favor one another a little
5	Quite Significant	Experience and judgment greatly favor one
7	Very much important	Experience and judgment very strongly favour one over the other
9	Absolutely important	The evidence favouring one over the other is of the highest possible validity
2, 4, 6 and 8	Intermediate values	When it's necessary to compromise

Source: *Saaty (2014).*

The AHP was computed using the following mathematical model (Eq. 1).

$$A = (a_{ij})\ n \times n = \begin{bmatrix} w1/w1 & w1/w2 & ...w1/wn \\ w1/w2 & w2/w2 & ...w2/wn \\ w1/wn & wn/w2 & ...wn/wn \end{bmatrix} \quad ...(1)$$

Where A denoted the $n \times n$ matrix which also comprises (a_{ij}). W represents a nonzero eigenvector, $1 \times n$ in size. The criteria weight (Table 2) was calculated from the pairwise comparison matrix undertaken and Eigen-vector values based on the Eq. 2.

$$\frac{\sum_i^n = 1\left(\frac{W1}{W2} x \frac{W1}{W2} x \dots \dots \frac{W1}{Wn}\right)^{1/n}}{\Sigma\left[\sum_i^n = 1\left(\frac{W1}{W2} x \frac{W1}{W2} x \dots \dots \frac{W1}{Wn}\right)^{1/n}\right]} \quad ...(2)$$

Consistency Ratio (CR) was calculated using (Eq. 7). During the judgment, the judgment matrix is only considered consistent if the ratio is < (0.1). A CR of 0.1 or less is more reasonable (Triantaphyllou and Mann, 1995) (Eq. 3).

$$CR = \frac{CI}{RI} \quad ...(3)$$

Where;

CI = Consistency Index and RI = Random Index

Suitability level assessment

The Tungi Farm's suitability level for maize production was evaluated using the modified FAO framework. Each composite sample was assigned the corresponding scoring rate by matching land requirements with land quality using modified suitability criteria for maize (FAO, 1976) (Table 2).

Reclassification

Raster maps for various soil characteristics were created, and those raster maps were classed using ratings for maize (Roy *et al.* 2006). With class values of 1, 2, 3, and 4, the classification was extremely low, low, medium, and high, in that order. Soil attributes were scored on a scale of 1 to 4 for every soil mapping unit (Table 3). When the parameter is very suitable, a higher value is assigned; when the parameter is low suitable, a lower value is assigned. Every parameter that was utilized was given an equal amount of class units.

Production of Maize Suitability Map

Land characteristics and maize crop requirements were matched to create the area's suitability map for maize cultivation. The reclassified layers for each parameter physical and chemical soil qualities and topography as determined by weights generated by the AHP procedure with GIS—were then integrated (Fig. 3). As explained by Tashayo *et al.* (2020), weighted layers for every criterion were superimposed using the weighted overlay analysis utilizing the raster calculator tool in the spatial analysis tool extension of ArcGIS 10.8 using the Eq. 4.

$$S = \sum_{i=1}^{n} W_i x_i \quad ...(4)$$

Where;

S = Suitability score; W_i = Weight of the i^{th} criteria; X_i = Weight of the i^{th} sub-criteria; n = Total number of criteria.

Table 2: Land requirement for Maize production

Criteria	Unit	Factor rating			
		S1	**S2**	**S3**	**N**
Soil Factors					
Textural class	class	sl, l, ls	scl, sil	cl, sicl	s, sc, sic, c
CEC	cmol kg^{-1}	> 24	16–24	16–6	< 6
OC	g kg^{-1}	> 2	2–1	0.5–1	> 0.5
pH	water	6.0–7.0	5.5–6.0, 7.0–7.5	5.0–5.4, 7.0– 8.0	< 5, > 8
Av.P	mg kg^{-1}	> 22	7–22	3–7	<3
Total N	g kg^{-1}	>2	2–1	0.5–1	< 0.5
Extractable K	cmol kg^{-1}	> 0.50	0.20–0.50	0.10–0.20	< 0.10
Climatic factors					
Temperature	^{o}C	20–25	20–18	18–15	< 15
Rainfall	mm/year	500–800	800–1000	1000–1500	> 1500
Topography factors					
Elevation	m	460–560	560–760	760–1100	> 1100
Slope	%	0– 3	3–8	8–16	> 16

Key: sl = sandy loam, l = loam, ls = loam sand, scl-sand clay loamy, sil = silt loam, c = clay, cl = clay loam, sicl = silt clay loam, s = Sand, sic = silt clay, sc = sand clay.

Source: *Modified from Kaaya et al. (1994).*

Table 3: Suitability classes

Suitability level	Percentage(%)	Corresponding Value	Symbol
Currently unsuitable	0 – 25	1	N
Minimally suitable	25 – 50	2	S3
Fairly suitable	50 – 75	3	S2
Vastly appropriate	75 – 100	4	S1

Source: *FAO (1976).*

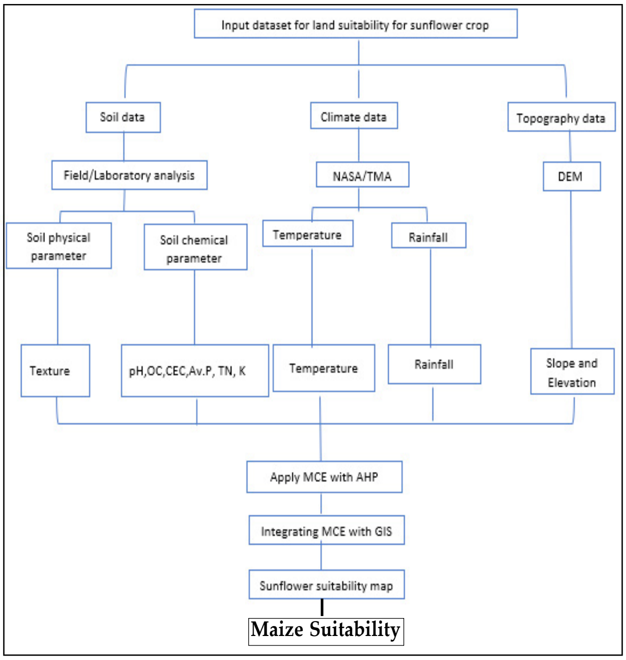

Fig. 3: Methodology workflow for suitability map of maize production

RESULTS AND DISCUSSION

Ranking of criteria for maize production

In maize productivity, soil characteristics were more important than topography and climate, according to the comparison decision matrix (Table 4). When comparing pairwise preference, the assigned values of 1 and 2 indicate that criteria are regarded as being equally important and that score values of 3 and 5 are much more significant. CR for soil throughout the ranking was 0.032, while CR for climate and topography was 0; this suggests that the decision was justified for maize cultivation because CR < 0.1 in all categories.

According to the weighting criteria for maize, the soil criterion was given the highest priority (score of 0.62), followed by soil and climate (score of 0.29), and topography (score of 0.09), which was the lowest priority (Table 5). Because it supplies vital nutrients and creates an environment that

Table 4: Pairwise comparison matrix for maize production

Main Criteria	Subcriteria	pH	OC	TN	Av. P	K	CEC	ST	CW	CR<0.1	CI
Soil	pH	1.00	2.00	2.00	3.00	2.00	3.00	3.00	0.27	0.032	0.04
	OC	0.50	1.00	2.00	2.00	2.00	3.00	3.00	0.21		
	TN	0.50	0.50	1.00	2.00	2.00	3.00	3.00	0.17		
	Av. P	0.33	0.50	0.50	1.00	2.00	3.00	2.00	0.13		
	K	0.50	0.50	0.50	0.50	1.00	1.00	2.00	0.09		
	CEC	0.33	0.33	0.33	0.33	1.00	1.00	1.00	0.07		
	ST	0.33	0.33	0.33	0.50	0.50	1.00	1.00	0.06		
Climate		Temperature	Rainfall							0.00	0.00
	Temperature	1.00	3.00						0.75		
	Rainfall	0.33	1.00						0.25		
Topography		Slope	Altitude							0.00	0.00
	Slope	1.00	3.00						0.75		
	Altitude	0.33	1.00						0.25		

For soil criteria; Max eigenvalue (λmax) = 7.248, n = 7, CI = 0.043. Climate criteria; Max eigenvalue (λmax) = 2, n = 2, CI = 0 and Topography criteria; Max eigenvalue (λmax) = 2, n = 2, CI = 0.

Table 5: Main Criteria ranking for maize production

Main Criteria	Soil	Climate	Topography	CW	Ranking	CR <0.1	CI
Soil	1.00	2.00	7.00	0.62	1	0.003	0.002
Climate	0.50	1.00	3.00	0.29	2		
Topography	0.14	0.33	1.00	0.09	3		

Max eigenvalue (λmax) = 3.003, n = 3, CI = 0.002.

is favorable for maize growth, development, and productivity, soil is the most important requirement for cultivating maize (Ochieng', *et al.* 2021). Because they limit the output of maize when it is grown continuously without fertilizer, which lowers the land's capacity for production, soil chemical properties such as OC, pH, TN, K, CEC, Av. P and soil texture are significant (Chikuvire *et al.* 2007; Nasar *et al.* 2022; Jamal *et al.* 2024). Due to their significance in determining the chemical and physical features of the soil, the pH was given a high weight of 0.27 when weighing the sub-criteria for maize development. This was followed by OC, which scored 0.021. Despite having a low weight score of 0.06 among the group criteria, soil texture is crucial for maize cultivation because it has a significant impact on the soil's ability to retain water and nutrients (Chappa *et al.* 2023; Shao *et al.* 2023; Zeqiang *et al.* 2024).

When the soil is unable to retain water and nutrients for an extended period of time, soil texture can also have an impact on crop yield (Table 5). Rainfall and temperature are two climate factors that affect maize yield (Mochoge *et al.* 2015; Nduwimana *et al.* 2020). The fact that temperature was given a weight of 0.75 while rainfall was given a weight of 0.25 suggests that maize may thrive in semiarid regions since it can tolerate dryness and does not require a lot of water to mature. Compared to soil and climate, which were given a weight of 0.09, topography criteria in the study area had little effect on maize output. Since water erosion occurs in the sloping area during the rainy season, resulting in nutrient depletion, crop damage, and decreased output in the research area, the slope in topography is given a high weight of 0.75 (Table 5). Consequently, flat land is preferable over sloping terrain.

Soil Suitability

The area's soil pH values in the current study ranged from neutral (7.2) to strongly acidic (5.5), with a mean of 6.3 (slightly acidic). With 1204 ha and 796 ha of the farm, respectively, the suitability analysis of soil pH for maize production reveals that 60.2% was hugely suitable (S1) and 39.8% was fairly suitable (S2) (Fig. 4).

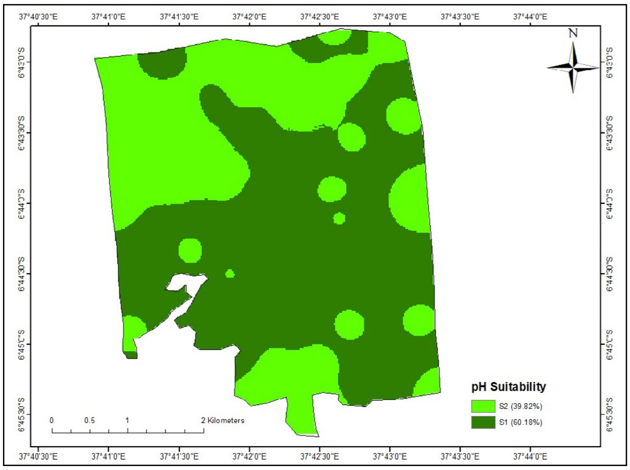

Fig. 4: pH suitability map for maize production

Organic carbon is also among the most crucial factors to take into account while choosing the land that is most suitable for farming (Ranjan *et al.* 2023; Kalala *et al.* 2017; Rahimi *et al.* 2023). With an average of 3.5 g kg^{-1}, Tungi Farm's soil organic carbon (OC) ranged from low (1.2 g kg^{-1}) to medium (4.9 g kg^{-1}). 97.5% of Tungi Farm's OC was found to be highly appropriate (S1) for maize production, while 2.5% was comparatively. With coverage of 1950 ha and 49 ha of the farm, respectively, the suitability analysis of Tungi Farm's OC for maize cultivation reveals that 97.5% was massively suitable (S1) and 2.5% was reasonably acceptable (S2) (Fig. 5).

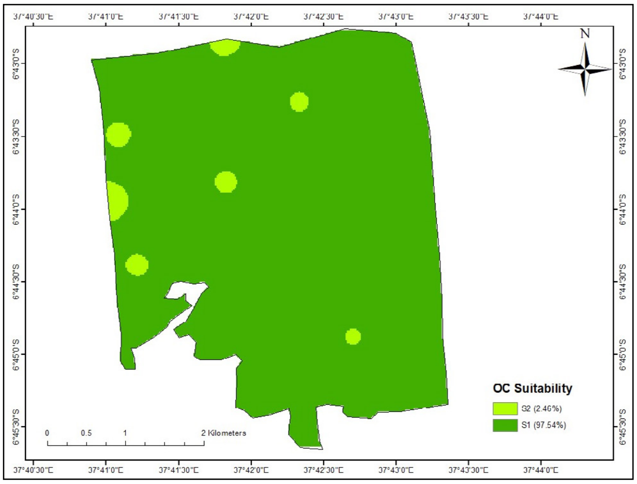

Fig. 5: OC suitability map for maize production

The range of total nitrogen (TN) was low (1.0 g kg^{-1}) to medium (5.0 g kg^{-1}), with a medium rating of 3.5 g kg^{-1} on average. With corresponding area coverages of 1952 ha and 48 ha, the suitability analysis based on Tungi Farm's total nitrogen for maize cultivation reveals that 97.6% and 2.4% are profoundly appropriate (S1) and fairly suitable, respectively (Fig. 6).

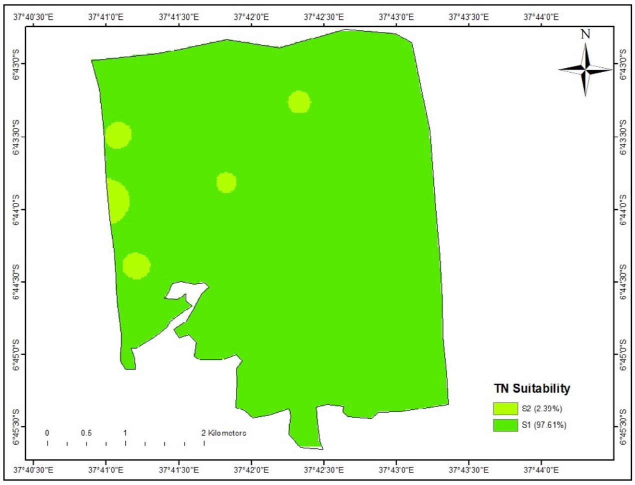

Fig. 6: TN suitability map for maize production of Tungi Farm

With a mean value of 6.28 mg kg^{-1}, the area's available phosphorus was classified as low (Marx *et al.* 1999) and ranged from low (3.34 mg kg^{-1}) to medium (14.34 mg kg^{-1}). A suitability analysis of Tungi Farm's available phosphorus for maize cultivation reveals that, with farm area coverage of 16.6 ha and 1983.4 ha, respectively, 0.83% was relatively suitable (S2) and 99.17% was minimally appropriate (S3) (Fig. 7).

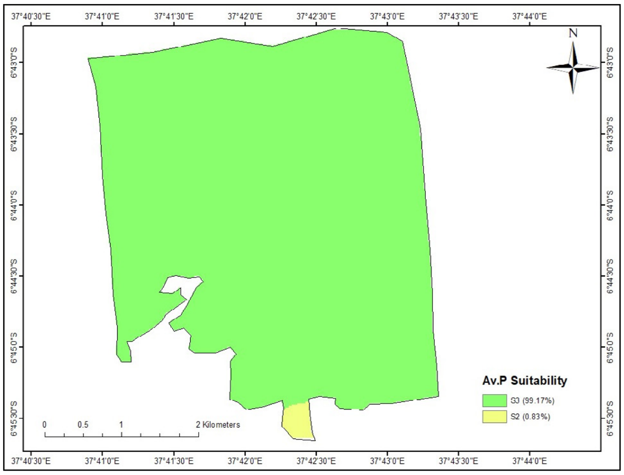

Fig. 7: Av.P suitability map for maize production

With an average of 0.44 cmol kg^{-1}, potassium levels varied from low (0.14 cmol kg^{-1}) to medium (0.84 cmol kg^{-1}) (Marx *et al.* 1999). The Tungi Farm's suitability analysis for potassium reveals that, with respective farm covering areas of 507.51, 1481.13, and 11.36 ha, 25.38%, 74.06%, and 5.68% of the farm were massively suitable (S1), fairly suitable (S2), and minimally suitable (S3) (Fig. 8).

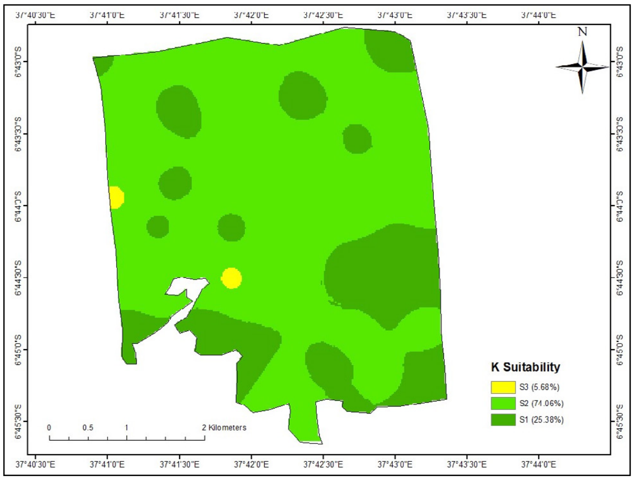

Fig. 8: Potassium suitability map for maize production

With an average of 6.67 cmol kg^{-1}, Tungi Farm's CEC value was deemed poor, ranging from 5.13 to 8.29 cmol kg^{-1} (Marx *et al.* 1999). With a farm area coverage of 78.6 ha and 1921.4 ha, the suitability analysis of Tungi Farm's CEC for maize production reveals that 3.9% was marginally suitable (S3) and 96.1% was currently not suitable (N) (Fig. 9).

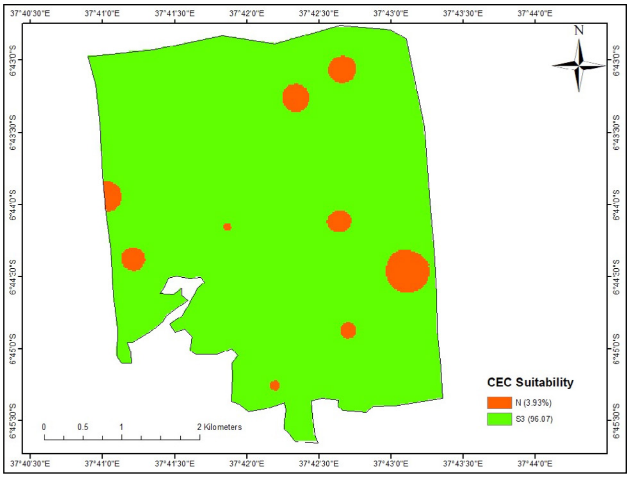

Fig. 9: CEC suitability map for maize production

At Tungi Farm, the texture classes generally ranged from sandy clay to sand. The observed soil textures promote maize production by facilitating root movement, aeration, water infiltration, and improved drainage, claim Brady and Weil (2017) and Saglam *et al.* (2014). 78, 6, and 16% of the land was hugely suitable (S1) (1564 ha), reasonably suitable (S2) (122 ha), and now not appropriate (N) (314 ha), according to suitability based on soil texture (Fig. 10).

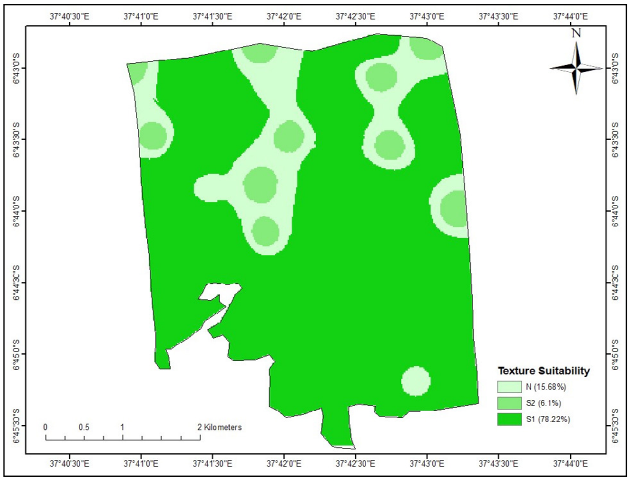

Fig. 10: Texture suitability map for maize production

Topography Suitability

As elevation ranges vary, so do altitude variations, according to the Digital Elevation Model result. The DEM data indicated an elevation range of 523 to 550 meters above sea level. According to elevation-based suitability, all of the land was extraordinarily appropriate (S1) (2000 ha) (Fig. 11).

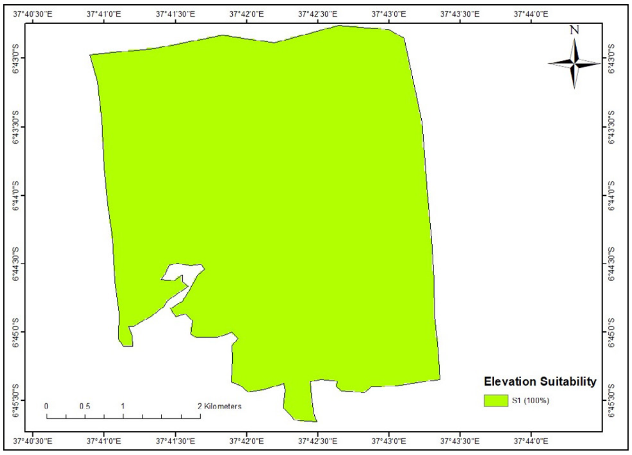

Fig. 11: Elevation suitability map for maize production

When determining whether regions are suited for maize, one of the aspects to consider is the area's slope, which has a significant impact on the intensity of soil erosion (Moges and Ajanaw, 2020; Nyawade *et al.* 2021). According to the results of the Digital Elevation Model, the slope varied between 0 and 1.5%, 1.5 and 2.4%, 2.4 and 3.3%, and 3.3 and 4.5%. According to slope-based suitability, 95.6 and 4.5% of the land were, respectively, massively appropriate (S1) (1911 ha) and reasonably suitable (S2) (89 ha) (Fig. 12).

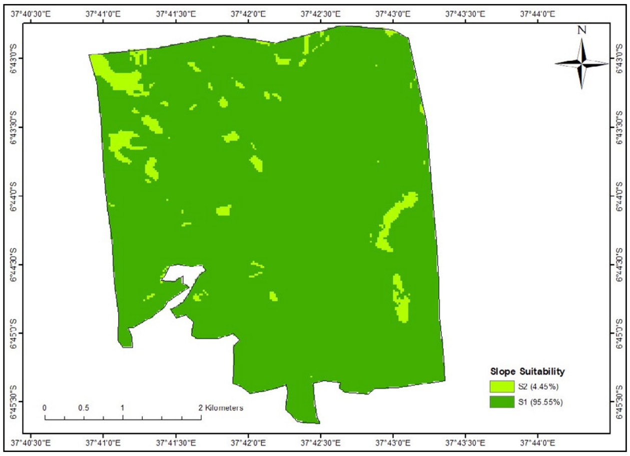

Fig. 12: Slope suitability map for maize production

Climate Suitability

Maize needs between 600 and 1000 mm of water annually, depending on the duration and volume of rainfall. 20% of water is used during the vegetative stage, 55% during the blooming stage, and 25% during the yield production and ripening stages. The amount of water used by any crop depends on its stage of growth (Goher *et al.* 2023; Andrew *et al.* 2013; Ochieng' *et al.* 2022). According to Egeru (2012), maize output should follow a medium-to-good trend of roughly 600 to 1000 mm annually during the growing season. Given that the rainfall at the Tungi Farm varies between 890 and 909 mm, this suggests that the region received enough rainfall. Consequently, despite rainfall, the farm was deemed highly appropriate (S1) for producing maize. Despite rainfall being not fairly stable (Fig. 13).

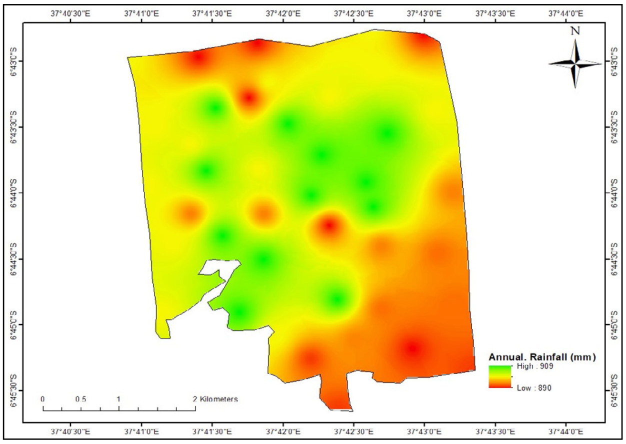

Fig. 13: Rainfall suitability map for maize production

According to Hollinger and Angel (2009), temperature plays a significant role in determining when and how quickly a crop will develop in response to solar radiation and precipitation. It is said that maize is a short-day plant that reacts directly to the length of daylight. It may thrive in a variety of climates, from semi-arid or temperate to arid regions (albeit with irrigation) (Seleiman *et al.* 2021). The maize crop grows best at mean temperatures between 18 and 25°C since it cannot tolerate frost (Chappa *et al.* 2022; Andrew *et al.* 2013). With an average temperature of 25°C, the entire region was largely favorable (S1) for maize production, according to the temperature reclassification (Fig. 14).

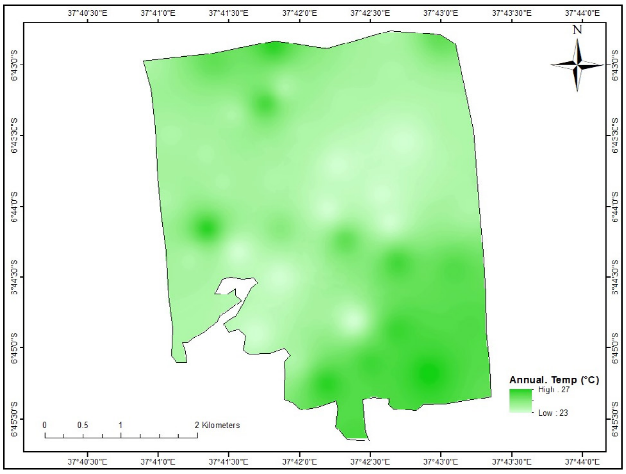

Fig. 14: Temperature suitability map for maize production of Tungi Farm

Maize suitability map

A maize suitability map was created by superimposing the soil chemical properties, soil texture, topography, and climate based on the properties chosen for evaluation of maize crop suitability (Fig. 15). S1 (vastly appropriate), S2 (fairly suitable), and S3 (minimally suitable) were determined by the land suitability results to be roughly 51% (1022 ha), 34% (671 ha), and 15% (307 ha), respectively.. According to the findings, extensive cultivation, crop residue removal, and continuous cultivation without fertilizer additives have left the majority of cultivated soils deficient in TN and accessible P (Emiru and Gebrekidan, 2013; Ogolla, 2021; Mwadalu *et al.* 2022). Therefore, an integrated approach involving land-use planners, researchers, farmers' communities, and agriculture extension is required to allocate the proper space for maize cultivation in order to achieve high economic agricultural production.

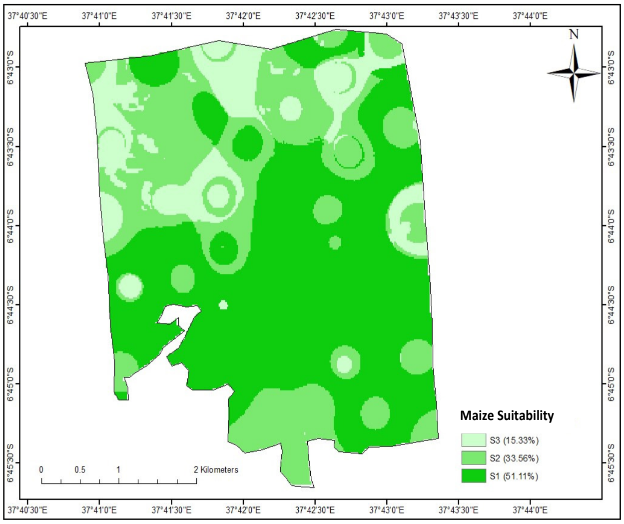

Fig. 15: Maize suitability map

Land suitability is an effort to take into account every factor that could affect vegetation and crop growth, especially when it comes to maize production (Cheptoek *et al.* 2021). Weighting the primary criteria and sub-criteria parameters for the final land suitability study was done using a model based on the Analytical Hierarchy Process (AHP). When there are conflicting criteria present, the consistency of AHP, a better way to determine the weights of numerous components, may be measured and regulated. Nevertheless, GIS is a versatile tool that may be used to define the study area, gather and process geographic data, and display the findings of a land suitability analysis. In order to assure better management for crop production there is a need to ensure integration of GIS-AHP that offer a potent combination for land suitability evaluation. Users can determine the appropriate weighting for the different criteria during the land suitability study by integrating the GIS-AHP technique. The results of precision agriculture are improved when such integrated techniques are used to conduct land suitability studies.

The ideal conditions for crop suitability management are provided by adopting GIS-AHP and including the various biophysical variables. Soil, climate, and terrain were among the biophysical characteristics that were evaluated in this multi-parameter study. By offering a biophysical analysis that enables farmers to choose and implement appropriate crop and soil management techniques to get high yields, this method improves the efficacy of crop management on the farm. Additionally, it will assist farmers and extension agents in creating efficient fertilizer application plans that would enhance crop performance and yields.

In order to ensure that management activities are carried out at the appropriate time, amount, and location, the study's findings offer suggestions for achieving high land productivity. Regular soil analysis is essential for tracking the amount of available nutrients in the soil throughout time and space (Ray *et al.* 2024). Additional research based on quantitative measures of soil compatibility is required because this study used qualitative data from soil analysis. According to the study's findings, farmers can also utilize the comprehensive information to decide whether to grow maize on their property because it could increase their income while preserving the quality of the land (Krishna *et al.* 2024). In order to create the best choices based on the chosen criteria, it was advised to use the GIS-AHP integration strategy, which involves a number of criteria. The judgment based on actual field conditions may be revealed by the criterion. Numerous elements that impact maize development and productivity in the research area were included in order to offer a thorough analysis. Furthermore, the sub-criteria were confirmed to be a significant need that could be applied to agricultural production planning.

CONCLUSION

Land suitability is an effort to take into account every factor that could affect vegetation and crop growth, especially when it comes to maize production. Weighting the primary criteria and sub-criteria parameters for the final land suitability study was done using a model based on the Analytical Hierarchy Process (AHP). When there are conflicting criteria present, the consistency of AHP, a better way to determine the weights of numerous components, may be measured and regulated. Nevertheless, GIS is a versatile tool that may be used to define the study area, gather and process geographic data, and display the findings of a land suitability analysis. In order to assure land use efficiency and better management for crop production there is a need to ensure integration of GIS and AHP that offer a precise and potent combination for land suitability analysis.

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