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Research Paper

GIS-AHP Technique Land Suitability Assessment for Capsicum (*Capsicum annuum* L.) Production

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ABSTRACT

This study was carried out to determine areas best suited for capsicum production in the peri-urban counties of Nairobi, Kenya for growing capsicum (*Capsicum annuum* L.). The study used a multi-criteria evaluation approach by applying the Analytic Hierarchy Process (AHP). These methods involved a selection of various criteria used for analysis and categorized according to their usefulness concerning capsicum growth conditions/requirements. Soil (pH, drainage, texture, and electrical conductivity), climate (temperature and rainfall), and topography (slope and elevation) were the main criteria selected from the literature for the study. The AHP was used to determine the relevance of a criterion based on its cumulative weights as per Saaty's table. The cumulative weights were used to construct output maps using Quantum Geographic Information Software (QGIS). A crop suitability map was produced through overlaying of the different thematic maps and suitability levels were based on Food and Agriculture (FAO) land suitability classification. The results showed that about 50% of land in Kiambu County, 8% in Kajiado County, and 12% in Machakos County is suitable for capsicum production. The remaining areas were reported unsuitable for the production of the crop due to the presence of some limitations such as texture, soil pH, drainage, and climate.

HIGHLIGHTS

- About 50% of land in Kiambu County, 8% in Kajiado County, and 12% in Machakos County are suitable for capsicum production.
- Soil pH, drainage, texture, and climate are the key limitation for declining capsicum yields.
- Optimizing capsicum production is possible through sustainable farming, which entails the production of a crop in a conducive and suitable environment.
- Geographic Information System (GIS) is used to support decisions for development in agriculture by providing information that helps farmers to optimize crop production.

Keywords: Land suitability, Suitability assessment, AHP, Capsicum suitability, QGIS, Kenya

Fertility of soils as determined by nutrient distribution is considered to be among the factors affecting the production of crops such as capsicum (*Capsicum annuum* L.) (Mugo *et al.* 2021; Otieno *et al.* 2022). Capsicum is among the first plants to be domesticated and is normally referred to as chili pepper plant due to its heat or pungency nature (Basu and De, 2003). The crop is believed to have originated from Mexico from where it diffused to other nations worldwide. Initially, the crop was

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introduced in Kenya by the Pan African Canners Company in 1975 which used to buy ripe capsicum from its fathers before it closed the business. Optimizing capsicum production is possible through sustainable farming, which entails the production of a crop in a conducive and favorable environment (Addeo *et al*. 2001). To practice this, crops need to be planted where they are most suited to grow. Determining where capsicum is suited requires a detailed evaluation of land; such studies help match crop requirements with land qualities (Mishra *et al.* 2011). Efforts towards enhancing the production of capsicum in the three selected counties saw an integration of agricultural practices with appropriate spatial information. According to Kato (1993), selecting suitable crops using computers has been done before with soil, climate, geological, and geomorphological conditions being used as determining factors.

Geographic Information System (GIS) has been adopted by different sectors in national development but little has been done to support decisions for development in agriculture. Petja *et al.* (2004) recommend the use of these technologies to improve quality of life. Previously, GIS has been applied under different scenarios. For instance, Ashraf (2010) assessed the suitability of growing wheat using multi-criteria evaluation and GIS. It provided information that helped farmers select their cropping patterns. Stickler *et al.* (2007) produced maps that determined the production capabilities of soybean, sugar cane, and oil palm. Crop nutritional and ecological requirements were identified and the data was used to develop spatially explicit variables, which were used to determine suitable regions where the crops could be grown. Abah *et al.* (2017) conducted a crop suitability study for mapping of rice, cassava, and yam in Nigeria. In the Philippines, Adornado *et al.* (2008) produced nutrient distribution and crop suitability maps for the growth of rice, maize, coconut, mango, bananas, and potatoes.

In Kenya, Mugo *et al.* (2016) used GIS to identify suitable land for green gram production in Kitui. They found out that all lands in Kitui are suited for green gram production. Kuria *et al.* (2011) used GIS technology to assess if rice could be grown in Tana Delta; a suitability map was prepared to identify the various areas of suitability. The study by Kihoro *et al.* (2013) investigated the suitability of growing rice in the Mwea region using a multi-criteria evaluation and GIS. The result showed that 75% of the total land already under production of rice was highly suitable, and only 25% was ranked as moderately suitable. In Nyandarua County, Kamau *et al.* (2015) determined potato suitability analysis using GIS and remote sensing. The results revealed that 38% of the agricultural land was best suited for growing potatoes with 51% and 11% being moderately and marginally suitable, respectively.

Nonetheless, little had been done in determining the suitability of growing capsicum in Kenya. To fill this gap, the current study evaluated land in Kiambu, Kajiado, and Machakos counties for its suitability for capsicum production. To apply GIS technology, the study aimed at assessing the suitability of growing capsicum based on critical factors considered to be affecting its growth using GIS. This was achieved by determining soil properties, climatic and topographic characters and utilizing GIS tools in the production of output maps (soil fertility maps and crop suitability maps). The study also involved the use of Multi-criteria evaluation (MCE) approaches in GIS by applying Analytical Hierarchy Process (AHP) where various suitability criteria chosen for the study were assessed and grouped according to their relevance in optimizing capsicum production (Perveen *et al.* 2008; Otieno *et al*. 2022).

MATERIALS AND METHODS

The study area

The study was conducted in three peri-urban counties of Nairobi (Kiambu, Kajiado, and Machakos Counties) (Fig. 1). Kiambu County borders Nairobi to the North with a total area of 2,449 km²; it lies between latitude 1.12°S and 1.08°S, longitude of between 36.52°E and 37.33°E and an altitude of between 1800 and 2100 m above the sea level. It falls in the upper midlands agroecological zone characterized as having medium potential for agricultural production (Jaetzold *et al.* 2006; Wanjiku, 2014). It receives an average annual rainfall of 962 mm and an average temperature of 18.8°C. June and July are the coldest months while January–March and September–October are the hottest months. Acrisols, Alisols, Lixisols, and Luvisols are the dominant soils in Kiambu County; characterized by increased clay content in the subsoil, low water storage capacity, and poor structure (Gachene *et al.* 2003).

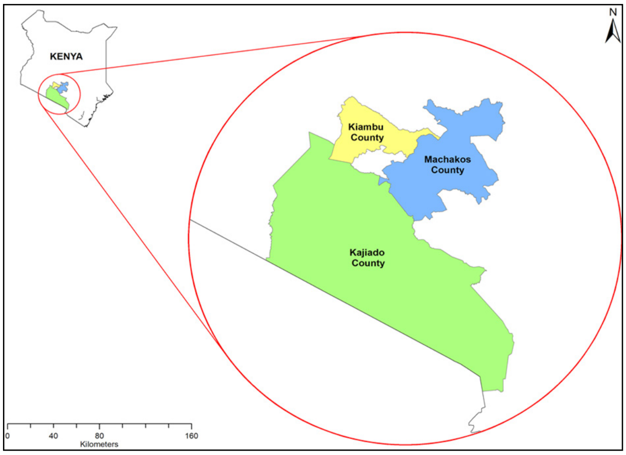

Fig. 1: A map showing the counties where study was carried out: Kiambu, Kajiado and Machakos

Kajiado County borders Nairobi to the south with a total area of 21,292.7 km²; it lies between latitude 2.01°S and 2.15°S, longitude 36.02°E and 37.64°E with altitudes of between 500 and 2500 m above the sea level. The climate in Kajiado County is characterized by steppe with an average annual rainfall of 500 mm and an average temperature of 18.9°C. Rainfall is mostly received in April with August being the driest month. It falls in the lowland's midlands agroecological Zone (Jaetzold *et al.* 2006). Ferralsols, vertisols, cambisols, leptosols, and acrisols are the main soils that dominate Kajiado County; characterized by uneven clay distribution with high sodium content (Gachene *et al.* 2003).

On the other hand, Machakos County borders Nairobi to the west with a total area of 5,953 km²; it lies between latitude 1.35°S and 1.44°S, longitude of between 36.94°E and 37.80°E and an altitude of between 1000 to 2100 m above sea level. It falls in the upper highlands agroecological zone hence classified as semi-arid (Jaetzold *et al.* 2006). It records an average annual rainfall of 830 mm and an average temperature of 19.0°C. The County is dominated by low fertile and easily erodible soils such as alfisols, ultisols, oxisols, and lithic (Barber *et al.* 1981). Each of the sub-counties within all three was covered wholly or partially in the study.

Data Collection

The methodology utilized for this study involved the collection of both primary (soil analysis data, from objective one) and secondary data (satellite imagery/ climate data) (Table 1). Remote Sensing was used to generate satellite imagery as land use/ land cover map and digital elevation model. GIS was used to integrate thematic maps, weighted percentages of the relevant criteria for the generation of soil fertility and crop suitability maps.

Topography data were obtained from Kenya Agricultural and Livestock Research Institution (KALRO) and entered into Micro Soft Excel sheets. The land use map was produced through Landsat 8 Satellite imagery obtained from the USGS website. Climate data (temperature and rainfall) were obtained from Kenya Meteorological Department (KMD). Climatic data were analyzed using the spatial multi-criteria evaluation model using GIS to produce an agro-climatic map.

The agro-climatic map was integrated with a soil fertility map, crop nutrient data, and biological data to produce a crop suitability map using Quantum Geographic Information System (QGIS) software.

Table 1: Datasets for the study

Data Set	Format of the data	Data Source
Climate (temperature/rainfall)	Microsoft Excel	NASA website
Topography (slope/elevation)	Shape file	Digital Elevation Model (DEM)
Soil (drainage)	Shape file	Field test
Soil (texture, major and minor elements)	Microsoft Excel	Laboratory analysis
Satellite image (Landsat 8)	Tiff	USGS website
Soil sample sites	UTM coordinates	Kobo Collect
Administrative boundaries	Shape file	Survey of Kenya

NASA: National Aeronautics and Space Administration; UTM: Universal Transverse Mercator; USGS: United States Geological Survey; DEM: Digital Elevation Model MS Microsoft Excel.

Suitability levels were based on the FAO land suitability classification structure, which was ranked as S1 for highly suitable, S2 for moderately suitable, S3 for marginally suitable, and N for not suitable.

Data Management and Analysis

Rainfall and temperature data obtained from the National Aeronautics and Space Administration were entered into an Excel format file. Using MS Excel, the data were cleaned to ensure that the values obtained are free from any obvious errors. The climate data was averaged for a given period and exported to QGIS software for further manipulation. Ordinary Kriging, a geospatial method of interpolation was used to interpolate data points into a continuous surface. The final image produced was then clipped to the study areas by use of County boundaries.

A land use map for the three counties was produced using Landsat 8 satellite. The Landsat 8 image for each County was procured from the United States Geological Survey website. The image was corrected for errors that arose from radiometric, atmospheric effects, etc. Digital image processing was done using Environment for Visualizing Images 5 software, to improve identification of features and exported to QGIS software for supervised classification for identification of various land uses. Topography data was also entered in Excel and then exported to QGIS software to be interpolated through ordinary Kringing to have a representation of elevation values for every study area. The resultant was a continuous surface, which formed a raster image. This was then clipped to the areas of study using the County administrative boundaries. Slope data were derived using the toolbox properties of the QGIS software.

Soil pH was determined using a potentiometric method using a high-impedance voltmeter on a soil suspension of 1:2 (soil: water) (Ryan *et al.* 2001). The electrical conductivity (EC) of the soil was determined using the potentiometric method, made with a conductivity cell by measuring the electrical resistance of a 1:2 soil water suspension in an air-dried sample. Soil texture was determined by the hygrometer method while drainage was determined on the farmer fields following the percolation test. Soil analysis data (Soil pH, soil EC, drainage, and texture) were exported to QGIS software where they were explored and displayed in a map format. Major and minor soil nutrients were also exported to QGIS software for the production of soil fertility maps.

Mapping of suitable locations for capsicum production

Climate, soil, topography, and landscape were used to determine the suitability of land for capsicum production. These characteristics were ranked differently and assigned a value between 0 and 100 (Table 2). These characteristics were then combined to give the optimal land use. Soil (pH, texture, Ec, drainage), climate (temperature, rainfall), landscape (land use), and topography (elevation and slope) data were used as the main criteria for land evaluation.

Table 2: Land suitability index for agricultural crops

Suitability index for a crop (average of a group of crops)	Degree of suitability	Symbol	Definition
80–100	Excellent	S1	Highly suitable land with no limitations to the specified use
60–80	Moderate	S2	Moderately suitable land with moderate limitations to the specified use
40–60	Marginal	S3	Marginally suitable with severe limitation to the specified use
20–40	Currently unsuitable	N1	Currently unsuitable land with severe limitations which cannot be corrected with existing knowledge and technology at currently acceptable cost
0–20	Permanently unsuitable	N2	Permanently unsuitable land with severe limitations which cannot be corrected

Data source: FAO (1976).

Standardization and reclassification of criteria

With the production of different thematic maps (Fig. 2), the relative importance of each criterion was required and was obtained by assigning weight to each criterion. For a reasonable comparison since the data used for the study were on different scales of measurements, a common standard was required to apply weighted overlay over each of the input criteria, this ensured that all factor maps produced correlated to the suitability.

This was achieved by use of spatial analysis tools (Mishra *et al.* 2015). The weight is a value assigned to an evaluation criterion indicative of its importance to other criteria under consideration with the larger weight being of more importance to the others. The selected criteria were subjected to processing, standardization, weighting, and overlaying using QGIS software in the production of output maps. Each criterion was rated based on FAO (1985) classification as highly, moderately, marginally, and not suitable.

Crop requirement characteristics were defined in relation to the listed criteria. Requirements were expressed by defining optimal, moderate and marginal and unsuitable conditions for each land attribute that influence capsicum production.

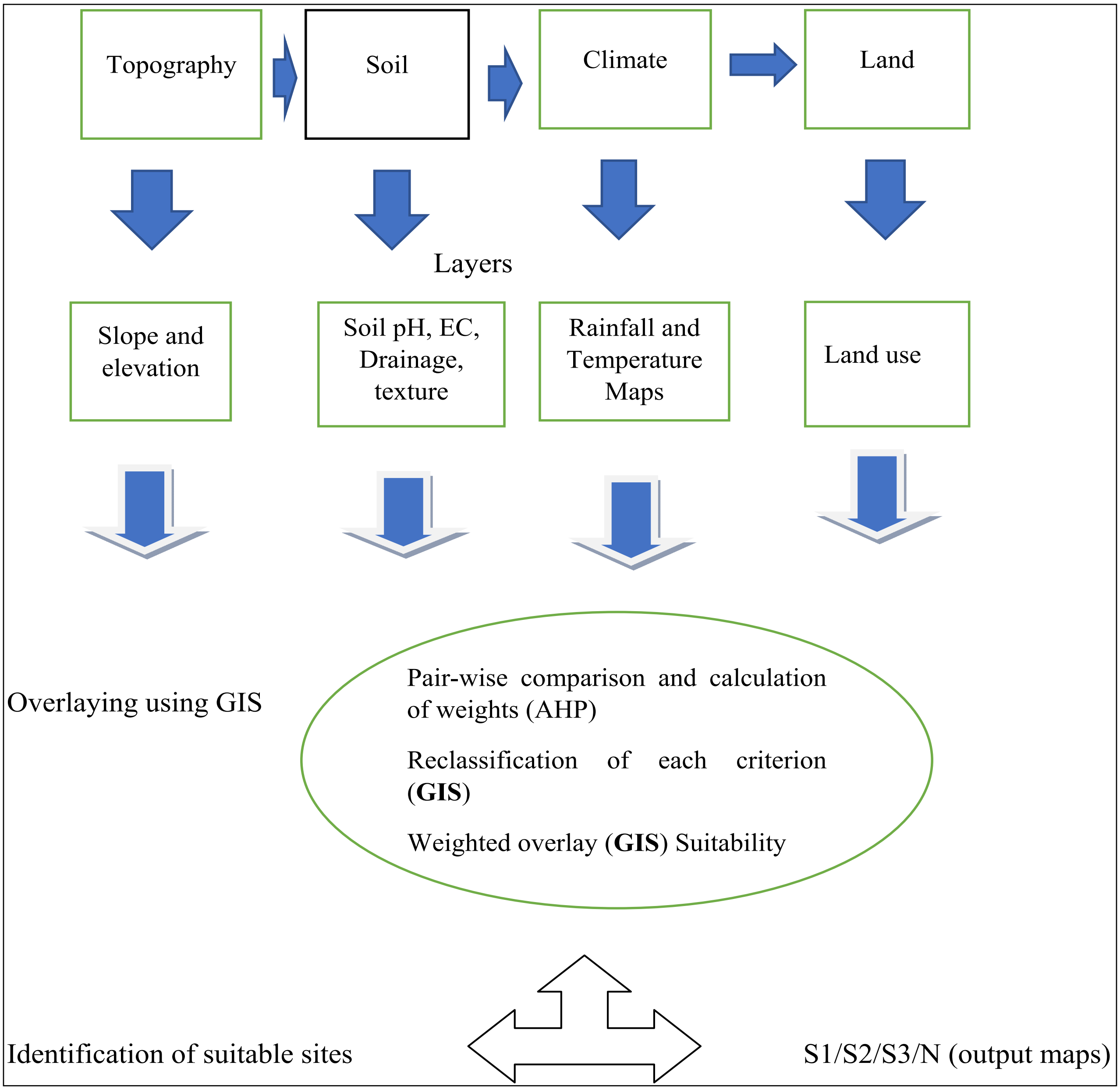

Fig. 2: A methodology flowchart showing what data to be collected and its integration with GIS

Applying multi-criteria evaluation and assigning a weight of factors

The analytic Hierarchy Process (AHP) method of Multi-Criteria Evaluation (MCE) was used to assign weights to the different criteria. A pairwise comparison matrix was constructed for the criteria using information obtained from literature reviews. Each criterion was compared to other criteria relative to their importance on a scale of 1-9 (Saaty, 2008) (Table 3).

When a factor is compared by itself, it's a signed value of unity, whereas when compared to a different factor, it assumes any value within the Saaty's range, the factor it is compared with assumes the reciprocal value. The criteria weight and weighted sum value were calculated to get the approximate eigenvector (λmax), this was used in the calculation of consistency ratio (CR) (Eq. 1) (Triantaphyllou and Mann, 1995).

$$CR = \frac{CI}{RCI} \qquad \ldots(1)$$

Where CI = Consistency index and RCI = Random consistency index.

In AHP, the judgment matrix that is the pair-wise comparison is only considered consistent if the CR is less than 0.01. The CI values were calculated using Equation 2 (Triantaphyllou and Mann, 1995).

$$CI = \frac{\lambda \max - n}{n-1} \qquad \ldots(2)$$

Overlaying map layers

To determine the potential of each peri-urban County of Nairobi for capsicum production, crop requirements (Table 4) were matched with land qualities; the reclassified thematic maps/layers of each variable; soil, topography, agro-climatic map, and land use map) were weighted using the weights derived from the AHP process. The weighted maps/layers were overlayed by performing the weighted overlay analysis using spatial analyst tools (QGIS), after which a suitability map was prepared.

Table 3: The Saaty's rating scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favour one over the other
5	Much more important	Experience and judgment strongly favour one over the other
7	Very much more important	Experience and judgment very strongly favour one over the other
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity
2, 4, 6 and 8	Intermediate values	When compromise is needed

Table 4: Capsicum land use requirements

Parameter	S1	S2	N
Altitude (m)	2000	2000–2500	> 2500
Slope (%)	0–15	15–30	> 35
Rainfall (mm)	600–1250	500–600 1250–1500	> 1500 < 500
Temperature (°C)	15–25	25–30	> 30 < 15
Soil drainage	Well drained	Imperfectly drained	Poorly drained
Soil pH	5.5–6.8	6.8–7.5	> 7.5
Soil texture	Loamy	Clayey	Very clayey Extremely sandy
Soil EC (µS cm^{-1})	0–800 µS/cm	800–1000	> 1000

RESULTS

Crop suitability for the selected areas of Kiambu, Kajiado, and Machakos counties

The current study classified land in Kiambu, Kajiado, and Machakos counties. A suitability table for capsicum (Table 4) was produced based on cropland use requirements and summarized into three classes; suitable (S1), moderately suitable (S2), and not suitable (N). Thematic maps of each criteria were first produced using the QGIS spatial analyst tools.

Spatial Variation of pH in Kiambu, Kajiado, and Machakos Counties

Soil pH indicates the acidity and alkalinity status of the soil. It also determines the availability of nutrients in the soil for crops and subsequently provides information on the suitability of crops in different regions (Mugo *et al.* 2016). The mean pH in Kiambu, Kajiado, and Machakos were 5.78, 7.71 and 7.02 respectively. After reclassification, the pH map shows that Kiambu County had the highest suitability at 99% while Kajiado had 20% of the area as not suitable, 70% as moderate suitability and 9% being highly suitable. Additionally, 85% of Machakos County had moderate suitability with only 15% being highly suitable for capsicum production (Fig. 3).

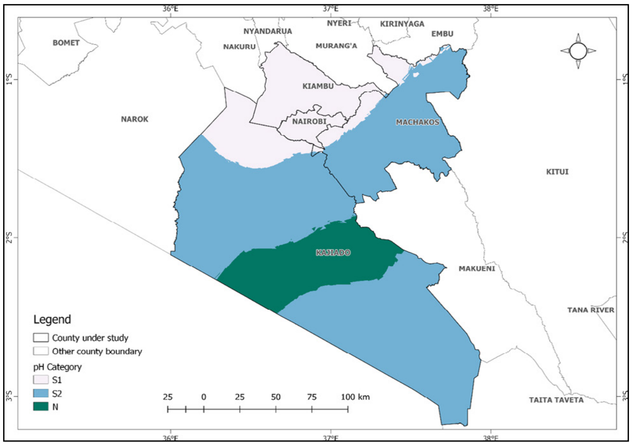

Fig. 3: Spatial variation of soil pH in Kiambu, Kajiado and Machakos counties

Spatial variation of soil electrical conductivity in Kiambu, Kajiado, and Machakos counties

Soil electrical conductivity (EC) is a measure of soil salinity. It is a critical indicator of soil health and greatly impacts the yield of crops, suitability of crops, nutrient availability, and activity of soil microorganisms (USDA, 2020). The reclassified EC map indicates that the counties had 98, 95, and 81% high suitability for Kiambu, Kajiado, and Machakos respectively (Fig. 4).

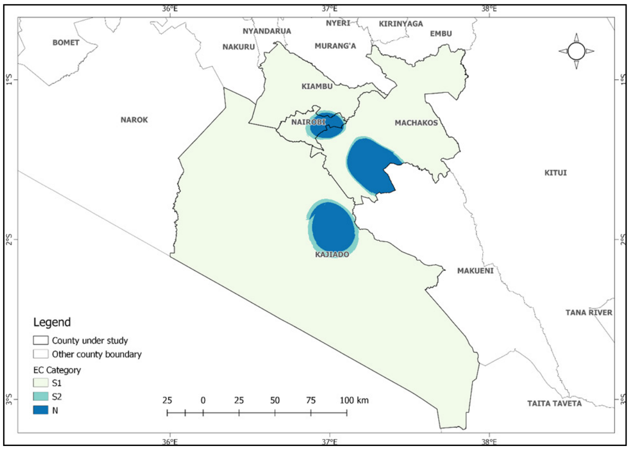

Fig. 4: Spatial variation of soil EC in Kiambu, Kajiado and Machakos counties

Spatial variation of soil texture in Kiambu, Kajiado, and Machakos counties

The relative proportion of sand, silt, and clay was combined to generate a texture class. Four textural classes were identified in the study areas namely clayey, loamy, and sandy and very clayey. The reclassified texture map indicates that most of the counties have clayey soils with 81, 62 and 66% for Kiambu, Kajiado, and Machakos respectively (Table 5) (Fig. 5). Therefore, based on soil texture, the counties under study are moderately suitable for capsicum production.

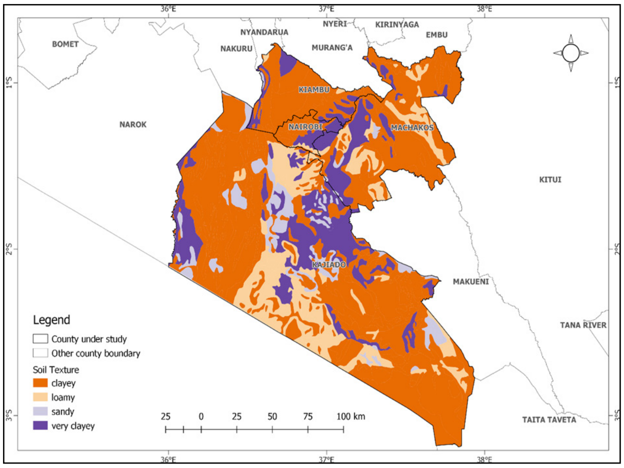

Fig. 5: Spatial variation of soil texture in Kiambu, Kajiado and Machakos counties

Table 5: Spatial variation of texture

	S1	S2		N	
County	**Loamy (%)**	**Clayey (%)**	**Sandy (%)**	**Very Clayey (%)**	**Sum of Area (km²)**
Kiambu	1.42	81.04	0.57	16.96	1275.55
Kajiado	15.93	61.74	7.96	14.37	1874.02
Machakos	16.27	65.57	1.23	16.93	790.52

Spatial variation of soil drainage in Kiambu, Kajiado, and Machakos counties

Soil drainage for the study areas was reclassified as well-drained, moderately drained, poorly drained, and imperfectly drained (Table 6) (Fig. 6). Kiambu County has 65% well-drained soils while Kajiado and Machakos have 46% and 53% respectively.

Table 6: Percentage (%) spatial variation of soil drainage in Kiambu, Kajiado and Machakos counties

County	S1 (%)	S2 (%)	N (%)	Total area (Km²)
Kiambu	65.48	25.00	9.46	1275.55
Kajiado	46.42	49.61	2.04	1874.02
Machakos	52.96	43.04	4.00	790.52

S1 = highly suitable; S2 = moderately suitable; N = Not suitable.

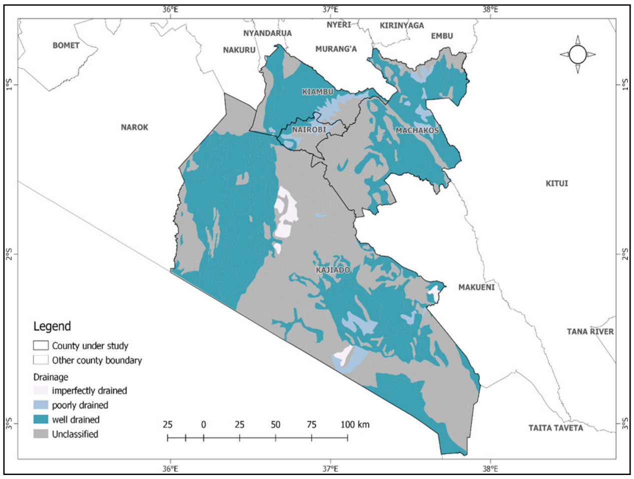

Fig. 6: Spatial variation of soil drainage in Kiambu, Kajiado and Machakos counties

Spatial variation of rainfall in Kiambu, Kajiado, and Machakos counties

Kiambu, Kajiado, and Machakos County receive an average annual rainfall of 962, 500, and 830 mm. After reclassification, the map shows that Kiambu County has a 64% high suitability for capsicum production with the respective values for Machakos and Kajiado being 94 and 48% (Fig. 7).

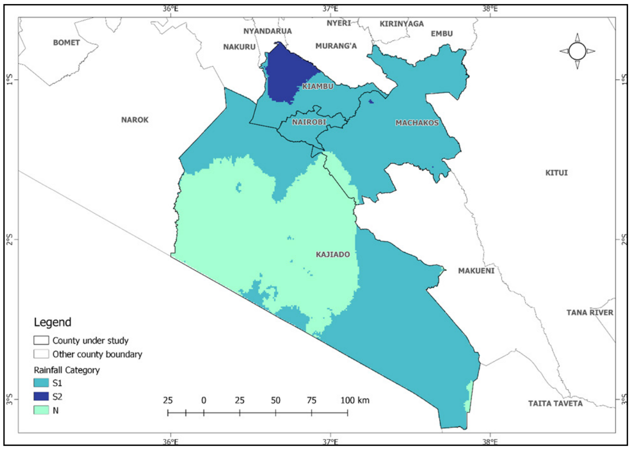

Fig. 7: Spatial variation of rainfall in Kiambu, Kajiado and Machakos counties

Spatial variation of temperature

The reclassified map shows that 99% of Kiambu County has temperatures of between 15°C and 25°C making it highly suitable for capsicum production. About 10% of Kajiado County has temperatures of > 30°C thus being unsuitable for capsicum production with 63% moderate suitability. Machakos County had moderate suitability of 53% with only 42% being highly suitable (Fig. 8).

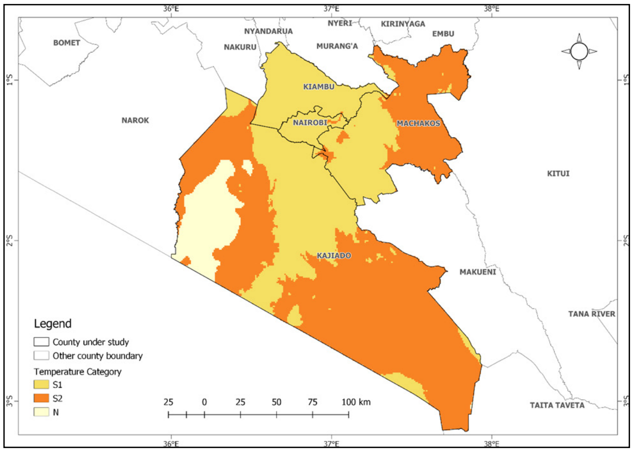

Fig. 8: Spatial variation of temperature in Kiambu, Kajiado and Machakos counties

Spatial variation of altitude

The altitude of the study areas ranged between 0 to 2710 m. After reclassification of altitude, the maps show that Kiambu County had 62% of the area falling between altitude 0 and 2000, 32% falling between 2000 and 2500, and 4% > 2500 being S1, S2, and N, respectively (Fig. 9). Kajiado and Machakos counties had most of the areas falling between altitude 0 and 2000 at 99% making them highly suitable sites for capsicum production with respect to altitude.

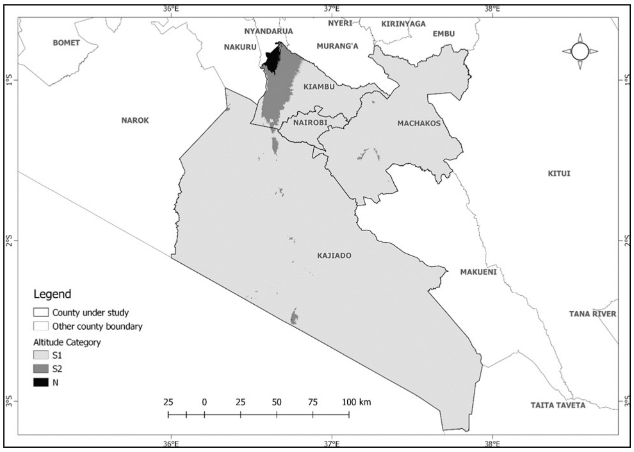

Fig. 9: Spatial variation of altitude in Kiambu, Kajiado and Machakos counties

Spatial variation of slope

The slope of the study areas ranged from 0 to 15°. It is within this range that capsicum production is highly suitable. Some areas in Kajiado and Machakos counties had slope ranges of 15–30° (Fig. 10).

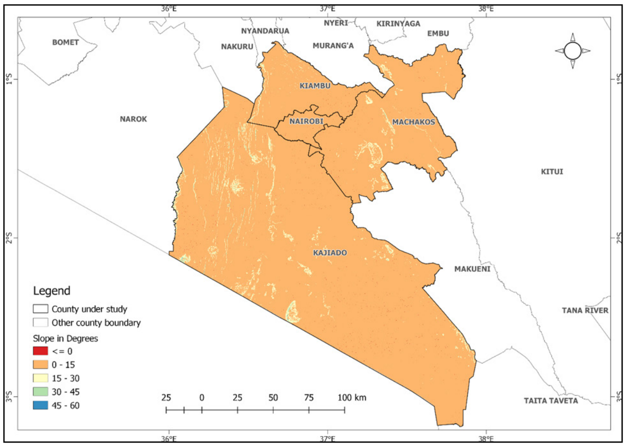

Fig. 10: Spatial variation of slope in Kiambu, Kajiado and Machakos counties

Supervised classification results

The results from Landsat satellite imagery of the study areas indicate that land cover is majorly divided into six classes (cropland, forest, open grassland, wooded grassland, water/wetland, and built-up) (Table 7) (Fig. 11). It further revealed that 50% of Kiambu is covered by cropland (agricultural land) while Kajiado and Machakos had 1 and 44%, respectively in this category.

Table 7: Land cover classes statistics of Kiambu, Kajiado and Machakos counties

Land cover	Kiambu (%)	Kajiado (%)	Machakos (%)	Nairobi (%)
Crop land	49.9	1.4	43.5	21.4
Forest	15.2	3	0.8	5.5
Open grassland	14.8	36.6	19.7	37.8
Wooded grassland	19.5	59.9	34.7	24.4
Water/wetland	0.2	0.6	0.7	0.4
Built up/other land	0.5	2.6	0.6	10.6

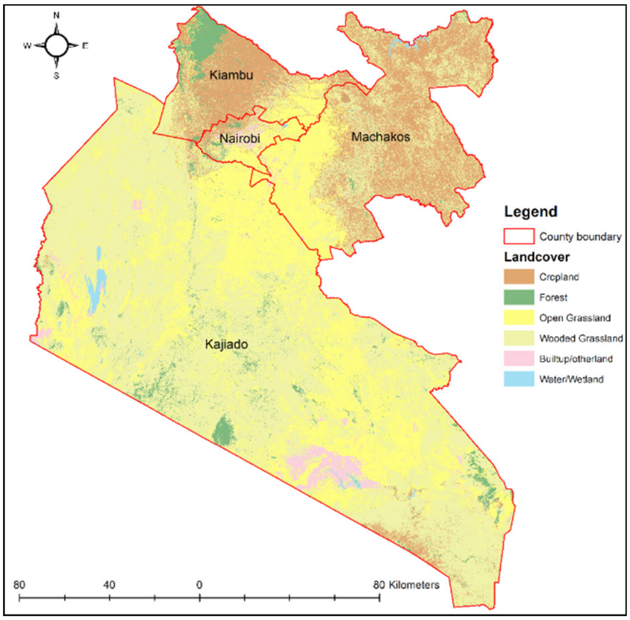

Fig. 11: Land cover map of Kiambu, Kajiado and Machakos counties

Capsicum suitability map

All the sub-criteria selected for evaluation (soil pH, EC, texture, drainage, rainfall, temperature, slope, and altitude) using the weighted overlay technique were overlaid together to produce capsicum suitability map (Table 8) (Fig. 12). The results from the map shows that about 50% of land in Kiambu County, 8% in Kajiado County and 12% is suitable for capsicum production. The remaining percentages were found not suitable for the production of the crop.

Table 8: Capsicum suitability area in percentage

County	Suitable (%)	Not Suitable (%)	Total area (km^2)
Kiambu	50.15	49.85	1275.55
Kajiado	8.56	91.44	1874.02
Machakos	12.73	87.27	790.52

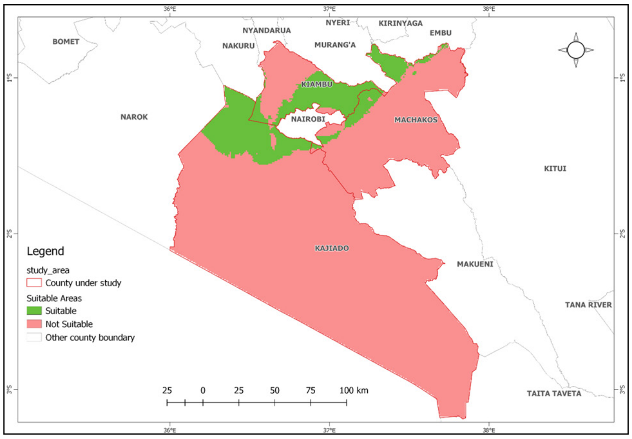

Fig. 12: Capsicum suitability map for Kiambu, Kajiado and Machakos counties

DISCUSSION

Suitable locations for capsicum production in the peri-urban counties of Nairobi

Suitable locations for capsicum production were obtained following analysis of the selected criteria for evaluation. The criteria included soil factors (pH, EC, texture, drainage), climatic factors (rainfall and temperature), and topographic factors (altitude and slope). The same criteria were used by Kamau *et al.* (2015) in determining the suitability of growing potatoes in Nyandarua County. Capsicum requires a soil pH range of 5.5–6.8 for optimal production (CABI, 2019).

Kiambu County had mean soil pH of 5.8 thus falling within the range the crop thrives best (Ochieng' *et al.* (2021). For this reason, Kiambu County had 99% suitability for soil pH. Kajiado and Machakos counties had mean soil pH of 7.71 and 7.02 respectively and therefore not falling within the range required by the crop. Therefore, for soil pH, Kajiado and Machakos counties had 9% and 15% suitability respectively. To increase suitability levels, soil pH in Kajiado and Machakos needs to be addressed by lowering it to levels that are acceptable for capsicum. Lime can be applied to achieve such goals (Cheptoek *et al.* 2021). Likewise, the salinity of the soils is indicated by soil EC and capsicum requires an EC level of less than 1000 µS cm^{-1}. The mean salinity level in Kiambu, Kajiado, and Machakos County was 96, 185, and 136 µS cm^{-1}, respectively. Therefore, for soil EC, Kiambu had 98%, Kajiado 94%, and Machakos 81% suitability meaning the salinity effects are negligible. A few locations mostly in Machakos County had EC values above 1000 µS cm-1 and therefore need to be corrected to the acceptable crop level.

Furthermore, capsicum does best in loamy to sandy loamy soils. Soil texture is important in determining the suitability of the crop as it affects most properties of the physical soil (Mugo *et al.* 2016). There were five textural classes in the study area namely loamy, clayey, sandy, and very clayey (more than 60% clay). Most soils in the study counties were clayey (sandy clay, silty clay, and clay texture classes). Kiambu, Kajiado, and Machakos counties had 81, 61, and 65 percent clay content and therefore based on soil texture, the counties had moderate suitability for capsicum production. It is difficult to alter the texture of the soil and thus the potential for these counties in the production of capsicum will be limited by their texture.

Soil drainage is an important indicator of water infiltration into the soil. Good drainage allows water and nutrients to move freely in the soil (Kamau *et al.* 2015; Gitari *et al.* 2019). Capsicum prefers well-drained soils for optimal production. Based on soil drainage, Kiambu County has 65, Kajiado 46, and Machakos 53% suitability for capsicum production. Soil drainage is a soil physical property that is not easily altered but frequent use of organic manure can help improve some of its qualities (Rahimi *et al.* 2023; Nyawade *et al.* 2019; Mwadalu *et al.* 2022; Faridvand *et al.* 2021).

The climate is critical in the production of capsicum. It requires an average temperature of 25 to 30°C and 18 to 20°C during the day and night, respectively (Basu and De, 2003). Very high and very low temperatures have a great impact on the setting of the fruits and their pungency (Seleiman *et al.* 2021). The mean temperature for the study areas ranged from 15 to 30 °C. Kiambu County had the most favorable temperature for capsicum production with a suitability of 99% followed by Machakos at 47% and Kajiado at 37%. The production potential of capsicum in Kajiado and Machakos County is limited by the very high and very low temperatures in the different locations within the counties. Additionally, rainfall is the main source of water for irrigation and capsicum requires rainfall of between 600–1250 mm per annum for optimal production. The reclassified maps showed that Machakos County had the most suitability for capsicum production at 94% followed by Kiambu County at 64%, Machakos County and Kajiado at 48% when based on rainfall alone.

Furthermore, the topography of the study area was also evaluated. The slope of the study areas ranged between 0 and 15 ° while its altitude ranged from 0 to 2710 m. Capsicum requires altitudes of up to 2000 m above sea level for optimal production. Based on topography alone, the study area was found to be highly suitable for optimal capsicum production.

The results from the land suitability assessment for capsicum production categorized land as highly suitable and not suitable. Of all the three counties, Kiambu County had the most suitability. 50% of agricultural land in Kiambu County was found to be most suitable for the production of capsicum. Kajiado and Machakos had 8% and 12% suitability respectively. The land found not to be suitable is due to the prevailing limitations that exist in the counties. This includes unfavorable climate, soil pH, drainage, and texture. Nonetheless, the land classified as not suitable for capsicum production is used by farmers for the production of capsicum and other crops due to the high demand for food. Kiambu County had the most suitability as its soil, climate, and topographic factors were found to be favorable for capsicum production.

CONCLUSION

Evaluation of land in the study area indicates that Kiambu County has the greatest potential for capsicum production. Kajiado and Machakos counties have numerous factors limiting the production of the crop such as soil pH, drainage, texture, and climate. These limitations are the key drivers for the declining capsicum yields that have been observed over the years in these counties. Therefore, to improve the suitability and production of capsicum in Kiambu, Kajiado, and Machakos counties, it is advisable to consider decreasing soil pH, particularly in Kajiado and Machakos, optimizing soil drainage through the use of organic manure/compost and increasing soil nitrogen and organic carbon through the addition of nitrogen fertilizer and organic manure respectively. In addition, farmers can consider the use of irrigation to supplement rainfall and the adoption of greenhouse farming to help control temperature. The findings of this study would therefore be useful to farmers, County governments, and stakeholders in their decision-making and planning and to other researchers for further studies.

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