**Evaluation of Land Suitability for Surface Irrigation in Kilosa District, Morogoro, Tanzania**

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**ABSTRACT**

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| The increasing demand for land resources to support a growing global population necessitates the optimization of land utilization for food and essential resources. Efficient land planning is critical, especially in Sub-Saharan Africa, where only a small portion of cultivated land is irrigated. This study focused on evaluating land suitability for surface irrigation in Kilosa district located in Tanzania, which has significant potential for paddy production. Utilizing the GIS-based Multi-Criteria Evaluation (MCE) approach, the study evaluated climatic factors, topography, soil properties, river proximity and land use/cover. Data from CHIRPS and ERA5 Ag datasets were utilized as a representative of ground data for precipitation and temperature respectively, revealing their suitability for long-term climate analysis. The factors were categorized for land suitability for surface irrigation, indicating that a majority of the area is moderately suitable. Land use/cover analysis identified significant portions as either not suitable or marginally suitable, with cultivated land being highly suitable. Overall, 16.23% (242,119.14 ha) of the district is highly suitable for Surface irrigation, 37.13% (553,905.34 ha) is moderately suitable, 43.72% (652,214.96 ha) is marginally suitable while the remaining area 2.92% (43,560.56 ha) is not suitable. The verified suitability maps demonstrate reliable use for irrigation strategic planning through both current and planned National Irrigation Master Plan (NIMP) revisions. |

***Keywords:***Land Suitability, Surface Irrigation, GIS-based Multi-Criteria Evaluation (MCE),

Kilosa District, Tanzania

**1. INTRODUCTION**

The increasing demand for land resources to accommodate the agricultural needs of a global population increase emphasizes the urgent necessity for optimizing land utilization, particularly to meet the increasing requirements for food (Mishenin *et al.,* 2021). A main purpose of agricultural land planning is to archive the efficient use of the land to enhance food production and profitability (Hemathilake *et al.,*2022). Despite irrigated land contributing more than 50 percent of the global agricultural product, not more than 4 percent (6 million hectares) of Sub-Saharan Africa's entire cultivated land, is irrigated (Darko *et al.,* 2020). Land suitability evaluation for surface irrigation involves solid policy and planning, thereby enhancing the long-term agricultural land resources management (Ozsahin & Ozdes, 2022). It plays a crucial role in sustaining and advancing of irrigation on a spatial scale by identifying geographical patterns, biophysical factors and assesses the potential size of agricultural land for long-term irrigation uses (Hagos et al.,2022).

Evaluation procedure for land suitability involves assessing and categorizing land areas relative to their suitability for particular uses such as agriculture (Mushtaq *et al.,* 2023). The evaluation is a crucial step in development planning as it provides essential insights into the constraints and opportunities associated with the land, primarily focusing on its inherent capabilities (Zhang *et al.,* 2024). The evaluation is derived from various relevant sources and available data. For surface irrigation, physical land features like land use/cover, soil composition, topography, distance from water source and climatic data including precipitation and temperature are emphasized (Akpoti & Zwart, 2019). The biophysical database undergoes characterization and geo-referencing through the collection and reclassification of datasets into different suitability classes (Fentaye, 2017). This study used GIS-based Multi-Criteria Evaluation (MCE) approach to investigate the spatial arrangement of land suitability for surface irrigation as recommended by Hussien & Birhanu, (2019), due to its capacity to combine various biophysical factors and spatial datasets so as to integrate a systematic and comprehensive assessment of the land suitability. To comprehend this phenomenon, several studies have been done in Tanzania (Al-Hanbali et al., 2022). However, majority of the studies focused on a regional scale rather than local scale (Al-Hanbali et al., 2022; Alavaisha et al., 2021; Mkilima, 2023). For this study, it scaled down to district level. Given that the diversity of land suitability within small geographical areas often leads to its variation greatly and downscaling suitability assessments is necessary to deliver more precision and practical planning.

Agriculture forms the foundation of Tanzania's economy, employing more than 65% of the people, either formally or informally (Mpogole et al., 2020). This industry accounts for around 33% of the GDP and has a significant impact on export revenues (USAD, 2024). It provides for the livelihoods of a great percentage of the people and is critical to the nation's economic stability and progress (Östberg *et al.,* 2018). The country is progressively enhancing food security and emphasizing on producing a surplus for export to meet the significant demand in East African markets, including Kenya and South Sudan (John, 2024). It is estimated that irrigated land accounts for less than 2.3% of Tanzania's total cultivable land (Uisso & Tanrıvermiş, 2021). Because of the minimal use of irrigation, the great majority of agricultural activities rely on variable rainfall, posing problems to consistent production of surplus for export (Kweka, 2023). Expanding irrigation infrastructure, specifically surface irrigation system as cost effective and practical method in Tanzania, could significantly enhance agricultural output in the area with insufficient rainfall (Gwambene & Mung'ong'o, 2023). The government's policy focuses on transition from rainfed to irrigation-based agriculture. The aim is to increase irrigated land from 0.2 million hectares in 2004 to 1.0 million hectares by 2035 (NIMP, 2018). To have achieved this goal of expanding irrigation, strategic planning is necessary that integrates land suitability assessments to gauge the appropriate areas for irrigation expansion to be sustainable and productive.

This study makes direct contribution to this policy by means of a detailed land suitability assessment for surface irrigation in the district. The findings provide a valuable tool in identifying areas that are very highly suitable, highly suitable, marginally suitable, or unsuitable for surface irrigation development. It provides critical biophysical constraints and opportunities in the district that are used for targeting infrastructure investments and resource allocation. It therefore provides a scientific basis for implementing the National Master Plan for Irrigation (NIMP).

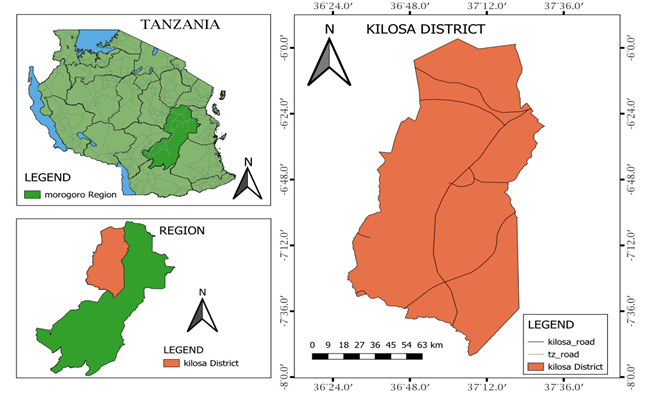
Thus, the primary objective of this study was to evaluate land suitability for surface irrigation in Kilosa district by examining factors that influence its efficiency. Specifically, the study focused on: (1) evaluating the suitability of individual factors influencing surface irrigation and (2) determining the overall land suitability for surface irrigation.

**2. material and methods**

**2.1 Description of the Study Area**

Kilosa district is in Morogoro region of Tanzania with latitude -6.8525 (6°51'9" S) and longitude 36.9916 (36°59'30" E) covering an area of approximately 14,918 square kilometers (Boku, 2014). Geographically the district is dominated by plains terrains, which create a perfect environment for varied ecosystems to succeed (Mselle, 2015). The local economy is driven by agriculture, with a considerable portion of the population engaged in farming activities (Luanda, 2020), this is due to its potential in fertile land and favorable climate which both contribute to the cultivation of various crops, consequently making the district a vital hub for food production in the region (Ntumva, 2020).

The district has a huge potential for paddy production, contributing significantly to Morogoro's agricultural output (Mkubya & Mahoo, 2023). The rainfall in the district varies spatially and seasonally, resulting in uneven distribution patterns (Kitasho *et al.,* 2020). The seasons are dry season which is spanning from May to October with little or no rains, and wet season which is from November to April, generally the rainfall regime is described as unimodal (Wilson & Ouedraogo, 2017). The variations are influenced by climatic factors such as latitude, altitude and prevailing wind patterns (Hamisi, 2013).



**Fig. 1. Maps showing Tanzania, Morogoro region and Kilosa district as the study area.**

**2.2 Suitability of individual factors**

**2.2.1 Precipitation and Temperature**

Precipitation data from the validated dataset (CHIRPS) ranging from 1981 to 2005 year were used (Gebrechorkos *et al.,* 2018). Thirty-five (35) gridded points of coverage area 500 km2 each were used as a representative of ground rainfall stations (Espinosa *et al*., 2023). The evaluation based on rainfall categorized areas, exceeding 1200mm as highly, 800mm/year to 1200mm/year as moderately, 600mm/year to 800mm/year as marginal, and the rainfall below 600mm as not suitable (Table 2). The spatial rainfall distribution map was produced by interpolating the point rainfall data.

Temperature data from the validated dataset (ERA5 Ag) ranging from 1981 to 2005 year were used (Gebrechorkos *et al.,* 2018). Nine (9) gridded points of coverage area 500 km2 each were used as a representative of ground stations as temperature is influenced by global factors rather than localized geography (Espinosa *et al*., 2023). The evaluation based on temperature categorized areas exceeding 250C as not suitable, those between 200C and 250C as moderately suitable, while temperatures less than 200C as highly suitable (Table 2). The spatial temperature distribution map was as well produced by interpolating the point data.

Overall suitability is highly dependent upon precipitation and temperature because these factors drive the availability of water to, and the evaporation and transpiration from, the Earth’s surface. Irrigation feasibility is enhanced by high precipitation levels but will have decreased irrigation efficiency with excessively high temperature. Therefore, surface irrigation is most suitable on areas with optimal precipitation and moderate temperatures.

**2.2.2 Soil properties**

The key soil properties essential for surface irrigation evaluation which are texture, drainage, and soil depth were categorized (Wang *et al.,* 2021). Soil texture was categorized as, clay and clay-loam as highly, clay and sand-clay-loam as moderately, and sand-loam as marginal. For drainage, well-drained soil was classified as highly, moderately well-drained soil as moderately, imperfectly drained-soil as marginal, and poor drained-soil as not suitable for surface irrigation. Regarding soil depth, soil exceeding 100cm was classified as highly, those between 50-100cm as moderately, soils between 10-50cm as marginal, and those less than 10cm as not suitable (Table 2).

Surface irrigation suitability is very dependent on soil properties because surface irrigated fields need to have soil that can hold enough moisture without excessive percolation. Highly suitable areas are found to be areas with well drained deep clayey soils; shallow or poorly drained soils limited irrigation efficiency.

**2.2.3 Topographic factors**

Topographic features (slopes and altitudes) significantly influenced the evaluation of land suitability for surface irrigation (Girma *et al.,* 2020). Using the Digital Elevation Model (DEM) data of a 30m resolution from the freely available Shuttle Radar Topography Mission (SRTM), slope and altitude were reclassified using QGIS package (Naranjo *et al*., 2021). Slope rated, 0–2% as highly suitable, 2–5% as moderately suitable, 5–8% as marginal, and >8% as not suitable. For altitude, the region classified 1500–2000m was assigned as moderately, 2000-3000m as highly suitable, and less than 1500m as not suitable (Table 2).

Overall suitability is influenced by topography related to water movement and retention. The surface irrigation requires gentle slopes as steeper slopes will increase runoff and erosion risks. Also, altitude affects microclimates in a similar way as soil properties and water availability are altered. Irrigation development is found to be more suitable in the areas having gentle slopes and moderate altitudes.

**2.2.4 Land use/cover (LU/LC)**

Map of the year 2023 Land use/cover (LULC) assessment of Kilosa district was analyzed in QGIS package. Land suitability evaluation for surface irrigation based on land use/cover rated, cultivated land as highly suitable, grass land as moderately, bushland as marginal, while natural forest, plantation forest, wood land, permanent swamp, urban area, water bodies, and bare soil as not suitable for surface irrigation (Table 2).

Existing land use/cover is determinant on the spread of expansion in terms of feasibility for irrigation. The cultivated land is considered suitable as it already supports agricultural activities, while other land types, such as natural forests, urban areas, water bodies, are unavailable for irrigation owing to the legal, environmental and logistical constraints associated with it.

**2.2.5 Distance from water source**

Distance from the water sources (river proximity) were one of the vital criteria in evaluation of land suitability for surface irrigation (Balew *et al.,* 2021). The evaluation rated, the regions with range 0-1000m as highly suitable, 1000-3000m as moderately suitable, 3000-5000 as marginal, and those exceeds 5000m as not suitable (Table 2).

The feasibility and cost effectiveness of irrigation infrastructure is however dictated by the levels of proximity to water sources. Areas closer to rivers are better since require less initial investment in conveyance irrigation infrastructure. Between the reaches, the overall suitability decreases as distance increases, due to costs and technical challenges of water conveyance.

**2.3 Overall land suitability for surface irrigation**

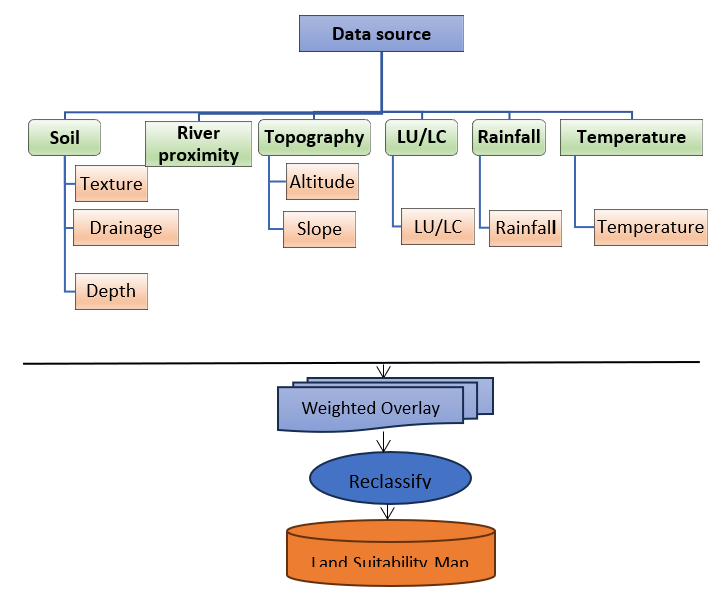
The overall land suitability shows areas categorized as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N) (Table 1). The general conceptual methodology utilized through the study is illustrated in the Figure 2, while Table 2 outlines the weights assigned to separately contributing parameter and its respective classes, along with the sources of the information.

**Table 1: Land suitability classification (FAO, 1976)**

|  |  |
| --- | --- |
| **Class Suitability** | **Description** |
| S1 Highly suitable | Land without major limitations |
| S2 Moderately suitable | Moderate limitations that reduce productivity, or increase the required inputs |
| S3 Marginally suitable | Significant limitations, making land only marginally justifiable. |
| N Not suitable | Limitations that cannot currently be overcomed with existing knowledge at an acceptable cost. |

**Table 2: Land suitability criteria established for the studied parameters.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Main factor** | **Sub factor** | **Factor rating** | | | | **Source** |
| S1 | S2 | S3 | N |
| Topography | Slope (%) | 0-2 | 2-5 | 5-8 | >8 | FAO (1984) |
| Altitude (m) | 2000-3000 | 1500-2000 | 3300-3800 | <1500 | FAO (1984) |
| Soil | Drainage class | Well | Moderately well | Imperfectly | Poor | Adem, A. F., & Danbara, J. H. (2022) |
| Depth (cm) | >100 (Very deep) | 50-100 (Moderately deep) | 10-50 (Shallow) | <10 (Very shallow) | Mandal et al., 2018 |
| Texture | Loam, Clay-Loam | Clay, Sand-Clay-Loam | Sand-Loam | N/A | Kilosa DC (2020). |
| Distance from water source | Euclidian distance (m) | 0-1000 | 1000-3000 | 3000-5000 | >5000 | Han et al.,2021. |
| LU/LC | LU/LC | Cultivated land | Grass land | Bushland | Constraints (Forest, Build-up, water, ponds) | Barman, J., & Das, P. (2023) |
| Precipitation | Precipitation (mm) | 1200 | 800-1200 | 600-800 | <600 | Angelakιs et al., (2020). |
| Temperature | Temperature (0C) | <20 | 20-23 | 23-25 | >25 | NIMP, (2018) |



**Figure 2: The Overall conceptual framework utilized in the study**

The Analytical Hierarchy Process (AHP) incorporated weighting to individually contributing criterion. AHP implemented a process for identifying and criteria for classifying and assessing the context of spatial planning decisions (Morales et al., 2021). Three key principles guided AHP were decomposition, comparative judgment, and synthesis of priorities (Darko *et al.,* 2019). A matrix of pairwise comparisons among parameters influencing land suitability for to surface irrigation was constructed by AHP. A scale ranging from 1 to 9 was utilized to indicate the relative importance of two factors. The prioritization of the factors for the study area was guided by insights from Tanzania's experience (NIMP, 2018). Reciprocal values from 1/1 to 1/9, represented the relative significance between the criteria (Table 3). Criteria weights were then determined by calculating eigenvalues (equation i) through pairwise comparisons of contributing factors and finally they were normalized (Odu, 2019). The random consistency indices (RI) established by Saaty (1980) were employed to calculate the consistency ratio (CR) (equation ii) for gauging the degree of consistency (Table 4).

**Table 3: Saaty’s scale in AHP (Saaty 1980)**

|  |  |  |
| --- | --- | --- |
| **Definition** | **Index** | **Definition Index** |
| Equally important | 1 | Equally important 1/1 |
| Equally or slightly more important | 2 | Equally or slightly less important 1/2 |
| Moderately/Slightly more important | 3 | Moderately/Slightly less important: Experience and judgment slightly favor one option over the other (with a ratio of 1/3). |
| Slightly to much more important | 4 | Slightly to weigh less important 1/4 |
| Strongly more important / Much more important | 5 | Way less important: Experience and judgment strongly favor one option over the other. 1/5 |
| Much to far more important | 6 | Way to far less important 1/6 |
| Very much more important/Far more important | 7 | Far less important: Experience and judgment strongly favor one option over the other. 1/7 |
| Far more important to extremely more important | 8 | Far less important to extremely less important 1/8 |
| Absolutely more important / Extremely more important | 9 | Extremely less important: The evidence supporting one option over the other (with a ratio of 1/9) is of the highest possible validity. |

**Table 4: Values of random index (RI)**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| n | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| RI | 0.00 | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |

The consistency index (CI) was calculated using the formula provided below.

………………………………………………………………………………………………………i

Where λmax is the largest eigenvalue of the pairwise comparison matrix and n is the number of classes.

The consistency ratio (eqn. ii) is defined as

……………………………………………………………………………………….…………………. ii

where RI is ratio index/average value of CI for random matrices using Saaty scale.

The consistency index (CI) (equation i) was compared to a random index (RI) (Table 4) (Pant, 2022). The RI represents the average CI of randomly generated reciprocal matrices, utilized the scale from 1/9 to 9/1 (Peláez et al., 2018). Saaty (1980) generated random matrices of varying dimensions (n) (Table 4) and determined their mean CI values. For matrices with n≥5, a consistency ratio (CR) of lower than 0.1 was accepted (Saaty, 1979). The QGIS weighted overlay analysis tool (Figure 2) assessed the overall land suitability spatially, generated a suitability map by aggregating the output from AHP (Salifu *et al.,* 2022).

**4. RESULTS**

**4.1 Suitability of individual factors**

**4.1.1 Precipitation and Temperature**

Rainfall suitability showed that 1,320,988.90(88.55%) hectares of the study area was dominated by moderately suitable. Only 50,721.20(3.40%) hectares of the area was highly suitable. Finally, the remaining 120,089.90(8.05%) hectares was assigned under marginal suitable (Figure 3a&b). Temperature suitability showed that the majority 1,013,976.46(67.97%) hectares of the study area was moderately suitable. A smaller portion of the area 300,597.70(20.15%) hectares was assigned as marginal suitable. Where the remaining 177,225.84(11.88%) hectares was assigned under highly suitable (Figure 3c&d).

**4.1.2 Soil** **properties**

Based on the soil texture, the area 1,019,496.12(68.34%) hectares was dominated by loam and clay-loam, which was allocated as highly suitable. The area 337,146.80(22.60%) hectares was dominated by sand-loam, which was classified under moderately suitable class. The remaining area 135,157.08(9.06%) hectares was dominated by sand-clay-loam, which was classified under marginal suitable class (Figure 3e&f).

Soil drainage analysis showed that the area 1,113,927.06(74.67%) hectares was dominated by somewhat excessive and well, which was classified under highly suitable. The area 73,247.38(4.91%) hectares was dominated by imperfect and moderately well, which was classified under moderately suitable. The area 197,365.14(13.23%) hectares was dominated by poor drainage, which was classified under marginal suitable. While the remaining area 107,260.42(7.19%) hectares was dominated by very poor drainage, which was classified under not suitable (Figure 3g&h).

Soil depth analysis of the study area was classified into two regions which were 75-100cm 1,135,707.34(76.13%) hectares and the one exceeding 100cm, 356,092.66(23.87%) hectares, which were moderately suitable and highly suitable respectively (Figure 3i&j).

**4.1.3 Distance from water source (river proximity)**

The analysis showed that 256,440.42(17.19%) hectares, fell within 0-1000 meters from the water source and was classified as highly suitable. The area 10,890.14(0.73%) hectares fell under 1000-3000m, which was classified under moderately suitable class. The area 224,814.26(15.07%) hectares fell under 3000-5000m, which was classified under marginal suitable class. while the remaining area 999,655.18(67.01%) hectares exceeding 5000m, which was classified under not suitable class (Figure 3k&l).

**4.1.4 Topographic factor**

The slope analysis showed that the area 606,715.06(40.67%) hectares was below 2%, which was assigned as highly suitable. In contrast, 199,006.12 (13.34%) hectares was ranging between 2-5% slope, which was moderately suitable. A significant portion of the study area 366,386.08(24.56%) hectares lied between 5-8% slope range, which was marginal. Finally, 319,692.74 (21.43%) hectares of the study area exceeded 8%, which was steep slope and not suitable for surface irrigation (Figure 3m&n).

The altitude analysis showed that the area 1,091,102.52(73.14%) hectares was between 2000-3000m, which was highly suitable. The area 255,246.98(17.11%) hectares ranged between 1500-2000m, which was moderately suitable. The remaining portion 145,450.50(9.75%) hectares was not exceeding 1500m altitude range, which was marginal (Figure 3o&p).

**4.1.5 Land use/cover (LU/LC)**

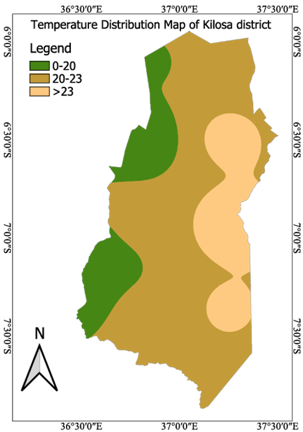
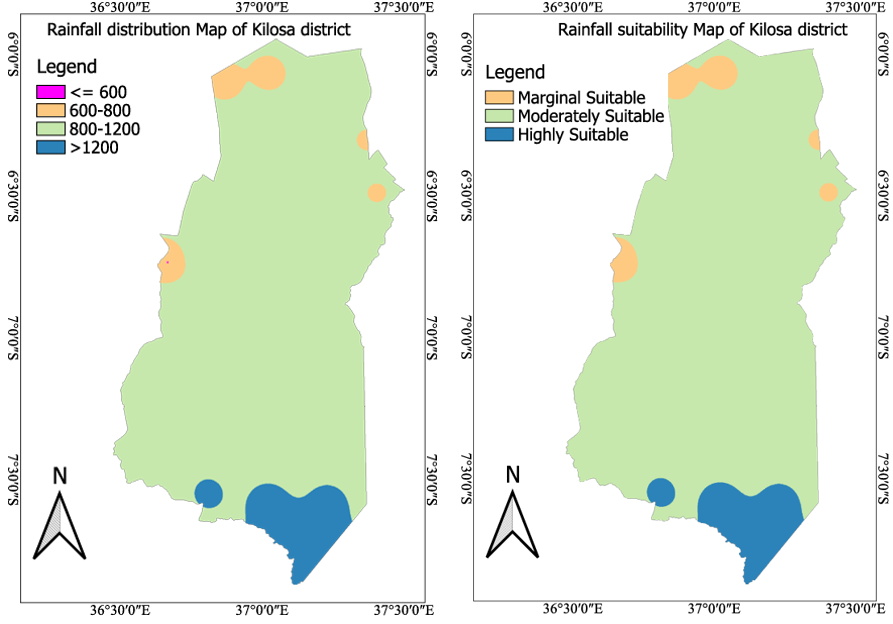
The study area's land use/land cover classification reveals a significant portion, 885,830.84(59.37%) hectares, including areas with plantation forest, water, urban regions, bare soil, natural forest, woodland, and permanent swamp, was not suitable. Grassland, covers 301,194.42(20.19%) hectares, was classified as moderately suitable, while bushland, accounting for 161,711.12 (10.84%) hectares, was marginally suitable. The highly suitable areas, comprising 885,830.84(9.59%) hectares of cultivated land (Figure 3q&r).

**4.2 Overall suitability/Weighting of factors using AHP**

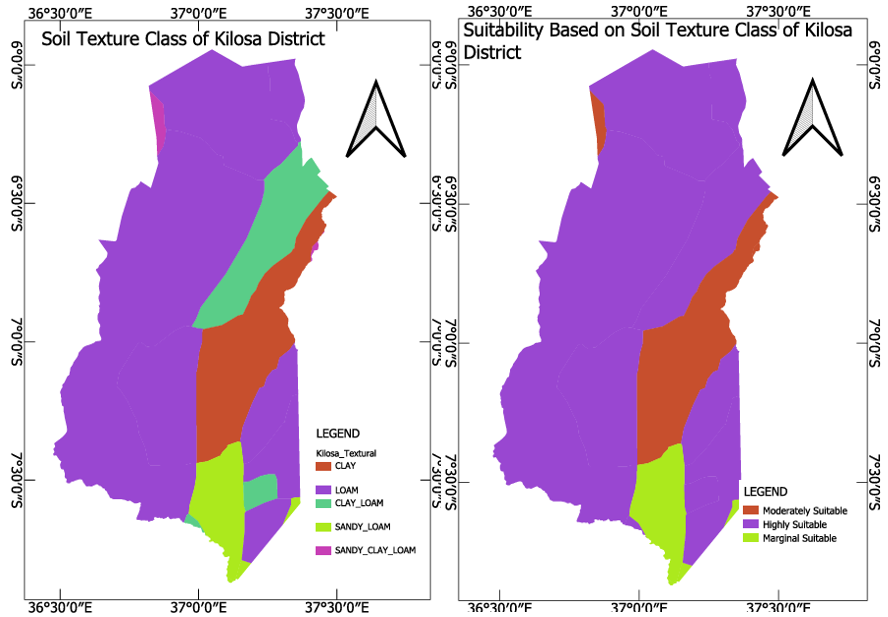
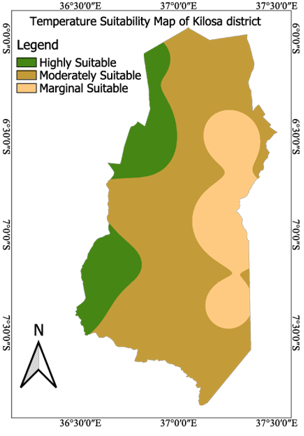
The pair-wise comparison matrix and the overall weights of the factors nominated for the study area are presented in table 5 and 6 consecutively. The nine (9) factors were mentioned in both columns and rows. Consequently, the factors in row and column were compared to assess their significance for surface irrigation. Using the scoring method outlined by Saaty (1977), as shown in Table 5, the pairwise comparison matrix in Table 6 was then prepared.

The distance from water source (measured as Euclidean distance) was the most critical factor, as all the values in its corresponding row exceeded 1(Table 5). It was followed by soil depth and rainfall. The least important factor was temperature, as its row values were all less than 1. Subsequently, the factor’s weights were then computed by normalizing the respective eigenvector with the cumulative eigenvector. The vector of eigenvalue is the nth root of the row’s product of the rows. The weights of each factor, determined using the pairwise technique, were presented in the last columns of Table 6, where a higher value showed a greater importance. The sum of the last columns was 100. The consistency ratio (CR) 0.02, showed that the comparisons and relative weights were consistent and properly assigned respectively.

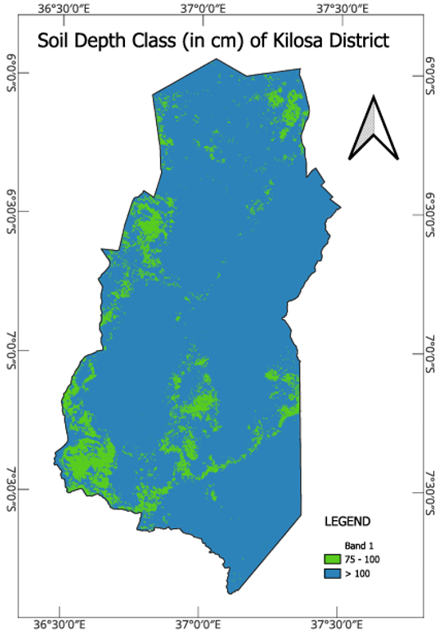
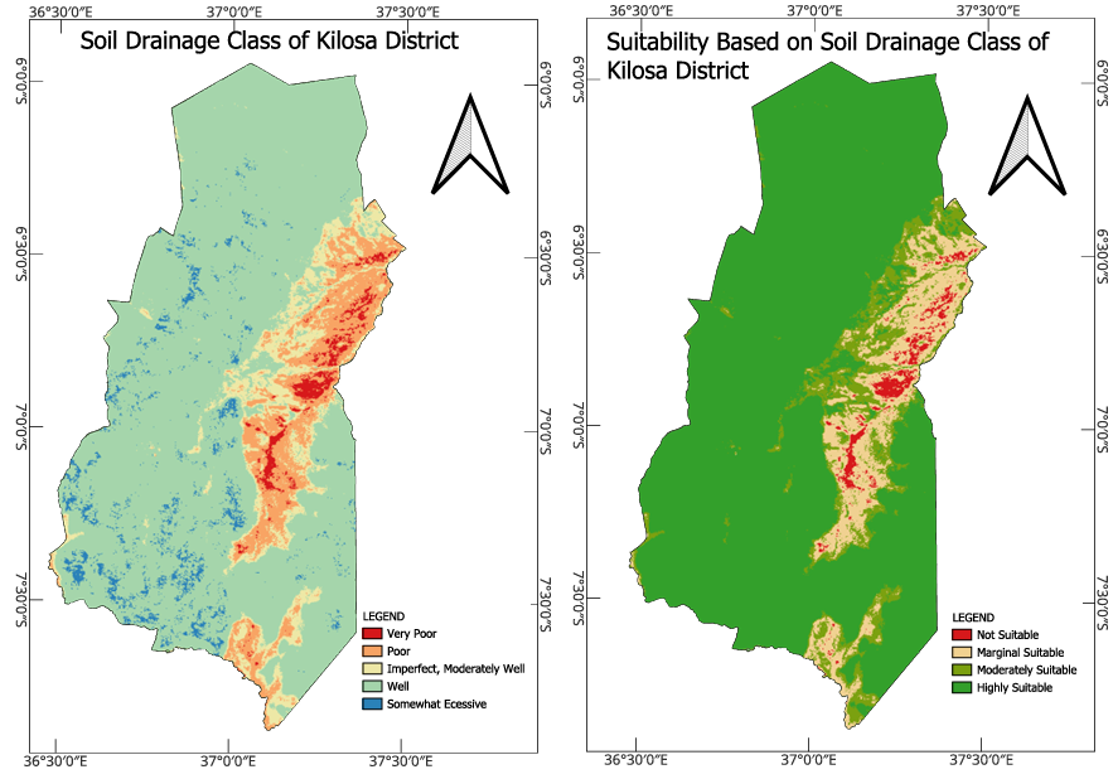
The overall land suitability evaluation for Surface irrigation based on the overlaid individual layers showed that about 16.23% of the study area were potentially highly suitable, 37.13% was moderately suitable, 43.72% was marginal suitable, whereas 2.92% of the district was accounted for not suitable (Table 7 and Figure 4).



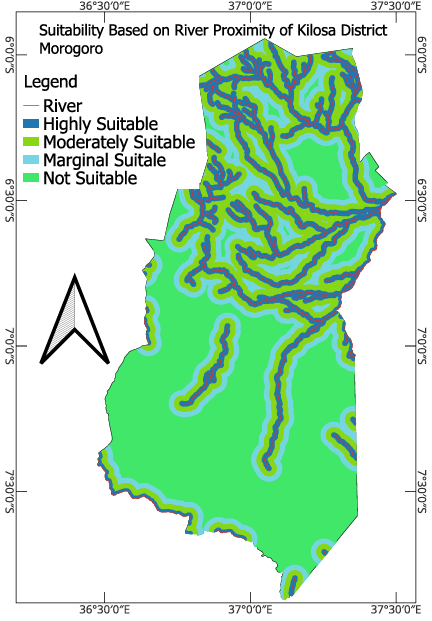
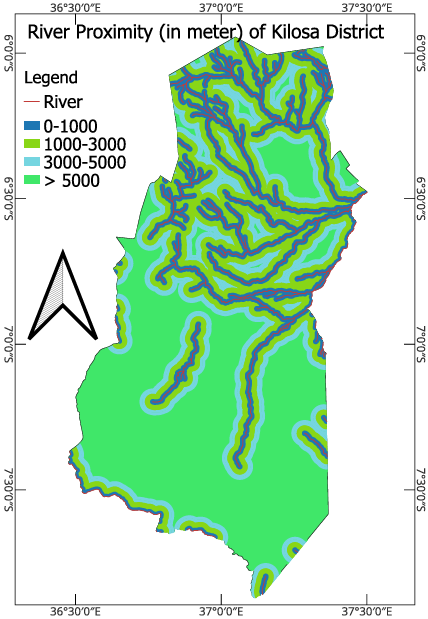
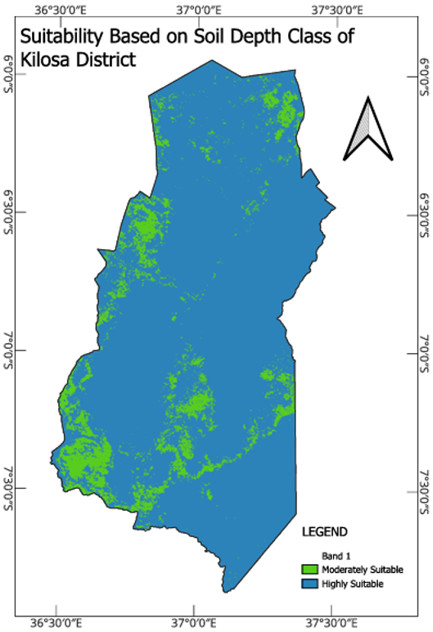
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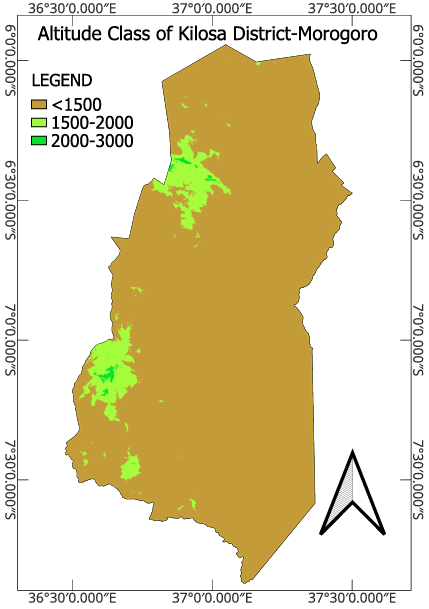
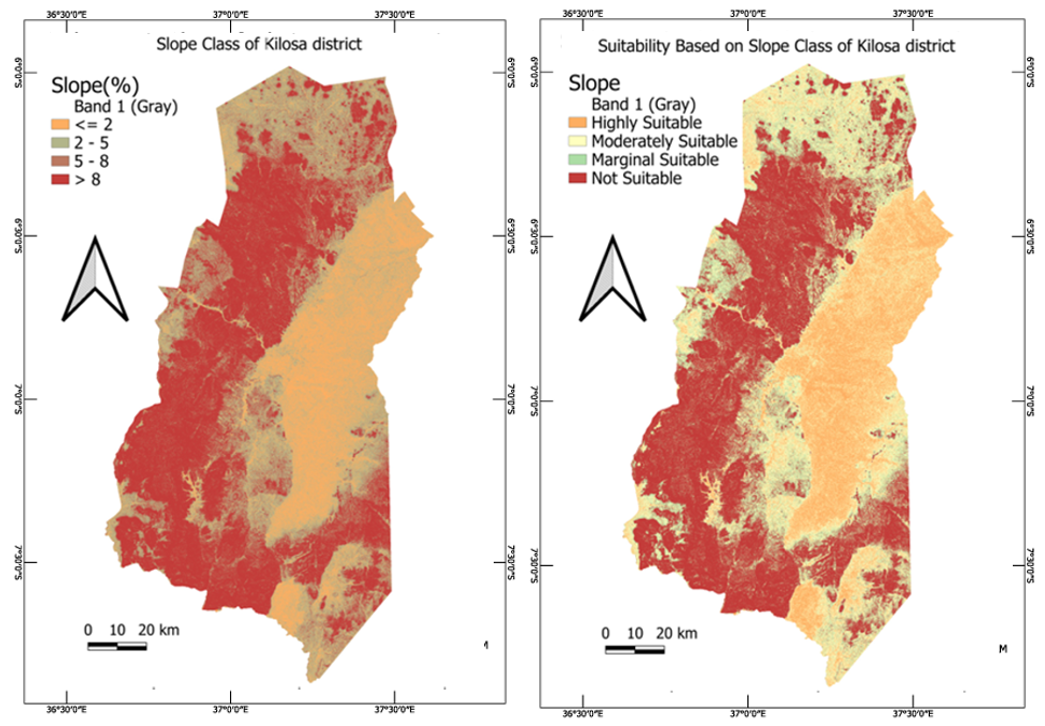
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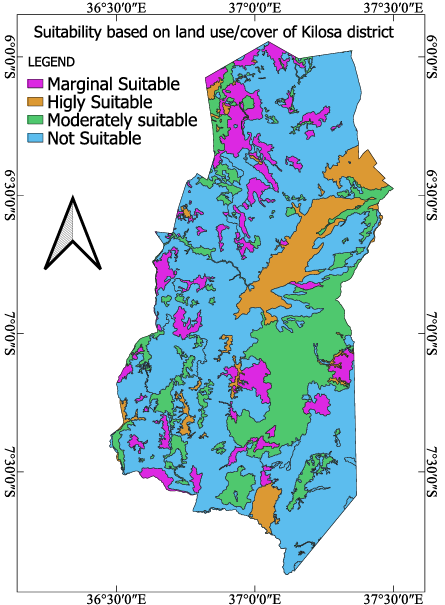
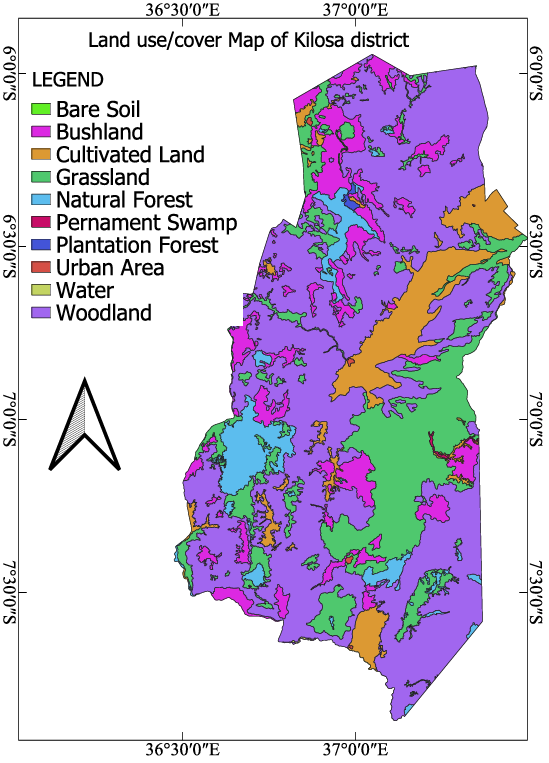
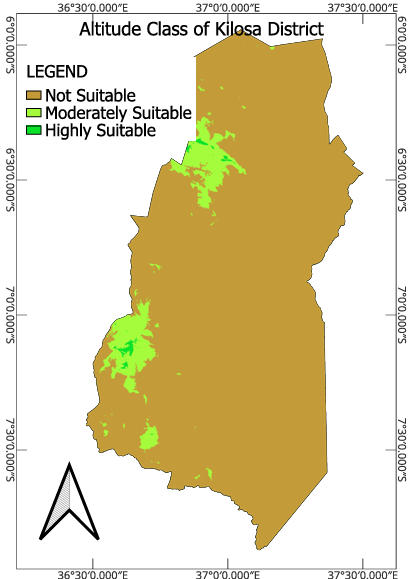
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**Figure 3(a-r): Factors map and degree of land suitability to assess the ideal location for surface irrigation**

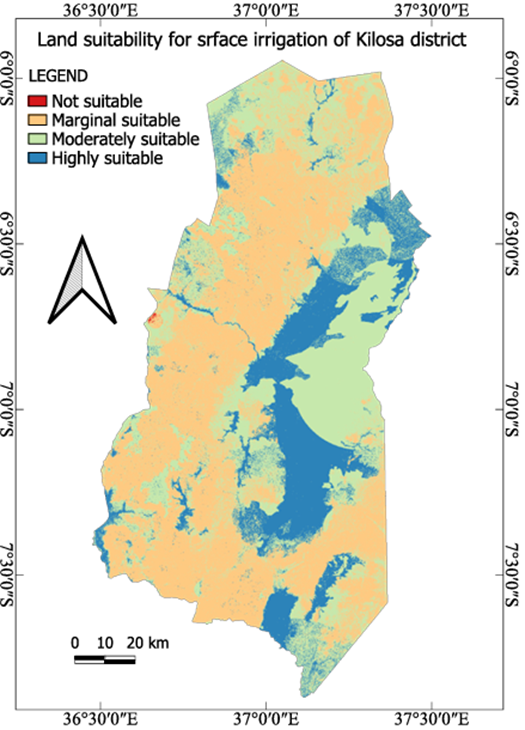
**Table 5: Pairwise comparison matrix for the selected criteria**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factors | Euclidian | Soil Depth | Soil Texture | Soil Drainage | Slope | Land use | Altitude | Rainfall | Temperature |
| Euclidian | 1 | 2 | 3 | 3 | 3 | 7 | 9 | 2 | 5 |
| Soil Depth | 1/2 | 1 | 2 | 2 | 2 | 9 | 7 | 1/2 | 2 |
| Soil Texture | 1/3 | 1/2 | 1 | 2 | 1 | 7 | 7 | 1/2 | 5 |
| Soil Drainage | 1/3 | 1/2 | 1/2 | 1 | 1 | 7 | 7 | 1/2 | 5 |
| Slope | 1/3 | 1/2 | 1 | 1 | 1 | 7 | 5 | 1/5 | 3 |
| Land use/cover | 1/7 | 1/9 | 1/7 | 1/7 | 1/7 | 1 | 2 | 1/5 | 2 |
| Altitude | 1/9 | 1/7 | 1/7 | 1/7 | 1/5 | 1/2 | 1 | 1/7 | 5 |
| Rainfall | 1/2 | 2 | 2 | 2 | 5 | 5 | 7 | 1 | 5 |
| Temperature | 1/5 | 1/2 | 1/5 | 1/5 | 1/3 | 1/2 | 1/5 | 1/5 | 1 |

**Table 6; Normalized pairwise comparison matrix and computation of criterion weights**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Factors | Euclidian  distance(m) | Soil Depth | Soil Texture | Soil Drainage | Slope | Land use/cover | Altitude | Rainfall | Temperature | Criteria Weight (%) |
| Euclidian(m) | 0.290 | 0.276 | 0.300 | 0.261 | 0.219 | 0.159 | 0.199 | 0.381 | 0.152 | 24.86 |
| Soil Depth | 0.145 | 0.138 | 0.200 | 0.174 | 0.146 | 0.205 | 0.155 | 0.095 | 0.061 | 14.65 |
| Soil Texture | 0.097 | 0.069 | 0.100 | 0.174 | 0.073 | 0.159 | 0.155 | 0.095 | 0.152 | 11.93 |
| Soil Drainage | 0.097 | 0.069 | 0.050 | 0.087 | 0.073 | 0.159 | 0.155 | 0.095 | 0.152 | 10.41 |
| Slope | 0.097 | 0.069 | 0.100 | 0.087 | 0.073 | 0.159 | 0.111 | 0.038 | 0.091 | 9.16 |
| Land use/cover | 0.041 | 0.015 | 0.014 | 0.012 | 0.010 | 0.023 | 0.044 | 0.038 | 0.061 | 2.88 |
| Altitude | 0.032 | 0.020 | 0.014 | 0.012 | 0.015 | 0.011 | 0.022 | 0.027 | 0.152 | 3.39 |
| Rainfall | 0.145 | 0.276 | 0.200 | 0.174 | 0.366 | 0.114 | 0.155 | 0.191 | 0.152 | 19.68 |
| Temperature | 0.058 | 0.069 | 0.020 | 0.017 | 0.024 | 0.011 | 0.004 | 0.038 | 0.030 | 3.03 |

*CR=0.02 Lambda (λmax ) that is the Maximum Eigen Value = 9.23*



**Figure 4: Overall land suitability for surface irrigation.**

**5. DISCUSSION**

The results indicate that a considerable portion of Kilosa district, particularly in the eastern region, is moderately to highly suitable for surface irrigation. This suitability is mainly determined by favorable climatic and topographical conditions, such as adequate precipitation, gentle slopes, and proximity to main water sources such as Mkondoa and Wami rivers. These influential factors reduce the amount of water required for supplementary irrigation and lower operational costs, emphasizing the importance of climatic stability in sustaining surface irrigation systems, as presented by Gebrechorkos et al. (2019b). However, the western, northeastern, and southeastern regions of the district display limited suitability due to steep slopes, poor drainage, and high evaporation rates, which lead significant challenges for surface irrigation. The overall suitability aligns with expectations based on Kilosa’s topography and climate. Highly suitable areas are intense where soil conditions, precipitation levels, and water accessibility are most favorable. However, an unexpected finding is the significant extent of marginally suitable and unsuitable areas highlighting greater extent than expected as mentioned by Kilosa district (2015) which inform that the area is with greater farms activities, particularly in the central and southern regions, this might be the resistant crops like millets and cassava depended on little rainfall. These areas are characterized by excessive slopes, poor drainage, and significant distances from water sources, necessitating advanced irrigation techniques such as sprinkler or drip systems to maintain productivity. Furthermore, land use constraints, including urban expansion and conservation zones, further restrict the potential for irrigation development in certain parts of the district.

These results are consistent with what was established by Wanyama et al. (2024), that topography and climate are among the key determinants of irrigation feasibility in East Africa. As their research representing, this study confirms that moderate slopes (2–5%) can support surface irrigation with slight land levelling. Additionally, the predominance of loamy and clay-loamy soils in suitable zones aligns with Mengistu et al., (2021) that soil-water retention and drainage characteristics favor surface irrigation. By employing an Analytical Hierarchy Process (AHP)-based weighting approach, this study extends prior knowledge by offering a spatially detailed analysis of irrigation suitability that integrates multiple environmental factors.

While these findings align with previous research, discrepancies arise regarding the influence of altitude on irrigation potential. Mitiku et al. (2024) suggested that lower altitudes generally favor irrigation due to natural water distribution. However, this study found that areas below 1500 meters in the district experience irregular water movement, limiting their suitability for surface irrigation. This suggests that local hydrological variations, rather than altitude alone, play a critical role in determining irrigation feasibility.

The study has significant implications for agricultural planning specifically surface irrigation, and water resource management. With 16.23% of the area classified as highly suitable and 37.13% as moderately suitable, policymakers should prioritize investments in irrigation infrastructure within these regions. Additionally, specific irrigation strategies are necessary, particularly in marginal areas where surface irrigation alone may not be viable. In steep or poorly drained zones, implementing soil conservation techniques such as terracing and contour ploughing can mitigate runoff and erosion risks. Further, integrating efficient water distribution systems, such as closed conduit networks, can enhance irrigation efficiency in water-scarce areas. Some might argue that land use restrictions, particularly in forest reserves and urbanizing areas, significantly limit the practical application of these findings. However, this study emphasizes the importance of sustainable land-use planning and policy enforcement to mitigate such constraints. Establishing buffer zones for irrigation and promoting reforestation efforts can help maintain water catchment integrity while supporting agricultural productivity. Additionally, adaptive irrigation methods, including rainwater harvesting and groundwater utilization, can supplement water availability in less suitable areas.

Future studies should incorporate socioeconomic factors such as farmers' willingness to adopt irrigation technologies, financial constraints, and institutional support mechanisms. High-resolution hydrological models can improve the accuracy of land suitability evaluation for surface irrigation, particularly under varying climatic conditions. Furthermore, remote sensing and GIS-based methods should be further explored to refine spatial analyses and optimize irrigation planning.

While this study provides a comprehensive assessment of land suitability for surface irrigation, limitations exist, particularly concerning the resolution of input data, including climate projections and soil classifications. However, the use of AHP weighting enhances the robustness of the findings by systematically integrating multiple environmental factors. The study’s strength lies in its multi-criteria evaluation approach, which offers a holistic perspective on irrigation feasibility. Future research should build on this foundation by incorporating real-time monitoring data and climate resilience modelling to support long-term surface irrigation planning.

**Table 7: Overall suitability class for Kilosa district**

|  |  |  |  |
| --- | --- | --- | --- |
| **Area (ha)** | **Suitability** | **Description** | **Percentage (%)** |
| 242,119.14 | S1 | Highly Suitable | 16.23 |
| 553,905.34 | S2 | Moderately Suitable | 37.13 |
| 652,214.96 | S3 | Marginal Suitable | 43.72 |
| 43,560.56 | N | Not Suitable | 2.92 |

**6. CONCLUSION**

The results indicate that most of the district is to a fair to high degree suitable or unavailable for surface irrigation, however, these results also reveal that large tracts still have only marginal suitability or are unsuitable because of steep slopes, poor drainage, and limited water access. The results from these provide vital information on how to optimally plan irrigation and how land use gets managed.

Although these findings, knowledge gaps remain specifically related to the socioeconomic dimension of irrigation feasibility, that is, willingness of farmers to adopt new irrigation technologies and the financial viability of new infrastructure investments. The study also elucidates the need for further development of hydrological and climate model that can increase the accuracy of land suitability assessments under new climatic conditions.

However, to address these challenges, policymakers should invest first in irrigation infrastructure in highly and moderately potential areas and subsequently in advanced irrigation techniques (drip and sprinkler system) in less potential zones. Sustainable water management strategies along with soil conservation measures need to be integrated into the land use planning in order to increase irrigation potential. In order to do more effective policy interventions for sustainable agricultural development in Kilosa district, future research should incorporate socioeconomic factors and high-resolution hydrological data.

**ACKNOWLEDGMENTS**

This research was sponsored by Tanzania National Irrigation Commission (NIRC) in the program of capacity building for internal staffs under the Division of Design and Research (DDR).

**AUTHOR CONTRIBUTIONS**

Said Hamisi Kambi comprehended, planned, and enrolled the paper, Boniface Peter Mbilinyi revised the plan of the paper and gave supplement literature, Festo Richard Silungwe revised the paper and subsidized to its writing,

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**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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