Land suitability assessment for surface irrigation development at Ethiopian highlands using geospatial technology

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Abstract
Irrigation development necessitates suitable lands for higher yield production and the development of long-term irrigation systems. The purpose of this research was to identify appropriate irrigation lands for irrigation in the Minch Yekest watershed in West Amhara, Ethiopia. Geospatial and multi-criteria decision-making techniques were used in this study. For land suitability analysis for surface irrigation, slope, land use, altitude, distance from the water source, soil characteristics, and available water storage capacity parameters were used. To find the best location for surface irrigation, the values were weighted and combined using the weighted overlay tool. The irrigation land suitability of each physical land parameter was classified into four suitability classes (S1, S2, S3, and N) based on the Food and Agricultural Organization guideline. According to the findings, 63% of the watershed area is highly suitable, 6.25% is moderately suitable, 28.69% is marginally suitable, and 2.06% is not suitable for the aforementioned purposes. The methodological approach and study findings could help policymakers make better decisions when developing irrigation projects in Ethiopia.

Keywords Ethiopia · GIS · Land suitability · Surface irrigation · Multi-criteria decision

Introduction
The use of land resources is becoming more common in order to fulfill the needs of the world’s rising population. The urgent need for land resource optimization is required to meet rising food demand and resource utilization trends (Kutter et al. 1997). The primary goal of land use planning, according to the UN report (FAO 1993), is to achieve the optimal use of land for higher production and profit. This entails making decisions about how to use land resources. Irrigated land produces approximately 40% of the world’s agricultural output (Albaji et al. 2008), but only 6 million ha (4%) of Sub-Saharan Africa’s total cultivated area is irrigated (Kadigi et al. 2019). According to the World Bank’s collection of development indicators compiled from officially recognized sources, Ethiopia’s agricultural irrigated land was 2.0807 percent in 2018. Crop production increases irrigable land for long-term production, maximizing irrigation practice (English et al. 2002).

Land evaluation for irrigation suitability was concerned with overall land performances, including landforms, climate, vegetation, and soils, for assessing land productivity when the land is used for specified purposes under a specified management system (SYS et al. 1991; Davidson 1992; FAO 2007). The evaluation of land suitability is critical in sustaining and developing land use on a spatial scale. It is used to identify geographical patterns and levels of biophysical factors, as well as to assess the potential capacity of land and its long-term use for irrigation. The suitability analysis leads to effective resource management through sound policies and planning, which improves the long-term
management of the land resource. As a result, evaluating land resources is critical for agricultural development planning (Ashraf and Normohammadan 2011). In contrast, unorganized use of natural resource scarcity, land resource obliteration, and associated socioeconomic issues occur as a result of inappropriate land use. Because land evaluation promotes rational land use planning and the appropriate and sustainable use of natural resources, it is an important aspect of the solution to the land-use problem.

Multiple-criteria decision-making (MCDA) methods include the analytic hierarchy process (AHP) (Saaty 1980), Topsis (Chen 2000), Electre (Tzeng and Huang 2011), and Grey theory (zcan et al. 2011). AHP is an MCDA method used for assessing and analyzing land-use suitability. AHP entails multiple selections within a hierarchical system based on the significance and weight of the parameters in comparison with one another (Saaty 1980). It is critical to use a hierarchical approach to develop a specific relationship between a large numbers of criteria. The system uses scoring and a pair-wise comparison matrix to determine the relative significance of factors on a level. For assessing land suitability, an integrated approach of remote sensing (RS), Geographical Information System (GIS), and MCDA techniques was used (Negash and Seleshi 2004). Several researchers (Joerin et al. 2001; Cengiz and Akbulak 2009; Mustafa et al. 2011; Adhikary et al. 2015; Worqlul et al. 2015; Zolekar and Bhagat 2015; Aldababseh et al. 2018) have used GIS to create land suitability maps in their research areas. The land suitability evaluation is critical in developing a land-use map based on irrigation potential on a spatial basis (Diallo et al. 2016). The irrigation potential can be assessed by incorporating Multi-Criteria Decision Analysis in the ArcGIS environment and employing the weight overlay rule (Hussien et al. 2019; Gurara 2020; Chen et al. 2010). The assessment of land suitability for irrigation is critical for designing and implementing worthwhile irrigation projects and increasing agricultural production. So far, no research has been conducted in this area to determine whether the land is suitable for surface irrigation. As a result, the main objective of this study was to determine the suitability of land for surface irrigation by considering various factors based on their influence on surface irrigation development such as slope, altitude, soil texture, soil drainage, soil depth, available water storage capacity, land use/land cover, and distance from water sources.

Materials and methods

Description of the study area

The research was carried out in the West Amhara Region’s Minch Yekest catchment, covering a total area of 3321.44 ha. It is located between 10° 25′ 19″ and 10° 28′ 17″ North and 37° 18′ 13″ and 37° 23′ 58″ East (Fig. 1). The study area's altitude ranges from 1671 to 2132 m.a.s.l. and the range of slope from 0 to 220 percent. The mean annual minimum and maximum air temperatures in the area are 10.3 °C and 20.1 °C, respectively. In the study region, the mean annual rainfall varies between 900 and 1800 mm.

The major soil types of the Minch Yekest catchment are Lithic Leptosols and Humic Nitisols, with Lithic Leptosols (clay loam) occurring in the upper part of the catchment covering an area of 1018.83 ha and Humic Nitisols (clay) is occurring in the lower part of the catchment covering an area of 2302.61 ha. Farmland, grassland, forest land, and shrub land cover 1530.27 ha, 59.30 ha, 1528.56 ha, and 203.31 ha of the Minch Yekest watershed, respectively. Farmers’ main crops include wheat (Triticum aestivum L.), maize (Zea mays L.), barley (Hordeum vulgare), and teff (Eragrostis tef).

Data collection

To achieve the study’s objectives, various data inputs (Table 1) were gathered from the study area and various sources, including land use data from Ethiopia’s Ministry of Water, Irrigation, and Energy, meteorological data from the National Meteorological Agency (NMA), ASTER DEM downloaded from the USGS website, and soil data obtained from the website of the Harmonized World Soil Database (HWSD) (Nachtergaele et al. 2010). Following the collection of data, additional analysis is carried out. To complete the investigation efficiently, ArcGIS 10.3.1, Excel, and ERDAS Imagine 2014 were used.

Data analysis

The necessary information was acquired from multiple sources, and the potential suitability of the area for surface irrigation was determined using the ArcGIS Spatial Analyst Toolbox’s Weighted Overlay tool, which is based on Multi-Criteria Decision Analysis (MCDA) methodology. The major factors were developed and weighted to determine land suitability (Ceballos-Silva and López-Blanco 2003; Hamere and Teshome 2018). The key irrigation suitability criteria (Table 2) addressed during this study were slope, altitude, soil texture, soil drainage, soil depth, available water storage capacity, land use/land cover, and distance from water sources (Girma et al. 2020; Kassaye et al. 2019; Yohannes and Soromessa 2018; Yalew et al. 2016; Bagherzadeh and Gholizadeh 2016; Pramanik 2016). Finally, using the Weighted Overlay tool of the Spatial Analyst Toolbox in the ArcGIS 10.3.1 environment, the reclassified and
weighted factor maps are overlaid, and the final irrigation suitability map is generated.

**Land suitability factors for surface irrigation**

Land suitability classification is the process of evaluating and classifying specific areas of land based on their suitability for specific uses (FAO 1976). This type of land suitability analysis is crucial for development because it provides important information about the many constraints and potential opportunities for land use that are being investigated based on land capabilities.

**Soil**

Soil is an important factor in determining an area's suitability for agriculture and long-term irrigation (Sultan 2013; USDIBR 2003). The irrigation suitability of the soil

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**Table 1 Sources of data**

| Data type     | Original sources format | Spatial resolution | Source of data | Derived map                                      |
|---------------|-------------------------|--------------------|----------------|-------------------------------------------------|
| Soil map      | Vector                  | 1:250,000          | MoWIE/HWSD V: 1.2 | Soil texture, soil drainage, soil depth and available water storage capacity |
| DEM           | Raster                  | 30 m               | USGS portal: http://www.earthexplorer.usgs.gov | Slope, altitude and distance from water sources |
| LULC data     | Raster                  | 30 m               | MoWIE           | Land use/cover                                  |

*DEM: Digital elevation model; LULC: Land use/land cover; MoWIE: Ministry of Water, Irrigation, and Energy of Ethiopia; HWSD: Harmonized World Soil Database Version 1.2; NMA: National Meteorological Agency*
was determined using the revised FAO/UNESCO soil map of the East Africa classification system (FAO 1997; Dent and Young 1981). Different soil characteristics, such as soil texture, drainage, depth, and available water storage capacity (AWSC), were used to determine whether or not soil was suitable for irrigation (USDIBR 2003). The depth of the soil profile from the top to the layer of obstacles for roots is critical for determining land suitability for irrigation. Deep soils are important for anchoring plant nutrients and promoting plant growth.

**Topographic factors**

The study area’s topographic features (slope and altitude) were used to assess land suitability. The altitude was divided into two classes: 1671–2000 m and 2000–2132 m, with 1596.44 ha (48.06 percent) and 1725.00 ha (51.94 percent) coverage, respectively (Table 8). The slope has a direct impact on irrigation methods, erosion susceptibility, land development, soil tillage, agricultural machine use, design of on-farm irrigation systems, plant adaptation, and drainage requirements. The slope of the area was calculated using a 20 m resolution DEM and classified into four groups based on the FAO (1996) and USDIBR (2003) classification systems as 0–2, 2–5, 5–8, and > 8 percent.

**Distance from the water source**

One of the fundamental criteria for determining land suitability for irrigation is the proximity of the water source (Paul et al. 2020). The distance from the water source was determined and categorized into three classes using ArcGIS 10.3 (0–0.721 km, 0.721–1.442 km, and 1.442–2.163.5 km).

**Land use/land cover**

Another important factor used is land use, which was obtained from the Ethiopian mapping agency. The primary land use types found in the study area are farmland, grassland, shrub land, and forest land. Expert judgment was used to divide the land use classes into four categories of suitability (S1, S2, S3, and N).

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**Table 2** Studies on land suitability evaluation

| Author               | Methods                        | Crop                  | Criteria                                                                                                                                                                                                 |
|----------------------|--------------------------------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Girma et al. 2020    | GIS and AHP                    | General agriculture   | Land use/land cover, soil, slope, and proximity to water sources                                                                                                                                         |
| Kassaye et al. 2020  | GIS and AHP                    | General agriculture   | Soil pH, soil type, soil drainage, soil depth, AWSC, impermeable layer, electrical conductivity (ECe), cation-exchange capacity (CEC), phase, organic carbon, texture classes, an obstacle to root, land use/land cover, slope, and distance |
| Nasir et al. 2019    | GIS and AHP                    | General agriculture   | Slope, texture, depth, drainage characteristics, land use/cover, and distance to the water source                                                                                                       |
| Yohannes and Soromessa 2018 | GIS and AHP                   | Barley & Wheat        | Soil depth, soil texture, soil drainage (permeability), soil erosion, slope, aspect, altitude fertility and soil chemical characteristics (pH, cation-exchange capacity (CEC), electrical conductivity (EC), organic matter (OM), available phosphorus, total nitrogen, and calcium carbonate), climatic parameters (temperature and rainfall) and accessibly (distance from road and water point) |
| Hailu and Quraishi 2017 | GIS and AHP                   | General agriculture   | Slope, soil texture, depth, drainage characteristics, soil type, and land use/cover                                                                                                                       |
| Yalew et al. 2016    | GIS and AHP                    | General agriculture   | Soil moisture, stoniness, soil group, water resources, elevation, slope, soil depth, distance from roads                                                                                                   |
| Bagherzadeh and Gholizadeh 2016 | Parametric and TOP-SIS approaches using GIS | Wheat                 | Soil, texture, electrical conductivity (ECe), exchangeable sodium percentage (ESP), CaCO₃, Gravel, Soil depth, organic carbon (OC), pH, Climate, Slope, Drainage, Flooding, Gypsum                          |
| Pramanik 2016        | GIS and AHP                    | General agriculture   | Slope, Elevation, Aspect, land use/land cover (LULC), Soil moisture, Drainage, Transport network, Soil characteristics, Geology                                                                            |
| Akinci et al. 2013   | GIS and AHP                    | General agriculture   | Soil group, land use capability class (LUCS), land use capability sub-class (LUCSS), soil depth, slope, aspect, elevation, erosion, other soil properties                                                  |
Structure of the land suitability classification

The land suitability classes of the Food and Agricultural Organization describe the degrees of suitability of a given type of land for a specific use (FAO 1976). The FAO (1976, 2007) proposed a method for evaluating land suitability in terms of suitability ratings ranging from highly suitable to not suitable based on the suitability of land characteristics to various crops. According to FAO (1976, 1983), land suitability maps are divided into two categories: suitable (S) and unsuitable (N). Based on their benefits and limitations, these orders are further classified into three and two classes, respectively: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N).

Table 3  Land suitability classification

| FAO symbol | Suitability   | Description                                                                                                                                                                                                 | Land index |
|------------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Class S1   | Highly suitable | Land having no significant limitations to the sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level | 75–100     |
| Class S2   | Moderately suitable | Land having limitations which in the aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land | 50–75     |
| Class S3   | Marginally suitable | Land having limitations which in the aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified | 25–50     |
| N          | Not suitable  | Land which has qualities that appear to preclude sustained use of the kind under consideration                                                                                                           | 0–25       |

Fig. 2  Overall Conceptual Framework used in the study
temporarily not suitable S4 (N1), and permanently not suitable S5 (N2) (Table 3).

The overall conceptual methodology employed during study presented in Fig. 2. Table 4 depicts the weights given to each of the contributing parameters and its classes.

**Weight assignment using the AHP**

The analytical hierarchy process was assigned weights to each contributing factor (AHP). AHP adopted a procedure that identifies and classifying criteria in order to assess the context of the spatial planning decisions (Vogel 2008). AHP assigns weights based on three principles: decomposition, comparative judgment, and priority synthesis (Eldrandaly 2007). AHP was used in the multi-criteria decision-making approach, which constructs a matrix of pairwise comparisons between the parameters affecting land suitability for agricultural purposes. A scale of 1 to 9 is used in AHP to indicate whether the two factors are equally important or one is more important than the others. Reciprocals of one to nine (1/1 and 1/9) indicate that one is less important than the other (Table 5).

To find the eigenvalues, which represent the parameter weights, a pair-wise comparison of contributing factors was

| Table 4 | Land suitability factor rating for irrigation |
| --- | --- |
| Main factor | Sub factor | Factor rating | Source |
| Topography | Slope (%) | 0–2 | 2–5 | 5–8 | > 8 | Mandal et al. 2018, USDIBR (2003) |
| Soil | Drainage class | Well | Moderately well | Imperfectly | Poor | Nachtergaele et al. (2009) |
| Soil | Depth (cm) | > 100 (Very deep) | 50–100 (Moderately deep) | 10–50 (Shallow) | < 10 (Very shallow) | Mandal et al. 2018 |
| Soil | Texture AWSC (mm/m) | L–SiCL, C | SiL, SCL, CL | SL | LS, Si–L | Nachtergaele et al. 2018 |
| Soil | Distance from water source | 0—721 | 721—1442 | 1442—2163 | – | USDIBR (2003) |
| LU/LC | LU/LC | Farmland | Grassland | Barren & shrub land | Constraints (Forest, built-up, water, wetland) | Yohannes and Soromessa, 2018 |

where, SiL = silty-loam, SCL = silty-clay, LS = loamy-sand, L = loam, SL = sandy-loam, C = clay, CL = clay loam, Si = silt

| Table 5 | Saaty’s scale in AHP (Saaty 1980) |
| --- | --- |
| Importance scale | Definition | Explanation |
| 1 | Equal importance | Two activities contribute equally to the objective |
| 3 | Moderately importance | Experience and judgment slightly favor one activity over another |
| 5 | Strongly more important/Much more important | Experience and judgment strongly favor one activity over another |
| 7 | Very strongly/Far more important | Demonstrated importance an activity is strongly favored and its dominance demonstrated in practice |
| 9 | Extremely more important | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values between the two adjacent judgments | When compromise is needed |
| Reciprocals | Values for inverse comparison |

| Table 6 | 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 |
performed and normalized. The random consistency indices (RI) (Table 6) developed by Saaty (1980) were used to determine the consistency ratio (CR), which measures the degree of consistency.

Consistency index (CI) computed using the formula below:

\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]

where \( \lambda_{\text{max}} \) is the largest eigenvalue of the pairwise comparison matrix and \( n \) is the number of classes.

Then, \( CR \) is given by the following formula (Saaty 1980):

\[ CR = \frac{CI}{RI} \]

Table 7 Pairwise comparison matrix for assessing the relative relevance of eight factors

|              | Euclidian distance | Depth | Slope | AWSC | Texture | Drainage class | LU/LC | Altitude | Average weights | Weights (%) |
|--------------|--------------------|-------|-------|------|---------|----------------|-------|----------|-----------------|-------------|
| Euclidian distance | 1                  |       |       |       |         |                |       |          | 0.331           | 33.1        |
| Depth        | 0.5                | 1     |       |       |         |                |       |          | 0.231           | 23.1        |
| Slope        | 0.33               | 0.5   | 1     |       |         |                |       |          | 0.157           | 15.7        |
| AWSC         | 0.25               | 0.33  | 0.5   | 1    |         |                |       |          | 0.106           | 10.6        |
| Texture      | 0.2                | 0.25  | 0.33  | 0.5  | 1       |                |       |          | 0.071           | 7.1         |
| Drainage class| 0.17               | 0.2   | 0.25  | 0.33 | 0.5     | 1              |       |          | 0.048           | 4.8         |
| LU/LC        | 0.14               | 0.17  | 0.2   | 0.25 | 0.33    | 0.5            | 1     |          | 0.033           | 3.3         |
| Altitude     | 0.12               | 0.14  | 0.17  | 0.2  | 0.25    | 0.33           | 0.5   | 1        | 0.024           | 2.4         |

CR = 2.9%
Consistency is acceptable

Results and discussion

Weight of land suitability parameters

For land suitability analysis, the distance from the water source (Euclidian distance), soil depth, and slope were given the most weight (Table 7). For various reasons, such as access to water and minimizing power consumption for the pump, land located closer to water sources (rivers) was deemed more suitable for surface irrigation. Soil depth influences agricultural production by determining the potential for rooting depth. Surface irrigation was prioritized over deep soil, and vice versa. Subsurface irrigation was prioritized in low slope to flat areas, while steep slopes were deemed unsuitable for surface irrigation.

Surface irrigation was prioritized in areas with the greatest available water storage capacity (AWSC) (Table 7). Surface irrigation was deemed highly and moderately suitable for clay and clay loam textured soils, respectively. As a result, in this study, clay textured soil was assigned a high relative influence value (Table 8). Weights are assigned based on the theme feature’s characteristics and its relationship to irrigation suitability. The geometric mean and normalized weights were calculated using the weights assigned to each feature and a pairwise comparison of the feature classes.

Land and soil characteristics of the watershed

In this study, approximately 74.81 percent of the area was found to be above an 8 percent slope. According to USDI-BR (2003) and Mandal et al. (2018), landscapes with 1–2 percent slope are 95 percent suitable, 2–5 percent slope are 90 percent suitable, 5–8 percent slope are 80 percent suitable, and more than 8 percent slope are 70 percent suitable for none terraced slopes. The distance between irrigable
land and rivers in the study area ranges from 0 to 2.16 km. Irrigated areas should be as close to rivers or other water sources as possible.

The depth of the soil ranges from 10 to 100 cm. About 2302.61 ha (69.33%) of the area has a soil depth of 100 cm with clay texture, while the remaining 1018.83 ha (30.67%) has a soil depth of 10 cm with clay loam texture (Table 8). The soil in the study area was moderately well and imperfectly draining. Soil drainage in a specific area can be classified into four types, according to Nachtergaele et al. (2010). These are well, moderately well, imperfectly well, and poorly drained. Drainage ensures that the soil is aerated properly. Excess or standing water on the land can choke the crops. According to USDIBR (2003), available water storage capacity (AWSC) is divided into four categories: > 100 mm/m, 75–100 mm/m, 15–75 mm/m, and 15 mm/m. AWSC of > 100 mm/m and 15–75 mm/m are found in approximately 69.33% and 30.67% of the study area, respectively (Table 8).

Farmland, grassland, shrub land, and forest land were identified as the area’s four land use/land cover classes, covering 1530.27 ha (46.07%), 59.30 ha (1.79%), 203.31 ha (6.12%), and 1528.56 ha (46.02%), respectively (Table 8).

Areas with slopes ranging from 0 to 2% were given high weights (S1 class) because they effectively infiltrate water to reach the crop root zone. Areas with slope percentages greater than 8 were deemed unsuitable because they tend to runoff rather than reach the crop root zone (Fig. 3 and Table 8).

### Irrigation land suitability

Due to the small Euclidian distance from the water source, deep soil depth, flat slope, and high available water storage capacity, the upstream and central parts of the area were found to be highly suitable for surface irrigation on the land suitability map. The northwest parts of the watershed, on the other hand, were found to be unsuitable for surface irrigation (Fig. 4). The watershed 2092.59 ha (63.0%), 207.62 ha (6.25%), 952.83 ha (28.69%), and 68.40 ha (2.06%) were found to be highly suitable, moderately suitable, marginally suitable, and not suitable, respectively, out of a total area of 3321.44 ha (Table 9 and Fig. 4).

### Table 8 Factors for surface irrigation land suitability assessment

| Main factor | Criteria | Classes | Suitability | Local weight (%) | Global weight (%) | Area coverage (ha) | Area coverage (%) |
|-------------|----------|---------|-------------|------------------|------------------|--------------------|-------------------|
| Topography  | Slope (%)| 0–2     | S1          | 46.7             | 15.6             | 87.60              | 2.64              |
|             |          | 2–5     | S2          | 27.7             | 286.96           | 8.64               |                  |
|             |          | 5–8     | S3          | 16               | 462.00           | 13.91              |                  |
|             |          | > 8     | N           | 9.5              | 2484.88          | 74.81              |                  |
| Altitude (m)|         | 1671–2000 | S2       | 33.3             | 2.4              | 1578.80            | 47.53             |
|             |          | 2000–2132 | S1       | 66.7             |                  | 1742.64            | 52.47             |
| Soil        | Drainage class | Moderately well | S2 | 66.7 | 4.8 | 2302.61 | 69.33 |
|             |          | Imperfectly | S3         | 33.3             |                  | 1018.83            | 30.67             |
|             | Depth (cm)| 100      | S2         | 75               | 23.1             | 2302.61            | 69.33             |
|             |          | 10       | S3         | 25               |                  | 1018.83            | 30.67             |
| Texture     |           | Clay     | S1         | 66.7             | 7.1              | 2302.61            | 69.33             |
|             |          | Clay loam | S2         | 33.3             |                  | 1018.83            | 30.67             |
| AWSC (mm/m) |           | 150      | S1         | 75               | 10.6             | 2302.61            | 69.33             |
|             |          | 15       | S3         | 25               |                  | 1018.83            | 30.67             |
| Distance from water source | Euclidian distance (m) | 0–721 | S1 | 54 | 33.1 | 3029.53 | 91.21 |
|             |          | 721–1442 | S2         | 29.7             |                  | 280.00             | 8.43              |
|             |          | 1442–2163.5 | S3      | 16.3             |                  | 11.91              | 0.36              |
| LU/LC       |           | Farm land | S1 | 56.4 | 3.3 | 1530.27 | 46.07 |
|             |          | Grassland | S2 | 25.8 |      | 59.30   | 1.79             |
|             |          | Shrubland | S3 | 10.9 |      | 203.31  | 6.12             |
|             |          | Forest land | N | 6.9  |      | 1528.56 | 46.02            |
Fig. 3 Factors map and degree of suitability to assess the ideal location for surface irrigation: a Distance from water sources, b Soil Depth, c Slope, d Available water storage capacity, e Soil Texture, f Drainage, g Land use/land cover, h Altitude

Fig. 4 Land suitability map for agriculture
Table 9: The distribution of land suitability classes for agricultural purpose in the study area

| Suitability           | Area (ha) | Percentage |
|-----------------------|-----------|------------|
| Highly suitable (S1)  | 2092.59   | 63.00      |
| Moderate suitable (S2)| 207.62    | 6.25       |
| Marginally suitable (S3)| 952.83  | 28.69      |
| Not suitable (N)      | 68.40     | 2.06       |
| Total                 | 3321.44   | 100        |

### Conclusion

The land suitability analysis for irrigation is critical for irrigation development and future planning. The assessment of land suitability for surface irrigation aids in decision-making and agricultural development planning. Using different thematic maps, remote sensing and GIS were integrated with the AHP for evaluating land suitability in the study area. The weights of thematic layers were assigned based on their land suitability characteristics, then they were overlaid and integrated for surface irrigation. According to the data, about 63% of the entire land is extremely suitable, indicating the possibility of agricultural and irrigation project development. This suggested that large area coverage could be used for small and medium-scale irrigation projects. This methodology, along with additional and modified parameters, can be used in future studies in various parts of the country. Before designing and constructing irrigation projects, development agents and policymakers could use this technique of suitability analysis.

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### Declarations

#### Conflict of interest

The authors declare that they have no conflict of interest.

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