



Research Article

Land suitability evaluation for surface irrigation development using parametric evaluation approach: The case of Gudina Wacho watershed, Western Ethiopia

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Abstract

Evaluating land suitability of a given watershed is vital to predict potential and limitation of the land for surface irrigation. The present study was evaluated the suitability of Gudina Wacho watershed for surface irrigation development using parametric evaluation approach. The watershed was classified in to four lands mapping units, based on three soil profile pits were opened at each land mapping unit. Soil samples from each profile pit have been taken to analyze each selected soil physical and chemical properties. Slop analysis of the watershed was computed from the DEM using GIS technique. Results of the land suitability evaluation for surface irrigation showed that, a total area of 3064 ha (72.6%) was slightly suitable (S3) and area of 1154 ha (27.4%) was currently not suitable (N1). The limiting factors were slop, soil texture and drainage. For all land mapping units, chemical soil parameters such as CaCO₃, ECe and pH, and the physical parameter (soil depth) were not limiting factors for surface irrigation in the study watershed. Therefore, the area is potential for irrigation production with some limitations and under proper management it can benefit the local community to meet the food demand. In order to sustainably develop the area for irrigation development; land leveling operation or soil conservation work has to be incorporated to break surface slope and to make it suitable for surface irrigation.

Introduction

Ethiopia is rain fed agriculture dependent country; with limited use of irrigation for agricultural production [1]. It is estimated that more than 90% of the food supply in the country comes from rainfed agriculture [2]. The major problem associated with this rainfed agriculture is the high degree of rainfall variability. Due to this variability, crop failures and food insecurity are frequent in the country [3,4]. Hence, the solution for food insecurity could be provided by comprehensive irrigation development that can lead to overcome the effects

of rainfall variability and improve the quality of life for rural population [1,5].

Land suitability evaluation of a given watershed is vital to predict potential and limitation of the land for irrigation [6]. Land evaluation on its soil properties and slop suitability are necessary and important steps in surface irrigation planning [7,8]. Accordingly, Sys, et al. [9], suggested a parametric evaluation approach for surface irrigation suitability evaluation which is concern on soil physical properties (soil texture, soil depth and drainage), soil chemical properties

(salinity/alkalinity status such as calcium carbonate content and gypsum content of the soil), and slop. Any land can be classified as suitable (S), or not suitable (N) orders for surface irrigation. Where, suitable order type of land quality is suitable for use with good benefits and not suitable denote land quality which is not enough for suitable outcomes [10]. The rate of the suitability is the function of characterization and alignment of land quality in to orders and classes in the framework of its fitness for irrigation [11,12].

Morphometric parameters of Gudina Wacho watershed was analyzed for surface irrigation development using GIS by Gebre, et al. [12]. The result of the analysis indicates that the watershed is elongated in shape, high runoff discharge and permeable subsoil circumstances. This revealed the watershed is good for surface irrigation on its hydrological status and topographic shape [12]. Although, the study by Gebre, et al. [12] lacks land suitability evaluation, it is important for surface irrigation development. So, to endeavor this gap, the present study was evaluated the suitability of Gudina Wacho watershed for surface irrigation development using its soil and slop parameters of the watershed. The result will recognize to the local government (regional and district land use planners), and it could serve as a base line for researchers and policy makers' concerning land use planning and management for irrigation.

Materials and methods

Description of the study area

The study was conducted in Gudina Wacho watershed, Hawa Galan district in Kellem Wollega Zone (KWZ) of Oromia Regional State (Figure 1). The district is located 618 km far from Addis Ababa and the capital town of the Zone, Dambi Dollo is found at about 64,2 km from Addis Ababa. The total land area of the zone is about 9672.4 square kilo meter with altitude ranging above 1200m a.s.l. Kellem Wollega zone is bounded by West Wollega Zone in the North, Buno Bedele Zone in the East, Ilu A/Bora Zone in South and Sudan in the West [13].

The climate of the area is a hot and humid type. This region is marked on most rainfall maps of Ethiopia. Ambient temperature of the Zone ranges from 12 – 32°C. The annual rain fall of this zone is minimum 1500mm, medium 1900 and maximum 3300 mm [13]. And; the Zone is characterized mostly by flat and undulating land features. The major soil types of the area are Leptosols, Chromic Luvisols, Vertic Cambisols, Dystric Nitisols, Lithosols and Orthic Acrisols [13].

Data types

To achieve the objectives of the study, soil data were collected from the representative pits by field survey, and

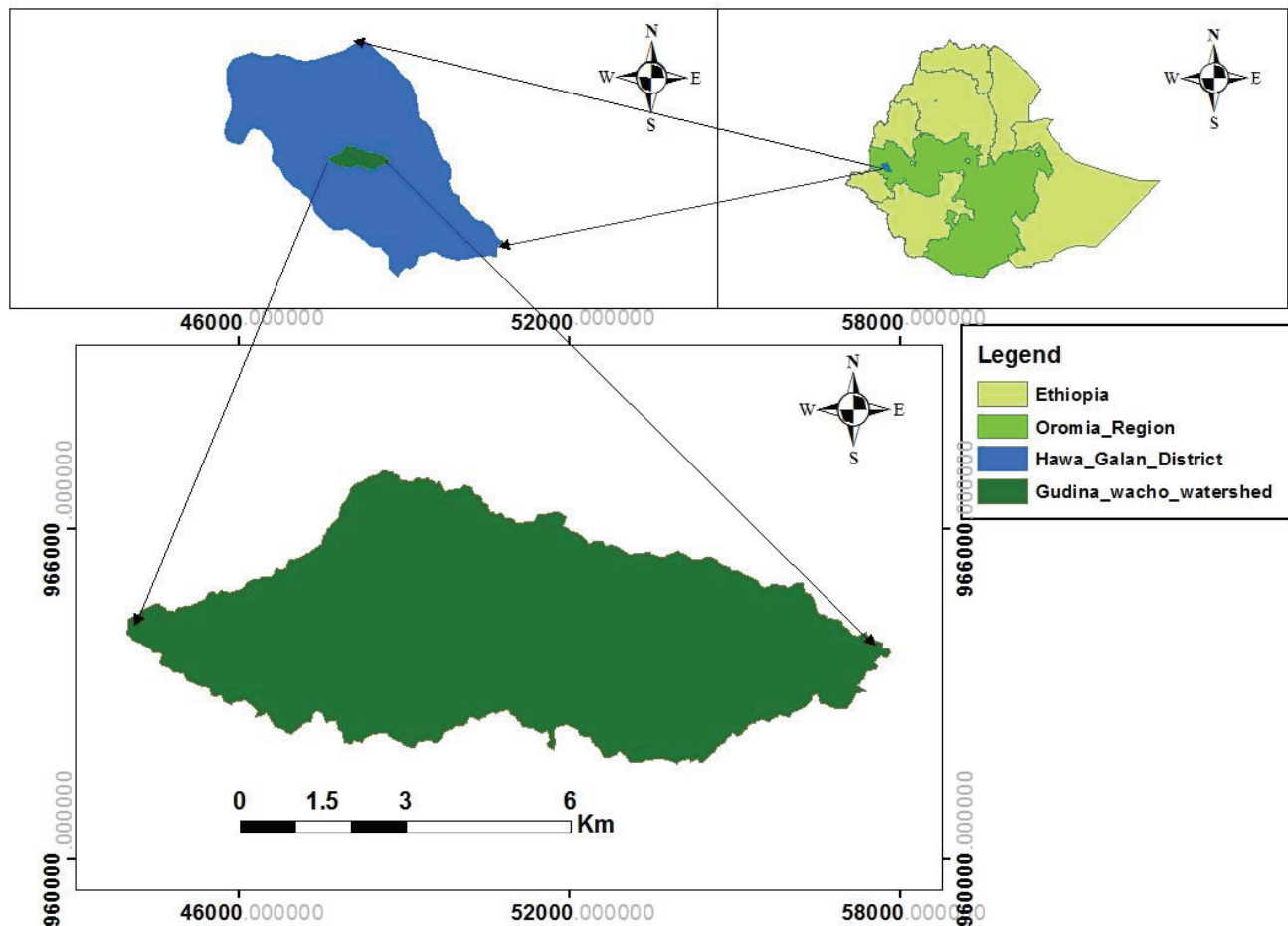


Figure 1: Location of the study area.



Shuttle Radar Topographic Mission (SRTM) Digital elevation Model (DEM) with 20-meter spatial resolution of the study area which is widely used for slope analysis was used.

Land mapping units and soil sampling

Using Digital elevation Model (DEM) of the study area, the watershed was classified into four slope classes (land mapping units). Based on the classified slopes, three soil profile pits were opened at each land mapping unit (LMU) (Figure 2). In line with this, the profile pits were geo-referenced using Global Positioning System (GPS). Soil samples from each profile pit have been taken for analysis of each selected soil physical and chemical properties such as texture, CaCO₃ status, Electric conductivity (EC_e) and pH. In addition, auger observations for soil depth and drainage measurement for soil drainage evaluation on each representative site were made.

Data analysis

Soil parameters analysis and rating for surface irrigation: The selected physical and chemical soil properties (soil texture, electrical conductivity and calcium carbonate content) of the watershed were analyzed in laboratory; while soil depth and drainage were measured on fields based on the standards [14]. And, the results were rated according to the guidelines of FAO [15] and Sys, et al. [9] for surface irrigation suitability.

Soil texture was determined by the hydrometer method [16]. Electric conductivity of saturation extract (EC_e) was determined by 1:2.5 ratio of soil to water suspension using EC

meter, and Percentage of calcium carbonate (% CaCO₃) was measured using rapid manometric method meter [14]. And, pH (soil reaction) was measured using a glass electrode pH-meter [14].

Slope analysis and rating for surface irrigation: Slope of a given area plays an important role for irrigation activities in general and predominantly in case of surface irrigation. Slope defines if an area is workable at all or not. In the present study, slope was generated from Digital elevation Model (DEM) by means of spatial analyst tool in Arc GIS, and the slope results were rated according to FAO [15] guideline.

Land suitability evaluation: After rating the soil and slope parameters, capability index (Ci) for surface irrigation was calculated using parametric evaluation approach (equation below) [9]. After calculating the capability index, the suitability class for each land unit was given using Table 1 below [9].

$$Ci = A * B / 100 * C / 100 * D / 100 * E / 100 * F / 100$$

Where, Ci = Capability index for surface irrigation

Table 1: Suitability class for the irrigation capability indices [9].

Capability Index	Class	Definition	Symbol
>80	I	Highly suitable	S1
60-80	II	Suitable	S2
45-60	III	Slightly suitable	S3
30-45	IV	Currently not suitable	N1
<30	V	Permanently not suitable	N2

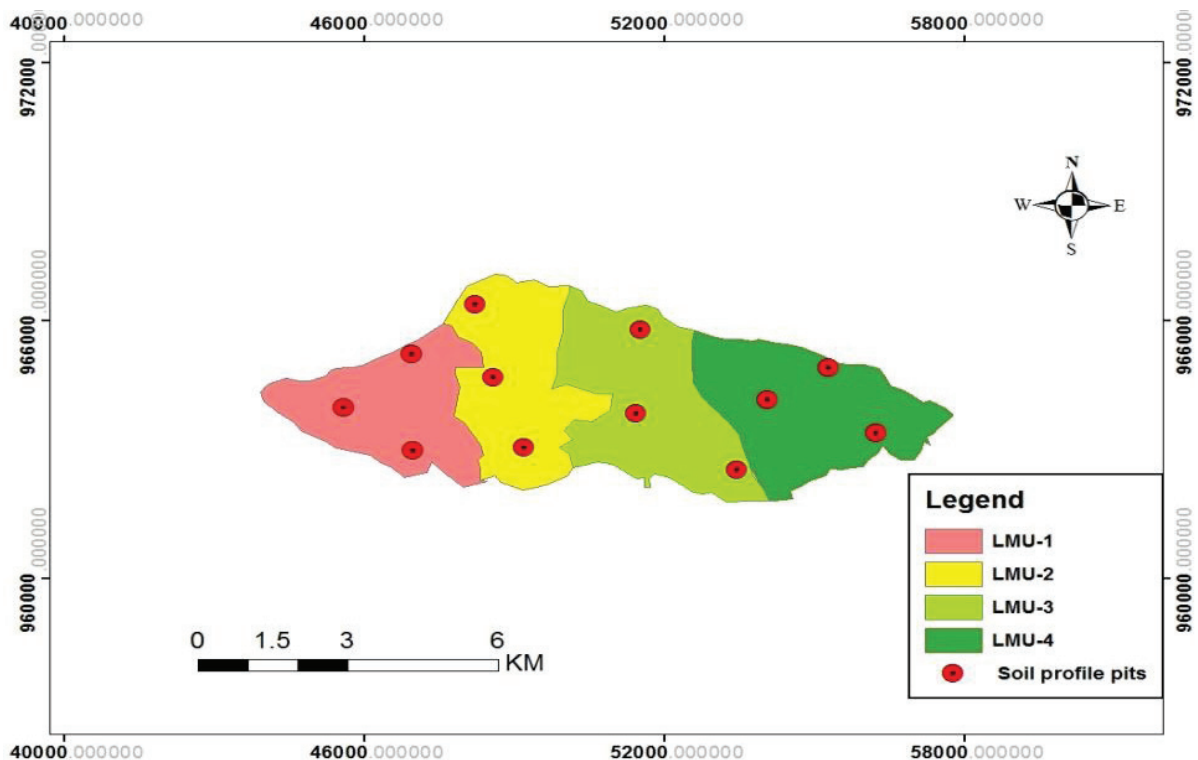


Figure 2: Land mapping units and soil sampled pits.

A = Rating of soil texture; B = Rating of soil depth; C = Rating of CaCO₃ status; D = Rating of electro conductivity; E = Rating of soil drainage; F = Slope rating.

Results and Discussion

Soil parameters evaluation

To evaluate the soil suitability of the watershed for surface irrigation, some selected soil physical properties (texture, depth and drainage) (Table 2) and chemical properties (CaCO₃ status, Soil salinity and pH) (Table 3) of the watershed were characterized, and rated for surface irrigation (Table 4).

Selected soil physical properties

Soil texture is important factor of soil physical analysis for surface irrigation suitability evaluation as it determines pore spaces of the soil which influence the soil permeability and infiltration rate [15]. In the present study, the soil textural class of the watershed was determined based on the particle size distribution. As a result, percent of clay takes the highest proportion of the soil's textural class followed by silt and sand. Consequently, the textural class was clay at all land mapping units (Table 2).

Soil depth refers to the thickness of the soil materials which provide structural support, nutrients and water for plants [14]. As it was seen from auger observation and profile description of the soils, soil depths at all sampling points were greater than 100 cm (Table 2), rock out crop was no observed. Hence, the soil in the present study area could be considered as deep soil which is highly suitable for surface irrigation [17].

Soil drainage is also an important factor for land suitability evaluation for surface irrigation as it is treated excess water on surface. Good drainage of the site is essential to allow the continuous movement of water and salt through the profile [14]. Without this continuous leaching, salt may build up to levels that may be harmful to the landscape and crops. In the present study, the soil drainage of the watershed (all land units) was classified as moderately drained (Table 2), which is considered as moderately suitable for surface irrigation [18].

Selected soil chemical properties

Soil pH results from the laboratory analysis showed that the average soil pH (H₂O) values were found in the ranges of 5.74 to 6.04 (Table 3), which was moderate acidic Sys, et al. [9] and the average salinity ranges from 0.03 to 0.04 dS/m (Table 3). Due to the moderately acidic nature of the soils of the study area, the E_{Ce} values were negligible. Moreover, there was no significant difference in E_{Ce} values. This indicates that there would not be any actual and potential salinity hazard in the soils of the watershed [15].

The average soil Calcium carbonate status(CaCO₃) values, were found in the ranges of 3.2–5.1 percent. The highest CaCO₃ value as 5.1 was observed on land mapping unit four and the lowest as 3.2 was recorded in land mapping unit one (Table 3). Similar results were found in Semaz irrigation Dam by Abram, et al. [18] Figures 3–5.

Slop evaluation

Characterizing slope of an area is important, which directly controls the balance between runoff response and soil infiltration rates of topography. Higher value of slope causes less infiltration of rainwater and high runoff water through top soil to recharge the groundwater [19]. The slope map of the study watershed was grouped in to five classes in percent for surface irrigation; flat or almost flat (0 – 3 %), gentle (3.1 – 5%), moderately steep (5.1 – 8%), steep (8.1–16%) and very steep (>16%) (Figure 6). After classified the whole watershed like that each land mapping unite (LMU) was grouped as flat (LMU-4), gentle (LMU-1&2,) and moderately steep (LMU-3) (Table 5). Consequently, most of the area of the watershed come under gentle(51.5%) and flat(27%) slopes, and can be classified as good category for surface irrigation [20].

Land suitability evaluation for surface irrigation

The capability index and its suitability class for surface irrigation of each land mapping unit(LMU) is presented in Table 6. The results showed that the LMU-1, 2 and 4, with a total area of 3064 ha (72.6%), were slightly suitable (S₃) (Figure 7) for surface irrigation. The limiting factors were soil texture, slop and drainage. It was found that LMU-3, covering an area of 1154 ha (27.4%) was currently not suitable (N₁) (Figure 6) for surface irrigation due to the high slop gradient. In addition, soil texture and soil drainage were other limiting factors in this LMU. Similar results were reported by Ibrahim, et al. [20]. For all LMUs, chemical soil parameters such as CaCO₃, E_{Ce}, pH and the physical property (soil depth) were not limiting factors for surface irrigation in the study watershed. Similarly, Abraham, et al. [13] and Kassa, et al. [21] found that these parameters were not limited factors for surface irrigation in Northern Ethiopia.

Table 2: Investigated selected soil physical properties of Gudina Wacho watershed.

Land Unit	Area (ha)	Ratio (%)	Texture	Depth (cm)	Drainage
1	908	21.5	Clay	>100	Moderately drained
2	1016	24.1	Clay	>100	Moderately drained
3	1154	27.4	Clay	>100	Moderately drained
4	1140	27	Clay	>100	Moderately drained

Table 3: Investigated selected soil chemical properties of Gudina Wacho watershed.

Land Unit	Area (ha)	Ratio (%)	CaCO ₃ (%)	E _{Ce} (ds/m)	pH
1	908	21.5	3.2	0.04	6.04
2	1016	24.1	3.7	0.03	5.74
3	1154	27.4	3.2	0.03	5.98
4	1140	27	5.1	0.037	5.98

Table 4: Rating of soil Physico-chemical properties of Gudina Wacho watershed for surface irrigation.

Land Unit	Area (ha)	Ratio (%)	Soil Physico-chemical properties					PH
			Texture	Soil drainage	Soil depth	CaCO ₃ (%)	E _{Ce} (ds/m)	
1	908	21.5	65	80	100	100	100	100
2	1016	24.1	65	80	100	100	100	100
3	1154	27.4	65	80	100	100	100	100
4	1140	27	65	80	100	100	100	100

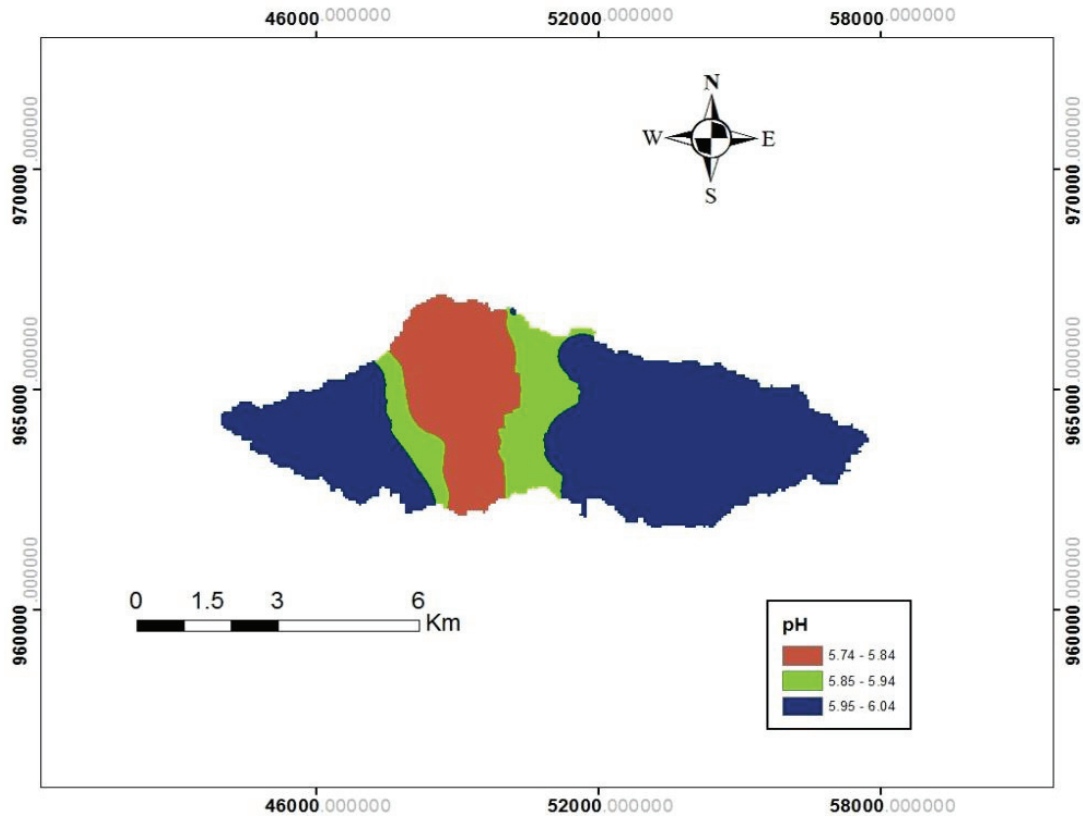


Figure 3: Spatial variability of soil pH in Gudina Wacho Watershed.

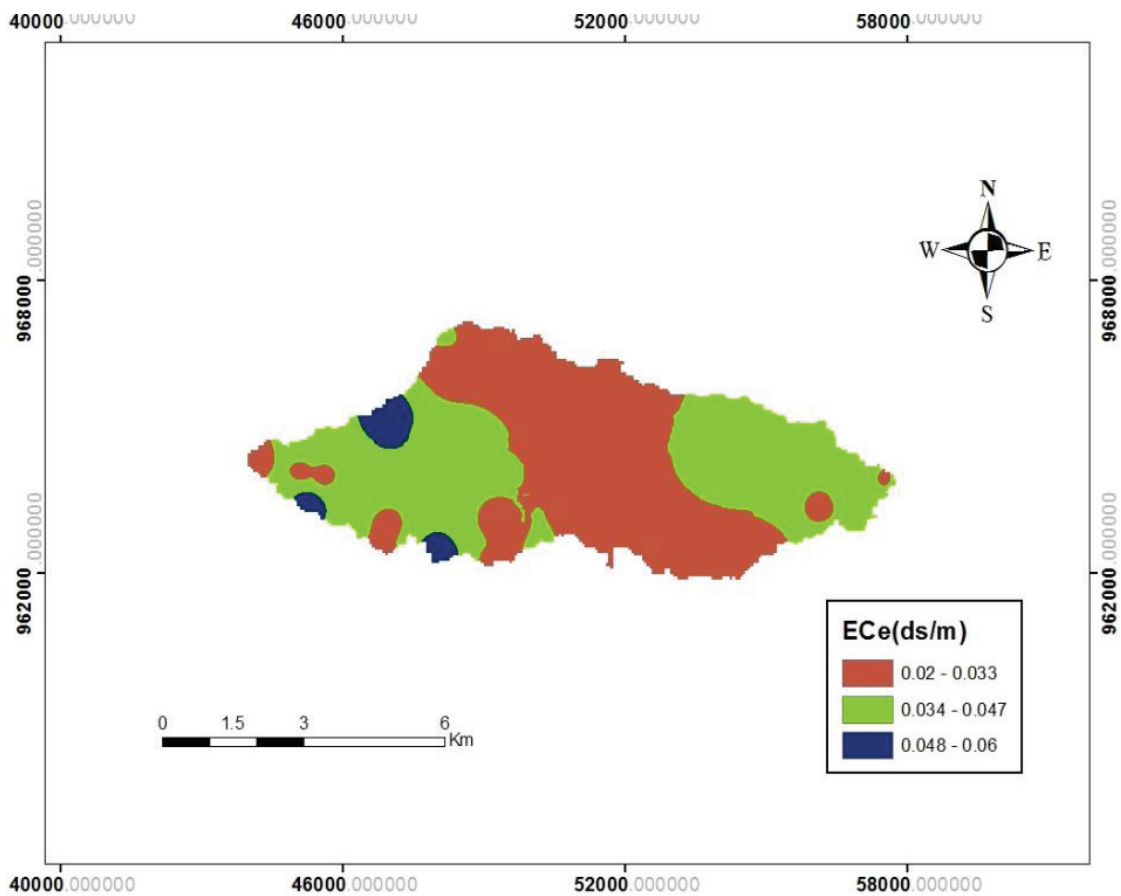


Figure 4: Spatial variability of soil ECe in Gudina Wacho Watershed.

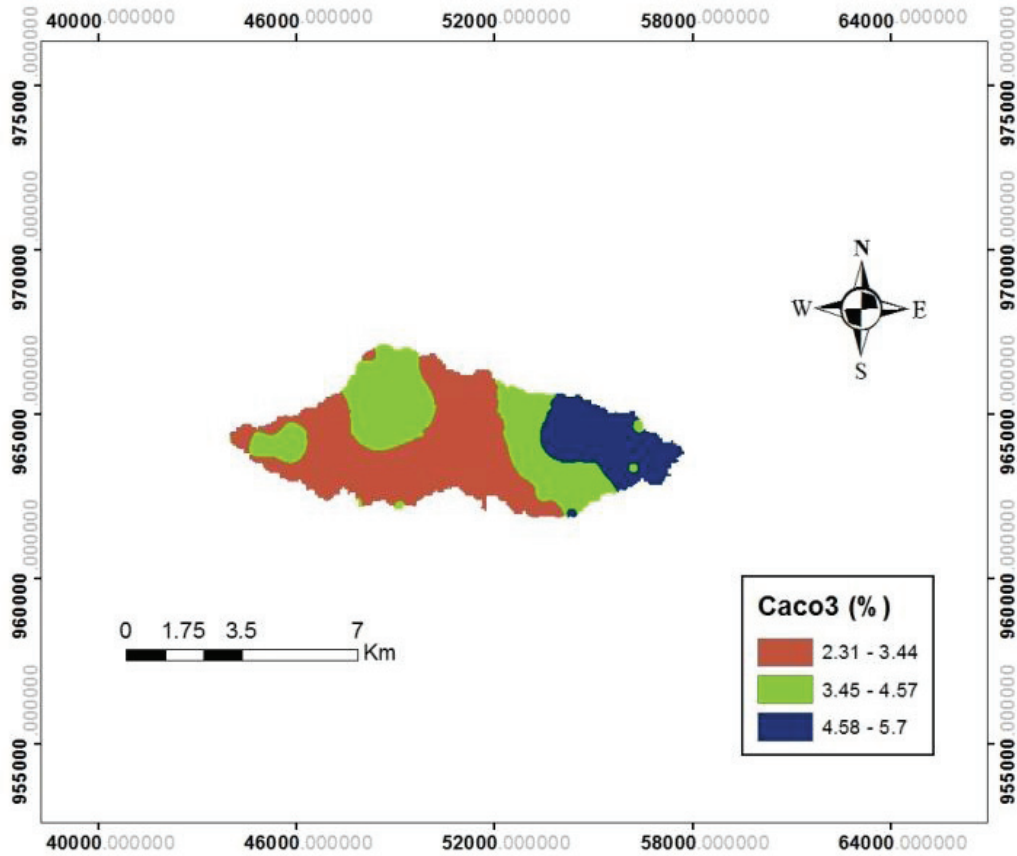


Figure 5: Spatial variability of soil CaCO₃ status in Gudina Wacho Watershed.

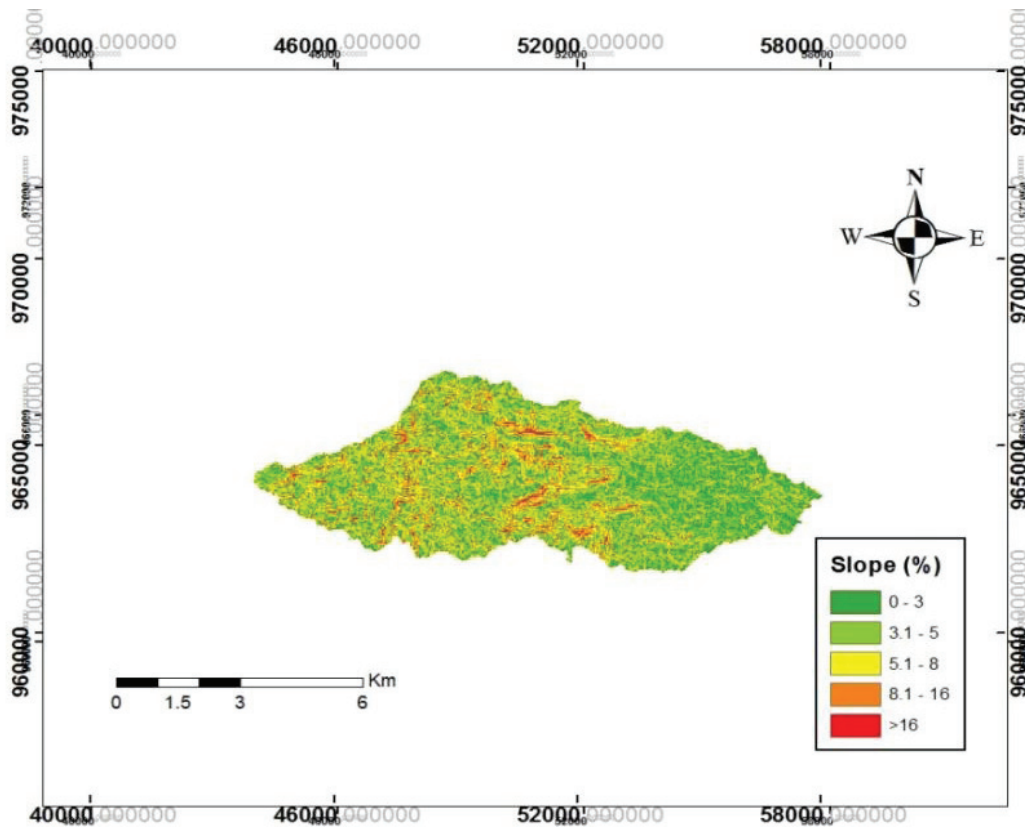


Figure 6: Slops in percent.

Conclusion and Recommendations

Conclusion

Sound information on watershed characteristics such as soils, slop and other land characteristics provide a basis for decision making on proper utilization and management of natural resources. The importance of land evaluation points to opportunities for influencing future developments of land resources in the region using management techniques that are tailored to the characteristics of the landscape elements. The result of the study depicted that large portion (72.6%) of

the study area was slightly suitable (S3) for surface irrigation purpose. The most important limiting factors in the area under study included land slope and physical properties of the soil, especially soil texture and soil drainage. While the soil chemical properties were highly suited for surface irrigation. Therefore, the area is potential for irrigation production with some limitations and under proper management it can benefit the local community to meet the food demand.

Recommendations

- ❖ In order to sustainably develop the area for irrigation development, the following points should be considered:
 - Land leveling operation or soil conservation work has to be incorporated to break surface slope and to make it suitable for surface irrigation.
 - Due to shallow water table depth and fine textured soil of the study area has poor drainage and workability problems under excessive moisture regimes. These soils could be made more suitable by adopting improved drainage system, soil and crop management practices.
 - In order to protect the flooding of lower catchment, watershed management activities including the construction of flood protection ditches is recommended.

Table 5: Slope class of Gudina Wacho watershed and rating for surface irrigation.

Land Unit	Area (ha)	Ratio (%)	Slope class (%)		Rating
				Definition	
1	908	21.5	3.1-5	Gentle	90
2	1016	24.1	3.1-5	Gentle	90
3	1154	27.4	5.1-8	moderately steep	80
4	1140	27	0-3	Flat	100

Table 6: Capability index and suitability class of the four land mapping units of Gudina Wacho watershed.

Land Unit	Area (ha)	Ratio (%)	Capability index (Ci)	Suitability Class	
				Symbol	Definition
1	908	21.5	46.8	S3	Slightly suitable
2	1016	24.1	46.8	S3	Slightly suitable
3	1154	27.4	41.6	N1	Currently not suitable
4	1140	27	52	S3	Slightly suitable

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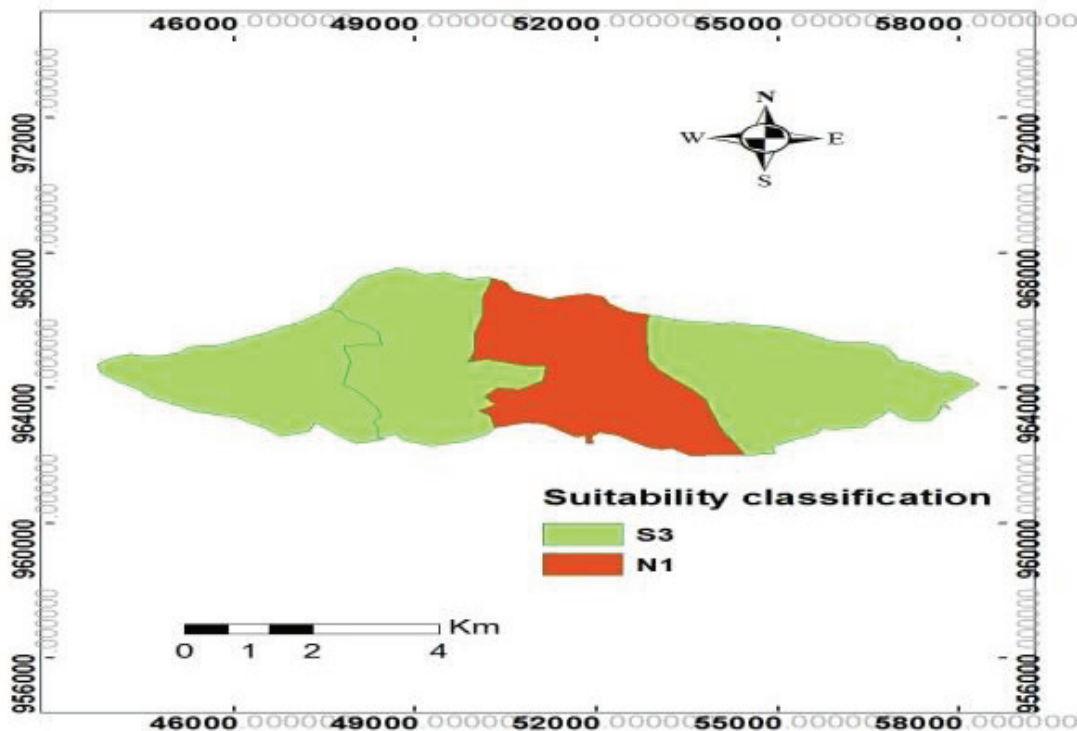


Figure 7: Suitability classification of Gudina Wacho watershed.



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