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Land suitability analysis for surface irrigation in Humbo woreda, wolaita zone, Southern Ethiopia

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Abstract
This study was initiated with the objective of analyzing land suitability for surface irrigation in Humbo woreda, Southern Ethiopia. For the suitability analysis of surface irrigation, soil type, slope, land cover, and distance from water supply were considered. The suitability factors data such as soil data was obtained from Ethio-soil, slope was derived from DEM-20 meter resolution, land use/cover was classified from satellite image of 2019 (Landsat 7 ETM+), and distance from the River was obtained from Ethio-River map. For each of the criteria suitability map was developed. Slope was classified as 0-2%, 2-5%, 5-8% and 8-15% as highly suitable, moderately, suitable, marginally suitable and not suitable respectively. LULC was classified by unsupervised classification. For the weighted over lay analysis as the most limiting factor slope was given (40%), land use and River proximity given equal weights (30%). The weighted overlay analysis gave irrigable area of 1.22% highly, 50.87% moderately, 45.77% marginally suitable for surface irrigation but 2.13% is not suitable. Thus, in Humbo woreda small area of the land is highly suitable however; more than half of the area is moderately suitable for surface irrigation. Thus, farmers and the government should invest in those suitable areas for surface irrigation.

Keywords
Surface irrigation, land suitability, suitability factors, GIS

Introduction

Background of the study

Land is a natural resource that can be used based on its capacity to meet human needs and ensure the sustainability of ecosystem. There is in appropriate land use which causes destruction of land resource and increase poverty and related social problems (FAO, 1995). In order to ensure food security, providing comprehensive, reliable and timely information on land suitability is very important for a country like Ethiopia with growing population who largely depend on rain fed and irrigated agriculture for their livelihoods (Gebremedihin et al., 2912).

Irrigation is the application of water to soil for the purpose of supplying the moisture essential for plant growth. It is thought of by government agencies as a panacea for subsistence farming. But it has remained quiet unprofitable and therefore unattractive especially

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in the developing nations of the world (Umweni and Ogunkunle, 2014).

Today, some 40% of all world food is obtained from irrigated agricultural lands. However, food production via irrigated agriculture does not correspond to the current rapid population growth (Bagherzadeh and Paymard, 2015). Only 4 per cent (6 million ha) of the sub-Saharan African total cultivated area is irrigated (Kadigi, 2012) cited in Teshome et al. (2013). In Ethiopia, the irrigation subsector accounts for only about 3% of the food crops production cited in Teshome et al. (2017).

According to Ministry of Water Resources (MoWR) irrigation development program document prepared for the year 2002-2016, the gross and net irrigation potentials of Ethiopia have been estimated to be 3.73 and 2.23million hectares respectively. The total area irrigated until 1991 was 176,015 ha, and this figure had increased to 197,250 ha in 1998. According to recent data compiled by MoWR from different master plan studies and regions, the area under irrigation in the country has increased to about 289,530 ha in 2007 livelihoods [Gebremedihin et al., 2012).

The hope of boosting agricultural output depends on the development of irrigation schemes in areas where rainfall is inadequacy and variability is a major environmental limiting factor. The irrigation represents an alteration of the natural conditions of the landscape by extracting water from an available source, adding water to fields where there was none or little before, and introducing man-made structures and features to extract, transfer and dispose of water (Vidya, 2013).

Land evaluation is an identification of parcel of land for various land uses (cropping, grazing, and irrigation) which are physically acceptable, environmentally friend and financially profitable (FAO, 1985); it supports the process of decision-making land to perform based on its potential (Teshome et al., 2013).

Many irrigation projects, especially in the developing tropical regions, are embarked upon without any land capability assessment, resulting in avoidable and undesirable ecological consequences (Umweniand and Ogunkunle, 2014).

Land suitability assessment is a valuable tool for land use planning in major countries of the world (Olaniyi el al., 2015).

The Ethiopian government has produced long-term overall economic development policy to achieve industrialization through robust agricultural development to achieve rapid and sustainable economic growth by improving the productivity of the agricultural sector. Ethiopian natural resources are the basis for development and economic growth; however, there were knowledge limitations about utilization and suitability of resources within farmers and other residents (Mathewos et al., 2018).

According to Seleshi (2010) Ethiopia has abundant rainfall and water resources, its agricultural system does not yet fully benefit from the technologies of water management and irrigation. In Ethiopia the potential irrigable land was 3.7 million hectares. But less than 5 percent (about 200,000 hectares) were under irrigation cited in Firehiwet et al., 2019).

Abrham and Azalu (2013) described that Ethiopia has immense potential in expanding irrigated agriculture. Despite its irrigation potential which is estimated to be about 3.7 million hectares, only about 190,000 hectare (5.3%) of the potential is currently under irrigation, which plays insignificant role in the country's agricultural production. Thus, to bring food security at national as well as household level, improvement and expansion of irrigated agriculture must be restored.

Humbo woreda is one of the moisture deficit areas in wolaita zone, southern Ethiopia. Food in security is a problem in the area. Farmers live by donors support and charcoal production which has negative implication to the environment. Similar to other parts of Ethiopia, the practice of irrigation is low in spites of the availability of potential land for irrigation. Besides there are many permanent rivers that drain to Lake Abaya but none of them have been utilized for surface irrigation. As a result agricultural production is limited to rain fall which is unreliable and erratic in nature. The land suitability for surface irrigation has not been studied.

Therefore, the objective of this study was to analyze the potential physical land suitability for surface irrigation in Humbo Woreda, wolaita zone, southern Ethiopia

Objective of the study

General objective. To analyze the potential physical land suitability for surface irrigation in Humbo Woreda,wolaita zone, southern Ethiopia.

Specific objectives. To develop soil suitability map for surface irrigation Humbo woreda - To make the slope of the land for surface irrigation in Humbo woreda - To classify land use/cover type of Humbo woreda - To prepare river proximity (distance from the river) map of the study area - To make land suitability map of slope, soil, land use and water source map of the study area - To identify suitable areas for surface irrigation based suitability factors analysis in Humbo woreda.

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Review of Related literature

Land use planning. According to the Food and Agriculture Organization (FAO, 1995) land use planning involves making decisions regarding the use of land resources with the primary aim of achieving the best use of land for maximum food production and profit. Land use planning is an iterative process based on the dialogue amongst all stakeholders aiming at the negotiation and decision for a sustainable form of land use in rural and urban areas as well as initiating and monitoring its implementation cited in Merga (2012).

Agricultural land suitability. Agriculture is the largest global consumer of water. In the world Irrigated areas constitute 40 % of the total area used for agricultural production (Jonas et al., 2017).The principle purpose of agriculture land suitability evaluation is to predict the potential and limitation of the land for crop production (Pan and Pan, 2012). Agricultural land suitability for irrigation assessment is defined as the process of land performance assessment when the land is used for alternative kinds of irrigations cited in Hoseini (2018). The principle purpose of the agricultural land suitability for irrigation evaluation is to predict the potential land and its limitation for kinds of irrigation methods Abdel Rahman MAE cited in Hoseini (2018).

Land Evaluation and Suitability Classification. FAO (1985) defined land evaluation as the process whereby the suitability of land for specific uses such as irrigated agriculture is assessed. Land suitability is the fitness of a given type of land for a defined use

As stated by FAO there are two land suitability orders represented by the symbols S(Suitable) and N (unsuitable). There are five classes (1, 2 and 3 for suitable and; 1 and 2 for unsuitable order) that express the degrees of suitability or unsuitability.

Land evaluation, thus, presents itself as a suitable technique for identifying the different land use options for purposes of decision-making at all levels of governance (Abushnaf, 2014). Land evaluation, using a scientific method, is essential to recognize the potential and limitation of a given land for specific use in terms of its suitability, and certifies its sustainable use. Land suitability assessment plays an important role in maintaining and developing land use on a spatial basis. It identifies the levels and geographical patterns of biophysical constraints and evaluates potential capacity of land and its sustainable use (Teshome et al., 2017).

Land Suitability Analysis. Land suitability analysis using a scientific procedure is essential to assess the potential and constraints of a given land parcel for agricultural purposes and suitability assessment is inherently a multi-criteria problem cited in [3] i.e., land suitability analysis is an evaluation/decision problem involving several factors. According to FAO methodology (FAO, 1976) cited in Jovzi et al. (2012) land suitability is strongly related to "land qualities". Land suitability analysis is a prerequisite to achieving optimum utilization of the available land resources (Gizachew, 2015).

Surface irrigation. The term "surface irrigation" refers to a broad class of irrigation methods in which water is distributed over the field by a free-surface, gravity flow. A flow is introduced at a high point or along a high edge of the field and allowed to cover the field by overland flow. he easiest water supplies to develop have been stream or river flows which required only a simple river dike and canal to provide water to adjacent lands. These low-lying soils were typically high in clay and silt content and had relatively small slopes. Surface irrigation systems are typically less efficient in applying water than either sprinkle or trickle systems. Since many are situated on lower lands with tighter soils, surface systems tend to be more affected by waterlogging and salinity problems (Wynn, 2003).

This is the most common method of irrigation and accounts for 95% of irrigation in the world. Surface irrigation is well suited for use on both small and large schemes. Basin, border and furrow are all surface irrigation methods. The choice between them depends on the crop, cultivation practices, soils, and topography and farmer preferences. Surface irrigation methods are often selected because they are considered to be simple methods well suited to farmers with little or no knowledge of irrigation. Surface furrow irrigation provides a mean for controlling and guiding water on steep, undulating and on very level land cited in Mahinga (2005).

Contribution of GIS for land suitability analysis. A GIS consists of various components, starting with the incorporation of geographical data from remote sensing sources or maps and then converted into a computer-readable form. Useful land suitability assessments can be based upon biophysical resource information. The strength of GIS lies in its ability to integrate different types of data into a common spatial platform. This information should present both opportunities and constraints for the decision maker (Ghafari et al., 2000).

Digital Elevation Model (DEM). Digital Elevation Models (DEMs) are a raster-geographic-digital-data-model developed by the US Geological Survey (USGS)

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(Gizachew, 2015). According to the United States' Geological Survey (USGS): "Digital elevation model" (DEM) data consist of a sampled array of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system. The grid cells are spaced at regular intervals along south to north profiles that are ordered from west to east (Gizachew, 2015).

Multi-Criteria Analysis (MCA)

Multi criteria analysis is one of the most important procedures for GIS-based decision making processes (Gizachew, 2015). MCA can be used to define the most suitable areas for irriagation. In MCA technique, generation of the suitability maps for given purpose is the very first step. The integration of multi-criteria analysis method with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis. GIS-based multi-criteria analysis can be thought of as a process that combines and transforms spatial and a spatial data (input) into a resultant decision (Gizachew, 2015).

Weighted overlay. Weighted overlay is a technique for applying a common measurement scale of values to diverse and dissimilar inputs to create an integrated analysis. Geographic problems often require the analysis of many different factors using GIS. For instance, finding optimal site for irrigation requires weighting of factors such as land cover, slope, soil and distance from water supply (Giap et al., 2003). To prioritize the influence of these factor values, weighted overlay analysis uses evaluation scale from least suitable factor to the most suitable factor. Weighted overlay only accepts integer rasters as input, such as a raster of land cover, soil types, slope, and Euclidean (the straight-line from the center of the source cell to the center of each of the surrounding cells) distance output to find suitable land for irrigation.

Land suitability for different irrigation systems. Different parameters of the field data can used to compare t he land s uitability for different irrigation systems. Soil evaluation for surface (gravity) and drip (localized or pressurized) irrigation systems have been used in different countries including Ethiopia. Physical and chemical factors of the land are the main parameters that determine irrigation potential of a given land. The attributes are physical and chemical soil factors as slope, soil depth, soil texture, soil drainage, soil fertility and soil salinity, Water resource factors as water availability, water quality and distance to water source (FAO, 1983). Study by (S.H. Abd El-Aziz, 2018) show that the drip irrigation system is more suitable for northwestern region of Libya than the surface irrigation one.

Surface Irrigation Land Suitability Factors. The suitability factors that affect surface irrigation were soil, slope, land use and water sources (Abebe, k. 2014).

The assessment of soils for irrigation involves using properties that are permanent in nature that cannot be changed or modified. Such properties include drainage, texture, depth, salinity, and alkalinity (Abebe, k. 2014). According to FAO (1983), Vertisols are characterized by their high clay content. They are often dark colored, Due to their semitite clay mineralogy, they are very hard and crack when dry, but becomes sticky and plastic (often impassible) when wet. These are chemically rich soils, but they may develop on an undulating micro relief, which hampers mechanization. Vertisols have great agricultural potential, but special management practices are required.

Slope is the incline or gradient of a surface and is commonly expressed as a percent. According to FAO standard guidelines for the evaluation of slope gradient, slopes which are less than 2%, are very suitable for surface irrigation. But slopes, which are greater than 8%, are not generally recommended (FAO, 1996). Land cover or land use is another suitability factors that affects surface irrigation. As the (Abebe, k (2014) defines land cover as the observed (bio) physical cover, as seen from the ground or through remote sensing, including vegetation (natural or planted) and human construction (buildings, roads, etc.) which cover the earth's surface. Water, ice, bare rock or sand surfaces also count as land cover. If water is in short supply during some part of the irrigation season, crop production will suffer, returns will decline and part of the scheme's investment will lay idle (FAO, 1996) water supply (water quantity and seasonality) is the important factor to evaluate the land suitability for irrigation according to the volume of water during the period of year which it is available (FAO, 1983).

Availability of water and is one of the most limiting factors. for implementation of irrigation systems. Water resources are estimated in accordance to three criteria: quantity, quality and location. Together they form water potential (Degnet ,S. 2013). Quantities of water required for irrigation are considerable and depend on water deficit, crops and size of the area. All three characteristics have to be met in order for water capture to satisfy long-term needs and if only one of

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them is not met, quantity, quality or accessibility of location such source of water becomes questionable. Usual sources of water for irrigation are rivers, ground water tables and reservoirs, and in the more recent times various non-conventional sources (Lidija,T. 2012).

Favorable conditions found in open water bodies for capturing of water for irrigation depend on their hydrological regime. Waterways with the glacial hydrologic regime are more suitable, since they have maximum flows during beginning of summer (June), while waterways with the pluvial regime have minimal flows during summer months in vegetation periods. It is important not to forget the global trends in the decrease of water quantities, increase of frequency and duration of low water regimes, which also cause droughts (Abebe, 2014).

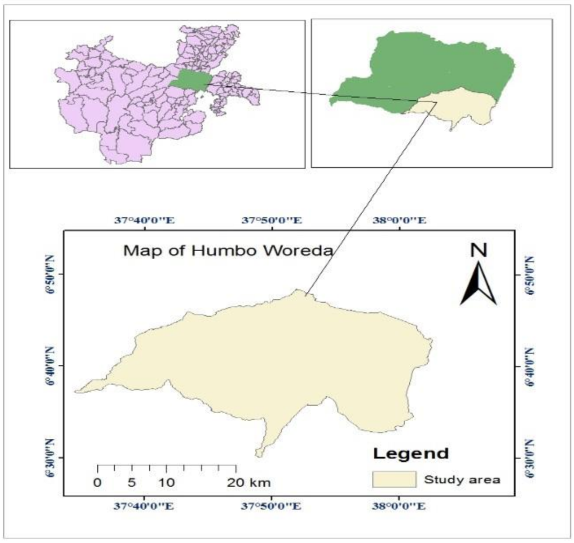

Figure 1. *Map of study area.*

Materials and methods

Description of study area

Humbo woreda is one of the woredas in wolaita zone in SNNPR located in the Great Rift Valley. It is bordered on the southeast by Lake Abaya which separates it from the Oromia Region, on the south by the Gamo Zone, on the west by Offa, on the northwest by Sodo Zuria, on the northeast by Damot Woyde, and on the east by the Bilate River which separates it from the Sidama Zone. It is located in 6° 39' 59.99" N latitude 37° 49' 59.99" E longitude. Based on the 2007 Census conducted by the CSA, Humbo woreda has a total population of 125,441, of whom 63,017 are men and 62,424 women; 6,247 or 4.98% of its population are urban dwellers. Besides, the woreda is located at an altitude of 1100-2335 meters above sea level. The woreda receives an average annual rainfall of 840-1400mm and the temperature ranges between 15^0_c to 29^0_c. The main crops grown in Humbo woreda are maize, sweet potato, teff and haricot beans, coffee, cotton and peas. The population of the Woreda is predominantly engaged in farming with a land holding size of 0.25 ha. The main stay of the population hence is subsistence agriculture.

The geologic formations of the Woreda belong to the Precambrian rock formation overlain by sedimentary rocks and volcanic ashes. The soils of the Woreda are mainly brownish red predominated by clay soil types.

Humbo Woreda lies within the 'kola' agro ecological zone and it has a maximum temperature of 32^0_c and a minimum of 27^0_c except at Bosa Wanchi village, where the maximum and minimum temperature are about 20^0_c and 25^0_c respectively. As result this village lies within the Woina Dega/Dega agro-ecological zone. The minimum and the maximum rainfall of this Woreda is about 200 mm and 600 mm respectively and rarely reaches 1200-1300 mm at Bosa Wanchi village (source, Humbo Woreda agriculture office and rural development, 2019).

Research methodology

Selection of Criteria. Different criteria were selected for evaluating land suitability for irrigation in the study area. These criteria were selected based on extensive literature review of potential factors affecting surface irrigation in the study area.

Data sources and collection. The most important data for this study were soil data extracted from Ethio-Soil, slope was derived from Ethio-DEM 20meter resolution, The Landsat 7 ETM 2019image was used to classify land use land cover of the study area. Data for river or water source was obtained from Ethio River.

Data Preparation for Spatial Analysis. Slope, soil, land use and water source data were aggregated to produce suitability map for surface irrigation in Humbo woreda.

Suitability Classification. This study used the four levels [highly suit- able (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N2) suitability classes commonly used by the Food and Agricultural Organization (FAO, 1976).

Method of data analysis

The soil suitability class's classifications were based on FAO class and soils of the study area were classified in ArcGIS10.2.The suitability classes of the soil type classification were based on the properties and their

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suitability for surface irrigation. Ethio-DEM 20meter resolution was used to derive slope map of the Humbo woreda. Then the slope map was reclassified to achieve the required slope status. The slope map was reclassified to suitability classes of surface irrigation. Landsat 7 ETM+ of 2019 image was used to prepare land use/ cover map of the study area through GIS software. In the process unsupervised classification was used for the researcher has no sufficient information about the area after necessary steps like preprocessing of image was done. After classifying land use land cover, suitability clasess were determined based on literature and basically FAO guideline

To measure the distance from river/river proximity/ to specific potential surface irrigation area Euclidian distance tool was used. The river flow data extracted from Ethio-River and the distances from identified Perennial River to a specific potential irrigation area were measured.

Weighted overlay analysis and multi criteria decision making. To identify potential surface irrigation area in Humbo woreda, a multi criteria decision making approach were used. The multiple criteria used for this analysis were soil, slope, land use, and river proximity/ distance from the River to the potential irrigable land. From the criteria, slope was given more weight than land use and river proximity for its most influence on surface irrigation based on literature. Soil was only analyzed qualitatively in separate way not included in the weighted overlay analysis.

The final step in the analysis was the use of the linear weighted overlay model. Here, the weights were assigned to the raster maps, each representing a criterion, and for each the weighted sum of all criteria values was calculated. The resulting score for each polygon represents its' productivity (relative to other) for the considered activity. The "Natural breaks" classification was used for the graphical presentation. Each of the three layers of maps was reclassified to decide suitability classes. The suitability class maps were added to weighted overlay tools. Finally areas suitable for the surface irrigation was identified

Generation of Criterion Maps. Based on the suitability criteria assigned, layer of the criteria were developed, an overlay analysis was done to generate one suitability map which have the attribute of all suitability factors such as slope, land use and distance from the river with their theme attribute table. An overlay analysis in GIS was operated operator (Degnenet, 2013) (Table1).

Table 1. *Land suitability classification.*

Code	Class	Description
S1	highly suitable	land having no significant limitation for agricultural productivity
S2	Moderately suitable	land having some limitations that are severe for sustained productivity
S3	Marginally suitable	land with major limitations for sustained agricultural productivity
N	Unsuitable	land with extreme limitations for sustained agricultural productivity

Results and Discussion

Irrigation land suitability map creation

For this irrigation suitability analysis four criteria have been used namely soil, slope, land use and River proximity/distance from the river.

Soil types suitability evaluation

According to FAO (1976) Nitisols are highly suitable for irrigation, Fluvisols are moderately suitable, Luvisols and Leptosols are marginally suitable and Histosols and Alisols are currently not suitable. However, in Humbo woreda the types of major soils identified include: chromic Luvisols, chromic vertisols, dystric cambisols, Eutric fluvisols, Eutric nitosols and Lithosols. Thus, in Humbo woreda chromic nitosols and cambisols with natural fertility and good drainage were classified as highly suitable (S_1), Eutric Fluvisols were moderately suitable, Chromic Luvisols were marginally suitable and vertisols and Lithosols were classified as not suitable for surface irrigation as indicated in Figure 2 below.

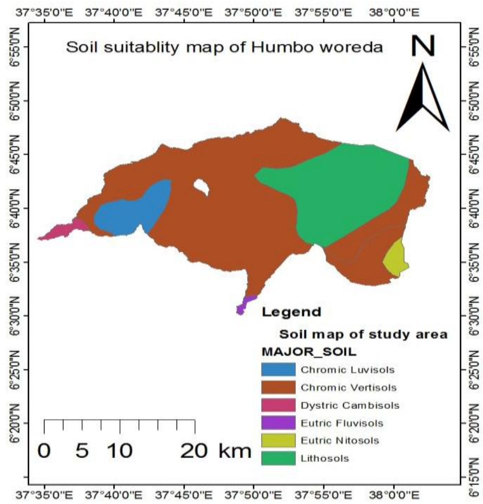

Figure 2. *Soil suitability map of Humbo woreda.*

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Slope suitability analysis of Humbo woreda

According to Nethononda (2014) slopes less than approximately 8% are in general, considered suitable for irrigation development. Slope has a strong effect on the cultivation of crops. As steepness increases, the use of machinery becomes limiting, and establishment and management costs increase as more erosion prevention measures become necessary (Wong, 1986). To do slope suitability analysis, DEM of Humbo woreda was derived from DEM 20meter resolution by Arc GIS 10.2 spatial analyst tool. The analysis tool produced the raster layer of continuous slope digital map. Then slope was generated by classifying it into four categories for surface irrigation (FAO, 1996) namely:0-2% is highly suitable(S1),2-5% is moderately suitable(S2),5-8% is marginally suitable(S3) and >8% is not suitable(N2). Therefore in Humbo woreda, the area with slope range 0-2% is classified as (S1)highly suitable 2-5% is moderately suitable(S2),5-8% is marginally suitable(S3) and 8-15% is classified as not suitable(N2) for surface irrigation (Table 2).

Table 2. *Suitability classes of slope.*

No	Slope range	Code	Suitability classes
1	0-2	S1	Highly suitable
2	2 -5%	S2	Moderately
3	5 - 8%	S3	Marginally suitable
4	8-15%	N2	Not suitable

As indicated in Figure3,S1(highly) suitable represents slope 0-2%,S2(moderately suitable), represents slope 2-5%,S3(marginally suitable) represents slope range 5-8% and N2(currently not suitable) represents slope range 8-15%.

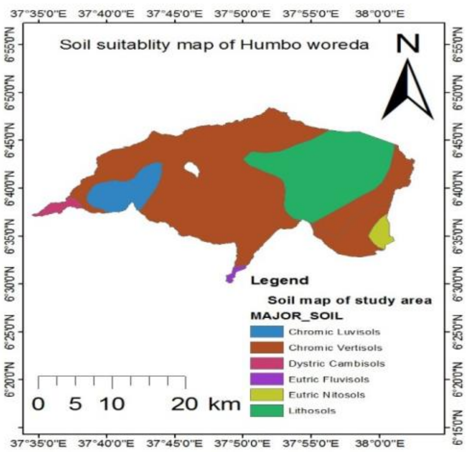

Figure 3. *Slope suitability map of Humbo woreda (Source: derived from DEM 20 M).*

Land Use Map of Humbo woreda

Landsat7 image of 2019 was used to classify land use of the study area. Land use and land cover influences irrigation practice to prepare the land for agriculture. Therefore it was taken as one input for the evaluation of land qualities for irrigation for the Humbo woreda. The type of land use/land cover in the study area includes forest land, scrub/ bush land, agriculture, water body and opens area. .

From satellite image of 2019 unsupervised classification, five LULC classes were identified namely, forestland, scrub/bush land, water body, agriculture and open area. As indicated in the Figure 4 above, the land use land cover classes of the study area ,agricultural land is classified as highly suitable(S1), open areas and shrub/bush land are moderately suitable(S2), forest land is marginally suitable (S3)and water body are not suitable(N2) for surface irrigation. The decision was made based on literature and the assumption that the agricultural lands can be used to irrigation without limitation and shrub/bush and open areas land can be used with less limitation. The forested area and water body were classified as marginally and not suitable for surface irrigation respectively. This is because of the forested area may be a choice when the cultivated and shrub/bush land no more exist in the study area (Table 3).

Table 3. *Area of LULC of Humbo woreda in unsupervised classification.*

Rowid	Value	Count	Area
0	1	998095	51.04043
1	2	122699	6.274562
2	3	302715	15.48019
3	4	13842	0.70785
4	5	385589	19.71819
5	6	132559	6.778781

As indicated in the table 4 above the forest occupies 6.27% scrub/bush land occupies 15.48%, water body occupies 0.7%, and agriculture occupies 19.72% and open area occupies 6.78% of the study area.

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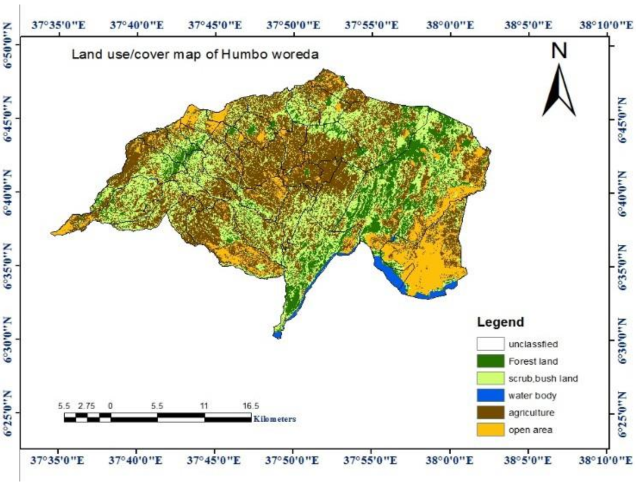

Figure 4. *Land use/cover map of Humbo woreda.*

River proximity/ Distance to the water/
Distance to water sources to be the variable most likely to influence the site location of surface irrigation (Firchiwot et al., 2019). Therefore, the map was made by creating a buffer area of a specified distance to water. The vector format of buffered stream polygon converted to raster format. The suitability class of river proximity/ distance from the river was categorized in distance of 1 kilometer, 3 kilometer, 4 kilometer and 5 kilometer with suitability range of highly suitable, moderately suitable, marginally suitable and not suitable respectively. In the study area there are permanent rivers such as Bisare River, Hamesa River,Zagre River, Jogere River, Ambe River,Seware River,Codo River, chore River etc. Thus as indicated in Figure 5 below, area found in 1 kilometer, 3 kilometer, 4 kilometer and 5 kilometer distance from each of these rivers were classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3), Not suitable (N2) respectively in the study area.

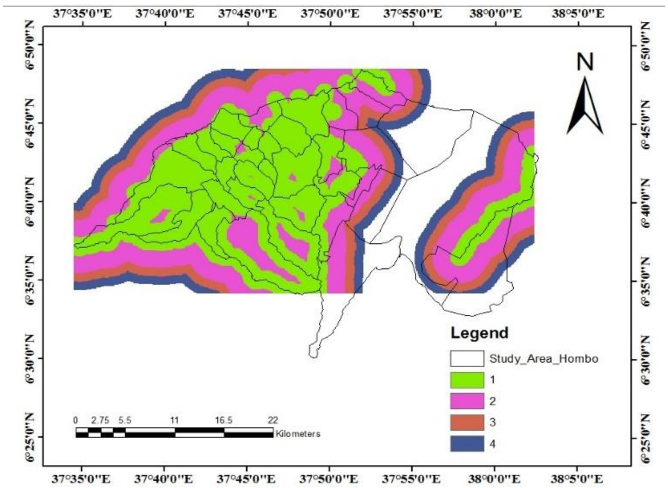

Figure 5. *River proximity (distance from the river/ map of the study area).*

Weighted Overlay

Weighted overlay table

Raster	% Influence	Field	Scale Value
Reclass_hriver	30	Value	
		1	1
		2	2
		3	3
		4	4
		NODATA	NODATA
Reclass_slop1	40	Value	
		1	1
		2	2
		3	3
		4	4
		NODATA	NODATA
Reclass_LULC	30	Value	
		0	1
		1	1
		2	2
		3	3
		4	4
		5	5

Sum of influence 100 Set Equal Influence

Evaluation scale 1 to 9 by 1 From To By

Table 4. *Weighted overlay classification table.*

Weighted overlay analysis
To identify potential surface irrigation area in Humbo *woreda*, a multi criteria decision making approach were used. The main physical land resources criteria were soil type, slope, land use /cover and rivers maps of Humbo *Woreda*. Then taking slope, land use and river proximity/ distance from the river, weighted overlay analysis was done in Arc GIS10.2 (Table 4).
As indicated in the table 5above slope was given more weight than river proximity and landuse/cover as the

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most limiting factor for surface irrigation based on the literature. Accordingly in the weighted overlay analysis slope was given 40%, River proximity was given, 30% and land use was given 30%. As indicated in the Figure 6, the suitability analysis model displayed that was used in weighted overlay process.

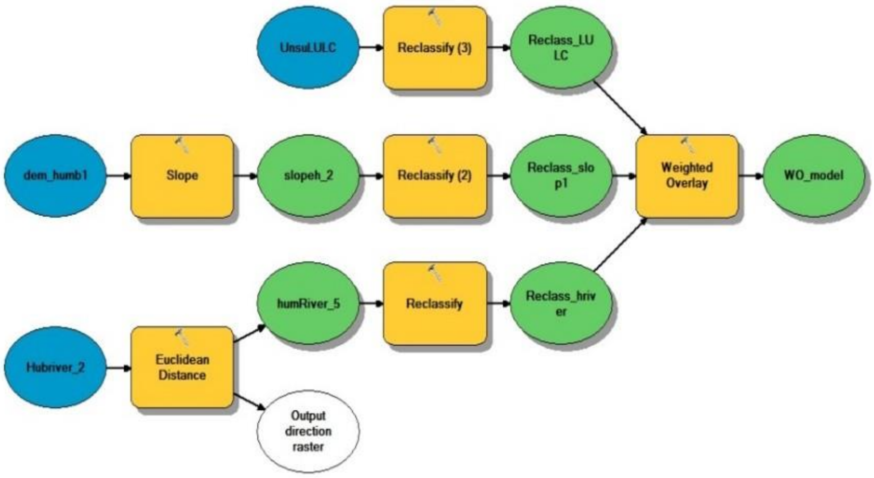

Figure 6. *Suitability Analysis model.*

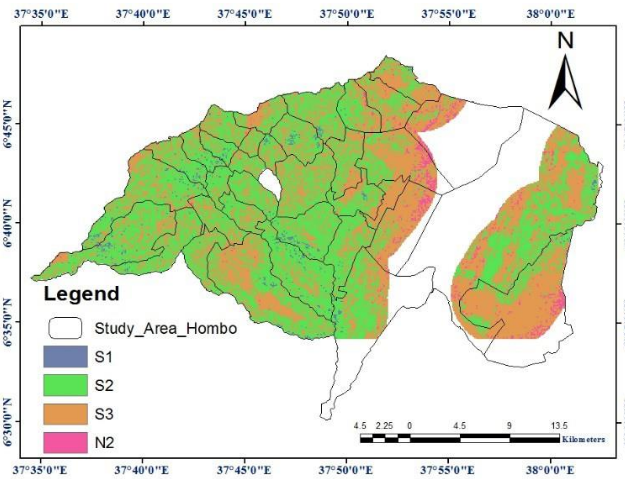

Figure 7. *Suitablity map of Study area.*

As indicated in Figure 7, the weighted overlay result shows thatS1, areas highly suitable, S2 areas moderately suitable, S3, areas marginally suitable, N2, areas permanently not suitable for surface irrigation in Humbo woreda (Table 5).

Table 5. *Suitable area for irrigation In Humbo woreda.*

Rowid	Value	Count	Area
0	1	756	1.224688
1	2	31406	50.8764
2	3	28254	45.77029

As displayed in the figure 7 above, 1.22% of the study area is highly suitable, 50.87% of the area is moderately suitable, 45.77% of the area is marginally suitable and 2.13% of the area is not suitable for surface irrigation in Humbo woreda. Based on this it is possible to conclude that only small area of the woreda is highly suitable whereas more than half of the study area is moderately suitable for surface irrigation.

Conclusions

In Ethiopia there are potential lands for irrigation to maximize the productivity of land so as to increase food security of the ever growing population of the country. However, irrigation practice is at lowest level in the country. There has not been evaluation of land for its potential for irrigation so that irrigation practice is not in a position to supplement or to replace rain fed agriculture in which there is uncertainty of the pattern and distribution of rainfall due to changing climate. Therefore in this research land suitability analysis for surface irrigation was made in wolaita zone, Humbo woreda using the available data taking soil, slope, landuse land cover and river proximity as suitability factors. .Based on the analysis, in Humbo woreda the types of major soils identified include: chromic Luvisols, chromic vertisols, dystric cambisols, Eutric fluvisols, Eutric nitosols and Lithosols. According to [1] nitosols are highly suitable for irrigation, Fluvisols are moderately suitable, Luvisols are marginally suitable.

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Thus, in Humbo woreda chromic nitosols and cambisols with natural fertility and good drainage were classified as highly suitable (S_1), Eutric Fluvisols were moderately suitable, Chromic Luvisols were marginally suitable and vertisols and Lithosols were classified as not suitable for surface irrigation In the study area, the area with low slope is highly suitable for surface irrigation whereas the area with highest slope which is cliff is not suitable for surface irrigation.

In Humbo woreda, the area with slope range 0-2% is classified as (S1) highly suitable 2-5% is moderately suitable (S2), 5-8% is marginally suitable (S3) and 8-15% is classified as not suitable (N2) for surface irrigation.

From the land cover/ use classes of the study area agricultural land was classified as highly suitable(S1) open areas and shrub/bush land were moderately suitable(S2), forest land was marginally suitable (S3) and water body was not suitable(N2) for surface irrigation.

Based on literature from the suitability factors such as, slope, land cover land use and river proximity, slope was given more weight for weight overlay analysis than river proximity and land use and cover and based on this in Humbo woreda, 1.22% of the area was highly suitable, 50.87% of the area was moderately suitable, 45.77% of the area was marginally suitable and 2.13% of the area was not suitable for surface irrigation in Humbo woreda. The finding of the study indicates that only small area of the woreda is highly suitable whereas more than half of the study area is moderately suitable for surface irrigation and also small area is not suitable that is water body. Therefore, the woreda has potential for surface irrigation according to the analysis made based on soil, slope, land cover, and distance from the river.

Recommendation

In order to identify the potential areas for surface irrigation soils, slope, land use and water sources were used as criteria and based on all these suitability factors areas suitable for surface irrigation were identified. Based on the finding the following recommendations were given

1. The farmers in low laying areas in vicinity to different permanent rivers can practice surface irrigation and maximize their agricultural productivity
2. Surface irrigation is a simple method of irrigation so that it can be practiced at small scale or large scale so that government agents can help farmers to use it on their small plots of land in Humbo woreda
3. This research is based on mainly the secondary data of soil particularly from Ethiop-soil compatible for GIS among others so that further research can be under taken by taking composite samples of soil from the field and analysis in the laboratory besides taking most recent data about the study area
4. The government should encourage farmers to invest in those highly and moderately suitable areas for surface irrigation.

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