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Research Article

GIS and AHP-Based Assessment of Land Suitability and Water Availability for Surface Irrigation in Beles Sub-Basin, Ethiopia

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Abstract

Assessing available water resources and identifying suitable land for irrigation at the basin level are crucial for effective planning and decision-making in irrigation development projects. Therefore, this study aims to utilize the Geographic Information System (GIS) and the Analytic Hierarchy Process (AHP) technique to evaluate surface irrigation suitability and surface water availability in the Beles Basin. We analyzed surface water availability by constructing a flow duration curve (FDC) and assessing the 90% available flow of the Beles River. Meanwhile, land surface suitability was determined through a GIS-based multi-criteria evaluation (MCE). This method integrates various factors, including slope, proximity to rivers, soil characteristics (type, texture, depth, drainage), proximity to roads, and land use and land cover. These factors were weighted using pair-wise comparison matrices to determine their relative importance in assessing physical land suitability. The results revealed that approximately 13.84%, 73.05%, and 13.11% of the catchment area were highly, moderately, and marginally suitable for irrigation, respectively. Regarding water availability, the FDC analysis indicated that the Beles River maintains a 90% available flow of 1.6 m^3/s throughout the year. Consequently, in December, the river can only irrigate 0.25% of the total irrigable land, whereas from May to September, it can irrigate the entire irrigable area. The river's low flow presents opportunities for extensive irrigation during the wet season but limits irrigation during the dry season. Therefore, the implementation of water storage structures is imperative to facilitate irrigation across the entire potential land during periods of low flow.

Keywords

Beles, GIS, Irrigation, Land Suitability, MCE, AHP

1. Introduction

Ethiopia depends on rain-fed agriculture with limited use of irrigation for agricultural production. It is estimated that more than 90% of the food supply in the country comes from low-productivity rain-fed smallholder agriculture, and hence rainfall is the single most important determinant of food supply and the country's economy [1]. The major problem asso-

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ciated with rainfall-dependent agriculture in the country is the high degree of rainfall variability and unreliability. Due to this variability, crop failures due to dry spells and droughts are frequent. As a consequence, food insecurity often turns into famine with the slightest adverse climatic incident, particularly affecting the livelihoods of the rural poor.

With declining productivity in rain-fed agriculture and the need to double food production over the next two decades, water has been recognized as the most important factor in the transformation of low-productive rain-fed agriculture into the most effective and efficient irrigated agriculture [2]. It is obvious that the utilization of water resources in irrigated agriculture provides supplementary and full-season irrigation to overcome the effects of rainfall variability and unreliability. Hence, the solution for food insecurity could be provided by irrigation development that can lead to security by reducing variation in harvest as well as intensifying cropping by producing more than one crop per year.

In this regard, sustainable food production that can be expected through the optimal development of water resources in conjunction with the development of land depends on the method of irrigation considered [3]. These methods, however, can be broadly classified into three categories: surface (basin, border, and furrows), sprinkler, and drip/micro irrigation methods. Surface irrigation is the application of water by gravity flow to the surface of the field; either the entire field is flooded (basin irrigation) or the water is fed into a small channel (furrow) or strip of land (borders). It is the oldest and still the most widely used method of water application to agricultural lands.

With an adequate database, Geographic Information Systems (GIS) can serve as a powerful analytic and decision-making tool for irrigation development [4]. The large area extent of GIS, as well as its ability to collect, store, and manipulate various types of data in a unique spatial database, helps perform various kinds of analysis and, thus, extract information about spatially distributed phenomena. In this kind of situation, the factors that are involved in irrigation potential assessment, such as soil, land cover or use, land slope, and distance between water supply and a suitable command area, should be weighted and evaluated by the use of GIS according to their suitability for irrigation.

Irrigation development could improve agricultural productivity and enhance socio-economic development through the growth of production [5]. But in most of Ethiopia, particularly in the study area, the exploitation of their water resources for irrigated agriculture is low. The efforts to establish small-scale irrigation schemes in the watershed are constrained by a number of uncertainties. Firstly, stream flows from some of the rivers are not known.

Secondly, potential irrigable areas in the basin have not been identified and matched with the water requirements of some crops commonly grown in the basin.

2. Materials and Methods

2.1. Description of the Study Area

The Beles sub-basin, situated in the northwestern region of Ethiopia within the Benshangul Gumz area, lies approximately 560 km from Addis Ababa. Geographically, it spans between latitudes 10°05'N and 11°47'N and longitudes 35°07'E and 37°00'E. Positioned within the Abbay (Upper Blue Nile) basin, the study area encompasses approximately 14,204 square kilometers. (Figure 1)

In terms of transportation infrastructure within the study area, accessibility is facilitated primarily by a main road linking Addis Ababa to the northwestern region of the country. This road serves as a crucial artery, connecting various towns, including Mandura, Mambuk, Chagni, and Pawe. Notably, all roads within the area are designed as all-weather roads, facilitating connectivity between different weredas (districts).

1. Climate

The rainfall over the study area is mainly received from June to September. Some of the rainfall is also available during October to half of November. However, this rainfall is not that much important to crop production. During this period (Oct to Nov) supplementary irrigation is required to protect crop from failure. Complimentary irrigation is followed from January to May.

2. Topography

On the southern part of the study watershed there has low elevation land which is sloped towards the river feature. Also on the northern part the watershed there is complicated land with higher and lower slopes. There is somehow gently sloping topography at the mid part of the watershed towards Beles River. Generally, the elevation of the land varies from 2719 m to 513 m above sea level (Figure 2).

3. Types of Data and Materials

The materials and data use to assess the irrigation potential of this study area:

a) Data: Soil Map and Land use land Cover map, Stream flow data, Meteorological data, DEM (Digital Elevation Model), Meteorological data, stream flow data, Road data, river data.
b) Tools: ArcGIS 10.8, CROPWAT 8.0 and Excel sheet, USGS Earth Explorer.

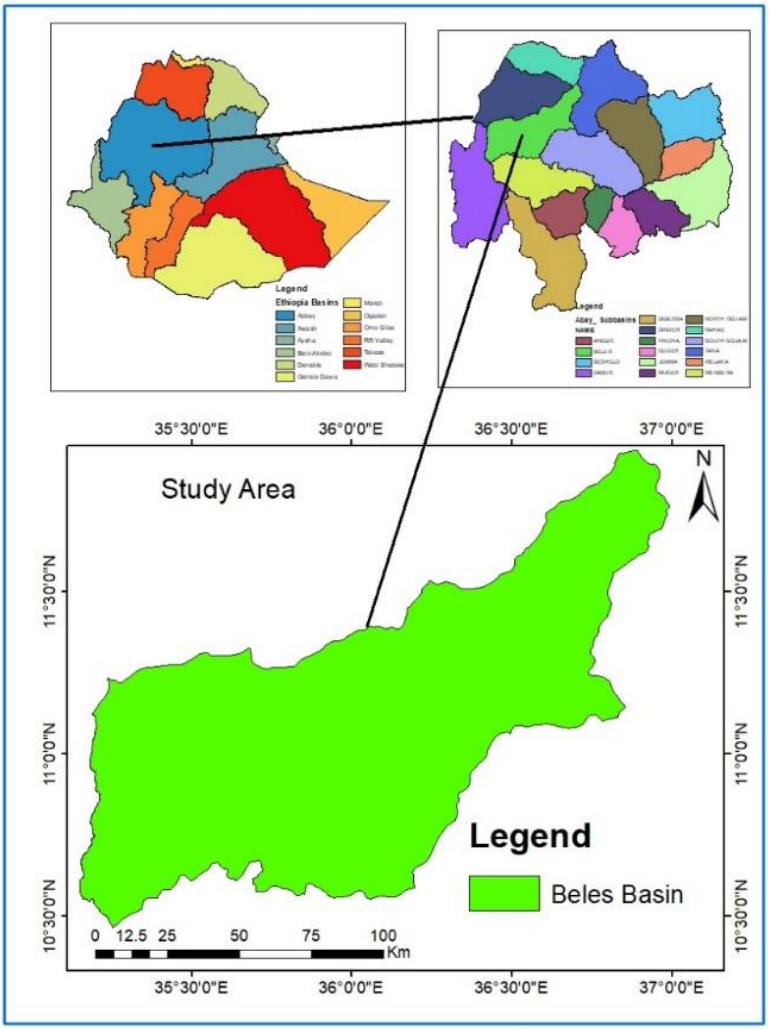

Figure 1. Map of the study area.

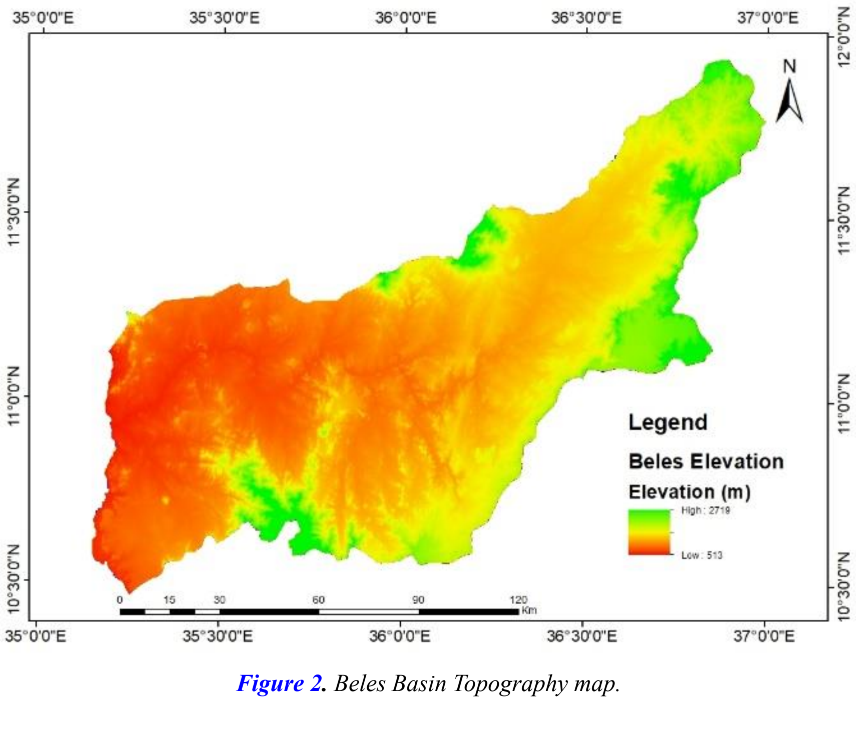

Figure 2. Beles Basin Topography map.

2.2. Sources of Data

1. Soil Map and Land use land Cover map:

Digital soil maps and land use map (shape file) will be obtained from Ministry of Water Irrigation and Electricity used to generate suitability map.

2. Stream flow data:

The daily stream flow data for the Main beles River was obtained from Ministry of Water Irrigation and Electricity. Maximum, minimum and annual average river discharge estimated to determine the surface water potential for irrigation.

3. Meteorological data

The meteorological data, including rainfall, temperature, relative humidity, wind speed and sunshine duration of the study area were collected from the Ethiopian national meteorological agency.

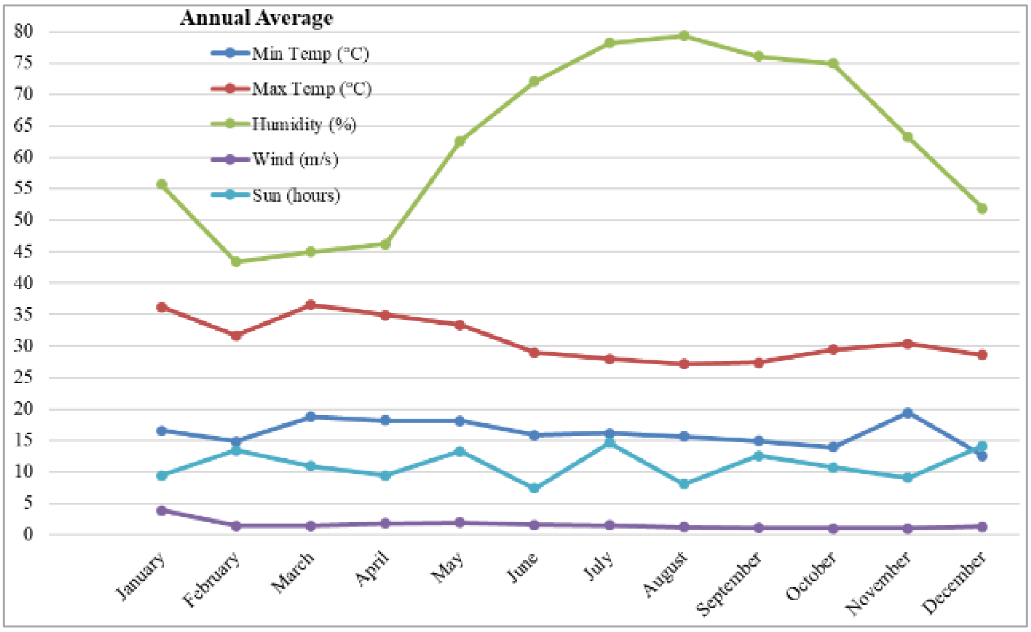

Figure 3. Beles meteorological (climate) value.

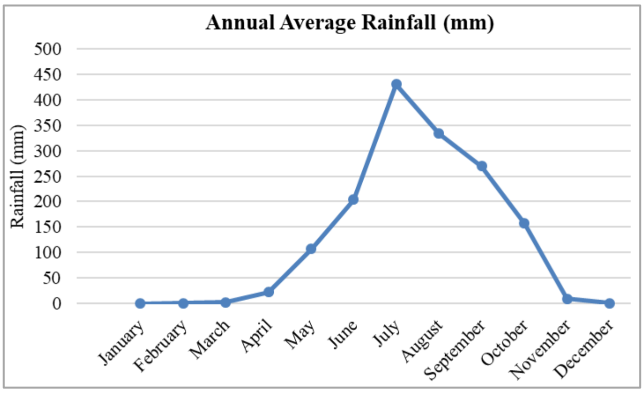

Figure 4. Beles rainfall data.

4. DEM (Digital Elevation Model):

DEM data are obtained from ILRI GIS database and used as input data in ArcGIS to delineate watersheds and to derive slope maps of the study area for irrigation suitability analysis.

5. Crop data

cropping pattern consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area) are the main component to calculate the irrigation water demand in combination with the climate data. The cropping pattern data will be obtained from ANRS (Amhara National Regional State) biro of Agriculture, and other sectors which are closed to the study areas. The crops that will cultivate in the study area include: pulse, fruits, and vegetables.

2.3. Methodology

Identification of Potential Irrigable Sites:

Potentially suitable sites for the irrigation agricultures are identify by considering the slope, soil, land use/cover and distance from water supply as a factor. Suitability of each factors are analyzing separately and final suitability is obtained by weighting all the suitability parameters together on the suitability model to get potential irrigable sites using pair-wise comparison method. The procedure is discussed in detail as follows.

To find suitable land for irrigation using surface and groundwater sources, the individual suitability factors were considered for irrigation land suitability evaluation. From selected multiple criteria, eight factors were selected as common for surface water, those were four soil characteristics, land cover, slope, river distance and road networks. To evaluate the suitability of the study area for surface irrigation using a surface water source, eight-factor were considered including river networks additionally from common factor. The factors listed above were prepared for weighted overlay with GIS Arc Map 10.8.

1. Approaches Used to Develop Suitability Map:

Multi-criteria decision evaluation (MCE) method in GIS environment is the best technique to evaluate different factors for a specific objective. It is concerned with how to combine the information from several criteria to form a single index of evaluation. Weighted Linear Combination (WLC) is most common technique used to create suitability map. Weight is used to develop a set of relative weights for a group of factors in a multi-criteria evaluation. The weights are developed by providing a series of pair wise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. In pair-wise comparison [1, 2], each factor was matched head-to-head (one-to-one) with each other, and a pairwise or comparison matrix was prepared to express the relative importance. A scale of importance is broken down from a value of 1 to 9. The highest value 9 corresponds to absolute importance, and the reciprocal of all scaled ratios is entered in the transpose position (1/9 shows an absolute triviality).

These pair wise comparisons are then analyzed to produce a set of weights that sum to 1. The factors and their resulting weights can be used as input for the MCE module for weighted linear combination. The procedure by which the weights are produced follows the logic developed by the Analytical Hierarchy Process (AHP) with a weighted linear combination; applying a weight to each followed by a summation of the results to yield a suitability map, i. e., combines factors [3].

2. Analytical Hierarchy Process (AHP):

After irrigation suitability of each parameter was assessed and the suitability map layer of each criterion were developed separately, an overlay analysis was done to generate one suitability map using "model builder" in Arc tools box and tools from spatial analysis tool sets.

Assessment of potentially irrigable land was done using the Multi-Criteria Evaluation (MCE) technique. MCE is a set of procedures designed to facilitate decision-making. The MCE technique identifies the potential suitable land by considering multiple factors affecting the suitability of a certain land area for irrigation. In MCE, these factors are mapped, weighted to determine their relative impact, and then combined to develop a single indexed output. MCE has been applied to land suitability analysis for irrigation [4]. The weights of the factor that were used in suitability evaluation were developed by providing a series of pair-wise comparisons of the relative importance of factors to the suitability. Saaty [5] developed the logic that used to develop weights under the Analytical Hierarchy Process (AHP). AHP was worked out by applying a weight to each parameter [6]. The AHP processes used in these studies could be a pairwise comparison, calculation of weight, and weight overlay analysis. In pair-wise comparison, each factor was matched head-to-head (one-to-one) with each other, and a pairwise or comparison matrix was prepared to express the relative importance. The average of expert opinions was used for comparison of factors one-to-one. A scale of importance would divide from a value of 1 to 9 (Table 1). The highest value 9 corresponds to absolute importance and the reciprocal of all scaled ratios were entered in the transpose position (1/9) and shows an absolute triviality.

The AHP is a mathematical method that may be applied to resolve highly complex decision-making problems involving multiple scenarios, criteria, and factors [2]. The AHP is a powerful and flexible decision-making process to help people set priorities and make the best decision when both quantitative and qualitative aspects of decisions need to be considered [7]. In Saaty, [8] technique, weights of this nature can be derived by taking the principal eigenvector of a square reciprocal matrix of pair wise comparisons between the criteria. The comparisons concern the relative importance of the criteria involved in determining suitability for the stated objective. Ratings are provided on a 9-point continuous scale.

Table 1. *Suitability classes [1].*

Class	Name	Land description
S1	Highly suitable	Land without significant limit, this land is the best possible and does not reduce productivity or required increased inputs.
S2	Moderately suitable	Land that is clearly suitable but has a limitation that either reduces productivity or requires an increase of inputs to sustain productivity compared with those need on S1 land.
S3	Marginally suitable	Land with limitations so severe that benefits are reduced and/or the input required to sustain production needs to be increased so that this cost is only marginally justified.
N	Not suitable	land having limitations that appear as severe as to preclude any possibilities of successful sustained use of the land of a given land use

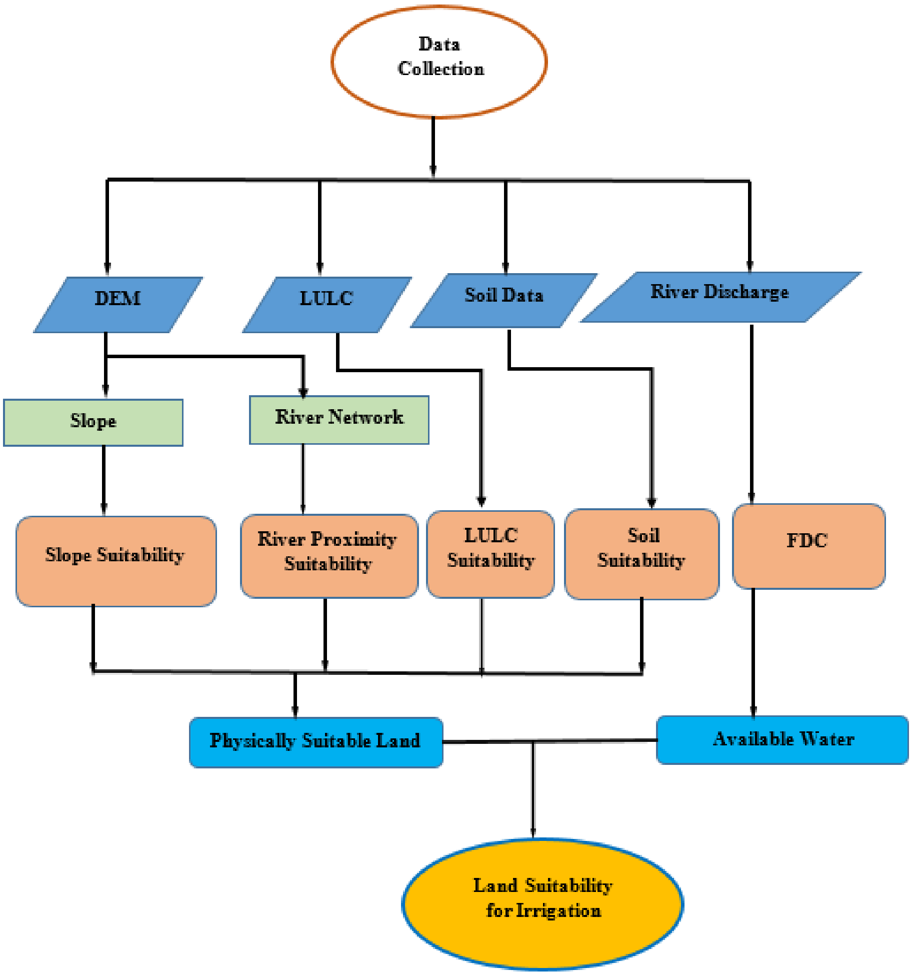

Figure 1. *Flow chart of the research.*

Table 2. *Pair-wise comparison scale and definition [5].*

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	somewhat more important	Experience and judgment slightly favorable one over the other
5	Much more important	Experience and judgment strongly favor one over the other
7	Very much more important	Experience and judgment are strongly favored one over the other, its importance is demonstrated in practice
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity
2, 4, 6, 8	Intermediate values	When compromise is needed

3. Standardizing the Factors:

Factors, which were selected to evaluate the physical land capability of the Beles basin, were soil depth, soil drainage, soil texture, slope, distance from water supply and land use land cover. In order to evaluate the factors for the selection of the physical land for suitability, the factors were standardized based on requirements of surface (gravity) irrigation.

Since the matrix is symmetrical, only the lower triangular half actually needs to be filled in. The remaining cells are then simply the reciprocals of the lower triangular half. In developing the weights, an individual or group compares every possible pairing and enters the ratings into a pair wise comparison matrix. The comparison is based on [9]. Since the complete pair wise comparison matrix contains multiple paths by which the relative importance of criteria can be assessed, it is also possible to determine the degree of consistency that has been used in developing the ratings. Saaty [8] indicates the procedure by which an index of consistency, known as a Consistency Ratio, can be produced.

$$CR = \frac{CI}{RI} \quad (1)$$

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

Where CI= consistency index
λmax = is the largest or principal eigenvalue of the matrix
n = number of elements being compared in the matrix
RI= random index (read from below table).

Table 3. Random index table (Saaty, 1980).

Matrices	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	1.46	1.49

The Consistency Index Ratio (CIR) indicates the probability that the matrix ratings are randomly generated. Saaty indicates that matrices with CIR ratings greater than 0.10 should be re-evaluated. In addition to the overall consistency ratio, it is also possible to analyze the matrix to determine where the inconsistencies arise. After the pair wise comparison matrices are filled, the weight module is used to identify consistency ratio and develop the best-fit weights. Once the criteria maps (factors and constraints) was developed, an evaluation (or aggregation) stage is undertaken to combine the information from the various factors and constraints. The weighted linear combination (WLC) aggregation method multiplies each standardized factor map (i. e., each raster cell within each map) by its factor weight and then sums the results [9]. By using below equation:

$$Su = \sum WjXi \quad (3)$$

$$Su = Wj * S + Wj * SuD + Wj * SD + Wj * T + Wj * LULC + Wj * DS + Wj * RP + Wj * ST \quad (4)$$

Where

Su= suitability of irrigation area, S= Slope, D = Soil drainage, SD = Soil depth, T= Soil texture, RP=Road Proximity, ST= soil type and Wj = weight value of a factor, LULC= Land use land cover, DS= Distance from water supply.

4. Computing irrigation water requirements:

To estimate irrigation water requirements of some selected crops in the potential irrigable sites, definition of area of influence of the climatic stations using Arc GIS inside and around the watershed are performed. To obtain a spatial coverage of climate data over the study area, each station is assigned to an area of influence using the Thiessen polygons method [10]. This method assigns an area of 'nearest vicinity' to each climate station gives an indication of the density of the stations over the study area.

Irrigation water requirement of the potentially irrigate able site (command area) computed by using the CROPWAT software. Meteorological data such as temperature (maximum and minimum), rainfall, wind speed, sunshine hours and relative humidity are used as data input in CROPWAT software. In addition to climate data inputs crop data commonly grown from the study area Such as banana, and onion are selected to estimate the water demand on monthly basis (cropping pattern consisting of the planting date, crop coefficient data files (including Kc values, stage days, root depth, depletion fraction) and the area planted (0-100% of the total area)) and soil data are used to compute crop water requirements. Then the gross irrigation water requirements of the crops at the identified potential irrigable sites are estimated by considering application efficiency for surface irrigation and water conveyance efficiency. Formulas use by CROPWAT software to calculate irrigation water requirement.

After evaluation of the suitability of the land for surface irrigation, it is very necessary to evaluate the water potential for crops produced in the study area. Therefore, the study aimed at to evaluate suitable land and water resources by considering major crops in the study area. The baseline to select types of crops, which are grown in the study area were types of crops, which are widely grown in the area and used by many farmers as commercial crops. According to [1] Sorghum, wheat and maize are major crops grown in the basin and were selected in order to evaluate the potential of water resources in the study area. Maize is widely grown in the study area. The farmers use rain water and sometimes use irrigation water to grow maize. Wheat is a crop majorly grown by irrigation in the basin. The evapotranspiration (ETc) for the dominant crop was calculated using CROPWAT 8.0 with climatic data for the area grown from the Ethiopian National metrological Agency weather station. The crop water requirement of the crop is calculated by multiplying the crop coefficient by evapotranspiration. The crop coefficients for the initial, mid, and late seasons and growing periods were extracted from the FAO - 56 manual [11]. According to this manual, most of the cereal crops have a close crop coefficient of 0.3, 1.15, and 0.4 for initial, mid, and late growing seasons, respectively. The growing period of the irrigated crops ranges between 130 and 140 days. The rain-fed crops which are planted in the summer season (Meher) are harvested between September and December [12]. Irrigated crops were planted in the dry season from December to April. Irrigation water requirement (IWR) was calculated, considering the effective precipitation (Peff). Net irrigation requirement is the difference between crop water requirement and effective rain fall. The crop water requirement depends on the prevailing climate condition, crop type, stage of crop growth, and soil properties. CROPWAT 8.0 software was used for analyzing the ETo and ETc of the selected crop in the study area. Root depth, depletion level and other agronomic parameters were obtained from FAO guidelines. Generally, the crop water requirement (CWR) was calculated as a product of the potential evapotranspiration (ETo) and the crop coefficient (Kc).

$$CWR\ (ETc) = ETo * Kc \tag{5}$$

$$IWR = ETc - Peff \tag{6}$$

The total crop water requirement or gross water requirement will compute with a 60% irrigation inefficiency of water application and water requirement for special needs such as land preparation and leaching [13, 14].

$$NIR = 1.6 * Kc * ETo - Peff \tag{7}$$

5. Estimating surface water resources potential of river watershed:

The hydrological data for watershed is obtained from Ministry of water resources, energy and electricity. Maximum, minimum and annual average magnitudes of river discharge and runoff from the watershed are estimated. This is helpful in determination of potential irrigation capacity of surface water.

6. Estimating irrigation potential:

Irrigation potential of the areas are obtained by comparing monthly gross irrigation requirements of identifying land suitable for surface irrigation and the available mean monthly dependable flows in the river watershed.

3. Result and Discussion

3.1. Factors Determining Surface Irrigation Potential

Physical and chemical factors of the land as well as climate are the major factors that determine irrigation potential of a given land [15]. However, the factors, which were evaluated to analyze suitability of the land for surface irrigation under the study area, are only physical land factors (slope, soil depth, soil texture, and soil drainage and soil type), water resource and climate. Water and climate differ from the others in that they are usually uniform throughout the specific area to be investigated. However, there is a small difference between places in temperature and rainfall. All these are factors which help to evaluate the physical land capability of the study area.

3.1.1. Slope Suitability

As it was mentioned earlier, slope gradient has great impact on work efficiency, erosion control practices and crop adaptability. First Rating factors were given for each slope gradient of the study area based on literature review and FAO guidelines (Table 4). Using this rating the basin was reclassified in to four classes according to its land qualities and characteristics of the slope for the selection of the land for suitability of surface irrigation potential. The classes include very suitable (S1), suitable (S2), marginally suitable (S3), and marginally not suitable (N). This type of land classification is very common and widely used in many researches and also recommended by FAO guidelines [16].

The slope is the incline or gradient of a surface and is commonly expressed in percent. The slope of the land affects the suitability of an area in terms of irrigation method selection, land preparation for irrigation and irrigation operation and surface irrigation requires a suitable slope for gravity flow. And also important for soil formation and management because it influences runoff, drainage, erosion, and choice of crops. Higher slope land results increase runoff and erosion, and water management is more difficult and land preparation cost is very high. So steep slope results in lower productivity and high production cost. According to FAO standard guidelines for surface irrigation slopes greater than 8% are not suitable and slope less than 2% are very suitable. For surface, irrigation slope is the main driving factor.

The slope of the basin was derived using the ArcGIS 10.8 by spatial analysis tool importing DEM with 30 m resolution of the basin downloaded from USGS. The slope derived from the DEM with 30 m resolution were classified in to five classes indicating the suitability class for surface irrigation based on [17] using the reclassification tool in ArcGIS 10.8. The slope from 0-2% was classified as highly suitable (S1), from 2-5% as moderately suitable (S2), from 5-8% as marginally (S3), slope from >8% were classified as not suitable (N). After the reclassification of the slope of the basin, a slope suitability map of the basin was developed for surface irrigation suitability assessment.

Table 4. Slope suitability and their area coverage.

No.	SLOPE (%)	Suitability	Area (Km^2)	Area Coverage (%)
1	0-2	S1	837.1719	5.90
2	2-5	S2	3028.575	21.35
3	5-8	S3	2781.453	19.61
4	>8	N	7537.601	53.14

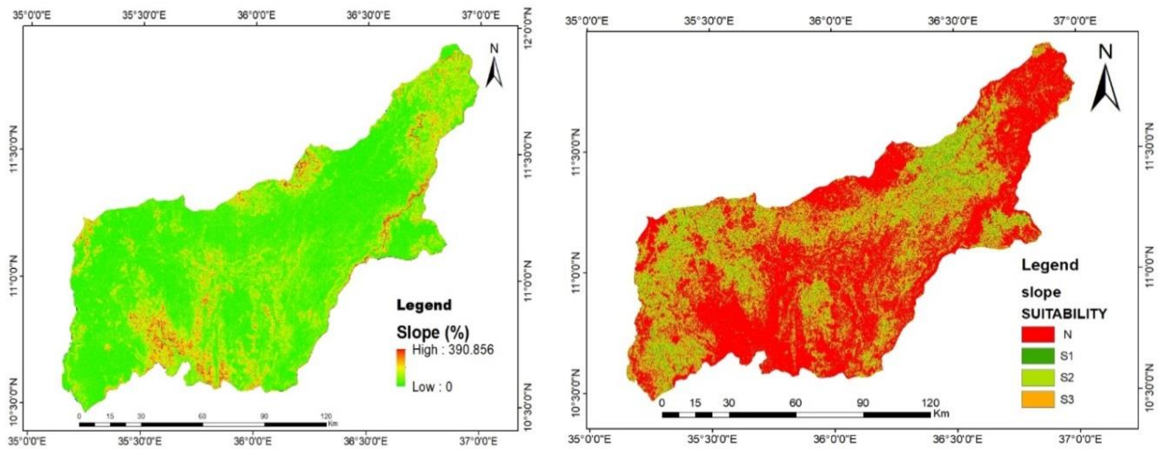

Figure 6. Slope suitability map.

After the reclassification of the slope gradient of the basin, slope suitability map of the basin was developed for surface irrigation (Figure 6). Surface irrigation is highly influenced by slope gradient. The land having slope gradient below 2 percent is very suitable for surface irrigation without any limitation with respect to slope. This type of land does not need much cost for construction of canals for waterway. Surface irrigation follows the slope gradient, which does not need great energy for distribution of water with in the irrigation field. In addition, it is known that most of the time gentle land is suitable for crops production.

The slope suitability result on Table 4 and showed that 5.9% of the area of the basin found within 0-2% slope and it is highly suitable for surface irrigation, does not need land leveling and irrigate the area with low initial cost and is classified as (S1) and very suitable for surface irrigation according to with slope suitability and 21.35% of the basin with the slope between 2%-5% is classified moderately suitable and requires a small quantity of land leveling for gravity water flow and classified as (S2). 19.61% of the basin has a slope between 5%-8% and is classified as marginally suitable classes (S3). It requires a large quantity of land leveling to fit the area for irrigation and needs a high initial cost for these operations. Whereas the rest 53.14% of the area are not suitable for surface irrigation and the slope is above 8% and steep slope. Most of the area (50%) is cover by a slope that is greater than 8% and not suitable for surface irrigation and requires land leveling.

3.1.2. Physical Properties of Soil

Soil is a major factor in the suitability of land for sustained irrigation. Its primary influence is on the productive capacity, but it also influences production and development costs.

Soil texture, soil drainage, soil depth and soil type are the major physical properties of soil which are very important for evaluation of irrigation potential of the basin. They affect the root growth of plant, infiltration of water in to the soil and the production of crops.

These physical properties of the Beles basin were evaluated independently to determine the irrigation potential of the land. This helps to see the land capability of the basin and determine the suitable area for irrigation.

Soil Texture

Based on its particles size soils, soils are divided in to three major type soil textures. These include clay, silt and sandy soils. These major types have mixtures like silt-clay, clay-loam, sandy loam etc. Generally, clay, clay loam and silty clay loam are classified as fine-textured soils while sandy clay loam, loam, and silt loam classified as medium textured soils and the others like sandy soils are classified as coarser-textured soils.

Infiltration (the rate at which water enters the soil) is influenced primarily by characteristics of the surface soil texture. When the infiltration capacity greatly exceeds the permeability of the subsoil, the permeability will greatly influence the basic intake rate of the soil. The infiltration rate may influence selection of the irrigation method, length of irrigation runs, field size, irrigation development costs, and crop selection.

According to [1], The soil texture was classified into four groups based on the soil water holding capacity, namely very high holding capacity (e. g. silt, silt loam, and silty clay loam), high capacity (e. g. silty clay, and clay), low capacity (e. g. loamy sands), and very low (e. g. sands, and loamy sands).

Table 5. Soil texture suitability.

No.	Soil Texture	Suitability	Area (Km2)	Area Coverage (%)
1	CLAY	S1	6165.479	43.41
2	LOAM	S3	7418.645	52.23
3	CLAY_LOAM	S2	619.9875	4.36

Fine-textured soils will have higher available moisture than coarser-textured soils. However, soils with extremely high clay content may actually have less available water than medium-textured soils.

The soil texture data was obtained from Ministry of Water Resource. The dominant soil textures of the study area were clay loam and clay soil (Figure 7). As it can be seen from the figure, clay texture was the dominant type of texture in the study area and the other small area was covered by clay loam. As a result, the clay type of the soil under the basin influences permeability, chiefly by its swelling and shrinking qualities with changes in soil moisture. The soils of the basin evaluated under the study area, which were fine textured, have higher soil moisture.

Soil moisture has great relationship with rainfall distribution. Thus, the basin has one rainy season, which is from May to August. The soil moisture content is closely related to the rainfall. After the rainy season the soil moisture content is at its maximum in September and October. After this period the soil dries down again. In winter and spring, the soil moisture content is very low due to absence of rainfall.

Soil texture of the land is determined by the requirements of crops. Different crops require different types of soil texture.

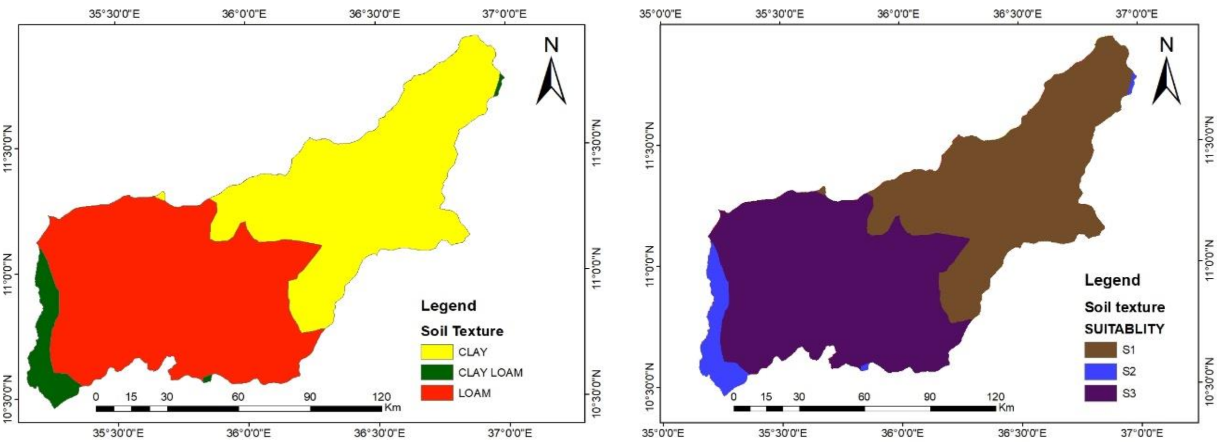

Figure 2. Soil Texture suitability map.

Soil type

Soil is the layer of the earth's surface, which has been changed by physical or biological processes. The five soil-forming factors that control the process of change are parent material, climate, topography, biota (plants and animals) and time. Soils are grouped into categories according to their observed properties. The USDA classification system consists of six categories. The highest category (soil order) contains 7 basic soil groups, each with a very broad range of properties. The lowest category (soil series) contains over 12,000 soils, each defining a very narrow range in soil properties.

Soil is a natural resource that can be categorized into different soil types, each with distinct characteristics that provide growing benefits and limitations. The soil type map of the study area according to FAO classification was derived from Abbay Basin authorities. There are 7 soil types in the basin in Cambisols, Fluvisols, Gleysols, and Nitsols, major soil groups (Table 6). Soil type has impacts on irrigation potential assessment and is considered as one factor to assess the suitability.

Soil Depth

The soil depth data of the basin were downloaded from the AfSIS database, and data of a study area were ranging from 13 cm to 175 cm. According to FAO standard guideline evaluation for surface irrigation, soil depth greater than 100 cm were very suitable (S1) and covers 40.3% of the basin, 50-100 cm were classified as moderately suitable (S2) which is 41.6%, and the rest 18.2 % of the area have a soil depth between <50 cm and classified as less suitable (S3) (Figure 9).

Based on soil depth requirement of most common crops, soil depth of the study area was divided in to suitability classes to select surface irrigation potential. Rating factor was given for the value of soil depth and weighting them to evaluate the suitability of surface (gravity) irrigation potential of the study area. Rating factor was adopted from FAO guidelines [18] (Table 7).

Based on the given weighting factors for each soil depth of the study area, soil depth suitability map of the study area for surface irrigation potential was developed (Figure 9).

Table 6. *Soil Type suitability and coverage area.*

VALUE	Soil Symbol	Soil Type	Suitability	Area (Km2)	Area Coverage (%)
1	Be9-3c-26	Eutric Cambisols	S1	256.3758	1.80
2	Ne12-3b-156	Eutric Nitosols	S1	5909.103	41.60
3	Re59-2c-246	Eutric Gleysols	S3	2579.198	18.16
4	Be47-2a-17	Eutric Cambisols	S2	15.9642	0.11
5	Je23-a-121	Eutric Fluvisols	S2	594.2178	4.18
6	Bh12-3c-31	Humic Cambisols	S3	4839.447	34.07
7	Bd31-2c-11	Dystric Cambisols	S2	9.8055	0.07

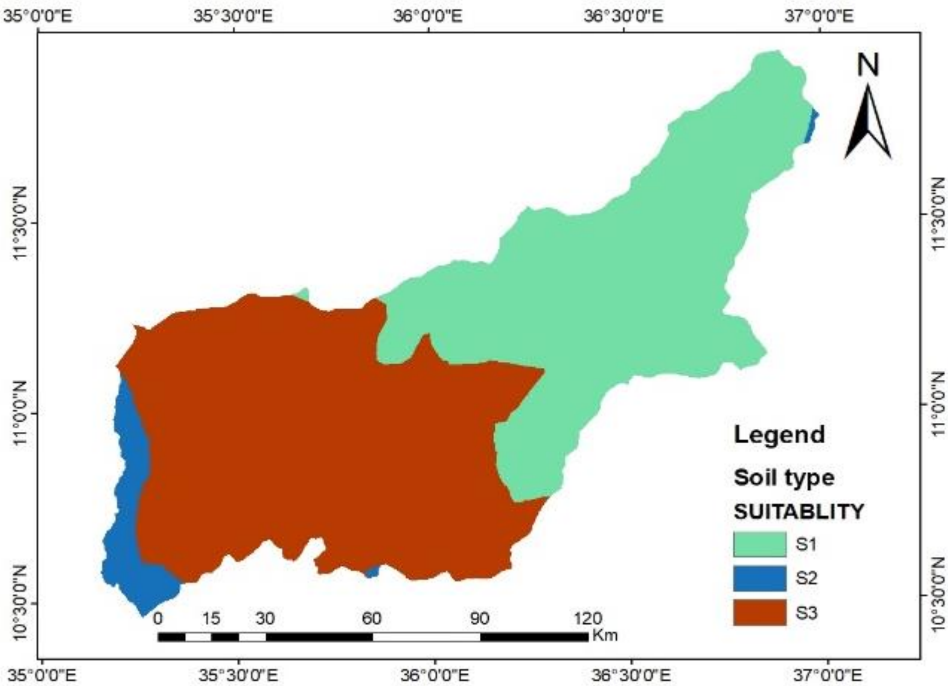

Figure 8. *Soil Type Suitability map.*

Table 7. Soil depth suitability and area coverage.

No.	SOIL DEPTH	Suitability	Area (Km^2)	Area Coverage (%)
1	>150 cm	S1	5111.8	36.0
2	50-100 cm	S2	5909.1	41.6
3	0-50 cm	S3	2579.2	18.2
4	100-150 cm	S1	604.0	4.3

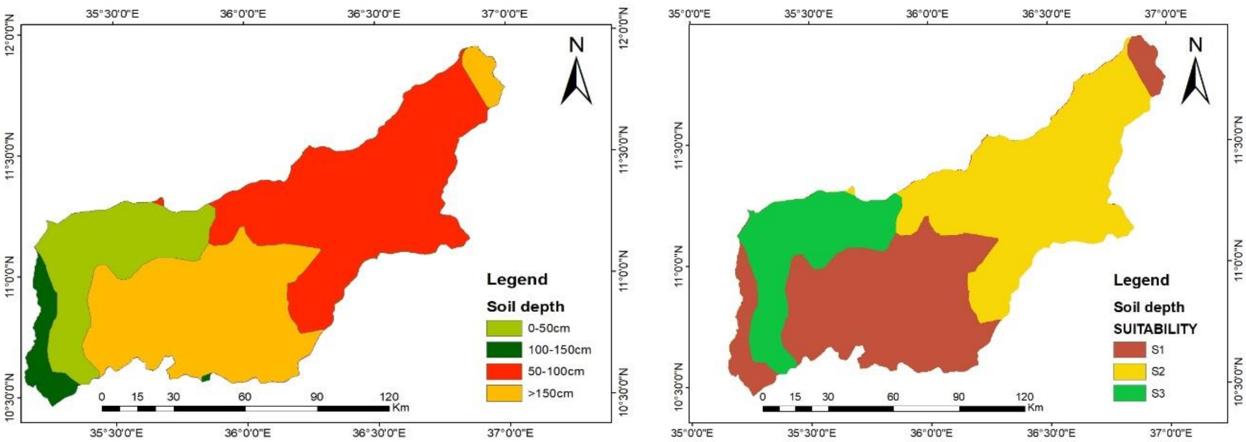

Figure 9. Soil depth suitability map.

Soil Drainage

The soil drainage data was obtained from the AfSIS data set. It has six drainage classes well-drained, moderately well-drained, somewhat excessively drained, poorly drained, somewhat poorly drained, and very poorly drained (Figure 10). Based on FAO guidelines soil drainage was classified into a suitable class. 70.2% of the basin have well and moderately well-drained soil type, provide good aeration and growth for crops and classified under highly suitable for crop production (S1),11.7% are somewhat excessively drained, and classified under moderately suitable (S2) because can release water easily compare with well-drained type, and 18.1 % of the basin is poorly and somewhat poorly drained soil and classified as marginally suitable (S3) because it can store water in plant root and make difficulty for air circulation in plant root. (Figure 10).

Table 8. Soil drainage suitability and area coverage.

VALUE	SOIL_DRAIN	Suitability	Area (Km^2)	Area Coverage (%)
1	Well	S1	9976.9	70.2
2	Imperfect	S2	1662.6	11.7
3	Poor	S3	2564.6	18.1

After conversion of soil drainage map of the study area in to raster form, the rasterized soil drainage map was reclassified based on the requirements of crops and surface irrigation potential. As a result, suitability map of soil drainage with in the study area was developed (Figure 10). The value was changed in to suitable classes based on the FAO guideline [16]. The suitability classes were three i. e. very suitable, marginally suitable and unsuitable (Figure 10).

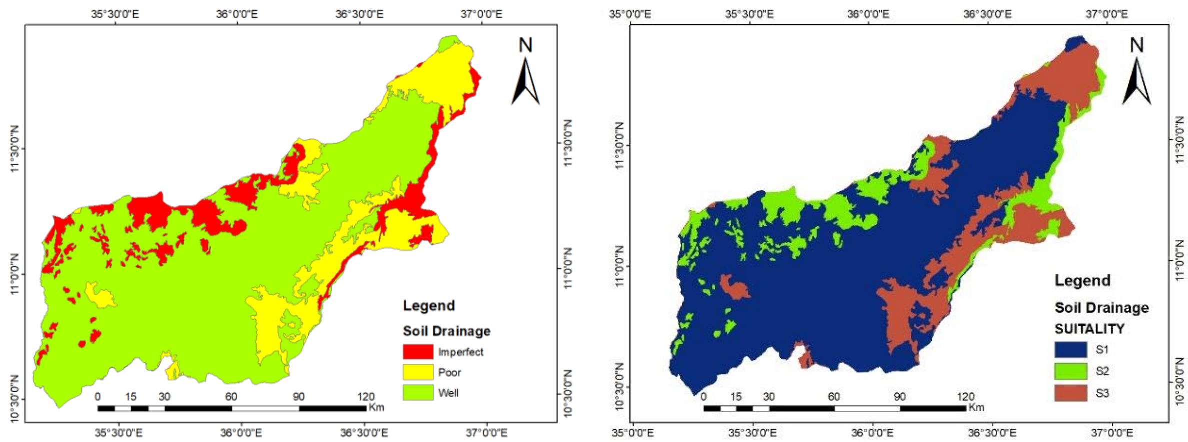

Figure 10. *Soil drainage suitability map.*

3.1.3. Land Use/Land Cover

Land use and land cover are one of the potential factors for irrigation land suitability assessment. Land use/land cover influences the cost of irrigation practice to prepare the land for agriculture and tillage practice. The land cover which limits irrigation like cultivated are very suitable and the other land cover types shrub and bush land can come to suitable for irrigation by removing the cover by high initial investment cost comparing with cost-benefit. The land use/ cover type of the study area was ranked based on their importance for surface irrigation potential, costs to remove or change for cultivation, and environmental impacts under the basin.

The land cover map of the basin has different types which include cultivated (dominantly and moderately) land, grass land and alpine, wood land, urban, water body, shrub, and bush land, state farm, perennial crops, and irrigated area, forest, woodland, plantation and bamboo, and Rockland. The suitability of land use for surface irrigation is categorized into four classes according to FAO [19] ranging from highly suitable class (S1) to not suitable class (N). Based on FAO [19] guidelines for surface irrigation suitability assessment the land cover data were reclassified, Dominantly cultivated, moderately cultivated, irrigation, perennial crops, and state farmland uses were grouped into highly suitable (S1) and do not need an extra cost and already prepared for tillage, grassland, and alpine, which requires a small amount of land clearing and leveling to come irrigable land, classified as moderately suitable (S2), it needs a small amount of land leveling cost. Shrub land and bush land, which require a higher initial investment for land clearing and preparation, were reclassified as marginally suitable (S3), whereas the rest of land cover type forest, wood land, urban areas, rock land, water body, swamps, bamboo, and plantation were classified as unsuitable (N) by considering the environment and conserving them.

Table 9. *Land cover suitability result.*

VALUE	LULC	Suitability	Area (Km^2)	Area Coverage (%)
1	Settlement	N	106.87	0.75
2	Grassland	S2	5578.23	39.27
3	Agriculture	S1	1776.75	12.51
4	Forest	N	6615.54	46.58
5	bare land	S3	0.96	0.01
6	Water	N	125.63	0.88

The result on (Table 9 and Figure 11) showed that 12.51% of the basin was classified as highly suitable (S1), activated, cultivated land, very suitable for surface irrigation, and does not need land preparation according to with land cover. 39.27% of the area is classified under moderately suitable area (S2), covered by grass land, and requires a small amount of land preparation. 0.01% of the basin is covered by bush and shrub land, this type of land requires high cost for land preparation and is classified under marginally suitable classes (S3). The remaining 47.21% of the area is not suitable for irrigation and covered with forest, water, hard rock, and other unsuitable covers for irrigation.

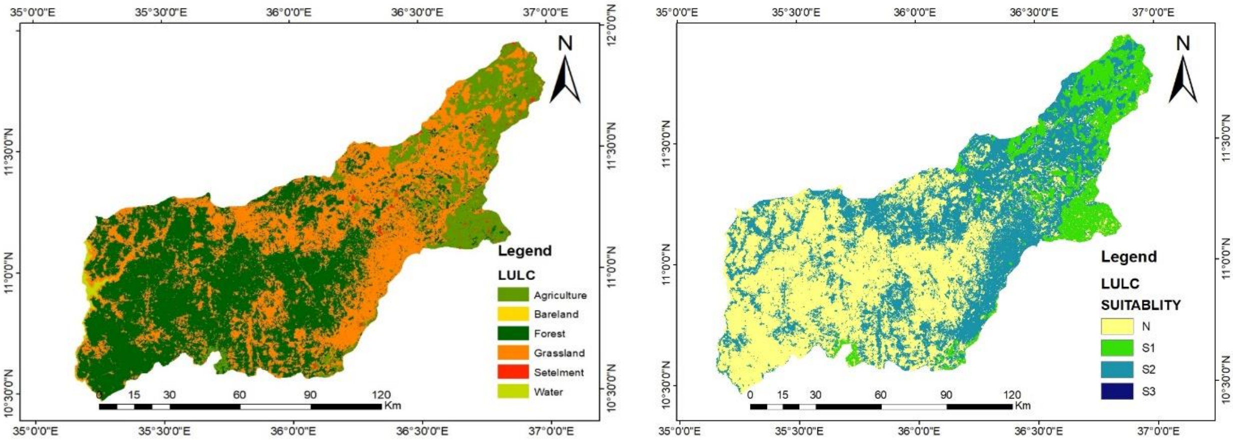

Figure 3. *Land use land cover suitability map.*

3.1.4. River Proximity (Water source)

Water resource is one of the major factors, which are needed for irrigation. Plant needs water to grow. Water is essential for plant growth. Without enough water, normal plant functions are disturbed, and the plant gradually wilts, stops growing, and dies. Plants are most susceptible to damage from water deficiency during the vegetative and reproductive stages of growth. Also, many plants are most sensitive to salinity during the germination and seedling growth stages.

Most of the water that enters the plant roots does not stay in the plant. Less than 1% of the water withdrawn by the plant is actually used in photosynthesis (i. e. assimilated by the plant). The rest of the water moves to the leaf surfaces where it transpires (evaporates) to the atmosphere. The rate at which a plant takes up water is controlled by its physical characteristics, the atmosphere and soil environment.

As water moves from the soil, into the roots, through the stem, into the leaves and through the leaf stomata to the air, it moves from a low water tension to a high-water tension. The water tension in the air is related to its relative humidity and is always greater than the water tension in the soil.

Beles River is grouped under the main rivers found in the country. It flows also in plain land of the study area. There are also other large tributaries like Dura, which are perennials and join to main Beles River. The Beles sub basin is characterized by well external drainage.

Euclidean distances were calculated for each major river in a basin and then an equal interval method was used for classified into four suitability classes for suitability analysis due to high variability. The farthest area of the basin is found 13.6 km far away from the major river and it makes it difficult to get irrigation water. The area closes to the river or the nearest proximity was classified as highly suitable (S1) and the land that is found far away from the water source or furthest proximity is classified as not suitable (N).

The 33.24% of the area coverage is found within the nearest proximity and near to the water source and can extract water easily from rivers for crop production within 1.5 km, these areas are categorized under highly suitable area (S1), and 21.22% of the land is categorized under moderately suitable area (S2) and access irrigation water with a moderate distance between 1.5 to 3 km and 22.31% of the study area classified under marginally suitable class (S3) and get irrigation water with long distance between 3 to 5 km. whereas the remaining 23.22% of the basin is found far away from the major river between greater than 5 km are classified as not suitable and can access water from major rivers after goes to13.6 km and the users are totally fussing to get water from a surface water source and it is not suitable for surface irrigation by a river (Table 10).

Table 10. *River proximity suitability results.*

No.	River Distance (Km)	Suitability	Area (Km^2)	Area Coverage (%)
1	0-1.5	S1	4720.7	33.24
2	1.5-3	S2	3014.4	21.22

No.	River Distance (Km)	Suitability	Area (Km^2)	Area Coverage (%)
3	3-5	S3	3169.1	22.31
4	>5	N	3298.3	23.22

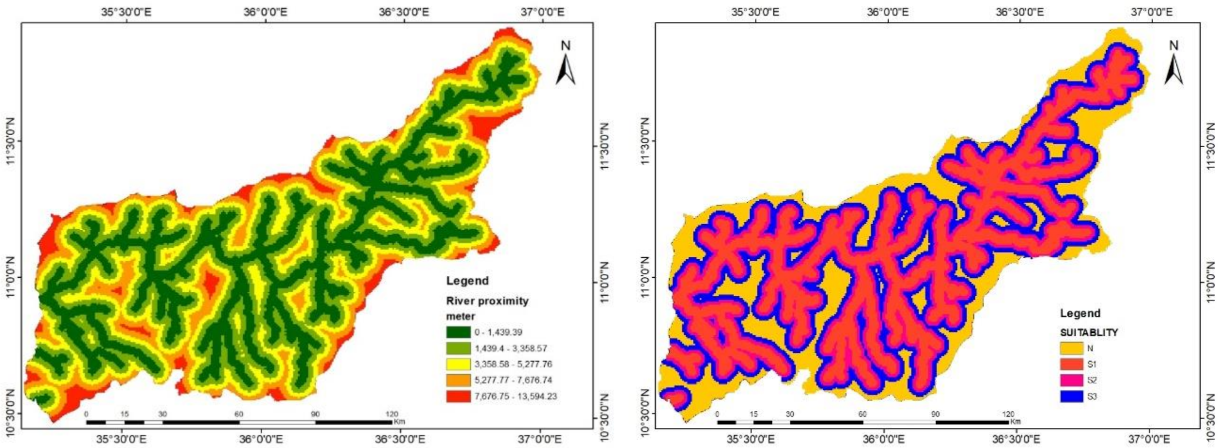

Figure 12. River suitability map.

3.1.5. Road Proximity

Implementation of irrigation requires access to the market to purchase agricultural inputs and to sell agricultural outputs. The market outlet is the most dominant factor that affects irrigation suitability of surface irrigation because agricultural products and inputs need markets and roads to access for users. These market outlets are expressed by population density, proximity to road networks, and urban centers. The lands close to the market and road can get inputs and sell their products easily and the area that the people lives densely is good and get market quickly without consuming time and other resources. So, the area near to road, city, and people lives densely are most suitable for surface irrigation based on market access. These three factors (i. e. road proximity, city proximity, and population density) do not identify the physical potential of the land but are used to assess market availability, because an irrigation scheme needs a market to sell the outputs and purchase the inputs. Every irrigation project is installed to increase the income of the users, the community, and also the country so to study the benefit of the project asses market availability using urban and rod proximity is essential.

Euclidean distances were calculated from road networks (Figure 13) and then classified into four suitability classes (Figure 13) due to high variability based on the equal interval approach for suitability analysis [1]. The road proximity showed that the farthest point is 48.8 km far away from the road. Suitability of the market outlet was assessed by dividing the proximity map of road calculated using calculated Euclidean distance, the nearest proximity assigned as highly suitable (S1) to the farthest proximity which is not suitable (N) (Figure 13). The nearest proximity area gets market access within a short distance for their input and output to purchase and sells and the furthest proximity indicates that the users or irrigators are fussing to purchase the agricultural inputs and to sell their output.

Table 11. Road suitability results.

No.	Road Distance (Km)	Suitability	Area (Km^2)	Area Coverage (%)
1	0-5	S1	4314.72	30.38
2	5-15	S2	5993.88	42.20
3	15-20	S3	1629.38	11.47
4	>20	N	2264.35	15.94

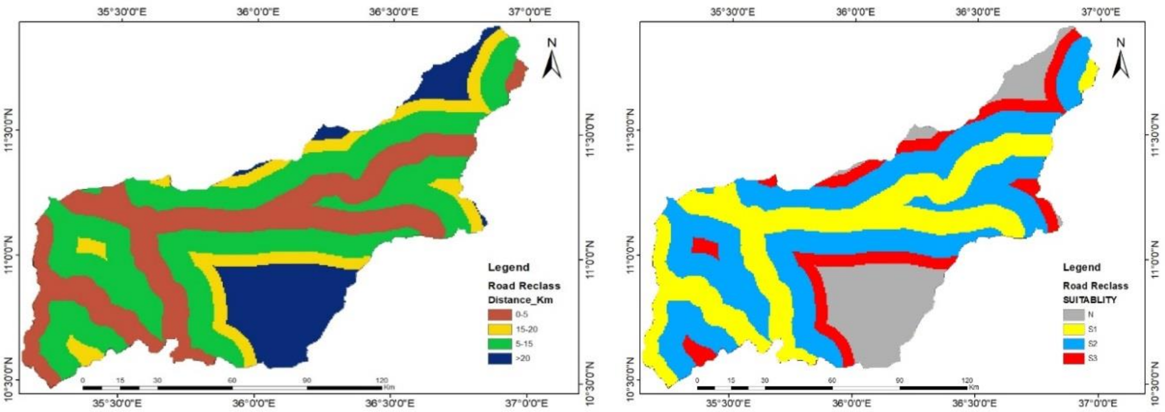

Figure 13. Road suitability map.

The result of road accessibility (Table 11) showed that 30.38% of the basin is highly suitable for surface irrigation and can get road accessibility within a short distance of 5 km for their transport need. 42.2% of the area is found 15 km away from the road and classified under moderately suitable classes and access roads within a moderate distance and 11.47% of the study area is classified as marginally suitable area and get road access within 20 km whereas the reaming 15.94% of the area found far from roads and accessed road after greater than 20 km and classified under not suitable for surface irrigation. The majority of the study area are suitable for surface irrigation and can get market access easily according to urban and road suitability analysis.

3.2. Weighting of Factors for Surface Irrigation Suitability Mapping

Multi-Criteria Evaluation (MCE) Technique for the Assessment of Irrigable Land

The factors used in suitability assessment were tabulated and compared with each other means that column factors with the rows for their significance to surface irrigation, the highest value (9) corresponds to absolute importance, and the reciprocal of all scaled ratios were entered in the transpose position (i. e., 1/9 shows an absolute triviality using (Table 2), and then the pair-wise comparison matrices were filled and the weights of the factors were computed by normalizing the eigenvector by the cumulative vector. The eigenvector was calculated as the product of the row matrix. The weights are done for both surface and groundwater sources. The weight of factors was computed separately for rivers (Table 12) and groundwater sources (Table 13).

Table 12 shows the comparison of each suitability factor and weights of suitability factor from river water sources and the consistency ratio of the pair wise matrix.

Table 12. Suitability factor's scale and weight from river.

	S	D	SD	T	LULC	ST	RP	ROP
S	1.00	0.33	0.33	0.33	0.33	0.25	0.33	0.33
D	3.00	1.00	2.00	5.00	5.00	0.25	3.00	3.00
SD	3.00	0.50	1.00	3.00	5.00	0.33	3.00	3.00
T	3.00	0.20	0.33	1.00	3.00	0.20	0.33	0.33
LULC	3.00	0.20	0.20	0.33	1.00	0.20	0.33	0.33
ST	4.00	4.00	3.00	5.00	5.00	1.00	5.00	5.00
RP	3.00	0.33	0.33	3.00	3.00	0.20	1.00	3.00
ROP	3.00	0.33	0.33	3.00	3.00	0.20	0.33	1.00
Sum	23	6.9	7.53	20.7	25.3	2.63	13.3	16

Source: ([5, 1])

S=slope, D= soil drainage, SD= soil depth, T= soil texture, LULC= land use land cover, ST=soil type, RP= River proximity, ROP= road proximity, w= weight

Table 13. Eugene Value vector.

	S	D	SD	T	LULC	ST	RP	ROP	Weight
S	0.04	0.05	0.04	0.02	0.01	0.09	0.03	0.02	0.0383
D	0.13	0.14	0.27	0.24	0.20	0.09	0.23	0.19	0.1859
SD	0.13	0.07	0.13	0.15	0.20	0.13	0.23	0.19	0.1522
T	0.13	0.03	0.04	0.05	0.12	0.08	0.03	0.02	0.0615
LULC	0.13	0.03	0.03	0.02	0.04	0.08	0.03	0.02	0.0454
ST	0.17	0.58	0.40	0.24	0.20	0.38	0.38	0.31	0.3323
RP	0.13	0.05	0.04	0.15	0.12	0.08	0.08	0.19	0.1031
ROP	0.13	0.05	0.04	0.15	0.12	0.08	0.03	0.06	0.0813
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.0000

Table 14. Eugene Value matrix.

Sum of Factor	Wight of Factor	Sum*Wight factor
23.000	0.038	0.880
6.900	0.186	1.283
7.533	0.152	1.146
20.667	0.062	1.272
25.333	0.045	1.151
2.633	0.332	0.875
13.333	0.103	1.375
16.000	0.081	1.300
	lamda=	9.28

Based on the results of the factors weight table above, Soil type was the most influential factor from the surface sources. Soil drainage and soil depth was found to be the second and the third influential factors from surface water. After all the consistency ratio was calculated using cumulative eigenvector and the weight module to check the consistency of the developed matrix, and the acceptable CR value is up to 0.1 based on [5]. The consistency of pairwise matrix was checked, CR = 0.09 and below the acceptable limit.

Overlay analysis (Weighted overlay)

After each suitability parameter was assessed, reclassified and the weight has developed separately the weights were distributed to individual factors of suitability classes based on an equal interval ranging technique, and the factors were combined using weighted sum overlay to obtain the final suitability map of both surface and ground water source.

Table 15. Area distribution of suitability class.

No.	Suitability	Suitability Range	Area (Km2)	Area Coverage (%)
4	S1	Highly Suitable	1956.613	13.84
3	S2	Moderately Suitable	10325.45	73.05
2	S3	Marginally Suitable	1853.272	13.11

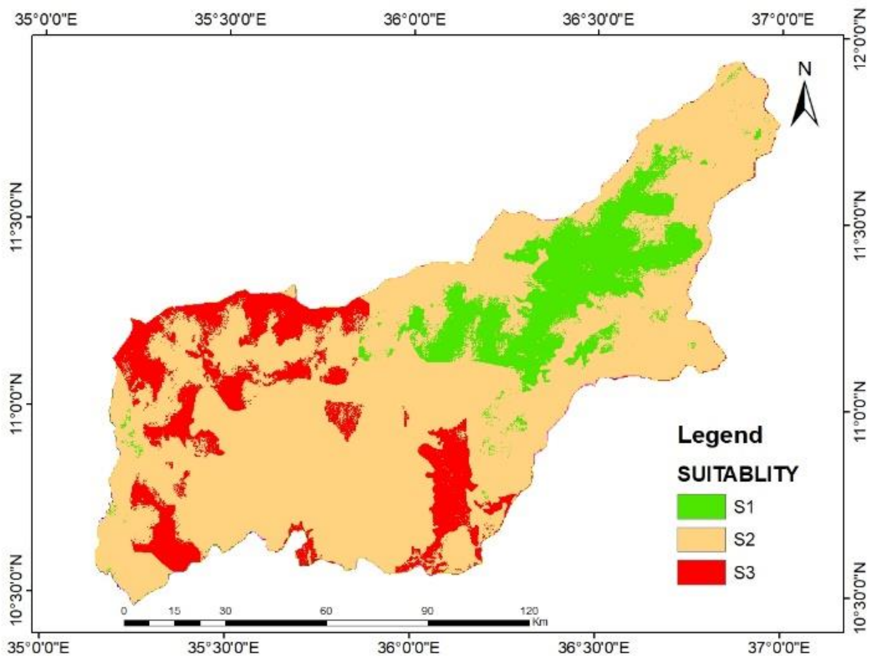

Figure 14. Potential suitability area.

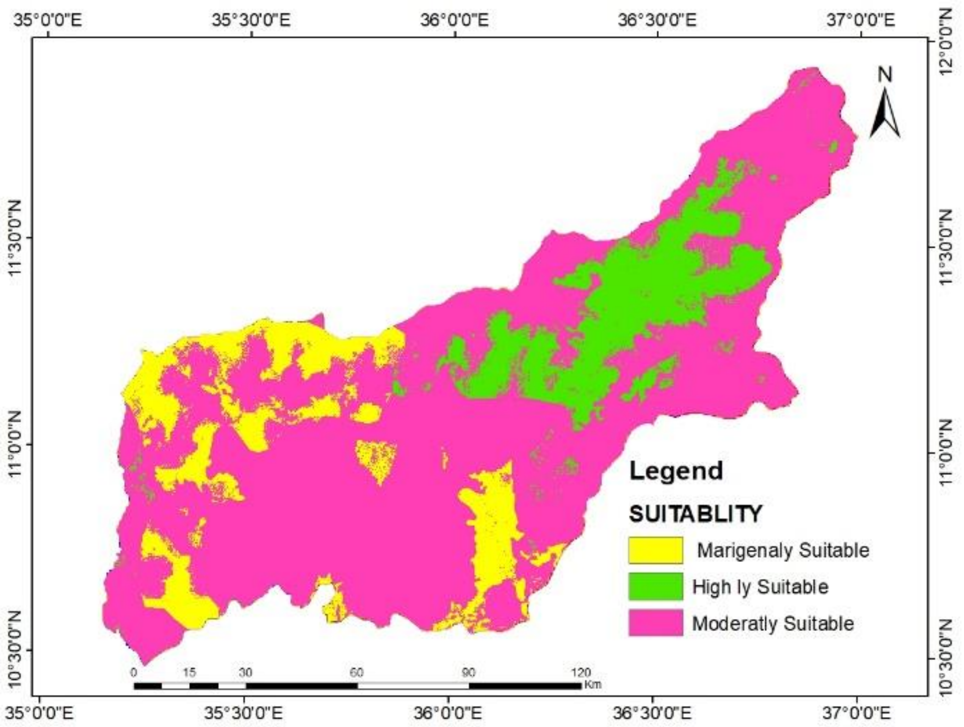

Figure 15. Land Suitability map.

A preliminary surface irrigation suitable area was computed by weighting the determining factors (slope, river proximity, LULC, and soil type, soil depth, soil texture, soil drainage, river proximity and road proximity) by applying the pair-wise comparison matrix as shown in Table 15. Subsequently, the credibility of the par-wise comparison matrix consistency was evaluated using the consistency ratio (CR). The result of CR was found to be reliable with value of 0.09. The value of CR is in the acceptable limit ([5, 20], and [17]), which ranges from 0 to 0.1, for the consistency of judgment of the weights of factors.

Based on the result of the analysis, physically suitable land and its suitability range for surface irrigation are shown in Figure 14 and Table 15. Figure 14 clearly shows that the highly suitable portion of land is situated along the side of rivers, and the non-suitable area is found far from the rivers. It is because the topography of the area which is far from the rivers is highly undulating (up and down terrain), while the area nearer to the rivers relatively characterized by flatten and flatten with gentle slope. As both, slope and river proximity factors are more important deciding factors [17] for land suitability than others; the result is more significantly influenced by these factors. It means that the more the closer to the river, the more suitable will be the land and vice versa. Naturally, most of the study area topography possesses undulating nature of the terrain.

Generally, as can be seen from Table 15, only 195661 ha (13.84%) of land was found to be highly suitable, and 185327 ha (13.11%) of the area was found to be Marginally-suitable for surface irrigation. In between the two extremes, about 1032545 ha (73.05%) of land was categorized under moderately suitable category for surface irrigation. So, most of the area (73.05%) laid under the category of moderately suitable which means land with limitations so severe that benefits are reduced and/or the inputs required to sustain production need to be that this cost is only moderately justified.

3.3. Surface Water Availability and Crop Water Requirement

In the study area, the water requirement for irrigation is high during dry season (time of low flow of rivers) and low to no during rainy season. So, the amount of low flow of the river was required to quantify the amount of water available for surface irrigation application during dry season. Hence, the low flow of the Main Beles river was computed by the technique known as flow duration curve (FDC) method. FDC for Main Beles River was generated from the recorded average daily discharge data of the year 1992 to 2020 (Figure 16). The FDC enables to determine the 90% of time available flow. The 90% available flow is described as the flow exceeded 90% (Q90) of the time for a particular year [17]. Hence, the 90% available flows were determined by ranking all average monthly flow data and finding the discharge exceeded by 90% of all values [21, 22].

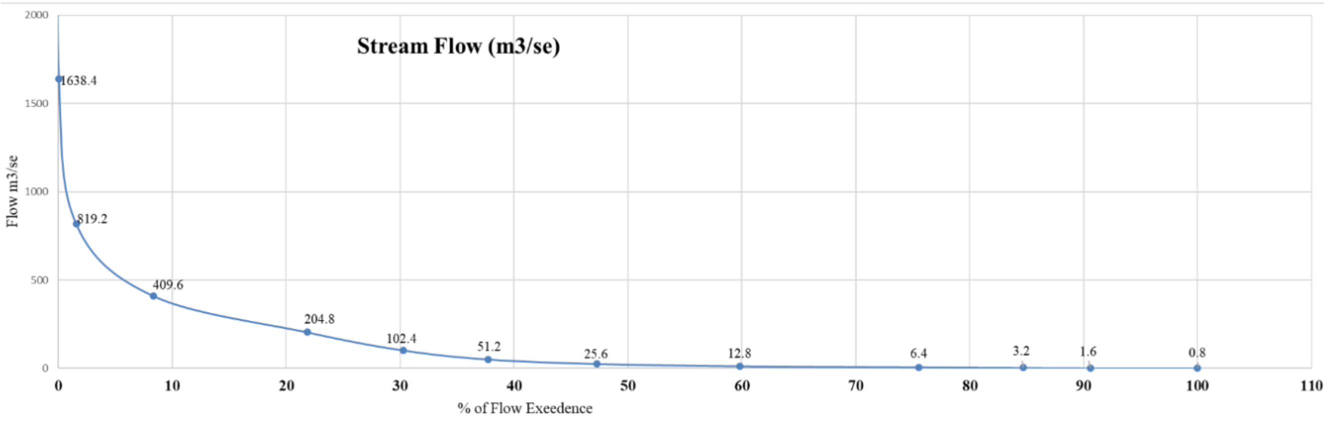

Figure 16. *Flow duration curve of Beles River.*

As shown on the figure above (Figure 16), the 90% available flow was found to be 1.6 m^3/s. Hence, the irrigation potential/capacity of the 90% available flow was computed by dividing this flow of water (90% available flow) by average monthly crop water requirement (CWR) for each month. So, the net irrigation potential of the study area was determined by considering two things. The first one is, amount of available low flow of the river. And the second one is, physically suitable land surface which is determined above (the "Weighting of the factors and suitable area for irrigation" section). So, the result of this study is presented based on the capability of the 90% available flow of river, to irrigate the identified irrigable area on a monthly base. Hence, the result indicated that the river has a potential of irrigating the first suitability class (S1) area which covers only 195661 ha (13.84%) fully and sustainably throughout the year. The highly suitable and moderately suitable area covers about 1,228,206.3 ha while the river has a capability of irrigating 4247.2 ha for Banana which is only 0.35%, 4450 ha for Sugar Cane crop which is only 0.36%, 2361 ha for Sugar Cane crop which is only 0.19% in the month of January. In the same way, the river has a capability of irrigating for Banana which is only 0.3%, for Sugar Cane crop which is only 0.31%, and for Sugar Cane crop which is only 0.17% of the total irrigable area (S1 + S2 + S3) in the month of January with an average monthly CWR of 1009 m^3/month/ha for Banana crop 963 m^3/month/ha for sugar cane crop and 1815 m^3/month/ha for Mango crop.

The capability of the river flow in different months of the year. On the other hand, the river has a minimum potential of irrigation at a season of low flow. In the month of December, the river has a potential of irrigating only 10083.4 ha for Banana; this is because, in the month December, the crop water requirement is very high, and the flow is low. The river irrigation potential is becoming increased from March to May because of the crop water requirement (CWR) becoming decreased from March to May and finally become nil crop water requirement (CWR) starting from June to September which is wet season in this area.

Table 16. Surface water availability and water requirement of Banana.

Months	Monthly CWR (m^3/mon/ha)	90% of available river flow (m^3/month)	Total land that can be irrigated by the available water (ha)	% area that the dry flow can irrigate (S1)	% area that the dry flow can irrigate (S1+S2)	% area that the dry flow can irrigate (S1+S2+S3)
January	1009	4285440	4247.22	2.17	0.35	0.30
February	799	3870720	4844.46	2.48	0.39	0.34
March	963	4285440	4450.09	2.27	0.36	0.31
April	967	4147200	4288.73	2.19	0.35	0.30
May	596	4147200	6958.39	3.56	0.57	0.49
June	0	4147200	0.00	0.00	0.00	0.00
July	0	4285440	0.00	0.00	0.00	0.00
August	0	4285440	0.00	0.00	0.00	0.00
September	0	4147200	0.00	0.00	0.00	0.00
October	242	4285440	17708.43	9.05	1.44	1.25
November	305	4147200	13597.38	6.95	1.11	0.96
December	425	4285440	10083.39	5.15	0.82	0.71

Table 17. Surface water availability and water requirement of Sugar Cane.

Months	Monthly CWR (m^3/mon/ha)	90% of available river flow (m^3/month)	Total land that can be irrigated by the available water (ha)	% area that the dry flow can irrigate (S1)	% area that the dry flow can irrigate (S1+S2)	% area that the dry flow can irrigate (S1+S2+S3)
January	963	4285440	4450.09	2.27	0.36	0.31
February	1365	3870720	2835.69	1.45	0.23	0.20
March	2260	4285440	1896.21	0.97	0.15	0.13
April	2145	4147200	1933.43	0.99	0.16	0.14
May	1662	4147200	2495.31	1.28	0.20	0.18
June	185	4147200	22417.30	11.46	1.83	1.59
July	0	4285440	0.00	0.00	0.00	0.00
August	0	4285440	0.00	0.00	0.00	0.00
September	0	4147200	0.00	0.00	0.00	0.00
October	226	4285440	18962.12	9.69	1.54	1.34
November	1046	4147200	3964.82	2.03	0.32	0.28
December	835	4285440	5132.26	2.62	0.42	0.36

Table 18. Surface water availability and water requirement of Mango.

Months	Monthly CWR (m^3/mon/ha)	90% of available river flow (m^3/month)	Total land that can be irrigated by the available water (ha)	% area that the dry flow can irrigate (S1)	% area that the dry flow can irrigate (S1+S2)	% area that the dry flow can irrigate (S1+S2+S3)
January	1815	4285440	2361.12	1.21	0.19	0.17
February	1440	3870720	2688.00	1.37	0.22	0.19
March	1707	4285440	2510.51	1.28	0.20	0.18
April	1614	4147200	2569.52	1.31	0.21	0.18
May	1193	4147200	3476.28	1.78	0.28	0.25
June	86	4147200	48223.26	24.65	3.93	3.41
July	0	4285440	0.00	0.00	0.00	0.00
August	0	4285440	0.00	0.00	0.00	0.00
September	0	4147200	0.00	0.00	0.00	0.00
October	185	4285440	23164.54	11.84	1.89	1.64
November	1103	4147200	3759.93	1.92	0.31	0.27
December	1223	4285440	3504.04	1.79	0.29	0.25

4. Conclusion

In this study, the irrigation potential of Beles Basin was evaluated based on the assessment of both the land suitability and water availability for surface irrigation. The land suitability was evaluated, considering major factors, which affect suitability of land for surface irrigation. These factors include slope, river proximity, soil type, Soil texture, road proximity, soil depth, soil drainage and LULC type. And then, the suitable land was identified by aggregating the effect of all factors by overlaying the factors map in ArcGIS Environment. The land evaluation of physical land qualities of the study area indicates that Beles basin has great potential for surface irrigation. Those factors were also used for suitability of crops under the study area. The selected crops for evaluation of physical land characteristics are Mango, Sugar cane and Banana. The water availability was determined by considering the low flow of the river by generating FDC from historical measured flow data. Hence, the result indicated that Beles sub basin has a potential of 195661 ha (13.84% total area) of irrigable land is highly suitable. But, the highly suitable land (S1) is relatively small. This is due to the topography of the basin, which is highly up and down, which is also influenced by the slope factor, indicating only 5.9% of land is highly suitable for surface irrigation. On the other hand, the river has a minimum potential of irrigation at a season of low flow. For instance, in the month of December, the river has a potential of irrigating only 10083.4 ha for Banana. So, future expansion of irrigation up to full irrigation potential of the Beles basin, there should be a construction of dams across the river to store runoff during the rainy season.

Abbreviations

AfSIS	African Soil Information Service
AHP	Analytical Hierarchy Process
CIR	Consistency Index Ratio
CWR	Crop Water Requirement
DEM	Digital Elevation Model
FAO	Food and Agricultural Organization
FDC	Flow Duration Curve
GIS	Geographical Information System
ILRI	International Livestock Research Institute
LULC	Land Use Land Cover
MCE	Multi-Criteria Evaluation
USGS	United States Geological Survey
WLC	Weighted Linear Combination

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Author Contributions

Alemnesh Abawa: Conceptualization, Data Curation, Resources

Zigiybel Firiew Berihune: Methodology, Software, Formal analysis, Writing – original draft

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Ethics Approval Declarations

Not applicable.

Consent to Participate Declarations

Not applicable.

Data Availability Statement

The data that support the findings of this study are available from the author (Zigiybel Firiew Berihune) upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interests.

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