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Physical Land Suitability Assessment for Tea Cultivation Using GIS-Based Multi-Criteria Approach at Dabus Basin of Oromia Region, Southwest Ethiopia

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Abstract: Tea is economically important export commodity for Ethiopia Predicting the physical land suitability of tea is vital to avoid a sightless expansion of tea plantations and significant to recognize the potential suitable area for tea to disseminate of tea plantations in the country. Land suitability analysis is pre-request for assigning specific land for specific purposes. The study incorporate applications of Geographic Information System, Remote Sensing and Analytical Hierarchical Process (AHP) to allocate suitability weights to criteria that influence tea plant's growth to produce a predictive suitability map for its cultivation. Topography, Soils, climatic and land use features were included in the process as an important contributing factor for tea plant's growth. Each of the evaluations criteria layers were classified into four suitability class of not suitable, less suitable, suitable, and highly suitable. The results indicated that important influential factors affecting tea cultivation suitability evaluation were Rainfall (23.9%) followed by soils pH (18.05%) Elevation (12.72%), land use (10.79%), Aspect (9.07%), soils texture (6.96%), Slope (6.43), soils Depth (5.25%) temperature (3.42%) and drainage class (3.42%) respectively with 8.23% consistency index. The results revealed that the moderately suitable suitability class occupied the largest proportion of Land (84.92%), followed by highly suitable area (11.42%) and the unsuitable area (3.66%). the study area were precipitation, soil reaction, Altitude, Aspect and current Land use were identified as main limiting factors for Tea productions.

Keywords: Tea Cultivation, Land Suitability Evaluation, GIS, Analytical Hierarchy Process

1. Introduction

Tea (Camellia sinensis L. O. Kuntze) is a perennial evergreen shrub and a high-value added cash crop, and it is renowned for its nutritional, medicinal, antimicrobial, and anticancer properties worldwide [1, 2]. Discovered about 2700BC, it is one of the oldest beverages in the world today and it is available for consumption in six main varieties, based on the oxidization and fermentation techniques applied [3, 4]. Tea is one of the most popular and lowest cost beverages in the world, and consumed by a wide range of age groups in all levels of society with more than three billion cups daily worldwide [5].

The tea crop has rather specific agro-climatic requirements that are only available in tropical and subtropical climates because it needs a hot, moist climate. Tea requires a well-distributed minimum rainfall ranging from 1200mm to 2200mm that is well distributed throughout the year, and temperatures' ranging from 13°C to 30°C is optimum [1, 3, 4, 6, 7]. Elevations, slope and aspect are the most topographic features that affect tea plant growth and chemical compositions because they influence microclimate that control water availability and soils drainage conditions [8, 9]. The tea plant requires gentle slope, ranging 5-10 Degree or 13-25% slopes and elevations of 1500 to 2250m for optimum growth [3, 4, 7, 10]. Tea plant requires soil having optimum soils drainage conditions and Soil reaction ranged from 4.5-5.6 for better development [3, 7].

Soil texture like sandy is significantly limited tea plant growth due to low water retention, low resistance to soil erosion, and insufficient nutrient were as clay loam, loamy clay and sandy clay loam are suitable texture for tea cultivation

[6, 11]. Tea was introduced to Ethiopia around 1928 by British missioners in Gore area of Gumaro which is the oldest tea farm in the southwest Ethiopia [12]. Ethiopia has 6 million hectares of land suitable for tea production, particularly the western part of country: however, up to date, only 2660 hectares of land were allocated for tea plantations [12, 13].

Despite the importance of tea production in Ethiopia, there is lack of basic information on tea cultivation land suitability which is vital to avoid a sightless expansion of tea plantations and significant to recognize the potential suitable area for tea plantations to disseminate of tea plantations in the country. Generally executed by examining natural and human factors, such as climatic conditions, topography conditions, and soil physical-chemical properties in response to the crop requirements for growth and production up to the extent of land unit quality which matches the necessity of a specific land use that influences tea cultivation to evaluate the potential and limitations of particular land use [1, 6]. GIS and Analytic Hierarchy Process (AHP) modeling-based approach is important for Physical Land Suitability Evaluation analysis for agricultural production. It enables different factors affecting land suitability to be considered under one umbrella in order to resolve highly complex decision-making problems involving multiple factors in suitability analysis for agricultural productions [14, 15]. Therefore, this study aimed to assess Physical Land Suitability of tea production cultivation using GIS and analytical hierarchical process in Dabus basin, Oromia Region, Southwest Ethiopia.

2. Materials and Methods

2.1. Description of Study Area

The Dabus basin is found in Qellem and west Wollega zone. The basin covered about 879287.9 hectares of land. It covers partially parts of Qellem and west Wellega zone. The Dabus basin location extent from 34.58° - 35.12°East and 8.45°- 9.58°North (Figure 1). The mean annual temperature of basin was ranged from 22.20 to 24.63°C and receives annual rainfall of 1309 to 1845mm.

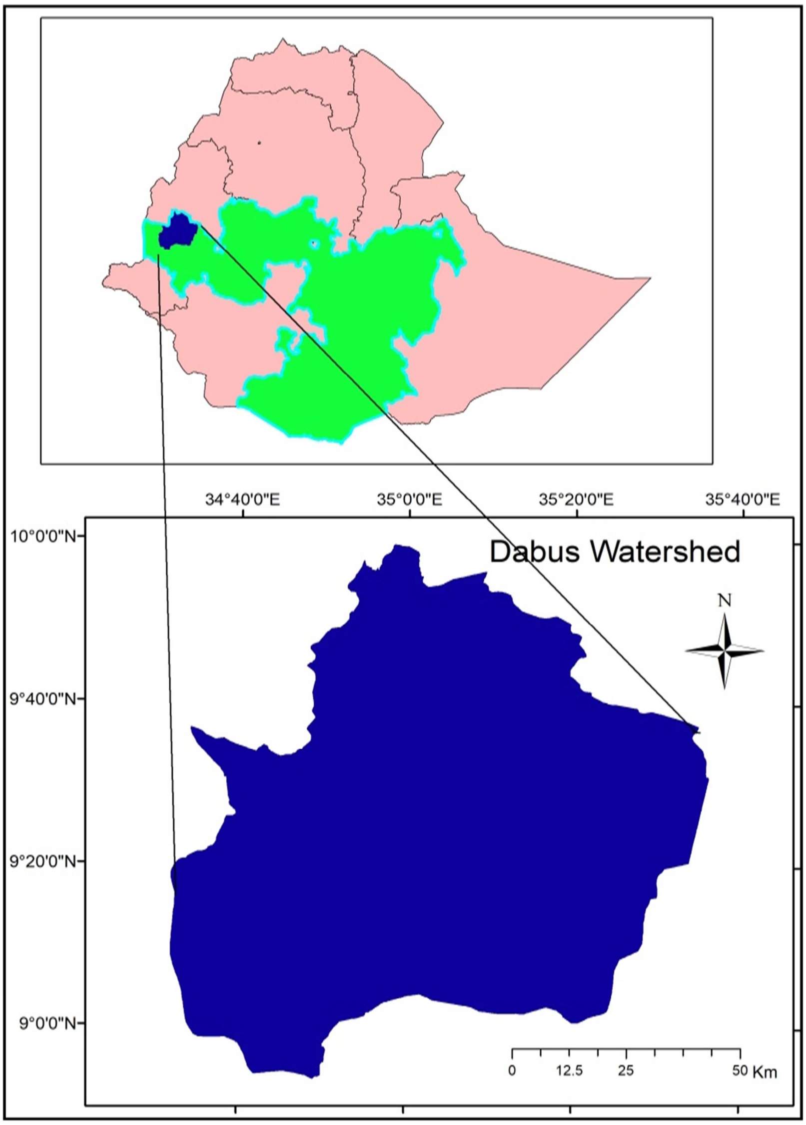

Figure 1. *Study Area.*

2.2. Data Source

To Predict Physical Land Suitability Evaluation for tea cultivation using GIS and analytical hierarchical process in the Dabus basin, all dataset was obtained from secondary data sources. High resolution climate data of mean temperature and annual precipitation of the study area were downloaded from the world climate website (www.worldclim.org). Climate data used in this study were obtained from the World Climate Data with a spatial resolution of 30 s (~1 km^2) and they represent the average monthly climate data of the year 2011-2020.

Digital evaluation models (DEM) of the study area were used as sources of for topographic features (Elevation, aspect, and Slope) and soil data (soil texture, drainage class, effective depth, and soil pH) used as criteria for Predicting Physical Land Suitability Evaluation for tea cultivation were obtained from Oromia Irrigation Development Authority (OIDA) data. Land use and land cover of 2021 with 10m spatial resolution was obtained from [16, 17] and it was used to produce the final land suitability map for tea crops. All raster layers used in this study were projected into WGS_1984_UTM_Zone_37N projection system.

2.3. Data Setting

In this study, a tea cultivation site selection model was developed based on the spatial analysis of multi-criteria decision making analysis. The process modeling has been done with the application of both spatial data and expert level opinions of decision makers in the integration of data and relationships between criteria. GIS has good ability for managing, manipulating, and analysis of spatial data, while AHP model-based multicriteria decision analyses were used for preparing a methodology for assessing and ranking decisions for tea cultivation site selection model development. Setting all of the criteria and their interrelationships is a crucial decision for developing an accurate model for the identification of suitable sites. The methodology and steps of applying AHP MCDA model for tea cultivation suitable site selection are presented in Figure 2.

2.4. Data Analysis

Factors affecting tea cultivation were selected as criteria to asses physical land suitability evaluation and site requirements based on different review results. In research, the AHP (Analytical hierarchal process) model approach was used for standardizing criteria by using a pairwise comparison method by transforming different input data into the same unit of measurement scale. Datasets of topography (Elevation, aspect, and Slope) and soil (soil texture, drainage class, effective depth, and soil pH),

Climate (rainfall and temperature) and LULC data were converted into raster format and reclassified into four suitability classes of 4, 3, 2, and 1 representing highly, moderately, marginal and not suitable respectively for tea cultivation. AHP model was used to develop a set of relative weights for each factor and parameter, which were developed by [18, 19]. Preferences for tea cultivation suitable site selection modeling development is done with respect to the evaluation criteria were integrated into the decision model development for the relative importance of each criterion categorized, ranked, and rated according to the reviewed literature and expert level judgments and opinions based on their relative importance using a pair-wise comparison. Relative weights were developed by making a pairwise comparison matrix at each level of the hierarchy [20].

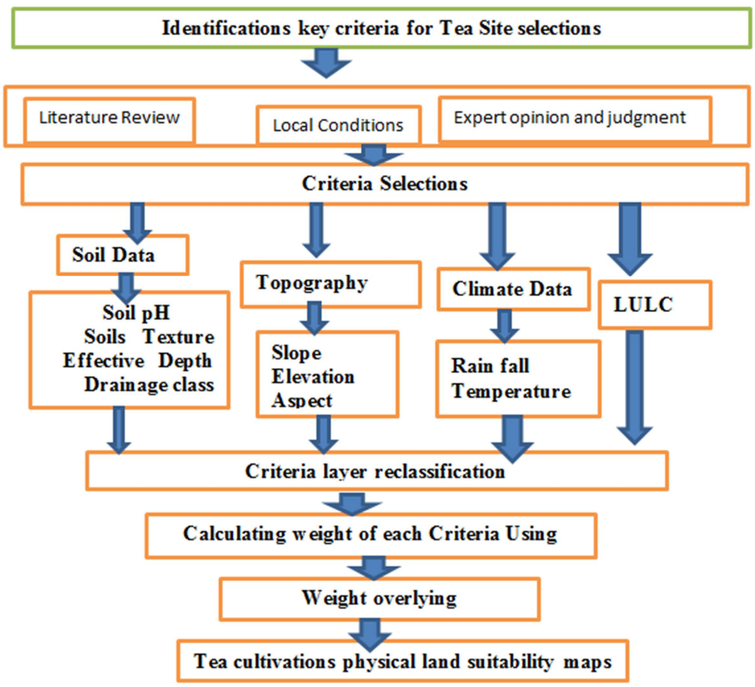

Figure 2. *Flow chart of the methodology for the identification of tea cultivation.*

According to Saaty the intensity of importance is 1 if both parameters are of equal importance, 3 for moderate importance, 5 for strong, 7 for very strong, and 9 for extreme importance, whereas the reciprocals are values for inverse comparison [21] (Table 1 and Table 2).

Table 1. *Scale of rating influence of factors 1 to 9 Scale (Saaty, 2005).*

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Very Strong or Demonstrated Importance	Its dominance demonstrated in practice.
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6 and 8	Intermediate Values	When compromise is needed

Table 2. *Pairwise comparison matrix.*

A	C1	C2	C3	…	Cn
C1	$a11$	$a12$	$a13$	…	$a1$
C2	$a21$	$a22$	$a23$	…	$a2$
…	… … …	… … …	… … …	… … …	… … …
Cn	$a\,1$	$a\,2$	$a\,3$	$a\,3$	a

The pairwise comparison square matrix is defined for main- criteria and subcriteria to determine the weights. The diagonal element of the comparison matrix is 1. Each element of the comparison matrix is divided by the sum of its own column sum to generate a normalized matrix with Formula 1.

$$aij = \frac{aij}{\sum_{i=1}^{n} aij} \quad (1)$$

Each column of the normalized matrix sum is equal to 1. Then, each row sum of the normalized matrix is divided by the matrix order. The average of the sum represents the weights of each criterion in the pairwise comparison matrix (Formula 2).

$$Wi = \left(\frac{1}{n}\right) \sum_{i=1}^{n} aij, (i, j = 1,2,3 \ldots .n) \quad (2)$$

The consistency of the pairwise comparison matrix must be calculated to decide the criteria, comparisons are consistent or not. The assigned preference values are synthesized to determine the ranking of the relevant factors in terms of a numerical value which is equivalent to the weights of each parameter. Therefore, the eigenvalues and eigenvectors of the square pairwise comparison matrix, revealing important details about patterns in the data matrix are calculated [22]. Consistency Index (CI) is one of the methods to define the consistency coefficient of the pairwise comparison matrix. CI is calculated with the consistency index (CI) which was estimated using the Formula 3 [20, 23].

$$CI = \frac{\lambda \max - n}{n-1} \quad (3)$$

Calculating the consistency index depends on the λmax value with Formula 4 (Saaty, 1991). The weight for each factor was calculated through a pairwise comparison matrix and the maximum eigenvalues (λmax) of the normalized matrix were computed [23].

$$\lambda\text{max} = \frac{1}{n} \sum_{i}^{n} = 1 \left[\frac{\sum_{j=1}^{n} aijwj}{wi}\right] \quad (4)$$

The random consistency index (RCI) was used to determine the degree of consistency or consistency ratio (CR) (i.e., CI/RCI). If the CR value is less than or equal to 0.1, the inconsistency is acceptable, or the pair-wise comparison may be revised. Accordingly, weights were assigned relevant to the importance of criteria for tea based on expert ideas and literature [23].

$$CR = \left(\frac{CI}{RI}\right) \quad (5)$$

3. Result

3.1. Reclassification Evaluation Criteria for Tea Land Suitability Classification

The spatial land suitability of tea cultivation was obtained after the analysis of selected evaluation criteria such as soil Data (Soil pH, soil texture, drainage class, and soil depth), topographic factors (slope, altitude and aspect) and climatic factors (temperature and rainfall) (Table 3). Identified evaluation criteria layers were converted into raster data format based on the value of the required attributed column to form each thematic layer and reclassified according to literatures and expert level judgments. Reclassification was used to simplify the interpretation of raster datasets by changing a single input value into a new output value. By using reclassified layers, which results in a generalization and simplification of the original dataset, the input layers were categorized based on the same ranking scheme that can be used to compare and rank the least and most suitable sites.

Table 3. *Suitability criteria and class for production of tea cultivations.*

Parameters	Highly suitable	Moderately Suitable	Marginally suitable	Not suitable
Soil pH (H_2O)	4.5-5	5.1-6 /4- 4.4	6.1-6.5/<4	>6.5/>3.5
Soil texture	Loam, Loamy sand, Sandy, Sandy loam	Clay loam, Sandy clay, Silty clay, Sandy clay loam	Clay	Clay heavy
Soil Depth	>150	100-150	100-50	<50
Drainage	Excessive to moderate	Imperfect	Poor	Very poor
Elevation (m)	< 2000	2000-2500	>2,500	
Slope (percent)	< 13	13–25	25–55	>55
Aspect	[South, southeast, southwest]	[East, west, northeast, northwest]	[North]	-
Temperature (°C)	18-25	26-28 /15-17	29-30/13-14	>30/<13
Rainfall (mm)	1800-2,000	1600-1,800	1000-1600	<1000
LULC	Tea plantation/ Forest	Cropland	Farmland	Building area/water body

3.1.1. Reclassification of Topographic Characteristics of the Study Area

The unclassified basin Altitude ranges from 1,269 to 3,129 m.a.s.l distributed to lowland (1269-15,00 m) with 20.67%, midland (1500-2300m) 79.13% and 0.21% of the area was of highland (2300-3094 m) altitude zone. The reclassified Altitude map shows that about 97.43 and 2.24% of basin has highly suitable and suitable altitude for growth tea plant (Table 4 and Figure 3). This indicated that the altitude does not limit tea plant growth in basin.

Elevation is one topographic feature that affects the growth, yield, and quality of tea crop performance through affecting water distribution and pedogenic process that influence soil properties in different landscape positions [24]. As elevation increases, the growth rates of tea crops especially shoot decreases that contribute towards slower growth at high altitudes. This Topographic feature also leads to improved quality of tea through influencing tea crop tannin content, total sugar, and scavenging effect [25]. Yield and quality of black tea, particularly theaflavin and its fractions, aroma composition and water extract were positively affected by elevation which increased as elevation resulted in higher levels [25, 26]. High elevations leads to higher concentrations of volatile compounds that include analgesic, antianxiety, antibacterial, anticancer, antidepressant, antifungal, anti-inflammatory, antioxidant, anti-stress, and cardioprotective as compared with Low elevations. In addition, teas grown in high elevations were sweeter, floral, honey-like compounds than tea growing in low elevation [8]. Tea is planted on elevated land slopes at 1,900-2,500 m, in addition, it is adaptive in a well-drained land at 1550 and 1800 m Rwanda [27].

Effect of slope tea cultivation; slope affected growth and yield performance indirectly had significant effect on pedogenic process which highly affects solum thickness, thickness of the epipedons, saturated soil moisture, clay content, total N, calcium carbonate content, and exchangeable Mg. Generally, slope affects tea cultivation through affecting physical, chemical, and morphological properties of the soil such as nutrient movement in landscape position and drainage condition of the soil which had significant on tea cultivation [9]. The slope aspect is one topographic feature affecting the growth, yield and quality of tea through affecting microclimate due due to the difference in surface runoff and risk of soil erosion as well as solar radiation difference received on different aspects [9].

Aspects influence the growth, yield, and quality of tea through affecting the hydrological cycle of landform and the rate of soil forming processes, particular affecting the infiltration rate and evapotranspiration by changing the microclimate of the specific area rapid evapotranspiration on southern aspect, and high rate of soil forming processes in the north facing slopes which results in a thicker solum with higher organic matter and denser vegetation were observed due doe to slopes aspects difference [9]. The unclassified slope of basin ranges from 0 to 289% that characterized by Very steep sloping (>0.22%) Steep sloping (2.67%) moderately steep sloping (19.45%), strongly sloping (38.95%), sloping to gently sloping slope (34.2%) and 4.5% of the area was Very gently sloping slope. The reclassified slope map shows that about 65.92 and 27.54% of basin has highly suitable and suitable slope for growth tea plant respectively (Table 4 and Figure 3). However the remaining 6.54% slope of basin has significantly affect tea plant growth in basin.

The reclassified aspects results show that about 35.98 and 51.95%, of basin has highly suitable and suitable aspects for growth tea plant respectively. However the remaining 12.07% aspects of basin faced to North, has significantly affect tea plant growth in basin (Table 4). Aspects are also an important indicator of land suitability as it influences drainage and soil erosion activity in specific areas. Elevation slopes, and aspects of the study area were reclassified in different classes as shown in Table 4 below.

Table 4. *Suitability criteria and area coverage of Elevation, Slope and Aspect for teacultivation.*

Factors	Reclassified	Classification	Area (ha)	Area (%)
Altitude (m.a.s.l)	< 2000	Highly suitable	864056.86	97.43
	2000-2200	Suitable	19845.62	2.24
	2200-2500	Less suitable	2177.14	0.25
	>2500	Not suitable	741.48	0.08
Slope (%)	< 13	Highly suitable	584566.75	65.92

Factors	Reclassified	Classification	Area (ha)	Area (%)
	13– 25	Suitable	244229.13	27.54
	25 – 55	Less suitable	54988.91	6.20
	>55	Not suitable	3044.05	0.34
Aspects	[South, southeast, southwest]	Highly suitable	319046.40	35.98
	[East, west, northeast, northwest]	Suitable	460708.87	51.95
	[North]	Less suitable	107075.94	12.07

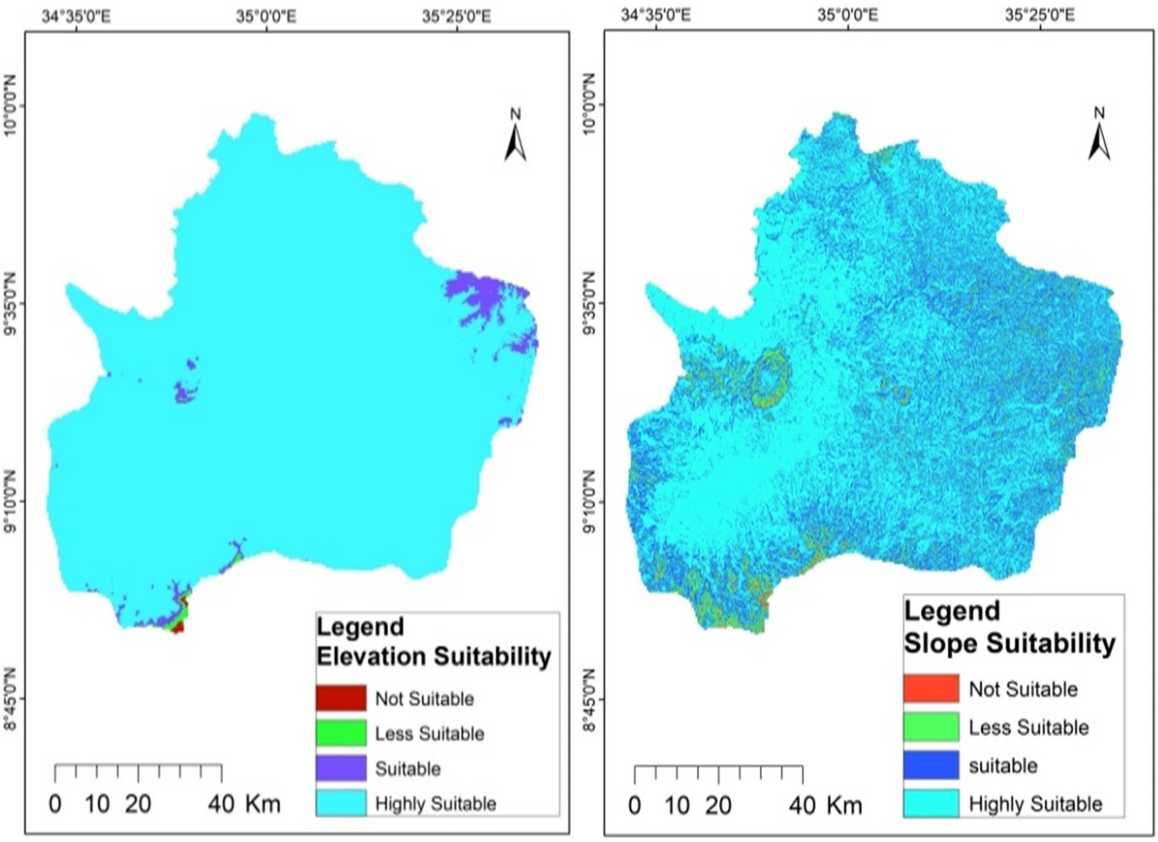

Figure 3. *Elevation and Slope Suitability Maps.*

3.1.2. Soil Factors Reclassification

The unclassified Soil pH of the basin ranges from 3.8 to 7.5 and the reclassified Soil pH map shows that about 35.98 and 51.18% of basin has highly suitable and suitable Soil pH for growth tea plant (Table 5 and Figure 4); this indicated that Soil pH is the most important factors affect tea plant growth in basin. Generally, tea plants require acid soils with soil pH range 4.5-5.5 for growing better [6, 28]. The unclassified Soil texture of the basin ranges from medium texture class to Heavy texture class and the reclassified Soil texture map shows that about 90.14 and 7.83% of basin has highly suitable and suitable Soil texture class for growth tea plant (Table 5 and Figure 4); This indicated that the Soil texture does not limit tea plant growth in basin significantly because Heavy texture class occupied only 2.02% of the basin area. Soil texture such as loam, sand, loamy, sandy clay loam, and clay loam are highly suitable for tea production, whereas clay, silty clay, and silty clay loam are considered as Moderately Suitable for tea cultivation [6, 11].

The unclassified Drainage class of the basin ranges from well drainage class to poorly drained class and the reclassified Drainage class map shows that about 68.4 and 21.46% of basin has highly suitable and suitable Drainage class for growth tea plant (Table 5 and Figure 5); This indicated that the Drainage class limit tea plant growth in basin significantly. However poorly drained Drainage class occupied only 2.03% of the basin area. Tea is grown in well-drained soil drainage class, deep and well-aerated soil with more than 2% organic matter is the optimum soil condition soil for tea growing [6].

The unclassified Soil depths of the basin ranges from very deep to Shallow depths of less than 50 cm and the reclassified Drainage class map shows that about 89.4 and 7.52% of basin has highly suitable and suitable Soil depths for growth tea plant (Table 5 and Figure 5); This indicated that the Soil depths slightly limit tea plant growth in basin significantly. Soil depths of less than 50 cm, soil gravel of more than 50% in top 50 cm of the soil layer and a rockiness of 20% negatively affect tea growth. Tea cultivations do not tolerate prolonged flooding or poorly drained clay soils. This tree grows in a variety of soil types and conditions from fine drained sandy loam soils to heavier clay loam soils. Well-drained to moderately drained soils, deep and well-aerated soil were recommended as optimum soil conditions for tea growth [3, 11].

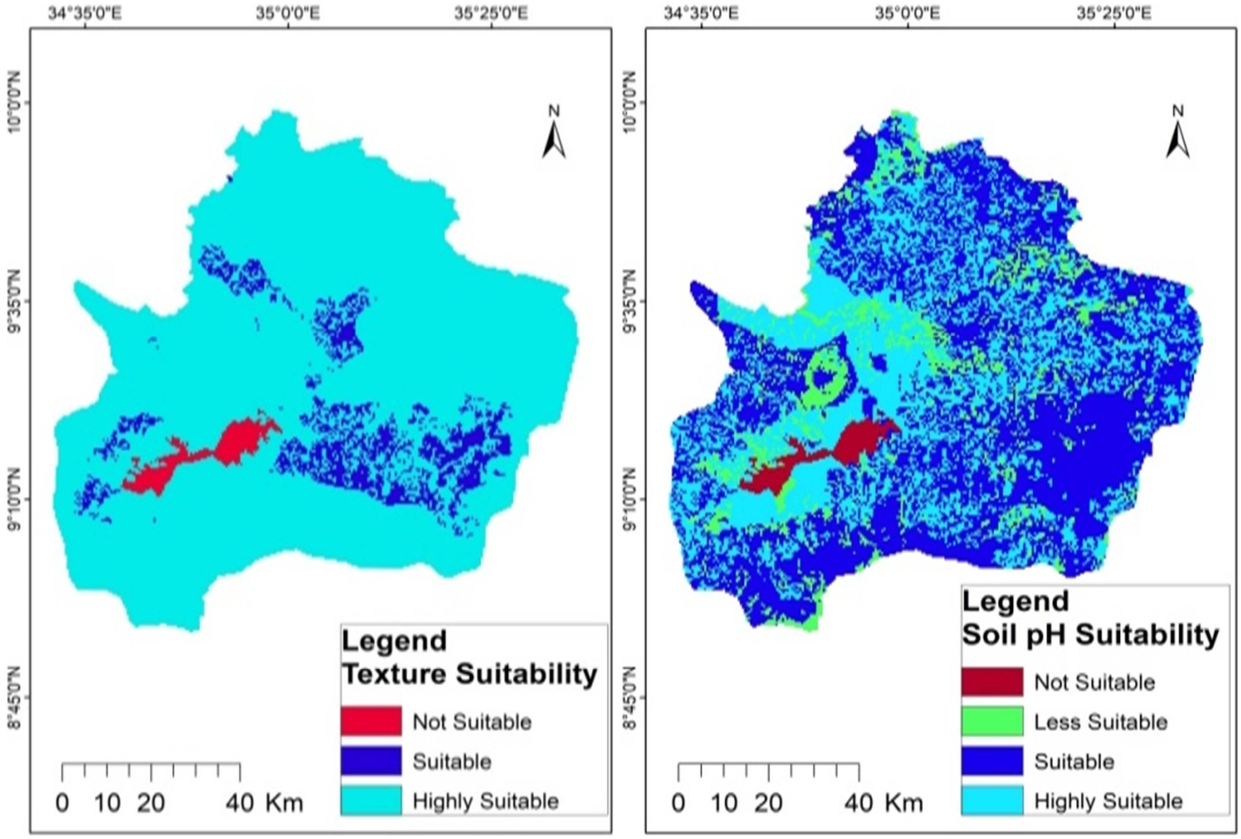

Figure 4. *Soil Texture and pH suitability Map.*

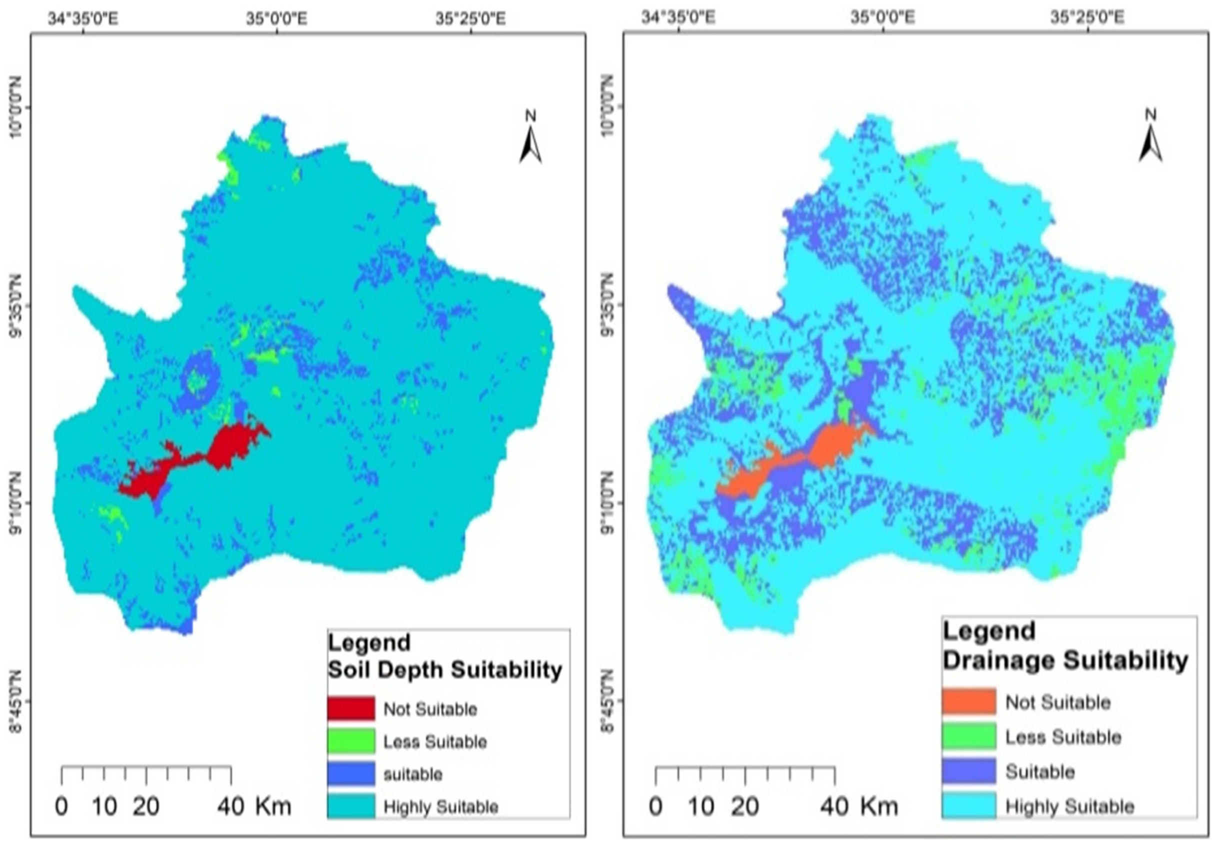

Figure 5. *Soil Depth and Drainage class Suitability map.*

Table 5. *Suitability criteria and coverage of Soil pH, Depth, Texture and Drainage for tea cultivation.*

Factors	Reclassified	Classification	Area (ha)	Area (%)
Soil pH	4.5-5.0	Highly suitable	318916.29	35.98
	5.1-6 /4- 4.4	Suitable	453643.38	51.18
	6.1-6.5/<4	Less suitable	95833.39	10.81
	>6.5/>3.5	Not suitable	18031.13	2.03
Soil Depth	>150	Highly suitable	792628.98	89.40
	150– 100	Suitable	66639.35	7.52
	100 – 50	Less suitable	9297.45	1.05
	<50	Not suitable	18020.73	2.03
Soil Texture	scl, l, cl, sl	Highly suitable	799507.78	90.14
	c, sicl, sic	Suitable	69490.91	7.83
	Heavy Clay	Not suitable	17958.80	2.02
Drainage	Well drained	Highly suitable	606326.82	68.40
	Moderately drained	Suitable	190242.57	21.46
	Excessively and Imperfectly	Less suitable	71938.40	8.12
	Poorly drained Water bodies	Not suitable	17970.94	2.03

3.1.3. Climatic Parameters Reclassification

The unclassified annual rainfall of the basin ranges from 1390.13 to 1845 mm pear year and the reclassified annual rainfall map shows that about 2.48 and 37.31% of basin has highly suitable and suitable annual rainfall for growth tea plant (Table 6 and Figure 6); This indicated that the annual rainfall significantly limit tea plant growth in basin as 60.21% of the basin receive less Suitable annual rainfall tea plant growth. The unclassified mean temperature of the basin ranges from 22.20 to 24.63°C and the reclassified mean temperature map shows that about 100% of basin has highly suitable for growth tea plant (Table 6 and Figure 6); this indicated that mean temperature of the basin is optimum for tea plant growth. The most important climatic factors for tea are temperature and rainfall, as tea growth and productivity are mainly controlled by water availability and temperature [28-30].

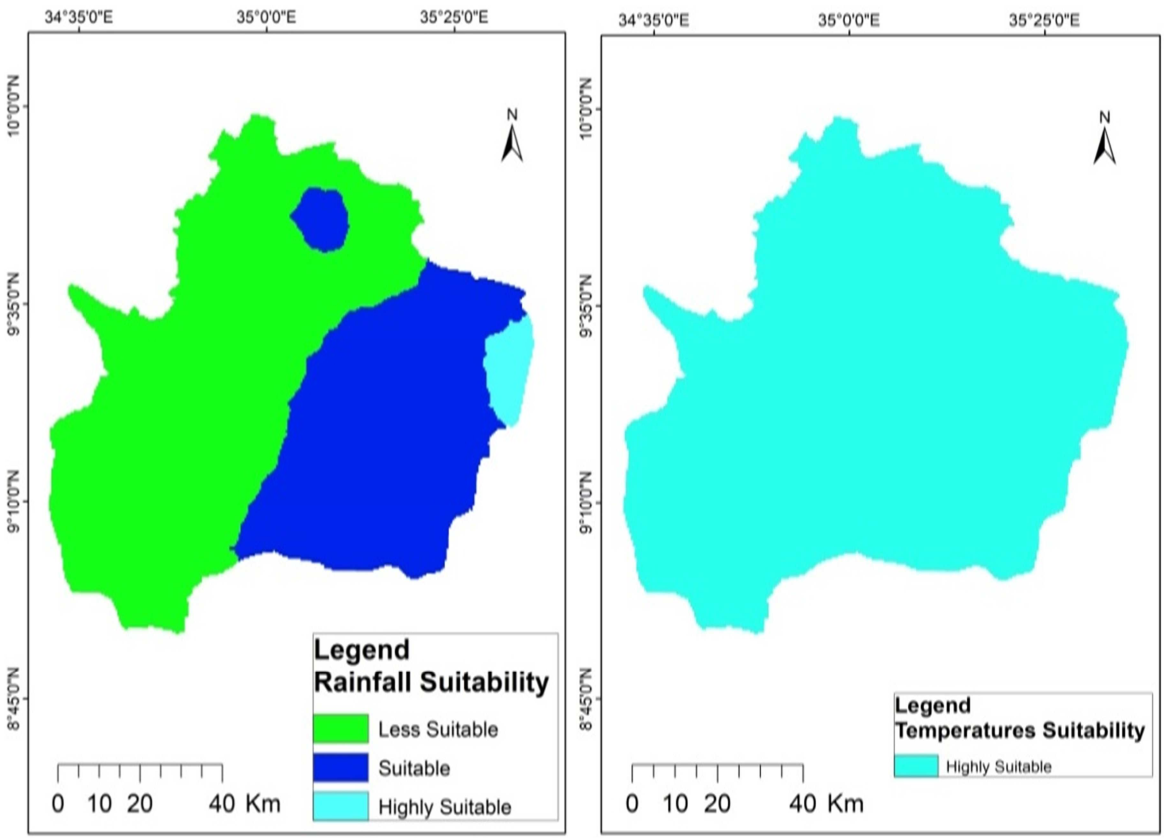

Figure 6. *Rainfall and Temperature Suitability map.*

Its specific requirements are: temperatures ranging from 13-30°C, minimum annual precipitation of 1250 mm [4]. Tea plant requires well-distributed rainfall and the optimum mean temperature in the range of 18 to 30°C that receive an annual rainfall of at least 1200 mm per year [3, 7]. The tea plant requires a minimum rainfall of 1200mmper year, but 2500-3000mmper years are considered optimum [3, 30].

Table 6. *Suitability criteria and area coverage of Rainfall and Temperature for Moringa oleifera cultivation.*

Factors	Reclassified	Classification	Area (ha)	Area (%)
annual rainfall (mm)	1800-2,000	Highly suitable	21962.82	2.48
	1600-1800	Suitable	330917.1	37.31
	1000-1600	Less Suitable	534077	60.21
Mean annual temperature (°C)	22.20-24.63°C	Highly suitable	886665.3	100

3.1.4. Land Use/Land Cover Parameter Reclassification

Land use types are an important factor that affects physical land suitability of tea cultivation. Tea can grow in forest land, shrubs lands, crop land, and grass land. According to [1], Tea plantation, Forest, Farmland lands are the optimal land use types for tea cultivations, whereas building land and water body are not suitable for tea cultivation. Existing tea-growing areas, crop lands, grass land, and forest lands are appropriate land use for tea and urban, rock, bare land, open water, wet lands, paddy, and road were not appropriate land use for tea cultivation [30].

The land use land cover of the study area was classified as forest, crops land, land (moderate to sparse cover of bushes, shrubs, and tufts of grass, savannas with very sparse grasses, trees or other plants), bare land, Built Area and water bodies' area (Figure 6 and Table 7). Current existing land use map of the basin was used to assess the condition of restricted land use for tea growing. Therefore, the existing land use classes were classified as "1" which possible and appropriate land use classes for tea such as existing tea-growing areas, crop land, tree cover and range land use, and "0" was where tea could not be grown (Built Area, bare land, water bodies, and seasonally flooded vegetation). A raster map was then developed. The newly developed land use restriction map was overlaid with the rasterized suitability map. The results of land use land cover suitability analysis indicated that about 869266.9 ha which is the largest part of the current land use of the study area was suitable (98.04%) for tea cultivation (Figure 7). Meanwhile, the remaining 1.96% was not suitable for tea cultivation in Dabus basin due to restricted land use condition that were not suitable of for tea growing.

Table 7. *Suitability criteria and area coverage of LULC for Tea cultivation.*

Factor	LULC Type	Classification	Area (ha)	Area (%)
LULC	Forest, Cropland, Rangeland	Suitable	869266.9	98.04
	Built Area, bare lands, water bodies and wet land	Not suitable	17398.43	1.96
	Total		886665.3	100

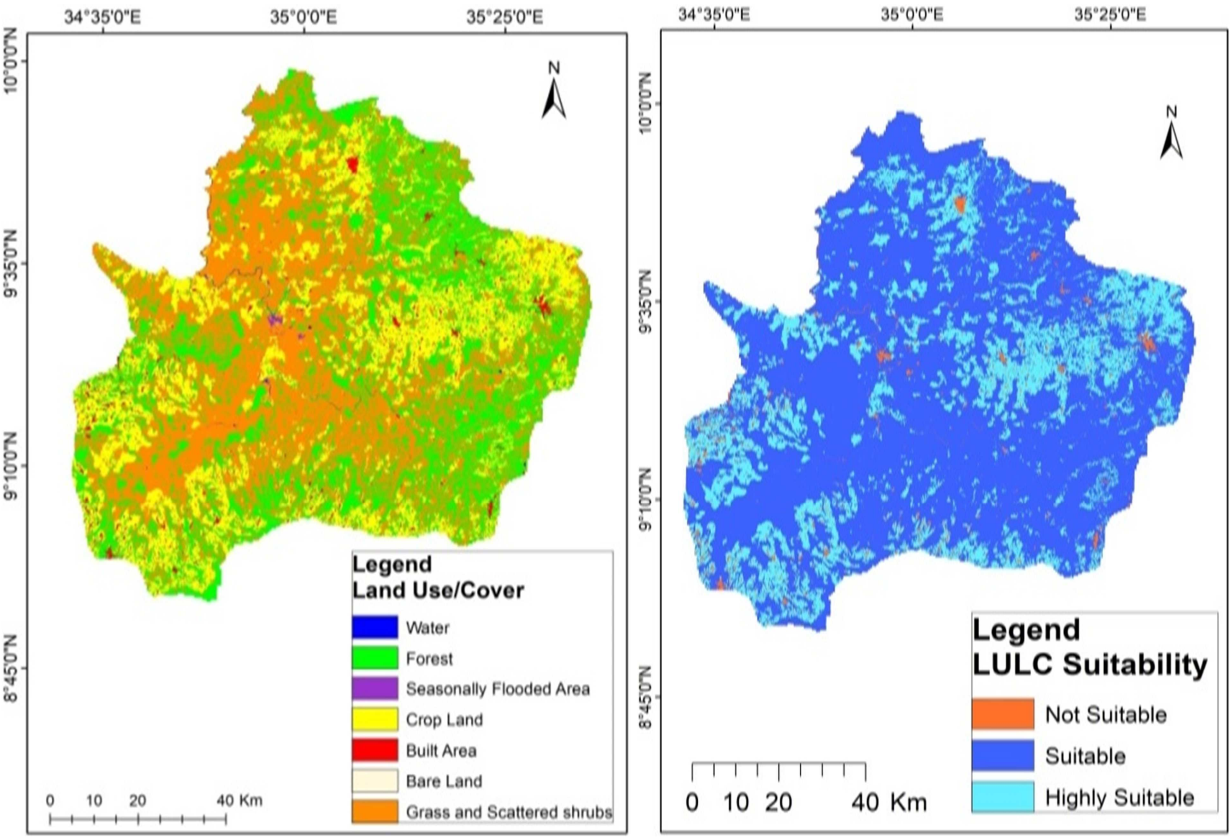

Figure 7. *Land use, land cover, and Land suitability map.*

3.2. Criteria Weights

In this study, the weights for selected parameters/factors were derived using AHP model. Relative importance of factors that affect the growth of tea plants was assigned in pairwise comparison matrix. In the matrix above, diagonal values were assigned in comparison with the column parameters. The values of each parameter were given in accordance with the parameter effect on the growth and productivity of tea plants. Below diagonal values of each parameter are the reciprocal of the above diagonal. After assigning the relative importance values of the above diagonal and the reciprocal of the above diagonal matrix, normalization of each cell value was done (Table 8).

Table 8. *Analytical Hierarchical Process Comparison Matrix.*

Criteria	pH	Temp	RainF	Slope	Altitude	Drainage	Depth	Texture	Aspect	LULC
Soil pH	1	3	0.33	3	3	3	3	3	3	3
Temp	0.33	1	0.33	0.33	0.33	1	0.33	0.33	0.33	0.33
RainF	3	3	1	5	3	3	3	3	3	3
Slope	0.33	3	0.2	1	0.33	3	3	1	0.33	0.33
Altitude	0.33	3	0.33	3	1	3	3	3	3	1
Drainage	0.33	1	0.33	0.33	0.33	1	0.33	0.33	0.33	0.33
Depth	0.33	3	0.33	0.33	0.33	3	1	1	0.33	0.2
Texture	0.33	3	0.33	1	0.33	3	1	1	1	1
Aspect	0.33	3	0.33	3	0.33	3	3	1	1	1
LULC	0.33	3	0.33	3	1	3	5	1	1	1
Sum	6.67	26	3.87	20	10	26	22.67	14.67	13.33	11.2

Normalization can be computed by dividing each cell value by the column total of each parameter. Normalization of the parameters values was performed to generate criteria weights for each parameter. Criteria of each parameter were obtained by summing up the row values of each cell. According to the criteria weight, the elevation parameter is the paramount importance for tea plant growth performance. Consistency ratio of all parameters was computed to check whether the calculated value is correct or not correct. Values of consistency ratio exceeding 0.10 are indicative of inconsistent judgments; whereas values of 0.10 or less indicate a reasonable level of consistency in the pairwise comparison. In this case, the computed CR is 0.083 and this indicates a reasonable level of consistency in the matrix (Table 9). Rainfall has the highest significance indicator value followed by Soil pH, Elevation, land use land cover, aspect and texture, indicating that these are the most important criteria for the land suitability assessment for tea in Dabus basin, however the relatively lowest position was indicated by Temperature, slope, soil drainage class and soils depth for the land suitability assessment for tea in the basin.

Table 9. *Analytical Hierarchical Process (AHP) analysis for the assessment of the relative importance of climate, soil, and topography parameters; normalized matrix results.*

Criteria	pH	Tem	Rain	Slope	Elevation	Drainage	Depth	Texture	Aspect	LU	Total	Influence%
Soil pH	0.15	0.12	0.09	0.15	0.3	0.12	0.13	0.2	0.23	0.27	1.76	18.05
Temp	0.05	0.04	0.09	0.02	0.03	0.04	0.01	0.02	0.03	0.03	0.36	3.42
Rain	0.45	0.12	0.26	0.25	0.3	0.12	0.13	0.2	0.23	0.27	2.33	23.90
Slope	0.05	0.12	0.05	0.05	0.03	0.12	0.13	0.07	0.03	0.03	0.68	6.43
Elevation	0.05	0.12	0.09	0.15	0.1	0.12	0.13	0.2	0.23	0.09	1.28	12.72
Drainage	0.05	0.04	0.09	0.02	0.03	0.04	0.01	0.02	0.03	0.03	0.36	3.42
Depth	0.05	0.12	0.09	0.02	0.03	0.12	0.04	0.07	0.03	0.02	0.59	5.25
Texture	0.05	0.12	0.09	0.05	0.03	0.12	0.04	0.07	0.08	0.09	0.74	6.96
Aspect	0.05	0.12	0.09	0.15	0.03	0.12	0.13	0.07	0.08	0.09	0.93	9.07
LU	0.05	0.12	0.09	0.15	0.1	0.12	0.22	0.07	0.08	0.09	1.09	10.78

Eigenvalue (λmax) = 11.09, Consistency Index (CI) = 0.12, Consistency Ratio (CR) = 0.083.

Final criteria weights were achieved by calculating each criterion's weight by models as indicated in Table 10 and applied to the land-use suitability for tea crops. Rain fall (24%) was highly contributed to the land suitability evaluation than other criteria followed by soil pH (18.05%) and (12.72%). The least impact on the evaluation of land suitability for tea was drainage class (3.42%) and Temperature (3.42%), while land use land cover (10.78%), Aspect (9.07%), soils texture (6.96) and Slope (6.43%) had an intermediate influence on tea land suitability predictions based on the results of normalized matrix assessment on relative importance of climate, soil, and topography parameters.

3.3. Land Suitable for Tea

The analysis of the final weighed results indicated that the basin had potential land for cultivation as the largest part of the land in the basin is occupied by suitable suitability class, about 746718.56ha (84.92) followed by 100421.84ha] (11.42%) of highly suitable land for tea cultivation in this area. Land

Suitability for Tea in Dabus basin comprises highly suitable, suitable and not suitable as shown in Figure 8. Most of the suitable lands found in East part of the basin. This is due to optimum Annual rain fall and dominance of acidic soils Alisols, Acrisol and Nitisols. Highly suitable class occupied only 100428.71ha (11.42%). Most part of the watershed was moderately suitable 746672.35ha (84.92%) for Tea crop production in Dabus basin. The rest area 32193.66ha occupied not suitable due to water logging problems (3.66%). The highest proportion of suitable" area for tea cultivation was found in south and Southwest part of basin, However highly suitable land for tea cultivation land in this area which is 11.42% of the area land cover basin area remains from the area covered by suitable and not suitable mostly consecrated particularly in Najo, Jarso Lete Sibu, Bambo, Gambel, Ayira, Guliso, Boji Darmaji and north of mena sibu districts of west wellega Zone and north of Dale wabera and Dale sadi districts of Qellem wellega Zone, which indicated that Soils, Climate and topographic factors particularly elevation is significant for tea cultivation in this area. The main limitation factors for Tea productions identified in the study area were rainfall, soil reaction, Altitude, Aspect and Land use (Table 9). Rainfall has the greatest positive value of relationship indicator, which means that it has a dominating, causal influence on the other criteria. According to the relationship indicators (Table 9), rainfall, soil reaction, Altitude, Aspect, Land use and slope belong to the cause group, and have a significant influence over the criteria of temperatures, soil drainage, and depth and soil texture. Rainfall in fact influences all other meteorological elements, including temperature, and the present Land use land cover of dabus basin.

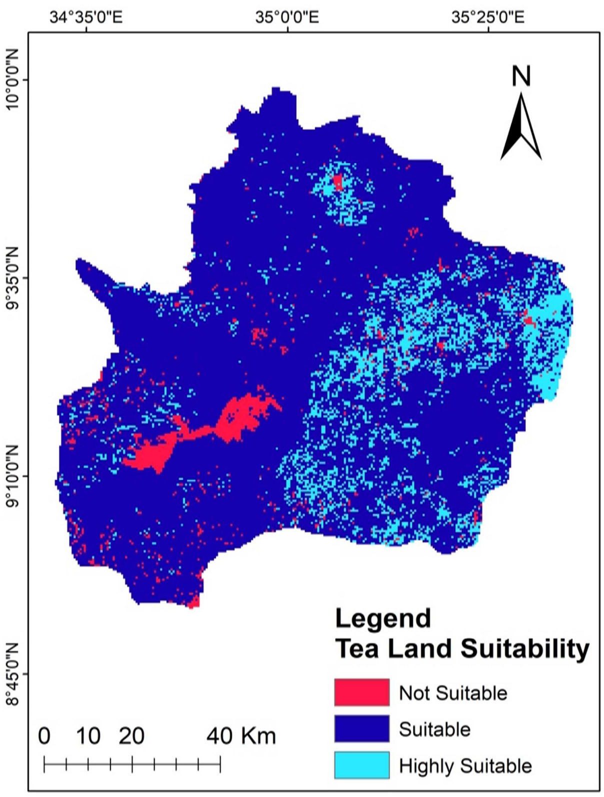

Figure 8. *Final Land suitability map for tea cultivation.*

Table 10. *Land Suitability class and area coverage of dabus basin for tea cultivation.*

Suitability class	Area (ha)	Area (%)
Highly suitable	100428.71	11.42
Suitable	746672.35	84.92
Not Suitable	32193.66	3.66
Total	879287.9	100

4. Conclusion

Investigation of physical land suitability evaluation for tea cultivation is important to generate basic information that critical in Ethiopia, particularly Oromia region. Geographic Information system (GIS) and Analytical Hierarchical Process (AHP) which is applied in this research is a accurate technique for allocating specific land for specific purpose. This examination used topography (elevation and slope), soil type (soil texture and soil pH), climate (rainfall and temperature) and land use land cover parameters were evaluated for suitability analysis for tea cultivation in Dabus basin where soil acidity is severe for crop productions Each criteria evaluation was performed to predict how individual parameter have paramount influence in model. Multicriteria Decision making techniques was employed to assign weights for each parameter in suitability analysis of. The final physical land suitability for tea cultivation was obtained after reclassifying the important selected evaluation criteria of soil topographic and climatic factors. Land suitability for tea cultivation was assessed according to land characteristics and crop requirements. In generally Agricultural land suitability land, suitable class of suitability for tea cultivation covers the major land of study area about 746718.6ha which is 84.92% of the total land and only 100421.8ha about 11.42% are identified as highly suitable for tea planation without significant limitation Whereas 1.6% land is not suitable for tea cultivation due to land use land cover. Tea plantations expansion is recommended as appropriate option of land use management as alternative income generation mechanism that help the poor farmers who are totally depend on fragmented small land for their daily life where soil acidity is severe for crop productions.

Conflict of Interest

The authors declare that they have no competing interests.

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