

# Land Suitability Evaluation for *Moringa oleifera* Tree Using GIS and AHP Techniques in Weyieb Sub Basin, Ethiopia

Getachew Haile Wondimu<sup>1, \*</sup>, Woubalem Abera Ayansa<sup>2</sup>

<sup>1</sup>Natural Resource Directorate, Oromia Agricultural Research Institute, Addis Ababa, Ethiopia

<sup>2</sup>Natural Resource Directorate, Fitch Agricultural Research Center, Oromia, Ethiopia

## Email address:

boqolo@gmail.com (G. H. Wondimu)

\*Corresponding author

## To cite this article:

Getachew Haile Wondimu, Woubalem Abera Ayansa. Land Suitability Evaluation for *Moringa oleifera* Tree Using GIS and AHP Techniques in Weyieb Sub Basin, Ethiopia. *Journal of Plant Sciences*. Vol. 10, No. 3, 2022, pp. 106-118. doi: 10.11648/j.jps.20221003.14

**Received:** March 13, 2022; **Accepted:** April 28, 2022; **Published:** May 12, 2022

---

**Abstract:** *Moringa* has been widely used for centuries due to its medicinal properties, nutritional (healthy diet), environmental protection, animal feed and for the purification of turbid surface water. This study examines and evaluates land unit of Weyieb sub basin for the cultivation of moringa tree based on factors that significantly influence the tree growth and productivity. Land suitability analysis is a basic premise for allocating specific land for specific purpose. The study used integrated Geographic Information System (GIS), Remote Sensing (RS) and Analytical Hierarchical Process (AHP) model and weight function to assign suitability weights to criteria and sub-criteria that affect the plant's growth and a predictive cultivation suitability map. Climatic, topographic, edaphic and land use land cover variables were considered in the model as a significant determinant of moringa tree growth factors. Each of criteria/factor layers were classified (not suitable, less suitable, suitable and highly suitable) based on reviewed literature and expert level judgement. The Analytical Hierarchical Process indicated that the most influential variable determining *Moringa oleifera* cultivation were, Elevation, mean annual temperature, mean annual rainfall, soil pH, soil texture, land use land cover and slope, respectively with 8% consistency index. The model results showed that approximately 15.46% (168,001.87 ha) of sub-basin area has optimal growth conditions, 72.75% (790,395.86 ha) suitable conditions and 11.79% (128,042.27 ha) less suitable conditions for cultivating *Moringa oleifera*. The results also reveal that the application and use of integrated GIS and RS with AHP model with weight function is useful for identification and evaluation of land units for *M. oleifera* cultivation for maximum production output. The results of this study can be useful information for the land-use policy makers and farmers for informed decision-making process regarding the cultivation of *M. oleifera* in Weyieb sub-basin and other watershed area.

**Keywords:** Weyieb Sub-basin, GIS, AHP, Multiple Criteria, *Moringa*, *Moringa Oleifera*

---

## 1. Introduction

An estimated 820 million people did not have enough food to eat in 2018, up from 811 million in the previous year, which is the third year of increase in a row [1]. World Global health index prevails that, GHI (Global health index) scores are worst across Sub-Saharan Africa and South Asia. In 2018, most countries in South Asia and Sub-Saharan Africa received a score within the 'serious' or 'alarming' category. Most countries across Latin America, East & Central Asia, and Eastern Europe had low hunger levels within the 'low' or 'moderate' categories [2]. Beside Hunger, malnutrition

affects one in every three people globally. Forty-five per cent of all deaths in young children can be attributed to poor nutrition. Without proper nutrition, neither individuals nor societies can reach their full potential. The cycle of poverty and inequality continues within families, communities and countries [3]. In Eastern Africa the prevalence of undernourishment was 32 percent between 2014-16 the highest prevalence in Africa. This amounts to approximately 125.8 million, which is an increase from 112.9 million people from 2004-2006 [4]. According to FAO's Global Information and Early Warning System on Food and Agriculture (GIEWS) has indicated that, an alarming food insecurity situation in several areas of East Africa due to severe drought. Which are

severely affected crops and rangelands in central and southern Somalia, south eastern Ethiopia, northern and eastern Tanzania northern and eastern Kenya, and south eastern Uganda. Among the total number of people in need of humanitarian assistance due to drought 5.6 million peoples are in Ethiopia [5]. Food insecurity is expected to significantly deteriorate further. Therefore, to reduce and alleviate hunger and malnutrition rate getting complementary foods using local ingredients and nutrition education are expected to improve community nutritional status. Such as *Moringa oleifera* tree leaves are the most popularly used food for fortification in Africa and South America [6].

Moringa is a part of the plant family *Moringaceae*, and having thirteen different species. Of all of these species, it is *Moringa oleifera* which is the most popular variety across the world. *Moringa oleifera* which is called in Amharic language ‘Shiferaw zaf’ is a plant that is often called the miracle tree, drumstick tree, the ben oil tree, or the horseradish tree. *Moringa oleifera* is native to the Himalayan region countries like; Pakistan, India, Bangladesh and Afghanistan and is found in abundance. This tree is deciduous tree with sparse foliage, fast growing, drought tolerant and grows in a wide range of rainfall and soil conditions [7].

Even though Moringa has been widely used for centuries due to its medicinal properties and health benefits, but it is significantly important for: Food (The leaves, a good source of protein, vitamins A, B and C and minerals such as calcium and iron, are used as a spinach equivalent. They are an excellent source of the sulphur-containing amino acids methionine and cystine, which are often in short supply), Lipids (Oil extracted from the mature pods (oil of Ben) is yellowish, non-drying, good keeping qualities but eventually turns rancid. It is used as a lubricant and in cosmetics and perfumes), Medicine (Moringa seeds are effective against skin-infecting bacteria, potent antibiotic and fungicide terygosperrin, flower of the tree is used as a cold remedy. The gum is diuretic, astringent and abortifacient and is used against asthma. Oil of Ben is used for hysteria, scurvy, prostate problems and bladder troubles. The roots and bark are used for cardiac and circulatory problems, as a tonic and for inflammation. The bark is an appetizer and digestive. The iron content of the leaves is high, and they are reportedly prescribed for anaemia), Apiculture (Its silviculture, involving regeneration by cuttings, coppicing and pollarding, keeps flowering on and off most parts of the year. This provides nectar to honey bees for a long period), Fodder: (Leaves are mainly used for human food and not to any great extent for livestock, but branches are occasionally lopped for feeding camels and cattle) and also used for different services such as erosion and pollution control, soil fertility improvement and intercropping.

Despite that Ethiopia has different variety of biodiversity of traditional useful plants/trees and other unused natural resources like Moringa tree, the people of the country are not getting enough benefits of this vast natural resources of the country. The variety *Moringa stenopetala* leaf or as it is known in Ethiopia ‘Shiferaw’, is very popular vegetable in

Southern Nations and Nationalities and Peoples Regional State of Ethiopia widely planted and used in some part of southern Ethiopia and Arbaminch area. Moringa tree is cultivated mainly in the Zones and Special districts such as South Omo, Wolaita, Dawaro, Gamo Gofa, Kaffa, Sheka, Bench Maji, Bale, Borena, Sidama, Burji, Amaro, Konso and Derashe [8]. Regardless of the economic, environmental as well as medicinal significance of the tree, not much research has been conducted by using Geospatial technique in Ethiopia specifically in the study area at detail scale, in order to obtain benefits of this huge resources of the country.

This study employs Spatial Analytical Hierarchy Process (SAHP) model, Geographical Information System (GIS) and Remote Sensing (RS) to generate detail valuable information in land allocation for *Moringa oleifera* tree production. Spatial Analytical Hierarchy Process model is used to resolve highly complex decision-making problems involving multiple factors. Geographical Information System tools bring new approaches to analyses enabling all factors affecting land suitability to be considered and weighted under one umbrella. The GIS based tools addresses the challenges of suitability analysis based on the collection, processing and analysis of spatial data. This approach is important for suitability analysis based multi criteria rankings and weights assigned to variables that affect *Moringa oleifera* tree production. The objective of the study was to analyze the suitability analysis of *Moringa oleifera* tree species in the area of Weyie sub-basin Bale zone of Oromia in Ethiopia. The key criteria/parameters considered in this study are soil pH, soil texture, elevation, slope, precipitation, temperature and land use land cover (LULC). The results of this study deliver more detail sub-basin level information for the investors, land-use policy makers and farmers for informed decision regarding the cultivation of *Moringa oleifera* in the study area.

## 2. Materials and Methods

### 2.1. Study Area

The total area of Weyie Sub-Basin covered under this study is about 1086436.84 hectares. It is situated totally in East Bale and Bale zone. It totally covers Districts of Dinsho. It also partially covers districts of Agarfa, Goba, Sinana, Gasera, Gindhir, Goro, Dawe Kachen, Dawe Sarar and Rayitu. Its location extent from West to East is 39.59° to 41.68° east and south to north is 5.73° to 7.43° north (Figure 1).

### 2.2. Data Source

In this study, both primary and secondary data were used to prepare factors. Remote sensing data of Landsat 8 satellite imagery for LULC, digital elevation models (DEM) for topographic (Elevation and Slope) factor, soil lab result data (texture and pH) and climate data (temperature and rainfall) were used for the land evaluation and site selection for moringa tree. The Landsat 8 Operational Land Imager (OLI) data with 30m resolution were obtained from the United

States Geological Survey (USGS) Global visualization viewer website with geo-reference to UTM zone 38, WGS 84, and was taken in September 2020. Slope map of the study area were generated using DEM. The soil texture and soil pH map of the study area was obtained from surveyed and lab result of the Oromia Irrigation Development Authority

(OIDA) data. Interpolated mean annual rainfall of 15 metrological stations data for 31 years (1990-2021) were collected from National Metrological Agency of Ethiopia. Infrastructure data (towns, roads and markets) were acquired from both Central Statistical Agency and Ethiopia Geospatial Agency.

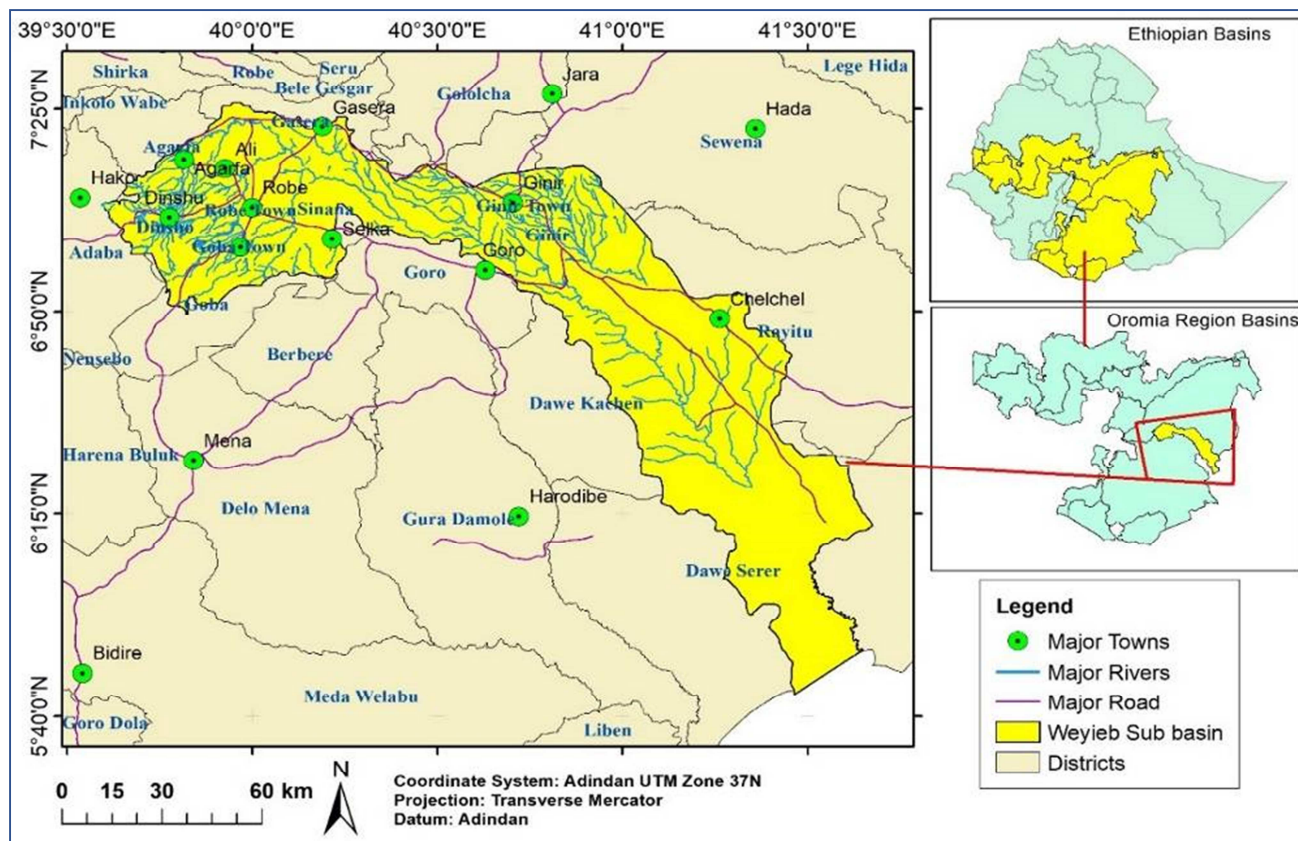


Figure 1. Location map of Weyieb Sub-Basin.

### 2.3. Data Architecture

In this study *Moringa oleifera* site selection model was developed based on the spatial analysis of multi criteria decision making analysis. The process modelling 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.

Geographical information System has good abilities for managing, manipulating and analysis of spatial data, while AHP model based multi-criteria decision analyses was used for preparing methodology for assessing and ranking decision for *Moringa oleifera* site selection model development. Setting all of 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 *Moringa oleifera* suitable site selection is presented Figure 2.

### 2.4. Data Analysis

In this research Analytical Hierarchical Process (AHP)

model for Weighting each criterion and factors. Weighting each criterion is an important step in establishment of the model. In this research Analytical Hierarchical Process (AHP) model was used to develop a set of relative weights for each factor and parameter, which is developed by [9]. Preferences value for *Moringa oleifera* tree suitable site selection modelling development is done with respect to the evaluation criteria were integrated into the decision model development for the relative importance of each criterion. Preferences value is a value assigned to an evaluation criterion that determines and indicates its importance relatively to each and other criteria under consideration. All the criteria were categorized, ranked and rated according to reviewed literature and experts level judgement and opinion based on their relative importance using a pair-wise comparison [10, 11]. Relative weights were developed by making a pair-wise comparison matrix at each level of the hierarchy [12]. 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 [13] (Table 1 and Table 2).

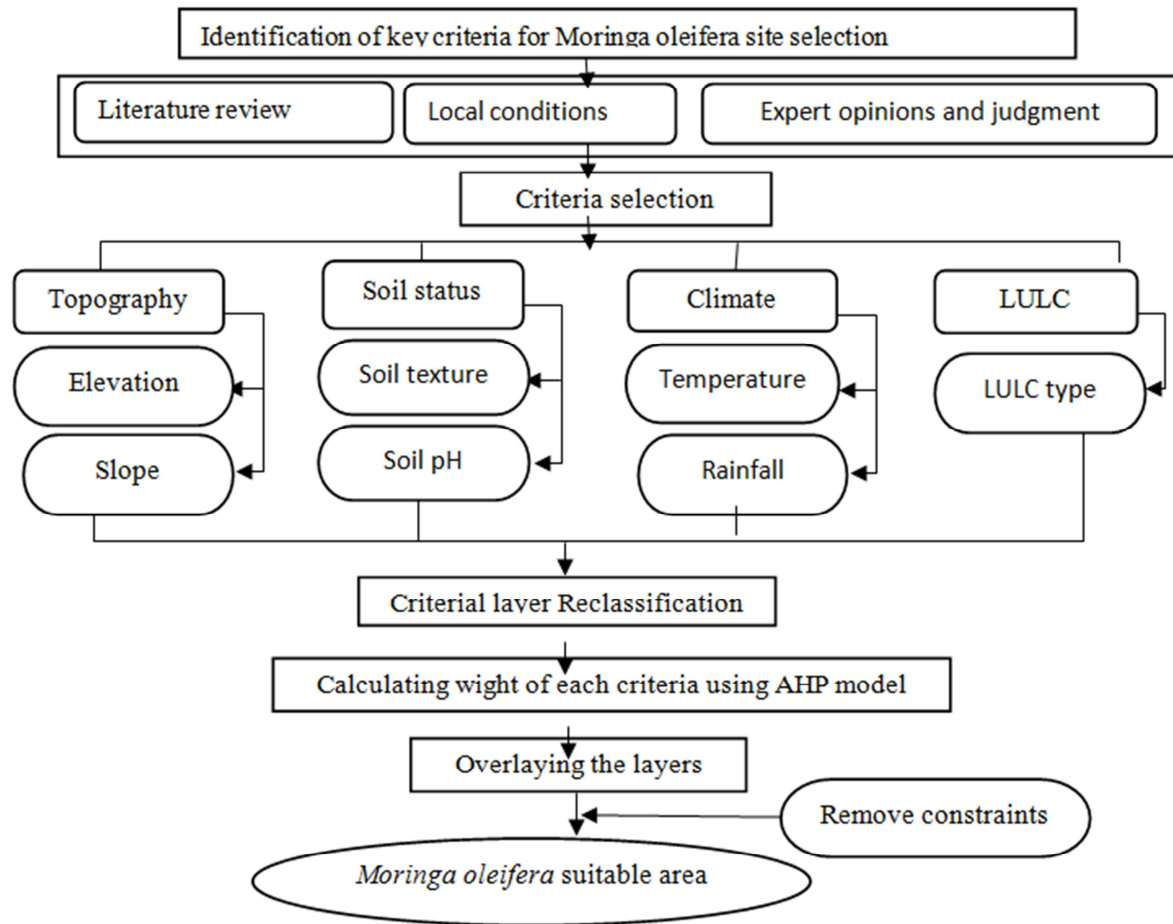


Figure 2. Flow chart of the methodology for the identification of *Moringa oleifera* tree potential zones.

Table 1. Saaty 1 to 9 Scale.

1	3	5	7	9
Equal	Moderately	Strongly	Very strong	Extremely strong

Table 2. Pairwise comparison matrix.

A	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	...	C <sub>n</sub>
C <sub>1</sub>	$a_{11}$	$a_{12}$	$a_{13}$	...	$a_{1n}$
C <sub>2</sub>	$a_{21}$	$a_{22}$	$a_{23}$	...	$a_{2n}$
...	...	...	...	...	...
C <sub>n</sub>	$a_{n1}$	$a_{n2}$	$a_{n3}$	$a_{n3}$	$a_n$

The pairwise comparison square matrix is defined for main- criteria and sub-criteria 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.

$$a_{ij} = \frac{a_{ij}}{\sum_{l=1}^n a_{il}} \quad (1)$$

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 pairwise comparison matrix (Formula 2).

$$w_i = \left( \frac{1}{n} \right) \sum_{j=1}^n a_{ij}, (i, j = 1, 2, 3, \dots, n) \quad (2)$$

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 a 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 [14]. Consistency Index (CI) is one of the methods to define the consistency coefficient of the pairwise comparison matrix. CI is calculated with Formula 3 (Saaty, 1994).

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

Calculating consistency index depends on the  $\lambda_{max}$  value with Formula 4 [15].

$$\lambda_{max} = \frac{1}{n} \sum_{i=1}^n \left[ \frac{\sum_{j=1}^n a_{ij} w_j}{w_i} \right] \quad (4)$$

In addition to this, the Random Index (RI) value must be calculated to determine the consistency index. After

calculating the CI and RI, consistency ratio (CR) can be calculated with Formula 5. In the AHP approach, the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding CR is less than 10%. If CR exceeds 0.1, based on expert knowledge and experience, recommends a revision of the pairwise comparison matrix with different values [16].

$$CR = CI/RI \quad (5)$$

**Table 3.** Suitability criteria and class for production of *Moringa oleifera* tree production.

Parameters	Suitability score			
	Most suitable	Suitable	Less suitable	Not suitable
Soil status				
Soil pH (H <sub>2</sub> O)	6.3-7	4.5-6.3 7- 8.5	-	8.5 < 4.5
Soil texture	Loam, Loamy sand, Sandy, Sandy loam	Clay loam, Sandy clay, Silty clay, Sandy clay loam	Clay	Clay heavy
Topographical status				
Elevation (m)	< 500	500-1,000	1,000-1,500	>1,500
Slope (degree)	< 4	4-12	12-16	>16
Climatical status				
Temperature (°C)	25-30	18-25	10-18	<10
Rainfall (mm)	>1,000	700-1,000	340-700	<340
Land-use/ Land-cover				
Land-use/Land-cover	Cropland, Grassland, Shrubland, Bushland	Vegetation, Dense Forest	Settlement, Swamps, Waterbody	-

### 3. Result

#### 3.1. Parameter Reclassification

Thematic layer reclassification was done on the criteria with their attributes for each of the criteria using the factor criteria as inputs. Slope dataset layers were derived from digital elevation model. Identified thematic layers were converted into raster data format based on the value of the required attributed column to form each thematic layer. All converted layers were reclassified according to reviewed literatures and expert level judgement and also some of them were customized in order to meet location-specific requirements. 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, input layers were categorized based on the same ranking scheme that can be used to compare and rank the least and most suitable sites [17, 18].

##### 3.1.1. Topographic Parameters Reclassification

*Moringa oleifera* tree widely grown in the tropics and sub-tropics. Studies investigated those nutritive values of leaves and green pods is highly influenced by elevation. The concentration of crude protein (CP), phosphorus (P), magnesium (Mg), calcium (Ca), potassium (K), and trace minerals zinc (Zn) and copper (Cu) increases as elevation decreases from mid to lowest elevation [19]. Slope is also an important indicator of land suitability science it influences irrigation, drainage, and soil erosion. Elevation and slopes of the study area was reclassified in four classes as shown in Figure 3 and Table 4 below.

**Table 4.** Suitability criteria and area coverage of DEM and Slope for *Moringa oleifera* cultivation.

Factor	Reclassified	Classification	Area (ha)	Area (%)
Elevation (m.a.s.l)	< 500	Highly suitable	16,959.869	1.562
	500 – 1,000	Suitable	441,726.23	40.658
	1,000 – 1,500	Less suitable	206,559.361	19.012
	>1,500	Not suitable	421,194.54	38.768
Total			1,086,440	100
Slope (Degree)	< 4	Highly suitable	713,684.725	65.69
	4– 12	Suitable	250,083.512	23.019
	12 – 16	Less suitable	48,426.792	4.457
	>16	Not suitable	74,244.971	6.834
Total			1,086,440	100



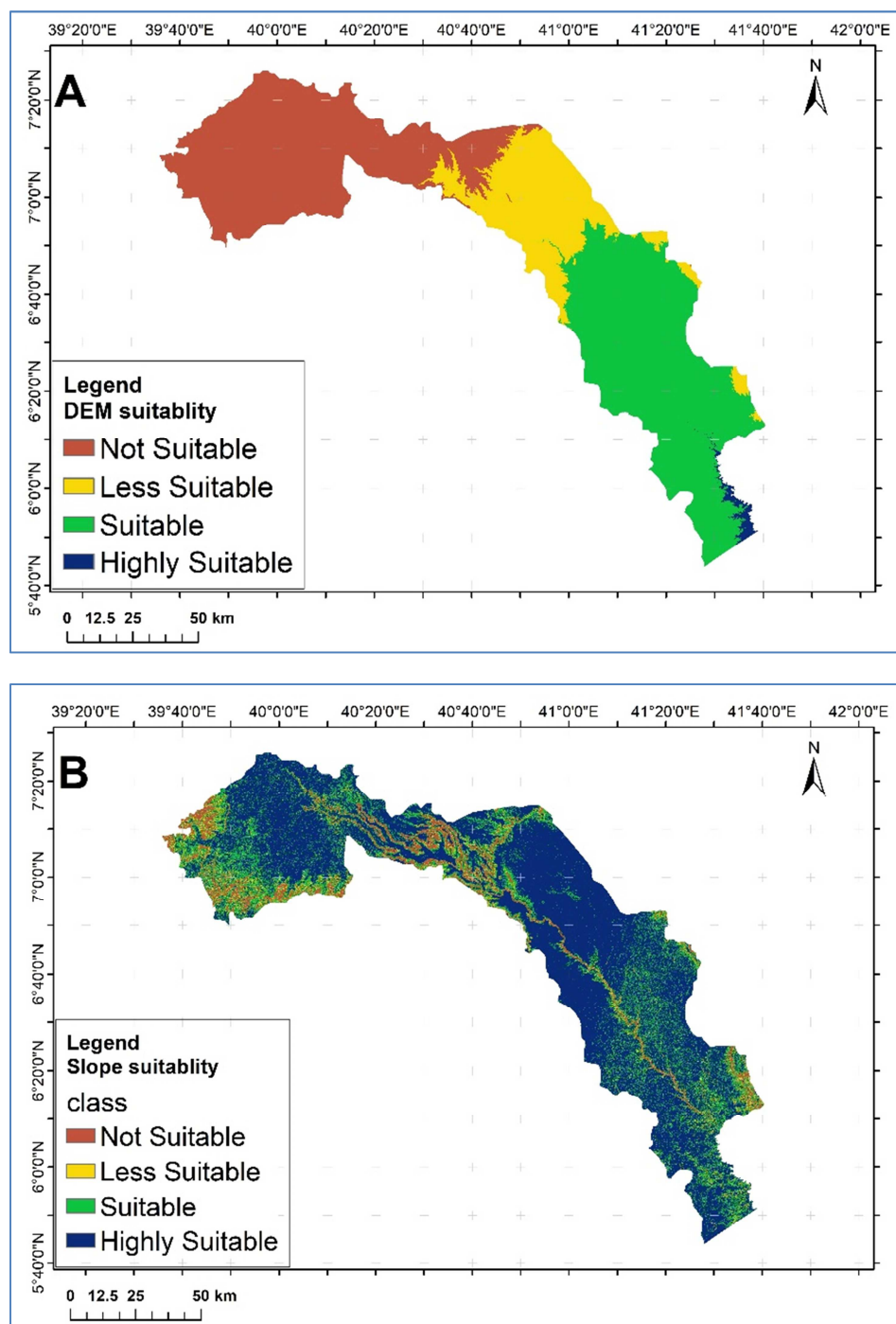


Figure 3. A) DEM suitability class B) Slope suitability class for *Moringa oleifera* cultivation.

### 3.1.2. Soil Parameters Reclassification

The soil type and the soil mapping units of the sub basin were delineated, classified, characterized and mapped using the revised FAO/UNESCO-ISRIC World Reference Base [20] system as shown in figure 4. The soil profile descriptions and auger observations in the field were taken geomorphology, slope geology land cover and previously done soil types and soil units. The soil laboratory result of the samples of Weyie sub basin are briefly described and discussed based on soil genesis, morphological and other

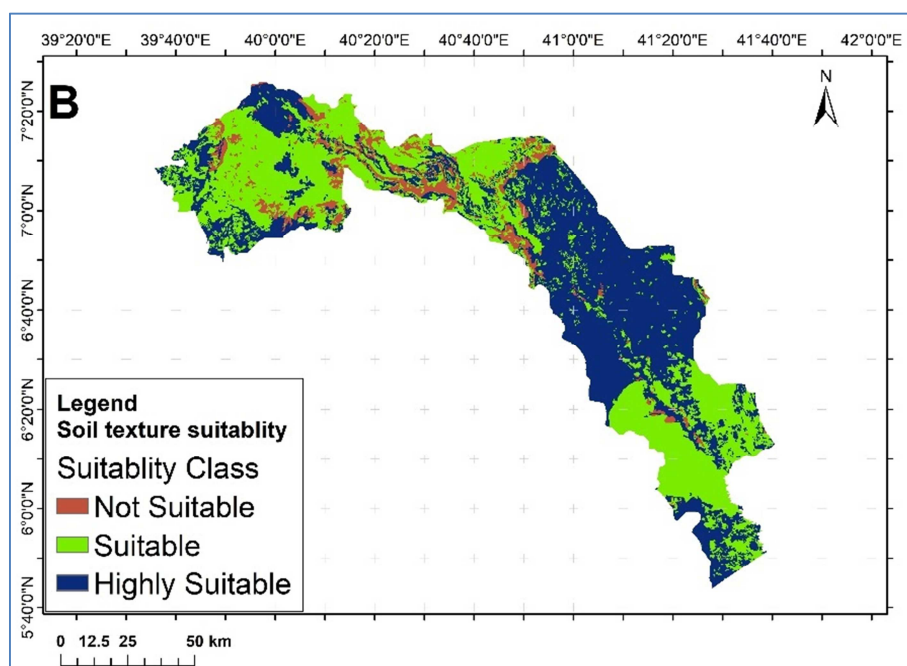
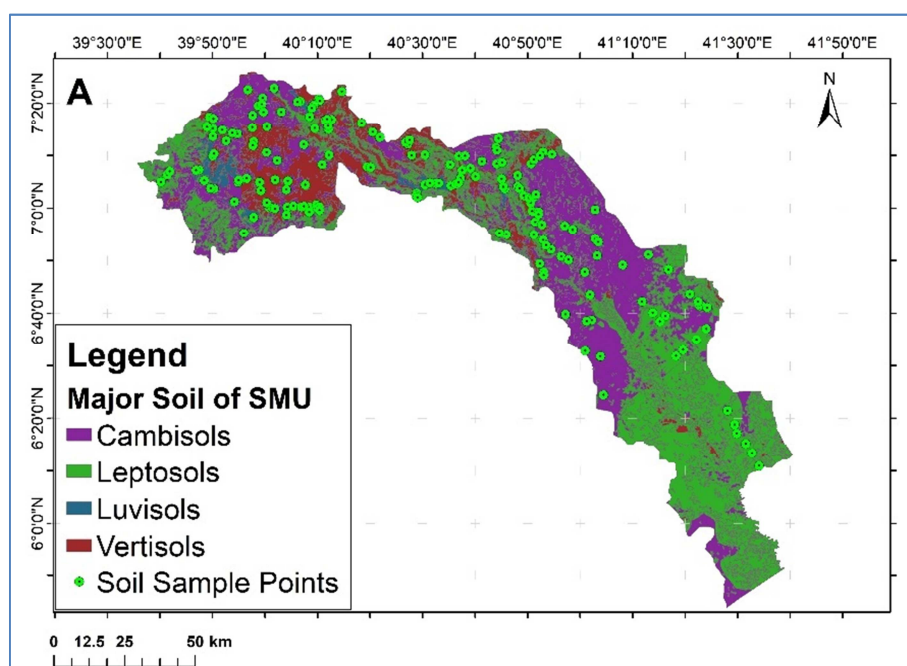
profile and surface characteristics such as effective depth, color, texture, structure, consistency, slope, micro relief, drainage, together with soil chemical properties. Soil pH and texture are selected as the significantly affects the moringa tree growth performance and productivity. *Moringa oleifera* tree does not tolerate prolonged flooding or poorly drained clay soils. This tree grows in variety of soil types and conditions from fine drained sandy loam soils to heavier clay loam soils. Excessively drained, moderately well drained and well drained tired soils are all categorized as well proper to Moringa tree growing. Soil texture types

such as loam, loamy sand, sandy, and sandy loam are highly suitable for moringa oleifera tree production, whereas clay loam, sandy clay, silty clay, and sand clay loam are

considered less suitable [21] and nearly neutral soil pH is more suitable for the cultivation as shown in Figure 4 and Table 5.

**Table 5.** Suitability criteria and area coverage of Soil texture and Soil pH for *Moringa oleifera* cultivation.

Factor	Reclassified	Classification	Area (ha)	Area (%)
Soil texture	Loam, Sandy loam	Highly suitable	509,990.308	46.941
	Sandy clay loam, Clay loam	Suitable	496,219.026	45.674
	Clay, Hard clay	Not suitable	80,230.686	7.385
Total			1,086,440	100
Soil pH	6.3 - 7	Highly suitable	616,130.977	56.711
	5.6 - 6.3 and 7 - 8.3	Suitable	435,855.916	40.118
	5 - 5.6	Less suitable	4,957.58	0.456
	< 5 and > 8.3	Not suitable	29,495.59	2.715
Total			1,086,440	100



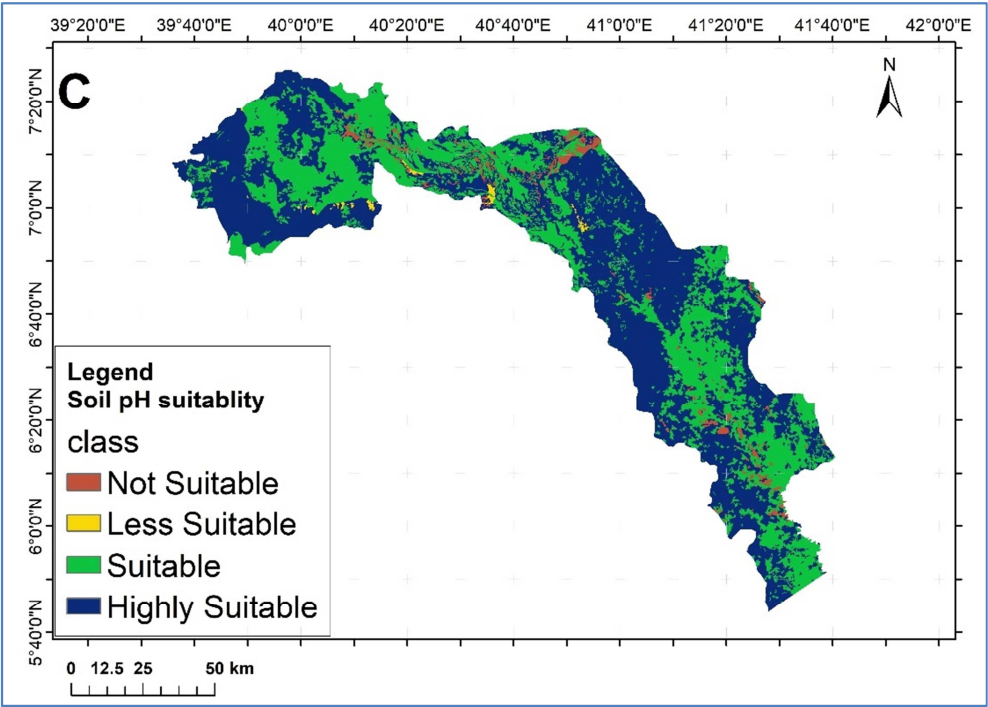
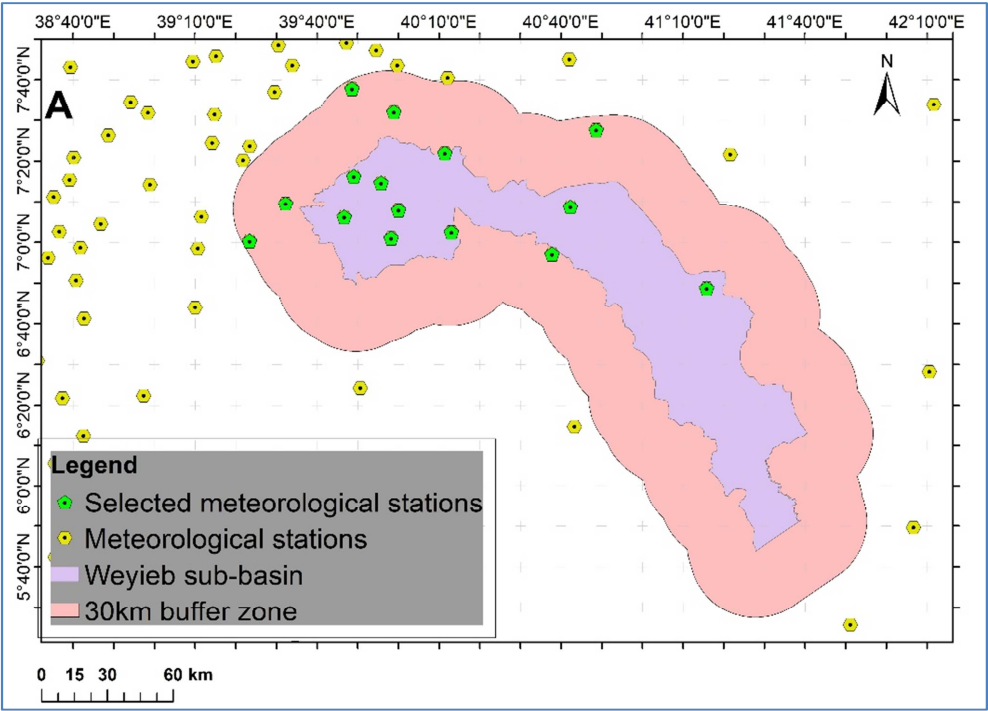


Figure 4. A) Soil Mapping Unit (soil type) and Soil sample location B) Soil texture suitability class C) Soil pH suitability class for *Moringa oleifera* cultivation.

3.1.3. Climatic Parameters Reclassification

Moringa is widely adapted to the tropics and subtropics. It grows well in a temperature range of 25°C to 35°C, but it also tolerates light frosts and temperatures up to 48°C [22]. Moringa is a drought-tolerant tree that can grow well in poor soil conditions or marginal lands with minimal rainfall. The tree grows well in areas receiving annual rainfall amounts

that range from 250 to 1500 mm. This tree is highly influenced by climatic condition. In this study fifteen metrological station data were used that completely found inside the study area and inside 30km buffer zone that influence the sub-basin climate to classify the rainfall and temperature as shown in Table 6 and Figure 5.





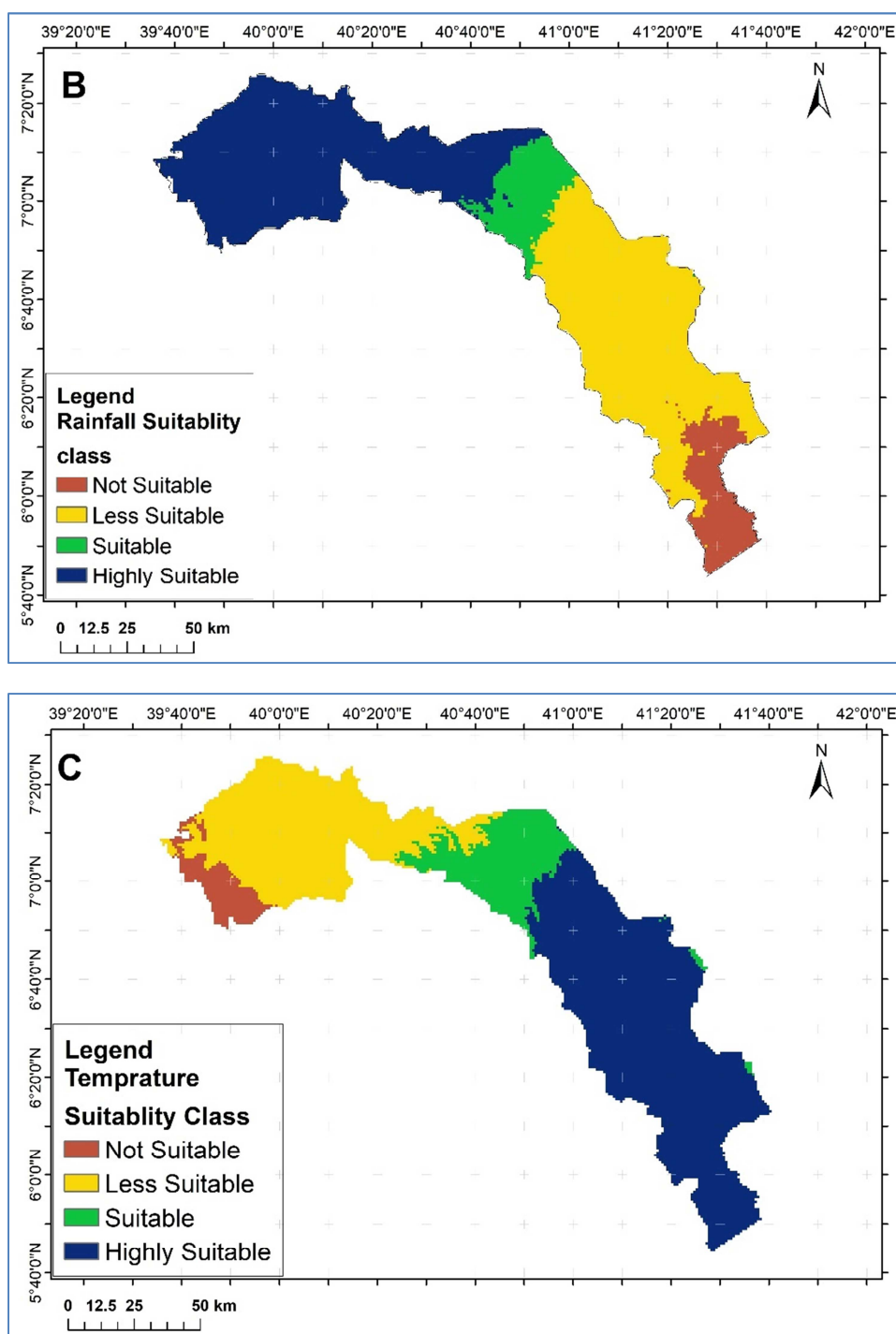


Figure 5. A) Meteorological stations B) Rainfall suitability class C) Temperature suitability class for *Moringa oleifera* cultivation.

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

Factor	Reclassified	Classification	Area (ha)	Area (%)
Mean annual rainfall (mm)	>1,000	Highly suitable	449,252.24	41.351
	700-1,000	Suitable	97,581.345	9
	340-700	Less suitable	444,707.715	40.933
	< 340	Not suitable	94,898.7	8.735
Total			1,086,440	100
Mean annual temperature (°C)	25-30	Highly suitable	557,692.11	51.332
	18-25	Suitable	143,334	13.193
	10-18	Less suitable	333,459.2	30.693
	<10	Not suitable	51,954.69	4.782
Total			1,086,440	100

### 3.1.4. Land Use/Land Cover Parameter Reclassification

Land use types are important factor which affects the growth of the *Moringa oleifera* tree. This moringa oleifera can grow in shrublands, cultivation lands, open lands and forest lands. The level of suitability of each land use is significantly different from each other.

According to [23], open and shrub lands are the optimal land use types for *Moringa oleifera* tree grow. The land use land cover of the study area was reclassified as Afro Alpine, Bushland, Cultivated land, Exposed surface, Forest, Grass land, Plantation, Settlement and Shrubland (Figure 6 and Table 7).

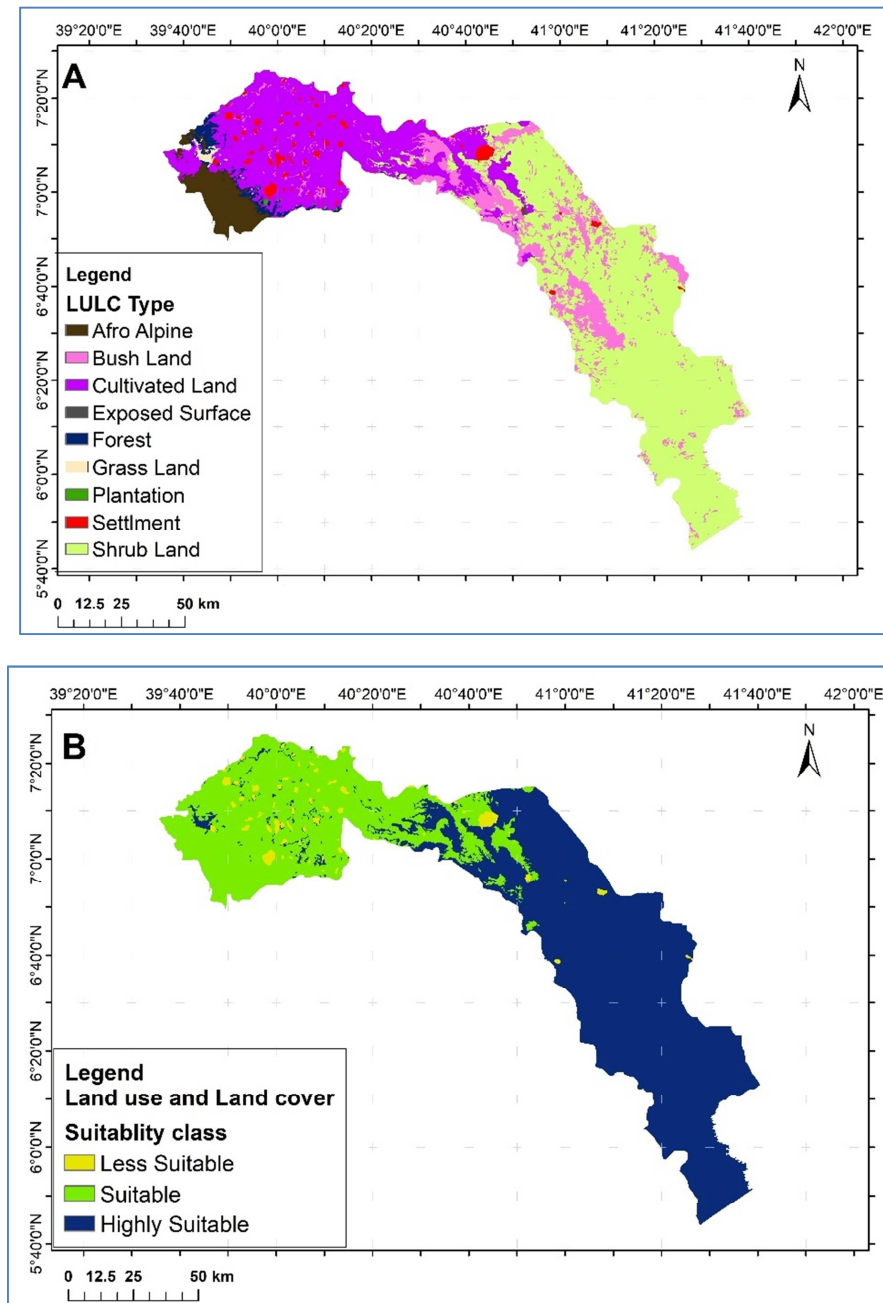


Figure 6. A) LULC type B) LULC suitability class for *Moringa oleifera* cultivation.

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

Factor	LULC Type	Classification	Area (ha)	Area (%)
LULC	Cropland, Grassland, Shrubland, Bushland	Highly suitable	676,999.401	62.314
	Vegetation, Dense Forest	Suitable	388,071.830	35.719
	Settlement, Swamps, Waterbody	Less suitable	21,368.769	1.967
Total			1,086,440	100

### 3.2. Criteria Weights

In this study weights for selected parameters/factors were derived using AHP model. Relative importance of factors that affect the growth of *Moringa oleifera* tree was assigned in pair-wise comparison matrix. In the matrix, above diagonal values were assigned in comparison with column parameter. The values of each parameter were given in accordance with parameter effect on the growth and productivity of *Moringa oleifera* tree production. Below diagonal values of each parameter are the reciprocal of the above diagonal. After assigning relative importance values of above diagonal and reciprocal of above diagonal matrix, normalization of each cell value was done. Normalization can be computed by dividing

each cell value to column total of each parameter. Normalization of parameters value was performed in order to generate criteria weights for each parameter. Criteria of each parameter were obtained by summing up row values of each cell. According to criteria weights value, elevation parameter is paramount importance for *Moringa* tree growth performance. Consistency ratio of all parameter was computed to check whether the calculated value of 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 reasonable level of consistency in the pair-wise comparison. In this case computed consistency ratio is 0.08 and this indicates reasonable level of consistency in the matrix (Table 8).

**Table 8.** Analytical Hierarchical Process Comparison Matrix.

Parameters	Elevation	Temperature	Rainfall	pH (H <sub>2</sub> O)	Soil texture	LULC	Slope	Weight (%)	Criteria weight
Elevation	1	2	3	3	5	6	8	32.9	0.329
Temperature	0.5	1	2		4	5	7	23.2	0.232
Rainfall	0.33	0.50	1	2	3	5	7	16.3	0.163
pH (H <sub>2</sub> O)	0.33	0.33	0.50	1	2	5	7	12.4	0.124
Soil texture	0.20	0.25	0.33	0.50	1	4	7	8.9	0.089
LULC	0.166	0.20	0.20	0.20	0.25	1	3	4.1	0.041
Slope	0.125	0.14	0.14	0.14	0.14	0.33	1	2.3	0.023

#### Weighted overlay

A Weighted Suitability Model was developed in ArcMap for proposing suitable locations for *Moringa oleifera* tree production depending on a number of parameters and based on the principle of Multi-Criteria Evaluation. Such models are used for applying a common measurement scale of values to diverse and dissimilar inputs in order to create an integrated analysis. In the suitability model parameters such as rainfall, temperature, elevation, slope, soil types and land use were reclassified and weighed together to produce overall optimal sites for *Moringa oleifera* tree production.

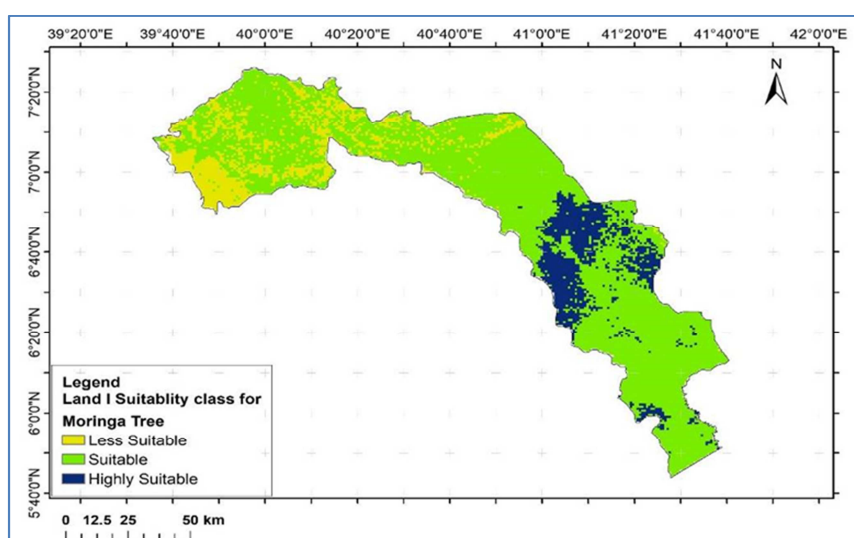
#### Proportions of suitability class

The selected factors overlay result shows that most part of the sub-basing area which is found in Dawa serer, Ginir and

Goro districts is categorized as suitable range. Highly suitable class is found in some parts of central sub-basin which is found in Dawa-kachen and Rayitu districts. However, the norther part of sub-basin in Agarafa, Sinana, Robe, Dinsho and Goba districts are classified as less suitable for *Moringa oleifera* tree production Table 9 and Figure 7.

**Table 9.** Land Suitability class and area coverage of Weyieb sub-basin for *Moringa Oleifera* tree cultivation.

Suitability class	Area (ha)	Area (%)
Highly suitable	168,001.87	15.46
Suitable	790,395.86	72.75
Less suitable	128,042.27	11.79
Total	1,086,440	100



**Figure 7.** Land Suitability Class for *Moringa Oleifera* tree cultivation of Weyieb sub-basin.

## 4. Conclusion

Increasingly, the world is experiencing severe environmental, social and economic problems that are challenging current production systems and the sustainability of all human activities. Indeed, the resources on which these activities depend are significantly imbalanced, land resources, in particular. This has severe consequences for all economic and social activities. Land-use planning is crucial measurement in order to elevate the above mentioned problems. Land-use planning is the process of evaluating land resources and proposing alternative uses of resources in order to improve the living conditions of a society. Land evaluation is the process of the assessment of land performance when used for specified purpose. Geographic Information system (GIS) and Spatial Analytical Hierarchical Process (SAHP) which is applied in this research is a precise technique for allocating specific land for specific purpose. In this study 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 of *moringa oleifera* tree production in Weyie Sub basin where land degradation is severe and food insecure area. Each parameter 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 *moringa oleifera* tree. The result of each parameter suitability analysis like, rainfall, slope and climate show highly suitable for *Moringa* tree grow in study area. Meanwhile, precipitation and land use parameter revealed moderately suitable range of the study area. The parameters such as soil texture and soil pH indicate not suitable for *Moringa oleifera* tree production in Weyie Sub basin. The overall suitability range shows most of the southern part of the study area is categorized as highly suitable. Meanwhile, the northern part of the study area was not suitable for *Moringa oleifera* tree production. In proportion, highly suitable range covers 13.623% (148,001.869 ha). Whereas Suitable and Less suitable class covers an area of 72.751% (790,395.864 ha) and 13.626% (148,042.267 ha) respectively.

## Conflict of Interest

There was no conflict of interest amongst the authors.

## References

- [1] FAO. 2019. The State of Food Security and Nutrition in the World 2018. Building resilience for peace and food security report. FAO, Rome.
- [2] Max Roser and Hannah Ritchie, (2019). "Hunger and Undernourishment". Published online at OurWorldInData.org.
- [3] Deborah Wolfe, (2021). Malnutrition: How it hurts people, societies and the world. World Vision Canada.
- [4] FAO, IFAD, UNICEF, WFP and WHO. (2017). *The State of Food Security and Nutrition in the World 2017*. Building resilience for peace and food security. FAO.. Rome.
- [5] FAO. 2017. Outlook: Drought and Food Security in Eastern Africa Volume 1, Issue 1 – 2017.
- [6] Zongo U., Zoungrana S. L., Savadogo A. and Traore A. S., Food Nutr. Sci 4, 991-997 (2014).
- [7] Kumssa DB, Joy EJ, Ander EL, Watts MJ, Young SD, Walker S. (2015). Dietary calcium and zinc deficiency risks are decreasing but remain prevalent. Scientific reports. 2015; 5: 10974. <https://doi.org/10.1038/srep10974> PMID: 26098577.
- [8] Edwards, S., M. Tadesse, M. Demesse and Hedberg I., (2000). Flora of Ethiopia and Eritrea: Magnoliaceae to Flacourtiaceae Volume 2, Part 1. Addis Ababa University, Sweden 532.
- [9] Saaty T. L., 1977. A scaling method for priorities in hierarchical structures. J Math Psychol 15: 231–281.
- [10] FAO, (2002). World Production of Fish, Crustaceans and Mollusks, etc., by principal species. FAO Fisheries Department Statistical Databases and Software, Yearbook of Fisheries Statistic; [online] Available: <http://www.fao.org>.
- [11] Shimelis s., (2020). Suitability Analysis for *Moringa Oleifera* Tree Production in Ethiopias- Spatial Moedlling Approach.
- [12] Saaty T L (1994). Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process. RWS Publications, Pittsburgh, Pa.
- [13] Saaty, T. L. (2005). Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Costs, and Risks. Pittsburgh: RWS Publications.
- [14] Saaty, T. L. and Vargas, L. G. (1991) Prediction, Projection and Forecasting, Boston: Kluwer Academic.
- [15] Saaty, T. L. (1994) 'How to make a decision: the analytic hierarchy process', Interfaces, Vol. 24, No. 6, pp. 19–43.
- [16] Saaty, T. L. (1980) The Analytic Hierarchy Process, New York: McGraw Hill. International, Translated to Russian, Portuguese, and Chinese, Revised editions, Paperback (1996, 2000), Pittsburgh: RWS Publications.
- [17] Haile, G., and Suryabagavan, K. V. (2018), GIS-based approach for identification of potential rainwater harvesting sites in Arsi Zone, Central Ethiopia. *Modeling Earth Systems and Environment*, 5, 353-367.
- [18] Getachew H. and Dinku S. (2020), Selection of Rainwater Harvesting Sites by Using Remote Sensing and GIS Techniques: A Case Study of Dawa Sub Basin Southern Ethiopia. *Journal of Environment and Earth Science*, 10, 2225-0948.
- [19] Melesse, A., Steingass, H., Boguhn, J., (2012). Effects of elevation and season on nutrient composition of leaves and green pods of *Moringa stenopetala* and *Moringa oleifera*. *Agroforest Syst* 86, 505–518 (2012). <https://doi.org/10.1007/s10457-012-9514-8>.
- [20] IUSS Working Group WRB, (2006): World reference base for soil resources 2006 - A framework for international classification, correlation and communication, Rome, Food and Agriculture Organization of the United Nations.

- [21] Palada, M. C., Ebert, A. W., Yang, R. Y., Chang, L. C., Chang, J., Wu, D. L., 2017. Progress in research and development of moringa at the World Vegetable Center. In: Acta Horticulture.
- [22] Pokhrel, C. P., Timilsina, A., Yadav, R. K. P., & Khanal, R. (2016). Moringa Oleifere: A potential cash crop in Nepal. In International Symposium on Healthy Society & Healthy World. Kathmandu, Nepal (pp. 33-41).
- [23] Palada, M. C. (1996). Moringa (*Moringa oleifera* Lam.): A versatile tree crop with 351 horticultural potentials in the subtropical United States. HortScience, 31, 794–797.