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# GIS-based Land Suitability Analysis for Mung Bean Production in Arba Minch Zuria District, Gamo Zone, Southern Ethiopia

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***Abstract***

*Land suitability analysis is of vital importance to maximize crop productivity of farming households. This study has aimed to investigate land suitability for mung bean production using the Analytical Hierarchic Process model. Four main criteria (soil, climate, land use land cover and topography), and 8 sub-criteria (slope, soil texture, soil depth, soil pH, soil cation exchange capacity, temperature, rainfall, and soil drainage) were selected to analyze land suitability. The sub-criteria were reclassified into 5 suitability levels: high, moderate, marginal, not suitable, and permanently not suitable. The Analytic Hierarchy Process (AHP) was used to determine the perceived weights that each criterion and sub-criteria carry. The land suitability for mung bean production during the October-November-December (OND) months showed by the final map was 32% (high), 26% (moderate), and 42% (marginal). 14%, 62%, and 24%, respectively were the suitability levels designated as high, moderate, and marginal during the January-February-March (JFM) months. Due to the prevalence of the climatic conditions, topography, spatially low lands, and fertile soil, the production of mung bean during the OND months was high. The major factors that impede higher land suitability during the JFM months include rainfall, soil, poor drainage, and slope. The production of mung bean is important in the agricultural sector for many benefits like human nutrition, local market, animal feed, export commodities, and soil fertility maintenance. So, stakeholders such as the district agricultural office, and governmental, and non-governmental actors should encourage farmers to produce more in conducive seasons and relieve food security shortfalls and livelihood problems in the entirety.*

**Keywords**: Land suitability; Geographic Information System; Analytical Hierarchic Process; Mung bean

# 1. INTRODUCTION

## 1.1 Background

Land Suitability Analysis (LSA) is a GIS-based process applied to determine the suitability of a specific area for considered use. It reveals the suitability of an area regarding with both suitable and unsuitable intrinsic characteristics (Jafari & Zaredar, 2010). Land assessment measures the degree of land usefulness for potential land use by land requirement and quality. The land evaluation process for a specified purpose in the light of land performance involves the execution and interpretation of surveys and studies of landforms, soils, vegetation, and climate. Besides, other aspects of land are duly considered to identify and make a comparison of promising kinds of land use in terms of applicability (FAO, 1981). Furthermore, the process of characterizing and assessing specific land for potential use needs suitability analysis for a defined implementation. In this regard, lots of data are required for the site suitability assessment of agricultural development. The assessment of a large amount and variety of physiographic, climatic, and edaphic conditions are among such data. Explicitly, the climatic characteristics (rainfall and temperature), internal soil conditions such as depth, salinity, texture, moisture, and natural fertility as well as, external soil conditions embracing slope, accessibility, and flooding are widely addressed with this concern ( Pramanik, 2016).

A Geographic Information System (GIS) is a powerful tool for storing, retrieving, processing, and analysing multi-source spatiotemporal data needed for spatial planning and management (Kamkar et al., 2014). Geographic information system fundamentally provides an excellent medium for data integration and a basis for a spatial decision-support as well as analytical system (Cowen, 1998). A spatial decision-support system can be based on the primary functions of a GIS, but these basic functions need enhancements for analysis and modeling. Specifically, this system also plays important role in identifying a conducive area for crop varieties to be produced by farming households. Accordingly, designating suitable land for Mung bean production demands certain factors and additional procedures that dictate the productivity of the crop. With this respect, the Analytic Hierarchy Process (AHP) is commonly employed and determines the weight of influence in certain land use based on pair-wise comparisons of parameters per the relative importance (Akbulek & Cengiz, 2009) of weights on each criterion before determining the final score (Bunruamkaew & Murayama, 2011).

Mung bean is a native crop to the Indo-Burma region including India, Burma, Thailand, and Indonesia that produce almost 90 percent of the world's production. Mung bean (Vigna radiata L.) is one of the most important pulse crops grown in tropical to sub-tropical areas around the world and used for multipurpose (Chadha, 2010; Kumar et al., 2012; Kaysha et al., 2020). The crop, with its very origin in Southeast Asia, is often grown with limited rainfall by utilizing residual moisture in the soil or as the main crop with a short rainy season and on a wide range of soil types. The green gram's (it's alternative name) origin can be traced to the Indian subcontinent where it was naturalized as early as 1500 BC. Later on, the cultivated green gram was established in Africa, southern and eastern Asia, America, and West Indies. It is currently widespread across the Tropics (Mogotsi, 2006; Swaminathan et al., 2012; MOA, 2014). Mung beans are categorized as lowland legume crops and are predominantly grown in the warmer and low land parts of Ethiopia. In Shewa, Harerghe, Illubabur, Gamo, Gofa, Gondar, and Tigray and in southern Ethiopia such as Konso, South Omo zone, Wolaita zone (Humbo district) as well as Konta have been producing Mung bean to supplement their protein needs at rainfall scanty periods. The SNNPR average productivity was reported to be far below its potential (CSA, 2018; Fekadu et al., 2021).

In Ethiopia, agricultural land suitability analysis is very important since agriculture supports 60%, 27%, and 13% of production from crops, livestock, and other agricultural areas of production (Gebre-Selassie & Bekele, 2010 as cited in Teshome & Lupi, 2018). Land suitability analysis predicts how the land would perform if used according to each of the proposed systems (Rossiter & Armand, 1994). In the country, as in many developing countries, current land use practices are not based on suitability analysis; therefore, there is an urgent need to use land in the most rational and possible way (Assefa, 2015). In the country, the Mung bean is recently introduced and grown in a few areas of North Shewa lowlands and South Wollo (Kallu) areas of the Amhara Regional State (MOA, 2014). The mung bean is commonly known as '*masho'* in Amharic. Mung bean is a legume cultivated for its edible seeds and sprouts, but can be used as a green manure crop and as forage for livestock. It is presently taking root in the Oromia, Southern Nations, Nationalities and People's Region (SNNPR), Tigray, and Benishangul Gumuz Regions (Mogotsi, 2006; MOA, 2014). Ethiopia's mung bean export trend has grown slightly mainly due to the Ethiopian Commodity Exchange which installed the mung bean as the sixth commodity to be traded on its floor since 2014. The export volume has increased by more than tenfold while the corresponding export value also rose from less than 2 million to more than 27 million USD between 2004 to 2013 (Habte et al., 2018).

The combination of GIS and AHP approach are suitable for so many assessments especially, for the selection of waste disposal site selection and urban settlement areas. In this research, GIS-based land suitability analysis was designed and developed for Mung bean production using the AHP model. Various research works have been contributed by scholars about land suitability analysis on mung bean production in different countries (Wondim et al., 2020; Hossen et al., 2021; Mequannit & Tefera, 2021). Even though, there was no research work conducted previously on land suitability analysis of Mung bean production using the GIS-based AHP approach in the Arba Minch Zaria district. This research work, hence, has aimed to 1) develop a spatial model for land suitability evaluation for Mung Bean cultivation using GIS tools 2) investigate the status of mung bean production) identify suitable land for mung bean production using the GIS-based AHP approach, and 3) examine the biophysical factors affecting the mung bean production in the study area. Among the research questions responded while achieving the intended objectives included: which part of the study area is suitable for mung bean production? what is the present status of mung bean production? and which biophysical factors affect the productivity of mung bean in Arba Minch Zuria district? The study was believed to be significant to identify a conducive land for mung bean production and contributing to relieving the problem of food security among the wider challenges of the community across the study district. Across the study areas particularly, and similar other areas, the study has crucial contributions for the current states demanding strong investigation of land suitability for the considered and other crops in light of changing climate where food security especially at a household level is at problematic situation with rapidly increasing population.

## 2. MATERIALS AND METHODS

### 2.1 Description of the study area

Arba Minch Zuria district is one of the districts located in the the former Southern Nations, Nationalities, and Peoples' Region of Ethiopia. It is a part of the former Gamo zone located in the Great Rift Valley area of Ethiopia. The district is bordered on the south by the Dirashe special district, on the west by Bonke district, on the north by Dita and Chencha districts, on the northeast by Mirab Abaya, on the east by the Oromia Region, and on the southeast by the Amaro Special district. Arba Minch Zuria is found in South Nation Nationalities and People's Regional State, in Gamo Zone at a distance of 490 km from Addis Ababa, and 275 km from Hawassa, the regional Capital. Its astronomical location is 05°40' N latitude to 06°10' N latitude and 37° 20' E longitude to 37° 40' E longitude. The study district also includes portions of the two lakes and their islands, namely, Abaya and Chamo. Where the Nechsar national park is located between these lakes (Fig. 1). Based on the 2007 census by the CSA, the district has a total population of 185,302, of which 92,680 were men and 92, 622 were women; none of its population is urban dwellers. With an estimated area of 1001 km², Arba Minch Zuria has an estimated population density of 138 people per square kilometre (CSA, 2017).

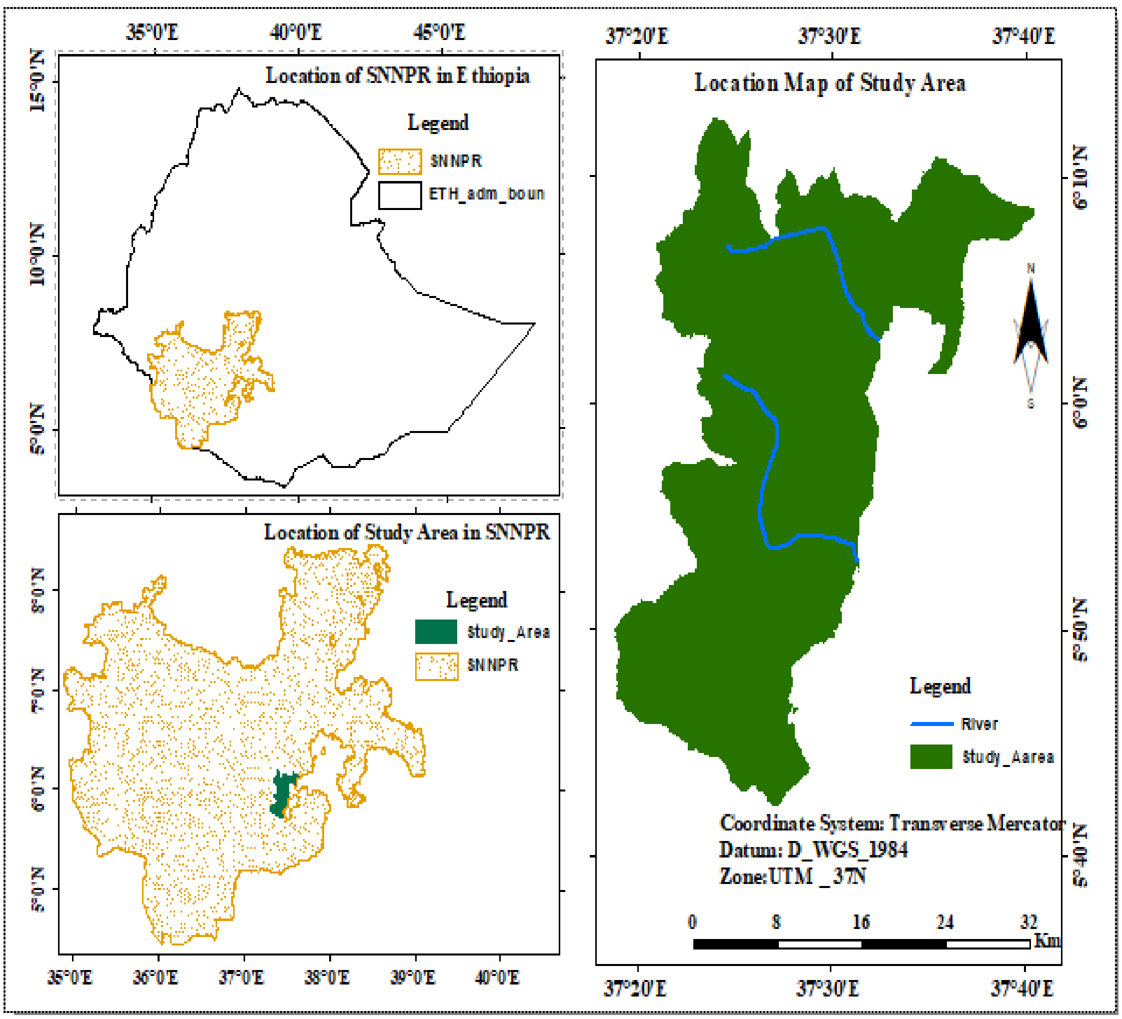


Fig. 1 Location map of the study area

On the bases of temperature and rainfall data which was obtained from the National Meteorological Services Agency (NMSA) in 2021, the average monthly temperature of the study area ranges from 24.7°C in April to 22.8°C in December. The mean monthly maximum and mean monthly minimum temperature of the study area range between 32.8°C in February to 27.4°C in June and 18.7°C in March to 15.6°C in December, respectively. The amount of rainfall ranges from 14.8 mm in January to 145.2 mm in April. The mean annual total rainfall of the study area is about 1129.5 mm. According to the data collected from the NMSA, the study area has two rain seasons. The main rain season is April, May, and June which has totally 347.9 mm and the second highest monthly rainfall is recorded in September, October and November with a total of 327.6 mm. The topography of the Arba Minch Zuria district is described as plain, gentle sloppy lands, and mountains. The eastern part of the study area is dominated by flat-lying topography, while the northern and northwestern parts are endowed with high altitudes. The slope ranges between 20% and 70% which has resulted in massive soil erosion. Its elevation ranges from 1170 meters above sea level around the eastern part to 3000 meters above sea level in the northwestern part. The study area consists of seven soil types on the basis of the Food and Agricultural Organization (FAO) soil classification system (Table 1).

Table 1:

Arba Minch Zuria district major soil groups

| S. No | Major soil group | Area (ha) | % |
|---|---|---|---|
| **1** | Acrisols | 28237.74 | 29.2 |
| **2** | Vertisols | 21425.3 | 22.14 |
| **3** | Xerosols | 12356.15 | 12.8 |
| **4** | Fluvisols | 9468.35 | 9.8 |
| **5** | Solonchaks | 8666.5 | 8.95 |
| **6** | Nitisols | 7290.41 | 7.5 |
| **7** | Leptosols | 6904.2 | 7.13 |
| **8** | No data | 1460.81 | 1.5 |
| **9** | Water | 952.47 | 0.98 |
| **10** | Total | 96761.93 | 100 |

Concerning the land use land cover status, the satellite image analysis shows that a large proportion of the land in the Arba Minch Zuria district (45%) is covered with agricultural lands. The study area involves six major types of land use/ land cover. These are agricultural land, settlement, forest, bare lands, bushlands, and water bodies. It is dominated by farmlands accounting for 45% of the total area. The second dominant land use land cover type is bushland area 16%, which includes short trees and shrubs found in different parts of the study area. The study area also includes settlement areas that account for 11%, small *Kebele* settlements, and dense forest covering 8% of the total area. Water bodies 2% and major rivers in the study area and bare lands account for 18% found in different parts of the district, which are left fallow. Annual crop production is practiced at the feet of the hills on lands that are not allocated for mung bean production (Fig. 2).

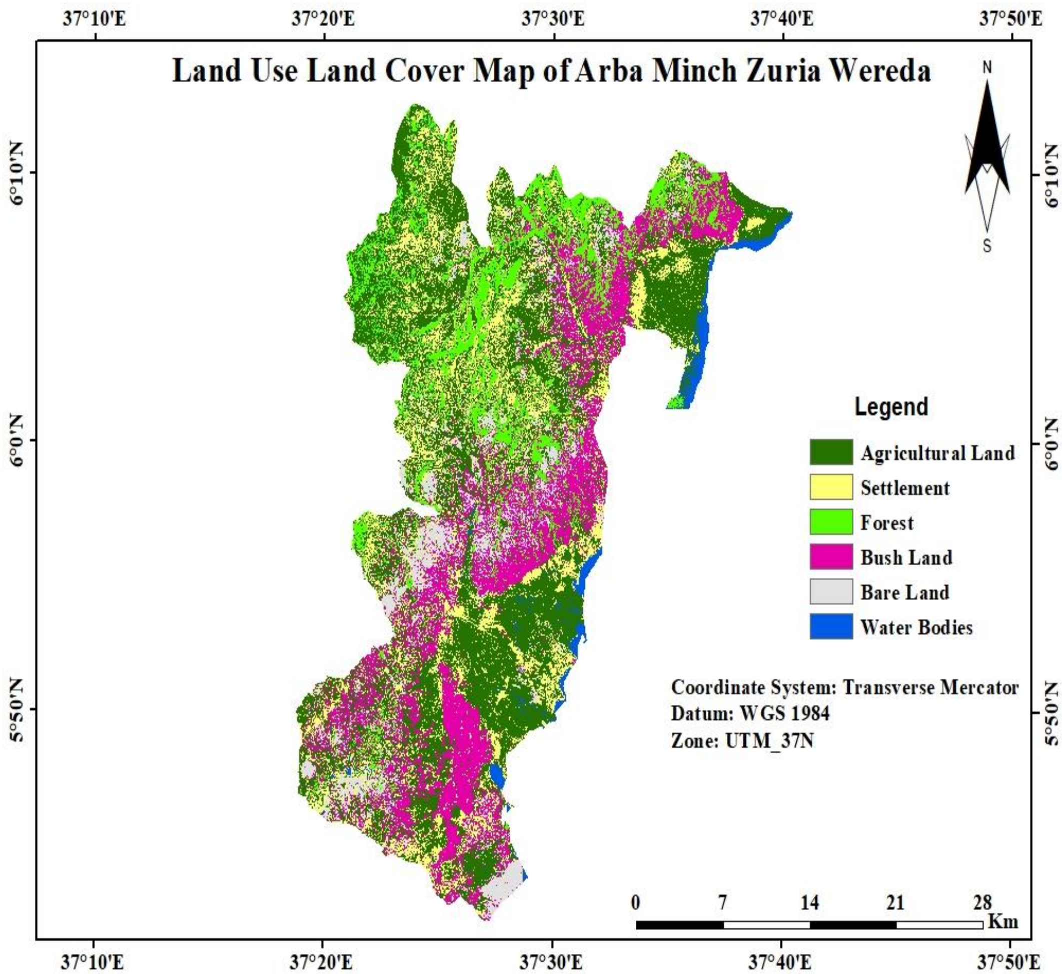


Fig. 2 LULC map of Arba Minch Zuria district

## 2.2 Research methodology

### 2.2.1 Data sources and types

Both primary and secondary data were used for land suitability analysis of mung bean in the study area. Inputs from discussions with government institutions, and opinions of eight experts were used to identify suitable land for mung bean production. The experts, namely, the agricultural extension professionals from offices and *Kebele* cluster coordinators were selected based on their qualifications and work experience. A land evaluation procedure was set based on the Food and Agriculture Organization (FAO) 1976 guideline of land suitability. Twelve criteria were used for land suitability analysis for Mung bean production in the study area. These criteria were soil, climate, land use land cover, topography, slope, soil texture, soil depth, soil pH, soil cation exchange capacity, temperature, rainfall, and soil drainage. The employed data and materials included satellite imagery Landsat Thematic Mapper (TM), Shuttle Radar Topography Mission (SRTM) 30 m resolution data, topographic map (1:50,000 scale), study area boundary shape file, ground control points, and soil map. Meteorological data, inputs of key informant interviews, questionnaire data and, ground truth were collected to supplement the GIS and remote sensing results. The types of data used along with their sources are described in Table 2.

Table 2:

Types and sources of data used

| No | Type of data | Source of data |
|---|---|---|
| **1** | Land Sat 8 satellite image (168/056), (30*30) | USGS Earth explorer |
| **2** | Topographic Map | Ethiopian Mapping Authority |
| **3** | Digital Elevation Model | Internet (SRTM) |
| **4** | Rainfall and temperature data | National Meteorological Services Agency |
| **5** | Study area boundary shape file | Central Statistical Agency |
| **6** | Ground control points | Field survey |
| **7** | Mung bean production data | District Agricultural Office |
| **8** | Soil map | Ministry of Agriculture (FAO, 1984) |

Arc GIS is the tool used in this study and several secondary digital databases were obtained from various sources (Table 3). The secondary databases were maps of soil depth, soil texture, soil chemical characteristics (PH, CEC), extracted from Water and Land Resource Center /WLRC/ and soil drainage (permeability), soil erosion, and slope percentage were taken from Digital Elevation Model (DEM) of the United States Geological Survey /USGS/, and rainfall and temperature data were accessed from the National Meteorological Services Agency /NMSA/. The secondary layers were used as inputs to the model and the data were resampled to a cell size of 10m. The study incorporated 5 suitability levels: S1, S2, S3, S4 and N which were assigned to the significance of each parameter. The highest value indicates the parameter that influences mung bean production the most. Relevant secondary data sources such as journal publications and books were also used in the study.

Table 3:

Sources of data layers

| Data layer | Source | Scale/ Resolution | Remarks |
|---|---|---|---|
| **Climate: Temperature and rainfall** | National Meteorological station of Ethiopian /NMSA/ | | Word format |
| **Soil: soil pH, and texture** | Ethiopian Soil survey map | Ethiopian layers | Vector format |
| **Topography/ DEM: Slope** | United States Geological Survey (USGS) | SRTM 30 ARC Second Dem | Raster format |

### 2.2.2 Software and materials used

The software types used for identifying a suitable area for mung bean production included are indicated in Table 4.

Table 1:

Software and materials used

| No | Software and material Used | Major application areas in the project |
|---|---|---|
| **1** | ArcGIS 10.3 | Identification of suitable area Reclassification of factors, and for weighted overlay analysis |
| **2** | ERDAS IMAGINE 2010 | Land use/land cover image classification and for accuracy assessment matrix preparation |
| **3** | GPS | For the collection of ground control points |
| **4** | IDRISI 32 | For weight derivation factors |

On the other hand, the entire process of the study is schematized in a way that illustrates all the basic concerns and procedures deployed (Fig. 3 ).

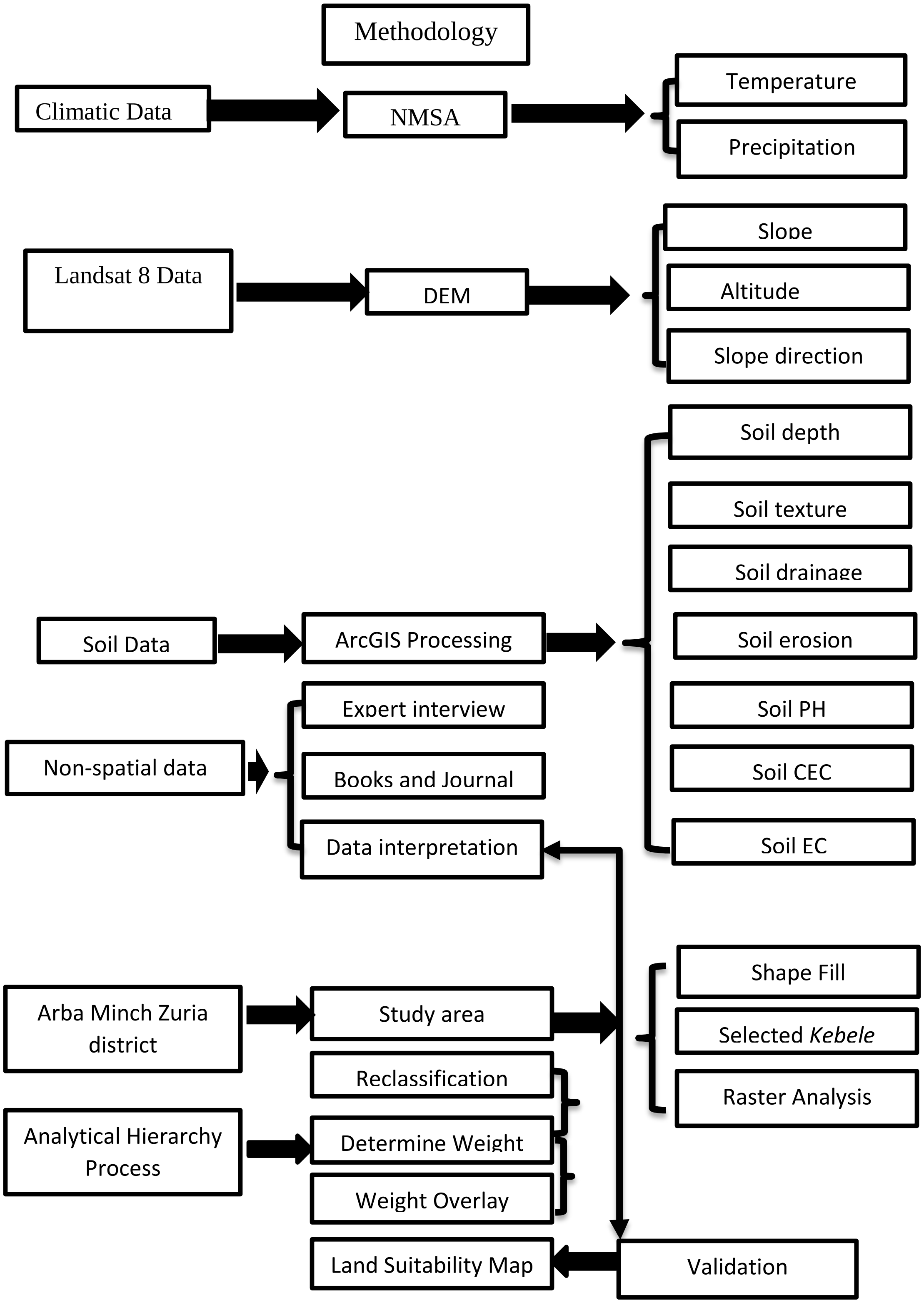


Fig. 3 Schematic presentation of the study Source Authors (2021)

### 2.2.3 The Analytic Hierarchy Process (AHP) Model

As mentioned earlier, the main objective of this research is a GIS-based land suitability analysis of mung bean using the AHP method in the study site. The AHP has been integrated with GIS tools to identify the importance of the criteria used and to calculate weights by using a scale of importance and the opinion of experts (Mahmoud et al., 2013). The AHP technique is used for LSA in this study for the determination of ranks, pairwise comparison, calculating of weights, determination of score, and weighted overlay analysis. The AHP is a widely used method in decision-making. It involves three main steps: selection of biophysical factors, pairwise comparison of key biophysical factors, and generation of weights (Dadfar, 2014). In this study, the due focus was given to the AHP approach to investigate the biophysical factors affecting mung bean production wherein the targeted factors were compared against each other. As the AHP model is a preference for a weight analysis and the employment of multiple criteria, it is implemented in this study. To make a decision in an organized way to generate priorities we need to make comparisons and need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property they are compared. The Analytic Hierarchy Process (AHP) is a theory of measurement through pair wise comparison. The comparisons are made using a scale of absolute judgements that represents how much more; one element dominates another with respect to a given attribute (Saaty, 2007). In the present study, for the determination of land suitability analysis, preference is given to physical parameters by using AHP module. Table of Saaty's Scale of pairwise Comparison

Table 5:
Saaty's Scale of pairwise Comparison

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two activities contribute equally to the objectives |
| 3 | Moderate importance of one over another | Experience and judgment strongly favors one activity over another |
| 5 | Essential of strong importance | Experience and judgment strongly favors one activity over another |
| 7 | Very strong importance | Activity is strongly favored and its dominance demonstrated in practice |
| 9 | Extreme importance | The evidence favoring one activity over another is of the highest possible order of affirmation |
| 2,4,6,8 | Intermediate values between the two adjacent judgments | When compromise is needed |

### 2.3 Methods used for analysis of factors

#### Climatic factors

The temperature and rainfall maps of the study area are generated from fifteen years of mean monthly temperature and mean annual rainfall data collected from the NMSA. The data was collected from thirty-two-point data, one of which was found in the study area, and the rest thirty-one-point data stations were found surrounding the study area. The data was collected with the geographical location of stations as point data. These stations are Mazo Doysa, Kuyle, Tsayti, Zigiti Peraso, Sulie, Kola Shara, Chano Chelba, Chano Mile, Chano Doriga, Dega Ocholo, Lante, Genta Mayiche, Zigiti Bakole, Kodo, Wusamo, Laka, Gatse, Garbanssa denisie, Zerigi Meriche, Genta Bonke, Genta Afeze, Genta Ochole, Genta Kanichema, Geribansa Koyra, Dega Change, Kola Shele, Shele Mela, Zeyise Elgo, Zeysie Dambile, Wezeqa, Abaya Dar Den, and Sile Ersha Limat.

#### Soil Data

The Arba Minch Zuria Wereda soil map was clipped from the Ethiopian Soils map and 5 data layers of interest for this analysis (soil texture, soil pH, soil depth, soil drainage and soil CEC) were extracted. The layers were then converted into raster format. The 5 raster layers were then reclassified according to the five classes of suitability defined in the crop requirement for mung bean.

#### Topography

Topography of the study area was obtained from Digital Elevation Model (DEM) in raster format and mosaicked to form a continuous layer. The percentage slope of Arba Minch Zuria Wereda was then calculated. The slope was then reclassified into three classes of suitability as defined in the crop requirements

## 3. RESULTS AND DISCUSSION

### 3.1 Mung bean growing condition and production status in the study area

The mung bean is introduced to the Arba Minch Zuria district in 2014 by VITA RTI, a Non-Governmental Organization. The production increment was observed between 2014 and 2015. In

2016 and 2017, productivity was identified with a decreasing trend due to the lack of agricultural extension for the crop by the concerned bodies, namely, the district agriculture office, and the NGO mentioned above. Despite these interventions, the mung bean's low production is still a major food security and income problem in the study area (Fig. 4). This result was found consistent with the recent review report of Itefa (2016) that reveals a very insignificant amount of mung bean production in Ethiopia despite its multiple importance and slight increment of the annual productivity in the last five years. The growing condition is variously described and found to be highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and not suitable (N).

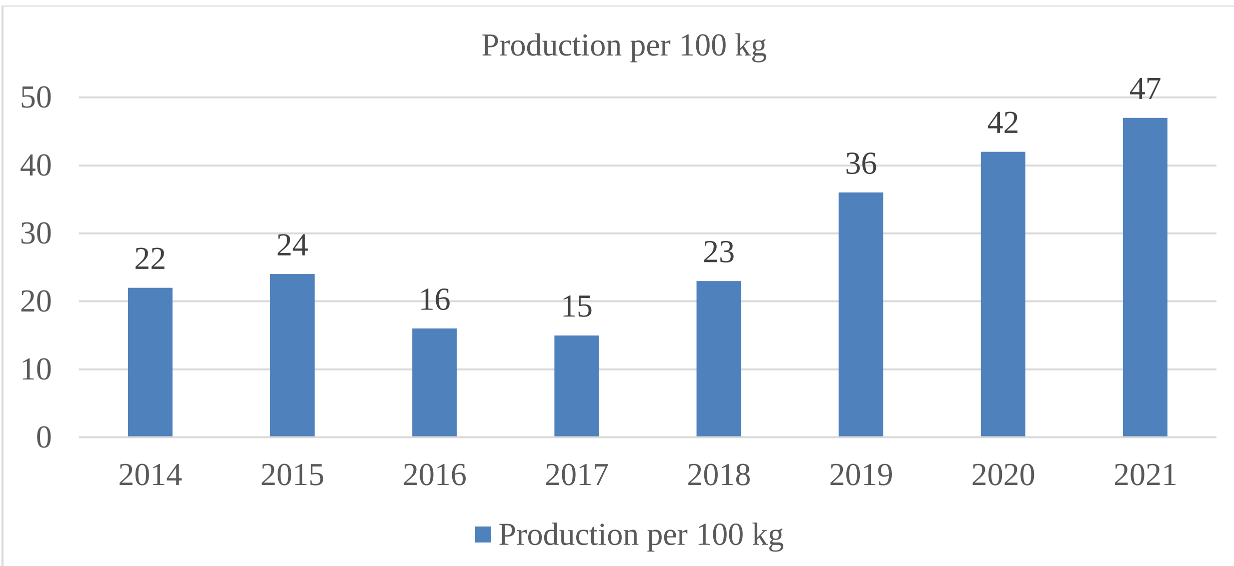


Fig. 4 The mung bean production status

Source: Arba Minch Zuria District Agriculture Office (2021)

### 3.2 Biophysical factors affecting mung bean production

#### 3.2.1 Spatial variations of temperature and rainfall dictating the mung bean production

**Spatial variation of OND temperature**

In a given area, climatic parameters a play crucial role in crop productivity dictating the water amount required for crops. This condition by itself influences the household-level food and livelihood security of the people significantly (De la Casa & Ovando, 2014 as cited in Subiyanto et al., 2018). The unclassified temperature map of the study area shows that all mapped area is not suitable for Mung bean production. In the reclassified map of the study area, 40% is in the range between 21.6°C – 23.8°C, which is a suitable temperature for mung bean production. A temperature amount less than 25.6°C is not a suitable condition for the growing period. On the other hand, during crop growth, mung bean does not tolerate high temperatures above 40°C during the reproductive stage with a major reduction in pollen viability (Yeshiva & Rex, 2018). So, the mung bean grows in a wide range of climatic conditions. A warm humid climate with temperatures ranging from 25°C to 35°C is suitable for mung bean production and this is assigned as highly suitable, moderately suitable, and marginally suitable (Table 5, Fig. 5a, 5b).

Table 6:

Spatial variation of reclassified OND temperature

| Suitability Class | Temperature ($^0$C) | Area (Ha) | Area (%) |
|---|---|---|---|
| **S1** | 21.6 – 23.8 | 38410 | 40% |
| **S2** | 20.1 - 21.5 | 38963 | 40% |
| **S3** | 16.6 - 20 | 19396 | 20% |

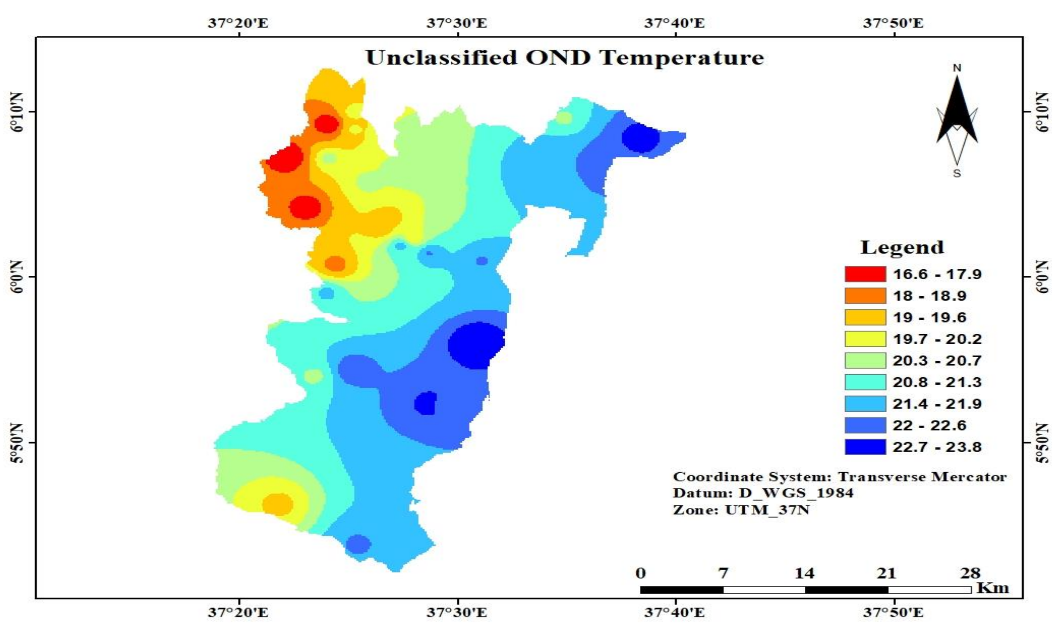


Fig. 5a Unclassified OND temperature

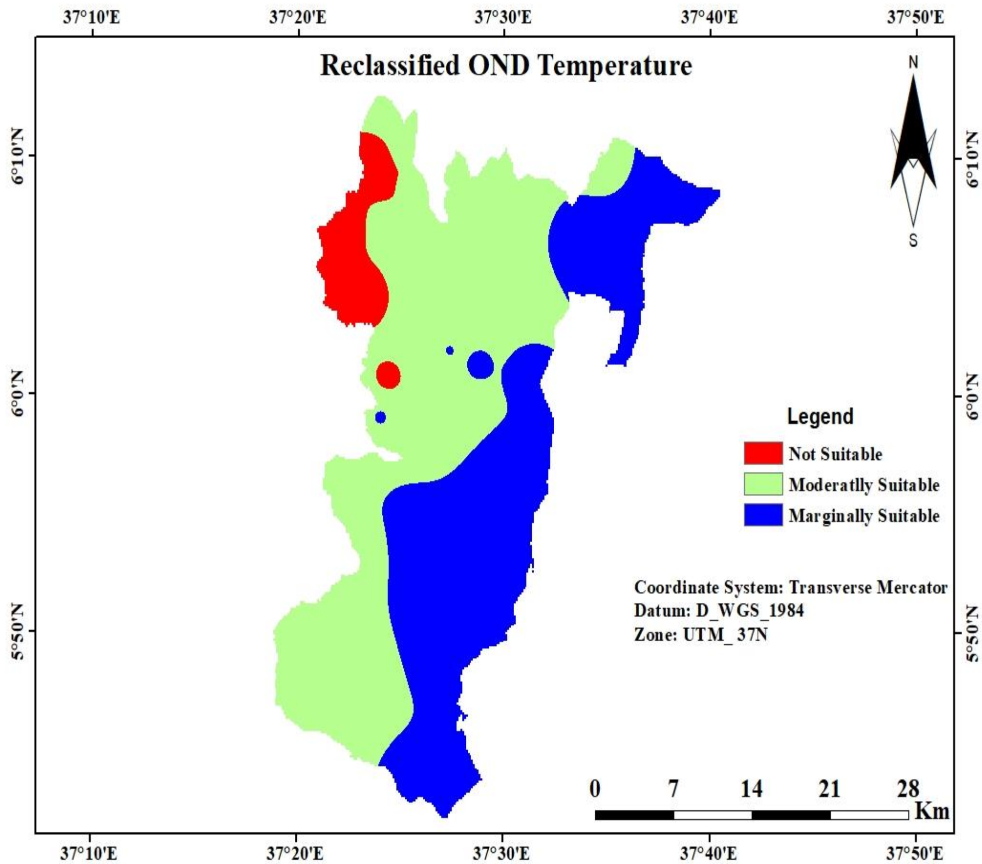


Fig. 5b Reclassified OND temperature

## Spatial variation of JFM temperature

The unclassified JFM temperature varied between 23.2°C to 32.5°C. The reclassified temperature map shows that during this season, 79% of the Arba Minch Zuria district had a highly suitable temperature for the growth of mung bean (Table 6, Fig. 6).

Table 7:

Reclassified JFM temperature

| Suitability Class | Temperature (0C) | Area (Ha) | Area (%) |
|---|---|---|---|
| **S1** | 26.9 – 28.5 | 30287 | 31% |
| **S2** | 28.6 – 32.5 | 46891 | 48% |
| **S3** | 23.2 - 26.8 | 19591 | 20% |

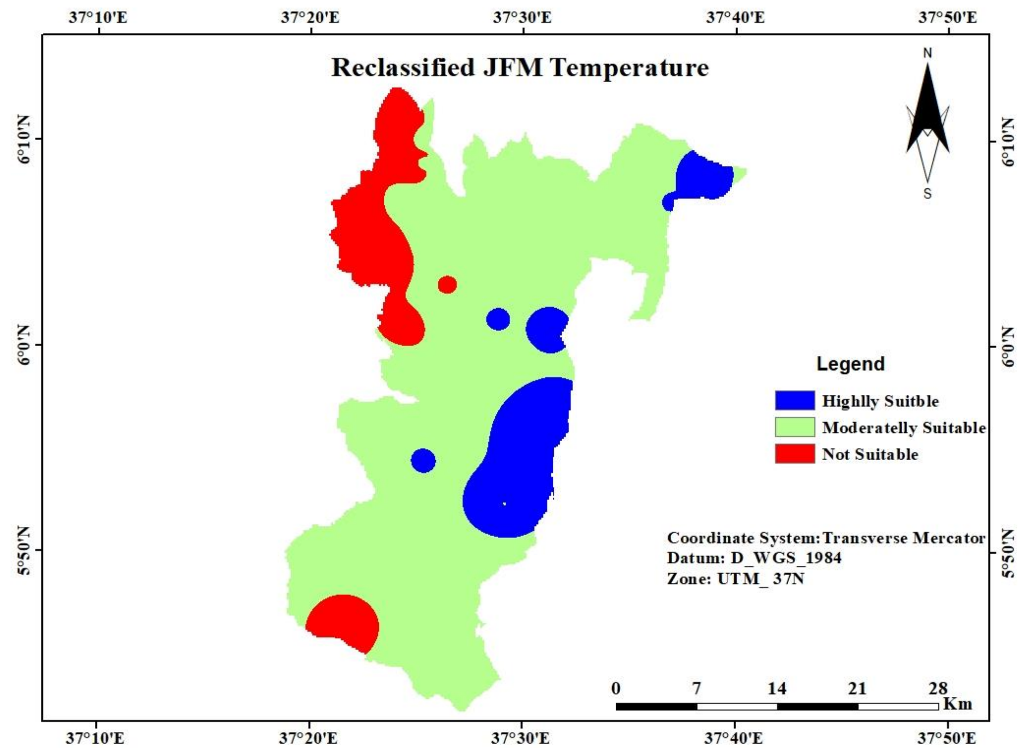


Fig. 6 The reclassified JFM temperature

## Spatial variation of OND rainfall

The unclassified OND rainfall map of the study area varied between, 197mm and 302.8mm (Fig. 7). The reclassified rainfall map shows that during this season, the study area is suitable for mung bean production where 47% is highly suitable while 31% and 22% is moderately and marginally suitable for mung bean production, respectively (Table 7, Fig. 8).

Table 8:

Reclassified OND Rainfalls

| Suitability Class | Rainfall(mm) | Area (ha) | Area (%) |
|---|---|---|---|
| **S3** | 241 - 303 | 45617 | 47% |
| **S2** | 224 - 240 | 29941 | 31% |
| **S1** | 197 - 223 | 21210 | 22% |

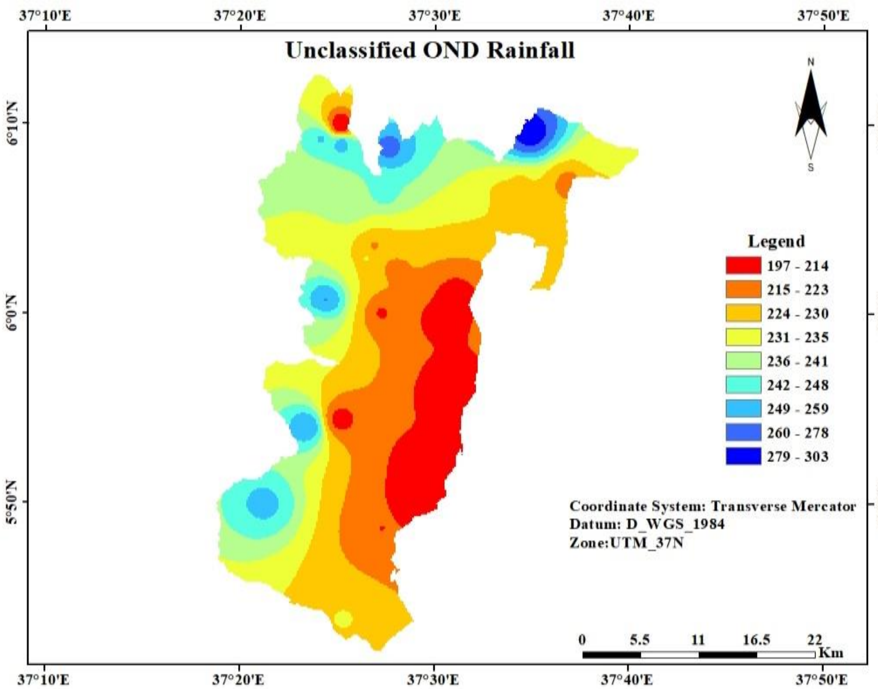


Fig. 7 Unclassified OND Rainfalls

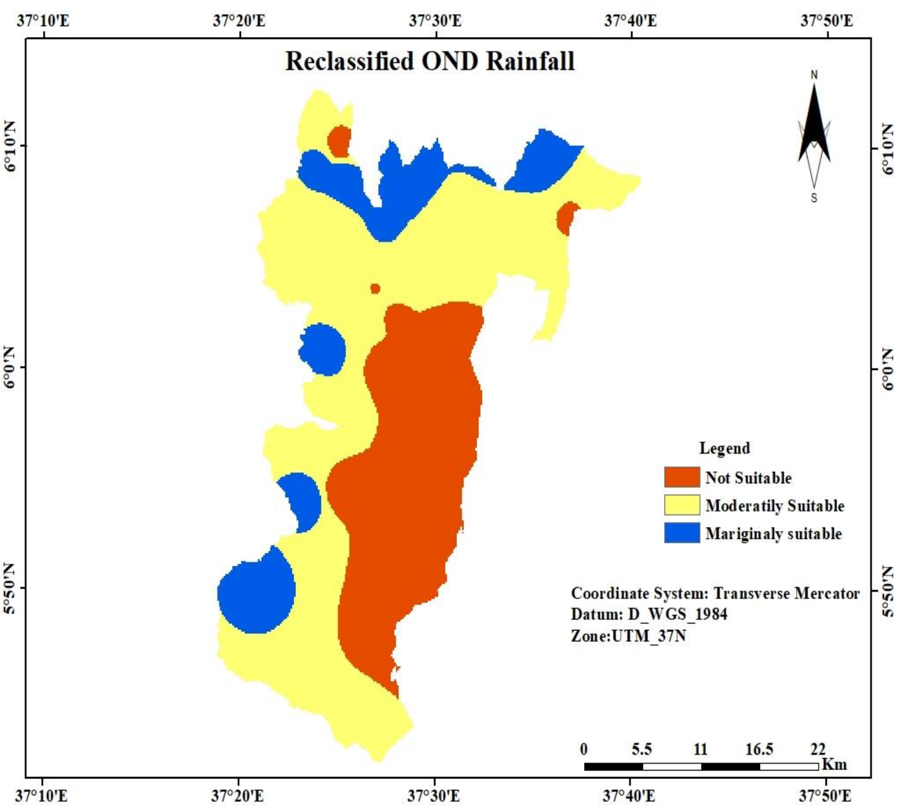


Fig. 8 Reclassified OND Rainfalls

## Spatial variation of JFM rainfall

The unclassified JFM rainfall varied between 531 mm to 756 mm (Fig. 9). On the other side, the reclassified rainfall map shows that during this season, all of the areas were not suitable for mung bean production (Table 8, Fig. 10).

Table 9 Reclassified JFM Rainfalls

| Suitability Class | Rainfall(mm) | Area (Ha) | Area (%) |
|---|---|---|---|
| **S3** | 531 - 756 | 96768 | 100 |

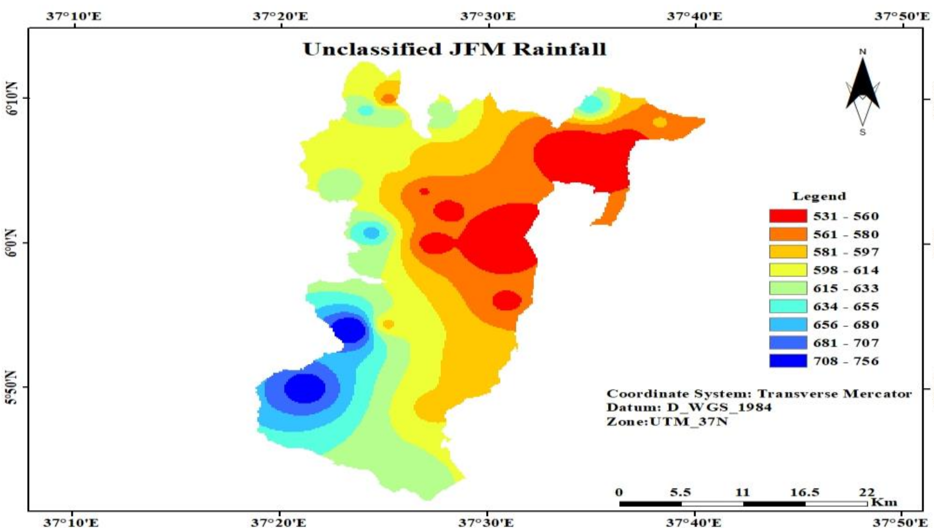


Fig. 9 Unclassified JFM Rainfall

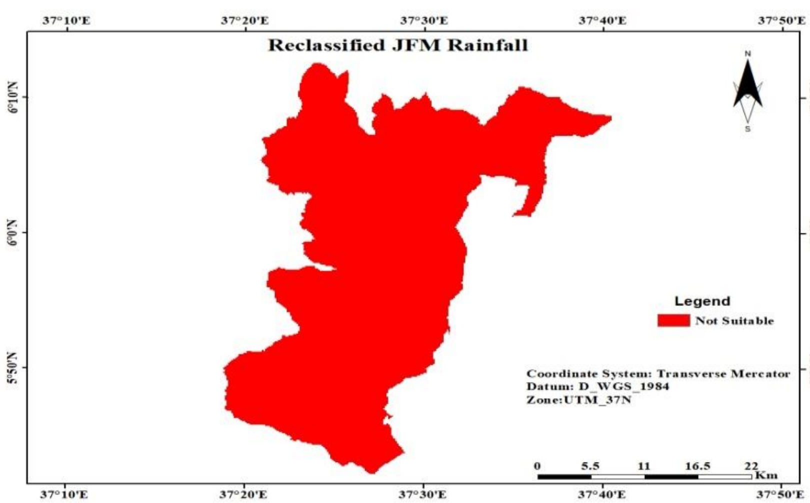


Fig. 10 Reclassified JFM Rainfall

### 3.2 Mapping climatic suitability for mung bean production

The temperature and rainfall rated using the pairwise comparison method were used to map the suitability of these climatic parameters. The AHP approach was put into practice ranging in weights between 0 and 100 using. Accordingly, the results showed that 70% of the major climatic factors were found to be suitable (Table 9).

Table 10:

Temperature and rainfall pairwise comparison

| Criteria | Rainfall | Temperature | Weight | Rank |
|---|---|---|---|---|
| **Rainfall** | 1 | 5 | 70 | 1 |
| **Temperature** | 0.20 | 1 | 30 | 2 |

CR=0%

As can be seen in Table 9, the CR< 10 the weights were assigned to the weighted overlay of rainfall and temperature. The comparison revealed three classes during OND season wherein 56% of the study area was highly suitable, 28% is moderately suitable, and 16% was marginally suitable for mung bean production (Table 10 and Fig. 11). There are 3 classes in the JFM season where 57% is highly suitable, 30% is moderately suitable and 13% is marginally suitable for mung bean production (Table 10, Fig. 12).

Table 11:

Mung bean climate suitability map

| Suitability (OND) | Area (Ha) | Area (%) | Suitability (JFM) | Area (Ha) | Area (%) |
|---|---|---|---|---|---|
| **S1** | 54452 | 56 | S1 | 55365 | 57 |
| **S2** | 27246 | 28 | S2 | 28967 | 30 |
| **S3** | 1507 | 16 | S3 | 12435 | 13 |

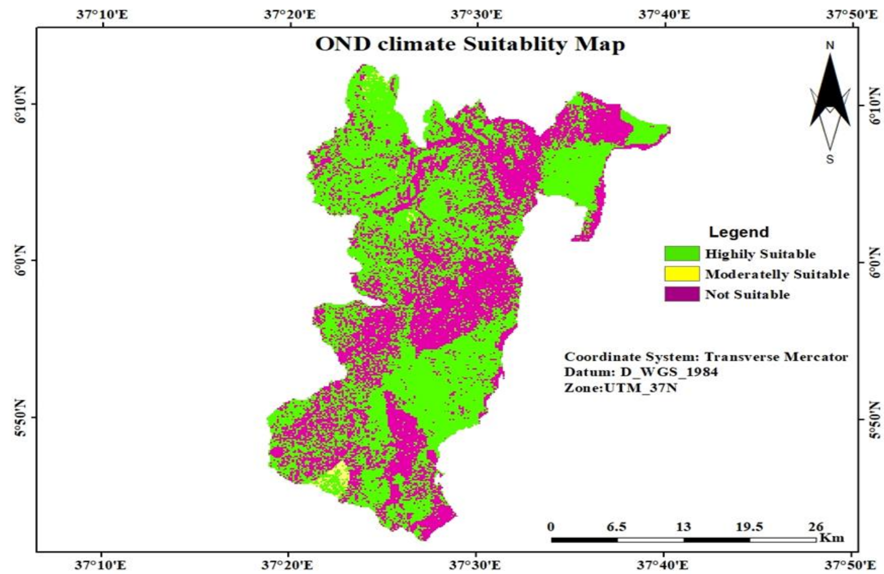


Fig. 11 Reclassified OND climate suitability map

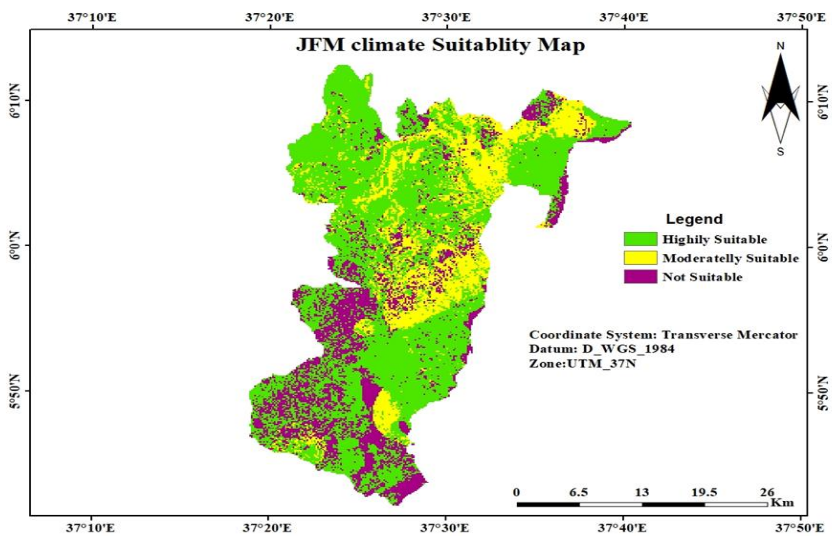


Fig. 12 Reclassified JFM climate suitability map

## Slope

The reclassified slope map showed that 39% of the area was highly suitable for mung bean production (Table 11, Fig.13) with a moderate and marginal suitability area of 31% and 21%, respectively. 9% of the land is not suitable for mung bean production in the study area. This was found to be nearly consistent with the finding of Subiyanto et al. (2018) which indicated the land unsuitability for the other pulse grain (soybean) to be 7.33%. On the contrary, this finding was highly incongruent with the 1.2% of suitable land for mung bean production across the coastal areas of Bangladesh (Hossen et al., 2021) through the employment of the GIS tools and multi criteria analysis.

Table 12:

Reclassified slope direction

| Suitability class | Area (ha) | Area (%) |
|---|---|---|
| **S1** | 37593 | 39% |
| **S2** | 29575 | 31% |
| **S3** | 20790 | 21% |
| **N** | 8810 | 9% |

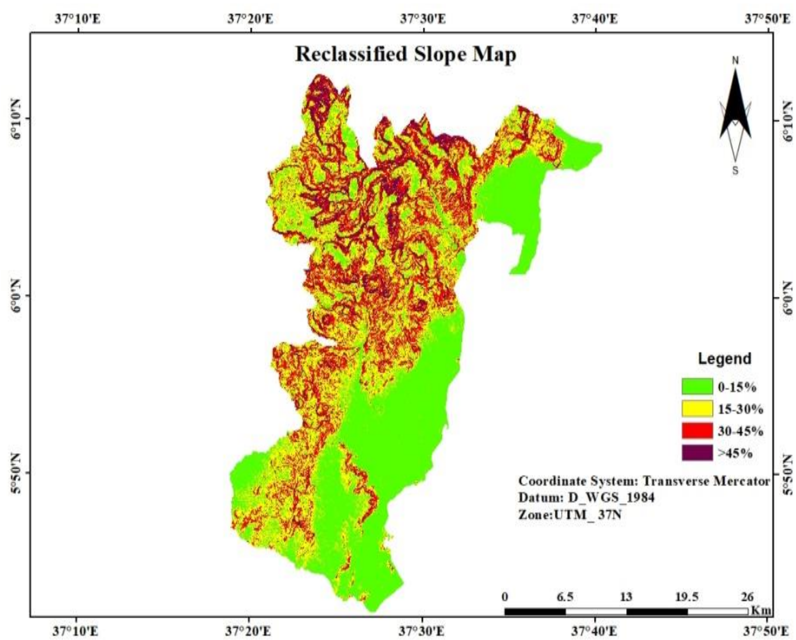


Fig. 13 Reclassified slope map

## The mung bean suitability map

The final mung bean suitability map produced by overlaying sub criteria maps for the OND and JFM season on soil and slope maps was done by using weighted overlay technique. To determine the weights of each main criterion, AHP was employed. The experts consider climate to be the most important criterion with an influence of 70% (Table 12).

Table 13:

Pairwise comparison results for main criteria

| | Climate | Soil | Topography | Weight | Rank |
|---|---|---|---|---|---|
| **Climate** | 1 | 4 | 8 | 70 | 1 |
| **Soil** | ¼ | 1 | 4 | 23 | 2 |
| **Topography** | 1/8 | ¼ | 1 | 7 | 3 |
| **CR=8.0%** | | | | | |

The suitability of mung bean during the OND season where three classes 32%, 26%, and 42% which is highly, moderately, and marginally suitable, respectively (Table 13, Fig. 14).

Table 14:
Overall suitability for mung bean during OND and JFM seasons

| Suitability OND | Area (HA) | Area (%) | Suitability JFM | Area (ha) | Area (%) |
|---|---|---|---|---|---|
| **S1** | 30,847 | 32 | S1 | 13,704 | 14 |
| **S2** | 24,889 | 26 | S2 | 59,673 | 62 |
| **S3** | 41,031 | 42 | S3 | 23,390 | 24 |

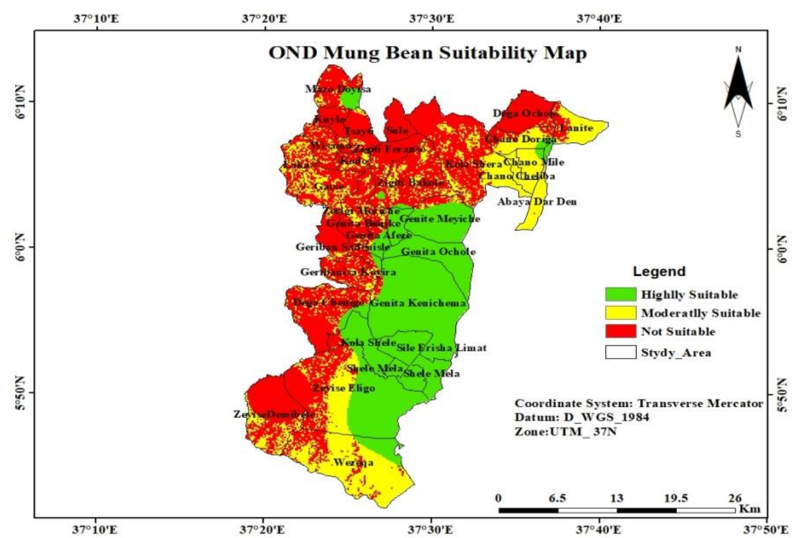

Fig. 14 OND mung bean suitability map

The suitability of mung bean during the JFM season was identified with three classes 14%, 62%, and 24% which are highly, moderately, and marginally suitable, respectively (Fig. 15). This result showed the divergence of the land suitability analysis finding of the study area with reference to the soybean land suitability report of Subiyanto et al. (2018) in Indonesia.

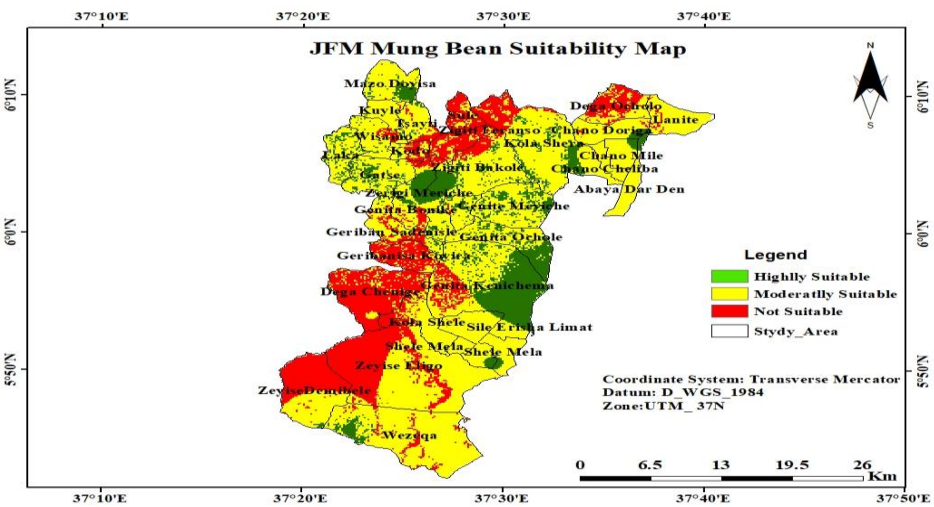


Fig. 15 JFM mung bean suitability map

## Spatial variation of soil characteristics

The spatial variation of soil depth, texture, drainage (permeability), erosion, and chemical characteristics (PH and CEC) were investigated and shown as follows.

**Soil depth:** The reclassified depth map of the study area shows that 82% and 14% are highly and moderately suitable for mung bean production, respectively (Table 14, Fig. 16).

Table 15:

Reclassified soil depth map

| Suitability class | Soil depth | Area (ha) | Area (%) |
|---|---|---|---|
| **S1** | >50cm | 78,917 | 82% |
| **S2** | 50-30 | 13,482 | 14% |
| **S3** | <30 | 4,369 | 5% |

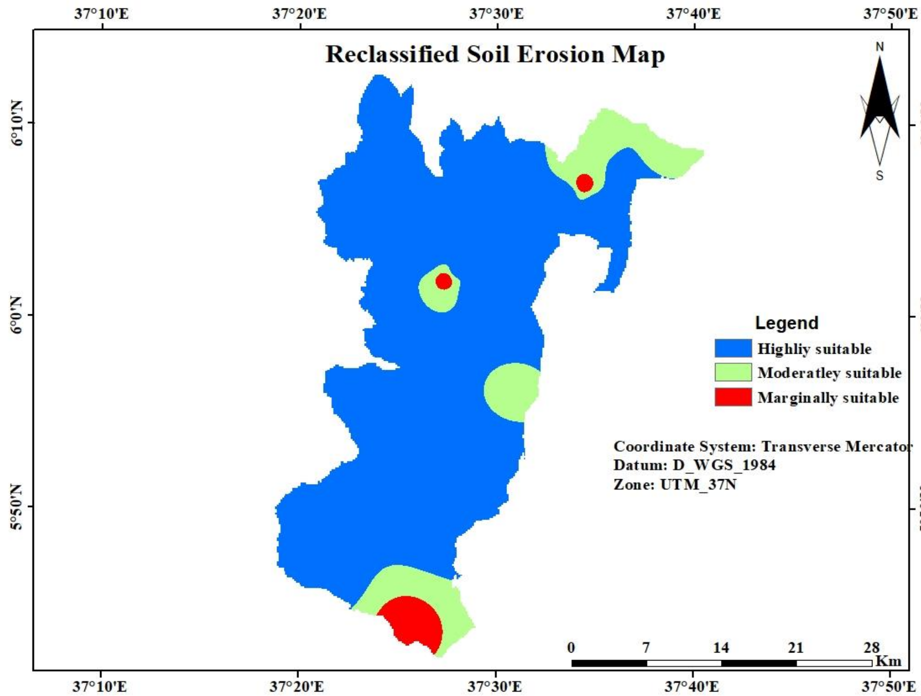


Fig. 16 Reclassified soil depth map

**Soil texture:** The soil texture classes of the study area are loam, sand, and loam clay

The reclassified texture map shows two classes, the highest percentage (69%) is highly suitable for mung bean production (Table 15, Fig. 17) and 31% is moderately suitable.

Table 16:

Reclassified soil texture

| Suitability Class | Soil Texture | Area (ha) | Area (%) |
|---|---|---|---|
| **S1** | Loam sand | 66478 | 69% |
| **S2** | Loam | 352 | 0% |
| **S3** | Clay | 29939 | 31% |

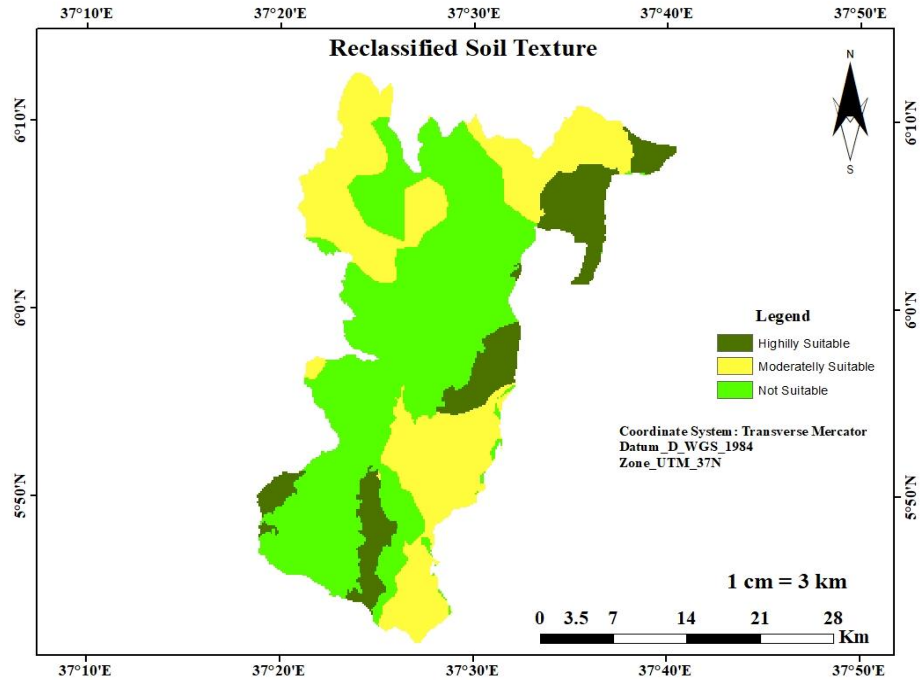


Fig. 17 Reclassified soil texture

**Soil drainage:** The soil drainage classes of the Arba Minch Zuria district are described as: excessive drained, well-drained, and moderately drained. The excessively drained is meant as water is removed from the soil rapidly on steep gradients wherein the soil is coarse-textured, shallow, or both. In the case of well-drained drainage, the water is removed from the soil readily but not rapidly and which makes the soil to be generally intermediate in texture and depth. On the other hand, the moderately drained situation indicates the fact that water is removed from the soil somewhat slowly in areas usually where the soil is characterized by medium to finely textured conditions. The reclassified soil drainage map shows that 28% is highly suitable for mung bean production (Table 16, Fig. 18) with moderate and marginal suitability areas 35%, 36%, respectively.

Table 17:

Reclassified drainage map

| Suitability class | Soil Drainage | Area (Ha) | Area (%) |
|---|---|---|---|
| **S1** | Excessive drained | 27274 | 28% |
| **S2** | Well drained | 34206 | 35% |
| **S3** | Moderately drained | 35288 | 36% |

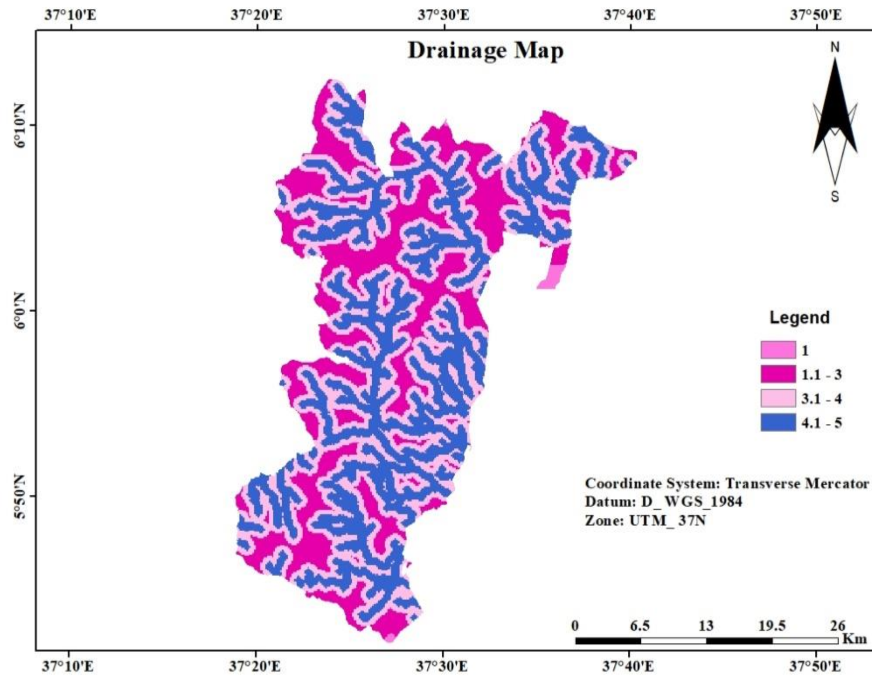


Fig. 18 Reclassified drainage map

## Soil Chemical Characteristics (CEC and PH)

### Soil CEC

The reclassified CEC map shows that the highest percentage (31%) is highly suitable for mung bean production (Table 17, Fig. 19) with moderate suitability of 35% and 34% were not suitable.

Table 18:

Reclassified soil CEC

| Suitability Class | Soil CEC | Area (Ha) | Area (%) |
|---|---|---|---|
| **S1** | >10 | 34077 | 35% |
| **S2** | 10-5 | 30165 | 31% |
| **S3** | <5 | 32527 | 34% |

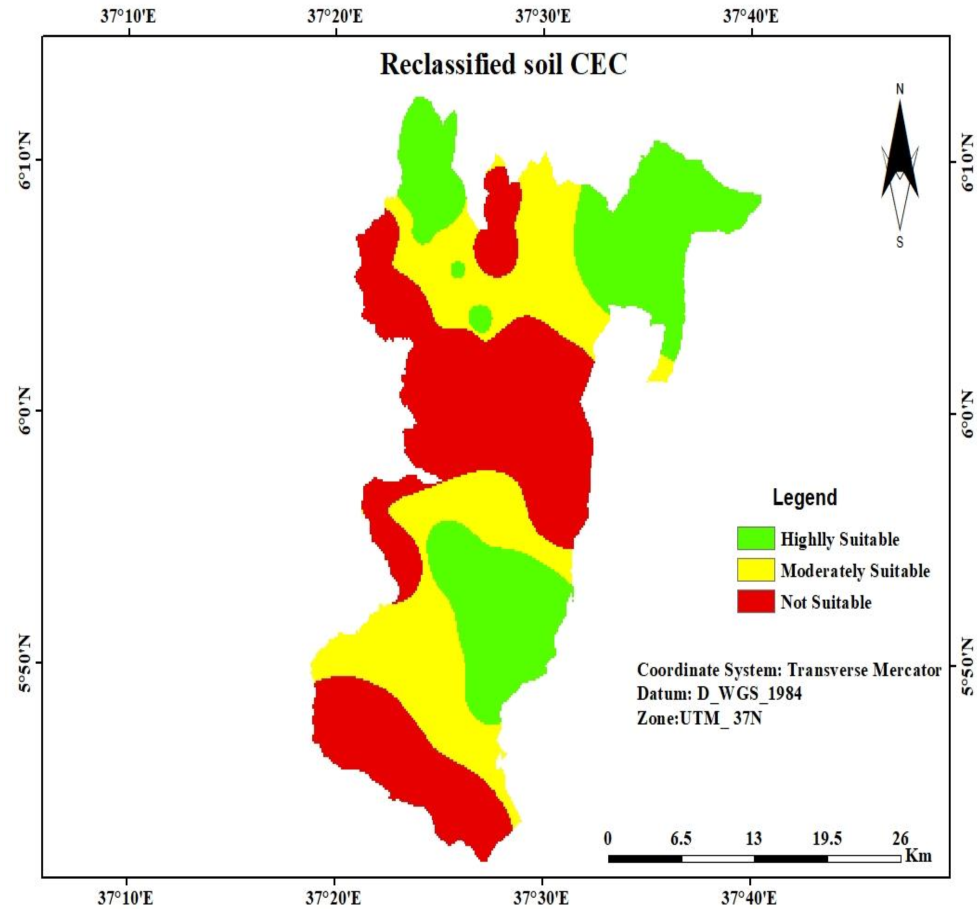


Fig. 19 Reclassified soil CEC

**Soil PH**

The reclassified PH map shows that the highest percentage of land (77%) is suitable for mung bean growth. Moderate and marginal suitable areas were identified to be 22% and 2%, respectively (Table 18, Fig. 20).

Table 19:

Reclassified soil PH

| Suitability Class | Soil PH | Area (Ha) | Area (%) |
|---|---|---|---|
| **S1** | > 6.2 | 20844 | 22% |
| **S2** | 6.2-7.2 | 74276 | 77% |
| **S3** | > 7.2 | 1649 | 2% |

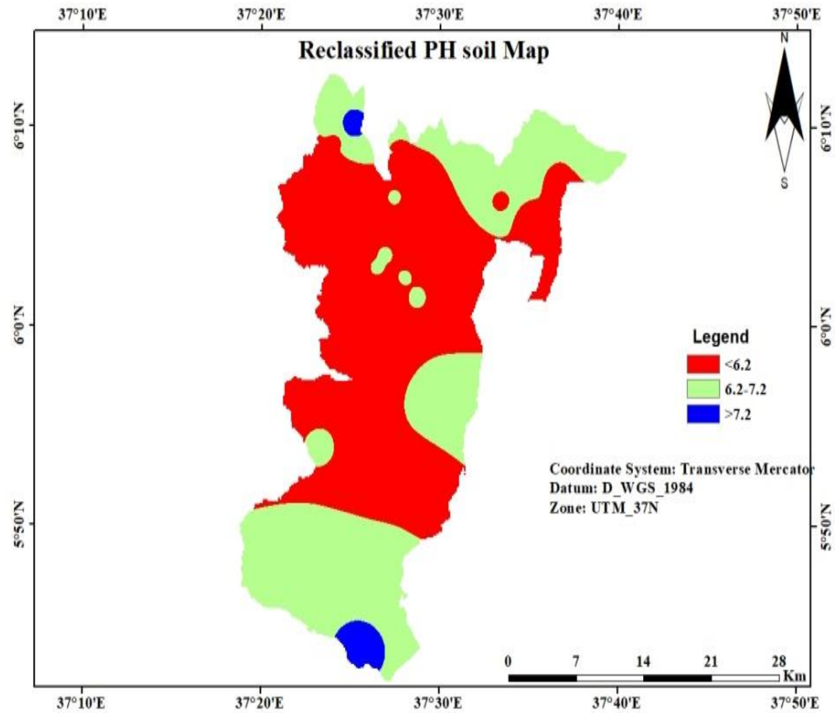


Fig. 20 Reclassified soil PH

**Soil suitability map of mung bean**

Using the AHP approach and the pairwise comparison method, depth, soil texture, soil drainage, soil erosion, and soil chemical properties (PH, CEC) were rated and resulted in weights between 0 and 100. The results show that experts consider soil drainage most important with an influence of 40% (Table 19).

Table 20

Soil suitability map of mung bean

| | **CEC** | **Texture** | **Drainage** | **Depth** | **PH** | **Weight** | **Rank** |
|---|---|---|---|---|---|---|---|
| **CEC** | 1 | 2 | ½ | 2 | 2 | 17 | 3 |
| **Texture** | ½ | 1 | ¼ | 4 | 1/4 | 12 | 4 |
| **Drainage** | 2 | 2 | 1 | 2 | 4 | 40 | 1 |
| **Depth** | ½ | 1/4 | ¼ | 1 | 1/4 | 22 | 2 |
| **PH** | 1/4 | 4 | 1/4 | 4 | 1 | 9 | 5 |
| **CR=0.14%** | | | | | | | |

CR<10% of the weights in Table 20 were assigned to the weighted overlay which revealed that the study area is suitable for mung bean production in varying degrees. The results show that 76% are highly suitable, 14% are moderately suitable, and 9% are marginally suitable for mung bean production (Table 20, Fig. 21).

Table 21:

Reclassified soil suitability map

| Suitability Class | Area (ha) | Area (%) |
|---|---|---|
| **S1** | 73,987 | 76% |
| **S2** | 8,874 | 9% |
| **S3** | 13,907 | 14% |

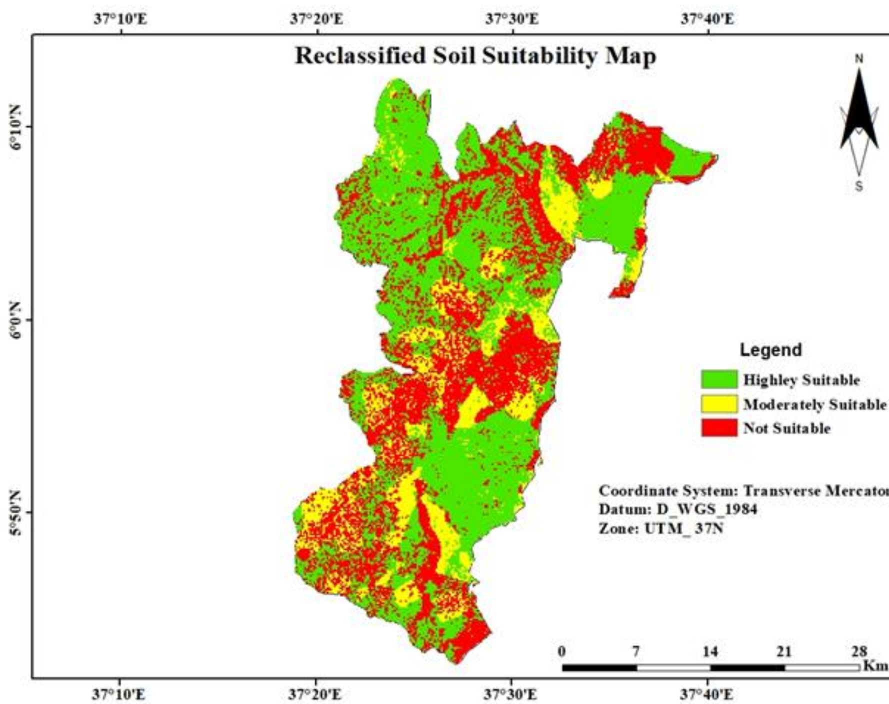


Fig. 21 Reclassified Soil Suitability Map

## 4. CONCLUSION AND RECOMMENDATION

This study assesses the land suitability for mung bean production using the GIS and AHP approach. The status of mung bean production across the study area was found to be differential both seasonally and spatially as a result of various climatic and biophysical factors. The final map showed suitable land for mung bean production. During the OND season, the land suitability was acknowledged as 32%, 26%, and 42% which is highly, moderately and marginally suitable, respectively and in the JFM season, it was identified as 14%, 62% and, 24% which is highly, moderately and marginally suitable, respectively.

The diverse agro-ecology of the study area permits different agricultural systems and production of agricultural crops, especially the mung bean. The production of mung bean, the prevalence of conducive climatic condition, topography, spatially low lands and fertile soil are important. The production of mung bean during JFM season is low due to the existence of high rainfall in high land area. Finally, this research work confirmed that GIS and AHP technology is important for land suitability analysis. In this study, GIS played great role in the generation of maps for environmental factors, reclassification, overlaying and identification of risk level. Therefore, GIS and remote sensing technology is a vital tool for agricultural sector. Hence, to further make the most of crop productivity and contribute to food security, land suitability analysis for other crops across agro-ecologies should be widely implemented by the concerned actors such as the government, agriculture experts, and non-governmental organizations among others.

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