International Journal of Applied and
Natural Sciences (IJANS)
ISSN (P): 2319–4014; ISSN (E): 2319–4022
Vol. 10, Issue 1, Jan–Jun 2021; 89–102

International Academy of Science,
Engineering and Technology
Connecting Researchers; Nurturing Innovations

LAND SUITABILITY ANALYSIS FOR WHEAT CROP BY USING MULTI-CRITERIA AND GIS TECHNOLOGY IN CASE OF SOUTH GONDAR, ETHIOPIA

Fekadie Bazie Enyew

Research Scholar, Department of Geography and Environmental Studies, Kabridahar University, Ethiopia

ABSTRACT

Agriculture being the most primitive occupation of the most civilized mans and it should be supported by scholars. Agriculture in Ethiopia is characterized by low productivity due to low external inputs, lack of good farming practice deforestation which results soil erosion and decreasing productivity. Land suitability analysis is an assessment of an area to determine how proper or appropriate it is for a particular use of the land (such as growing a crop variety) in a particular location. Land suitability tools have been extensively applied to identify better management practices in agricultural areas. Wheat is one of the most common food crops cultivated in Ethiopia. However, the current production supply couldn't satisfy demands for this crop. As a result, effective method of assessing environmental suitability analysis to increase the production of this crop is needed. A multi factor spatial analysis can effectively assess the environmental suitability of an area for wheat cultivation. However, there are no any comprehensive agricultural land suitability spatial analysis for the study yet. In an attempt to underscore its significance, this study conducted GIS based land suitability analysis. It involves identifying suitability factors, hierarchical organization, standardization, rating and ranking, and weighing the factors selected and finally implementing the suitability map. The evaluation criteria used are elevation, slope, soil, rainfall, temperature variations. They were collected from different government agencies. The weights of factors were estimated by computing map algebra values. Different suitability maps were prepared for each variable by combining different ArcGIS 10.3 extension tools were used, in this regard as it has the capacity to integrate these modules. The results of the analyses show that most of Farta, Debre Tabor, Dera, Ebinet area have apotential forcultivating wheat crop. On the other hand, Simada, Tach gaynt, Lay gaynt, Limokemkem, Merab Este and MisrakEste).

KEYWORDS: *GIS, Remote Sensing, Cultivation, Crop, Suitability*

Article History

Received: *20 Apr 2021* | ***Revised:*** *30 Apr 2021* | ***Accepted:*** *05 May 2021*

INTRODUCTION

Background of the Review

Over the 10,000 year since agriculture began to be developed, people everywhere have discovered the food value of wiled plant and animals, and domesticated and bread them. The most important crops are cereals such as wheat, rice, barley, corn and rye. The population of the world is increasing dramatically in order to meet the high demand for food production there will be a suitable land (Teak & Haft 2012). In order to achieve this, the first and foremost requirement is carrying out land

suitability analysis (Kihoro, *et al*., 2013).

Africa is the world's second-largest and second- most-populist continent. Although it has abundant natural resources. however Africa remains the world's poorest and most underdeveloped continent, the result of a variety of causes that may include corrupt governments that have committed serious human right violation's, high levels of illiteracy, lack of access to foreign capital, poor farming system, and frequent tribal and military conflict (Sayre & April pulley, 1999). In the United Nations' human development report in 2003, the bottom 24 ranked nations (151st to 175th) were all in Africa. Africa's economy is inherently dependent on agriculture. More than 32% of the continent's gross domestic product comes from the sector. However the productivity still remains far from developed world standards the reality of agricultural development is far from ideal and Ethiopia is one of them.

According to (Alemayehu, 2003). Agricultural sector in Ethiopia plays a central role in the economic and social life of the nation and is a cornerstone of the economy, about 80-85 percent of the people are employed in agriculture, and especially farming the sector contributes about 40 percent of total GDP; livestock and their products account for about 20 percent of agricultural GDP. Smallholders, the backbone of the sector, cultivate 95 per cent of the cropped area and produce 90-95 percent of cereals, pulses and oilseeds. Subsistence agriculture is almost entirely rainfed and yields are generally low Land has been a common property of nations and nationalities and shall not be subjected to sale or to other means of transfer, Land resources in Ethiopia face pressures from continuing land degradation and increasing the number of people. The population in growing very rapidly, the degradation of the land resource due to overexploitation and misuse and consequent economic, Social and environmental impact has intensified the pressure on the land resources of the country(EFAP, 1994)Therefore, the efficient management of natural resources in Ethiopia is essential for ensuring food supplies and sustainability in agricultural development. In order to manage land resources properly, land suitability assessment is often conducted to determine which type of land use is most appropriate for a particular location (Bodaghabadi*et al*., 2015).

According to Amhara national regional state food security research assessment report may (2000) the population of the Amhara region is approximately 15 million people of whom 89 percent live in rural, agricultural households Cereals account for more that 80 percent of cultivated land and 85% of total crop production. The principal cereal crops in the Amhara region are teff, barley, wheat, maize, sorghum and finger millet. But it's characterized by low productivity. Amhara region suffers from recurrent droughts and pest invasions. Of the 105 wored as in the region, forty-eight are drought-prone and chronically food-secure. There has been no single year since 1950 where there was no drought in the eastern part of the region. Famines have been recorded as far back as biblical times. On the other hand, much of the western half of the region has good soils and adequate rainfall and typically produce agricultural surpluses, but the productivity level does not meet the growing demand for food.So in order to increase the productivity the land should assess. Suitability of land is assessed considering rational cropping system, for optimizing the use of a piece of land for a specific use (Sys *et al*., 1991).

Land suitability assessment is the examination of a piece of land for its capacity to support a specific agricultural use. (Little boy *et al*., 1996) Thus, land suitability assessment (LSA) consists of analysis of soil, topography and temperature with the aim of comparing land characteristics with crop requirements (Wang *et al*., 2006). The suitability is a function of crop requirements and land characteristics and it is a measure of how well the qualities of land unit match the requirements of a particular form of land use (FAO, 1976). Land assessment is a tool for predicting land performances in

terms of the expected proceeds, constraints and environmental problems from the productive use of land (Rossiter, 1996). This may be solved by integrating GIS and MCE methods recently, geographical information systems (GIS) have been found useful in accomplishing the task of land suitability assessment (Anagnostopoulos*et al*., 2010). Multi Criteria Decision Making an effective tool for multiple criteria decision-making issues (Malczewski, 2006). Integration of the GIS and MCE can help land-use planners and managers to improve decision-making processes (Malczewski, 1999). In this study, integrated MCD with GIS was applied to evaluate the suitability of the agricultural land of the study area for wheat crops using the relevant variables of soil type, rainfall, slope, altitude and temperature parameters through the MCE technique.

The historical evidence suggests that the growth of the productive potential of global agriculture has so far been more than sufficient to meet the growth of effective demand, but now a day due to rapid population growth the sector have high pressure on productivity. In Ethiopia the poor performance of agriculture is reflected in the national annual food deficit. The sector has been beset by natural disasters, in particular periodic severe droughts. Lack of modern inputs for the subsistence sector, especially fertilizer; inadequate availability of credit, poor credit recovery and widespread disorder and civil war are the main constraints. These situations have drawn resources from productive use in the agricultural sector. In south Gonder zone currently, of the total 777,096 population of four wereda i.e., Simada, Ebnat, LayGaint and Tach Gaint, 147, 188 populations i.e. 19% of the Woreda population are food insecure. Wheat crop is considered the most important crop in south Gondar zone, but in current situation there are many challenges faced in wheat production in the zone, as due to this reason the area characterized by low quality and quantity wheat production and wheat crop was not well studied in the study area so far. Some studies in the area were shallow due to the complexity of study, which will difficult to generalize and acquire basic information.

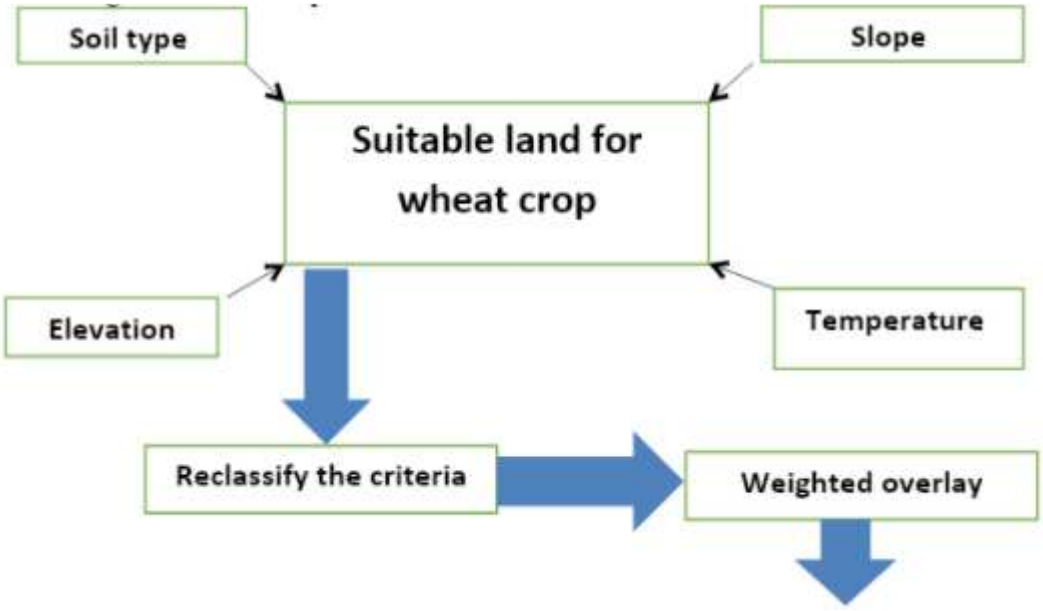

Figure 1: Analytical Frame Work.

METHODS AND MATERIAL

Description of the Study Area

Geographical Location

Geographically the south Gondar zone is located between 11°0' 0"-12°30' 0" N latitude and 37°30'0"-38°30'0"E longitudes. The zone is bordered on the south by east Gojjam, on the southwest by west Gojjam and Bahir Dar, on the west by Lake Tana, on the north by north Gondar, on the northeast by Wag Hemra, on the east by north Wollo, and on the southeast by south Wollo; the Abbay River separates south Gondar from the two Gojjam Zones.

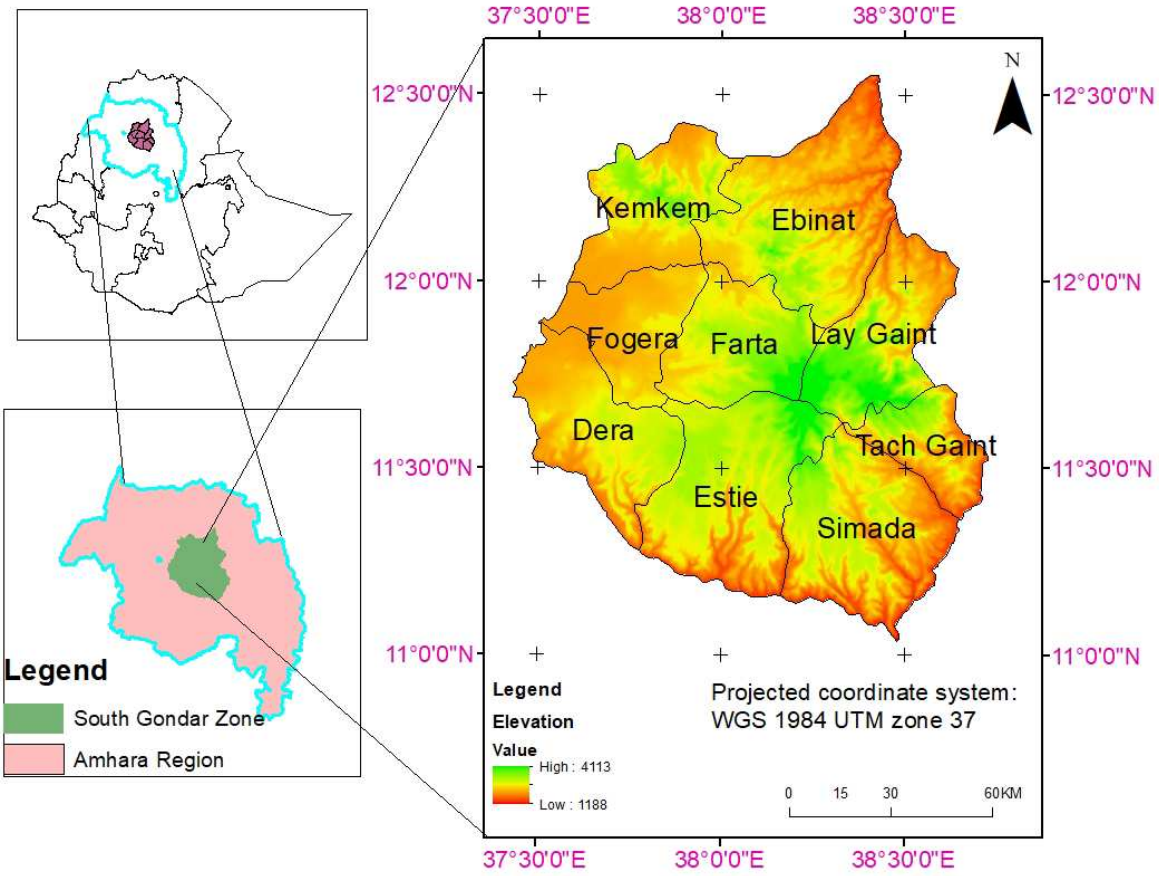

Figure 2: Map of the Study Area.

Topography

South Gonder zone was located on its elevation is 2,706metres (8,878ft) A.S.L, with coverage of an area 14,095.19 square km.

Climate

The climate of the zone is more influenced by altitude and latitude than others. Based on the simplified agro climatic classification of Ethiopia, it lies within four agro climatic zones. Wurch (Alpine), Kola (tropical), WoinaDega (Sub tropical) and Dega (temperate). The zone has bimodal rainfall pattern, summer is the main rainy season with its peak in July (June to August) and the short rainy season from February to April. Rainfall varies from 900 mm to1599mm. The average annual rainfall in the zone is 1300mm. The average temperature in the zone is 17°C (Board, 2012)

Demographic and Socio-Economic Condition

Population

The study area is the home to 55,596 people of which 35,372 are males and 35,728 are females and has a population density of 145.56; 195,619 or 9.53% are urban inhabitants. A total of 468,238 households were counted in this Zone, which results in an average of 4.38 persons to a household, and 453,658 housing units. The main ethnic group reported in south Gondar was the Amhara (99.7%); all other ethnic groups made up 0.3% of the population. Amharic was spoken as a first language by 99.7%; the remaining 0.3% spoke all other primary languages reported. 96.14% practiced Ethiopian Orthodox Christianity, and 3.68% of the population said they were Muslim(Board, 2012)

Economic Activities

In the study area, various economic activities are undertaken, Farming is the major economic engagement crop production such as a teff, barley, wheat, maize, sorghum, potato, triticale, fava bean, field pea. The farming system in the zone is characterized by mixed farming. Hence, more than 85% of the farm households engage in mixed farming systems and more than 93% of the farm households plough their land using traditional farming technology (Boared, 2014)

Research Methodology

Research Design

In order to address the stated objectives, the researcher was used quantitative research design. . The various factors affecting land suitability were then processed, standardized, weighted and overlaid to produce individual suitability maps and a final suitability map. Furthermore some simple statistical methods, such as percentage, regression analysis and other also was employed for the analysis and interpretation.

Selection of Criteria

Soil, temperature, altitude and slop are parameters for wheat crop suitability analysis. Four criteria were selected for evaluating agricultural land suitability for wheat crop in the study area these criteria were selected based on extensive literature review of potential factors affecting.

Standardization of Criteria

After data preparation and processing, the different factors were arranged in an order matching their importance or weight. As indicated earlier, the order was climate, soil, topography. This process is also referred to as rating. As there were two classes, considering the optimum conditions for wheat cultivation the classes were numbered 0 to 1 with two being listed in class that fulfilled the optimum requirements, two indicating the class that moderately met the requirements and one numbered the class that least met those optimum requirements. Following this individual suitability maps were obtained. Using these ratings, the sub factor maps were re-classified and this was performed in ArcGIS 10.3. the results of this process are the individual suitability maps for sub factors which would be weighted and overlaid to produce the individual suitability maps for the four identified main factors.

Weighting and Overlaying

The sub factors under each of the four main factors were determined to bear same weight as to production of factor suitability maps. The combination of sub factors was carried out through the weighted sum tool in ArcGIS 10.3 under overlay. Following these the four factors and their suitability in the same two classes were produced.To get the final suitability map, overlaying had to be carried out. The individual maps had two classes and the expected final map was to have two classes of suitability

DATA ANALYSIS AND INTERPRITATION

ANALYSIS

Wheat Suitability Analysis Based on Altitude

According to (Hossein *et al*., 2015), Wheat is grown in an elevation less than 3000m above sea level. The need for elevation criteria because of it has effect on climate and vegetation are considered as important factor in land suitability. Less than 1600maslis not suitable for wheat crop production.

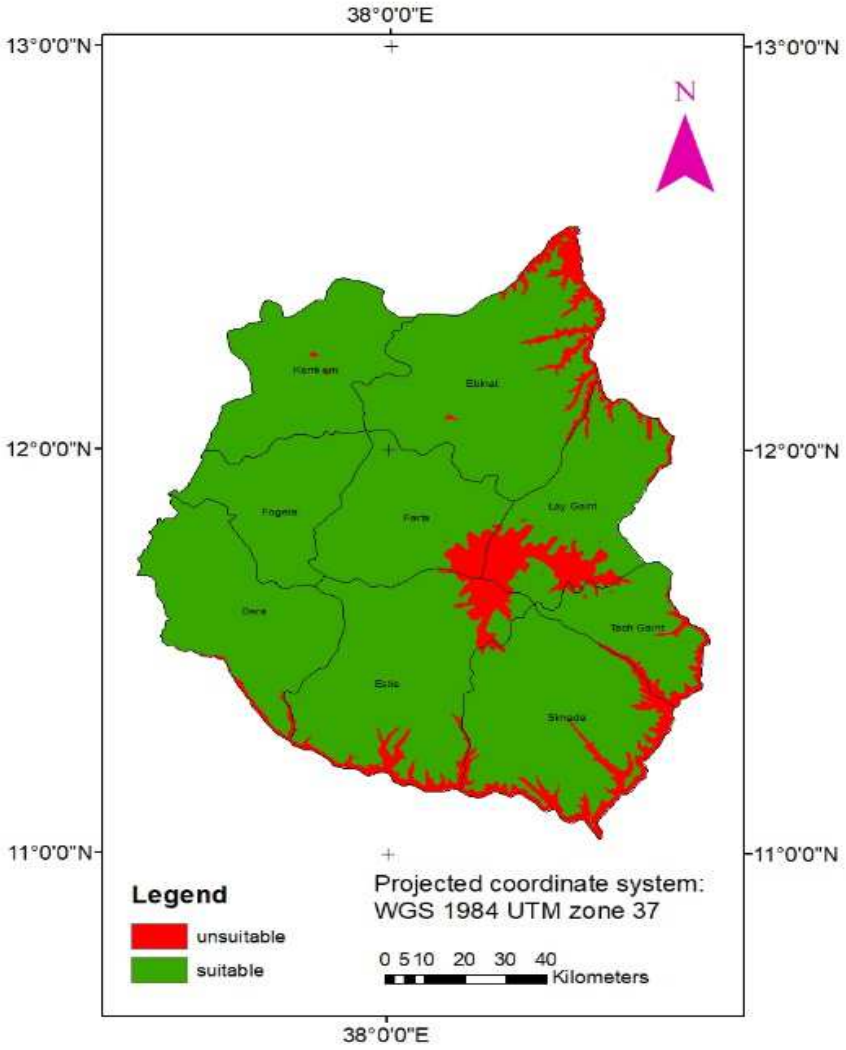

Figure 3: Suitability Map of Wheat Based on Elevation.

The results in Fig. 3, The red color show that unsuitable of the land for wheat crop based on elevation, and the green color indicate that suitable of the area, Revealed that about most of area are suitable for growing wheat crop, whereas area like some parts of Farta, Lay gaynt and Misrak Este are not suitable for wheat crops due to elevation variation.

Table 1: Suitability Table Based on Elevation

Range	Class	Color	Area (km^2)	Percentage
>3000m and <1600	Unsuitable	Red	4,087	29%
1600-3000m	Suitable	Green	10,007	71%
Total	Total		14,094	100%

The result from the table. 1 that the suitability of wheat crop based on elevation, shows that, 71% of the study area are suitable based on elevation, the remaining 29% unsuitable, which indicate , the area have a potential for growing wheat crop

Wheat Suitability Analysis Based on Slope

According to hossein*et al*., (2015) and farmanullah et al (2007), slope is an important element of land form, which plays an important role for mechanization and irrigation. Wheat crop grown on slope less than 12% in slope which is above 12%wheat crop can't grow.

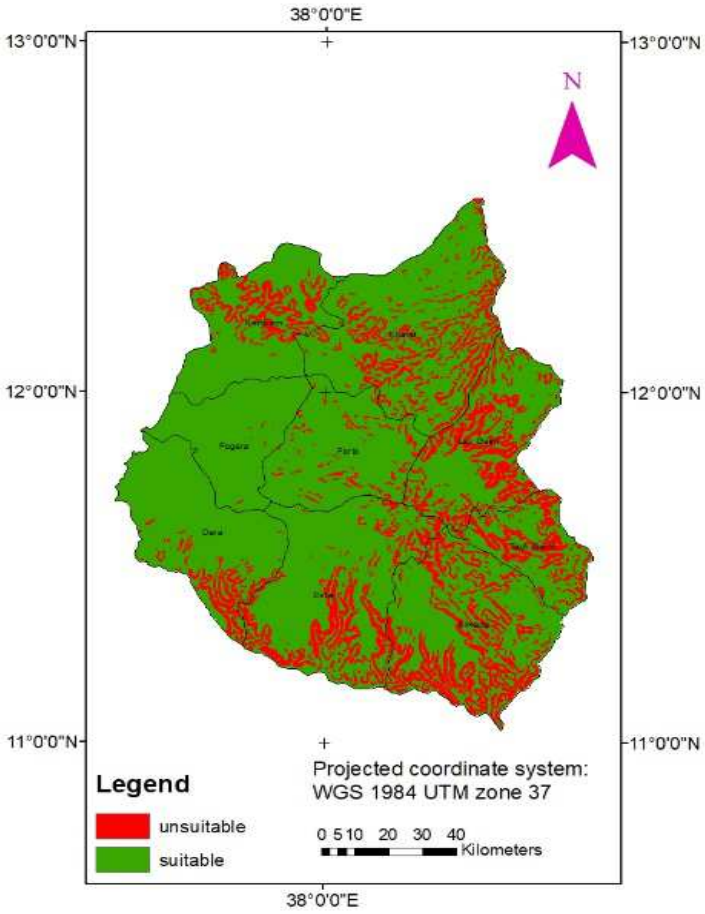

Figure 4: Suitability Map of Wheat Based on Slope.

The results in Fig. 4 show that the green color indicate that suitable of the area and red color indicate that unsuitable of the land for wheat crop based on slop, some parts of like Lay gayint, tachegayint, simada, misrakeste, mirabeste and limokemkemare unsuitable.

Table 2: Suitability of Wheat Based on Slope

Range	Class	Color	Area (km^2)	Percentage
>12%	Unsuitable	Red	9,443	67%
0-12%	Suitable	Green	4,651	33%
	Total		14,094	100%

The result from the table. 2 show that the suitability of wheat crop based on elevation, shows that, 33% of the study area are suitable based on elevation, the remaining 67% unsuitable, this indicate, most of the area are unsuitable for wheat crop production in terms of slope.

Wheat Suitability Analysis Based on Temperature

Relationship between Altitude Temperatures

Elevation and temperature have indirect relationship. The higher the elevation is the cooler the temperature will be. The two relation was analyzed by using regression analysis tool. The regression analysis tool is an advanced tool that can identify how different variables in a process are related. The regression tool will tell you if one or multiple variables are correlated with a process output

Maximum Temperature and Elevation

According to Rasul. G (2009) wheat crop can grow at maximum temperature less than 35°. If an area have a maximum temperature more than 35°it's unsuitable for wheat crop.

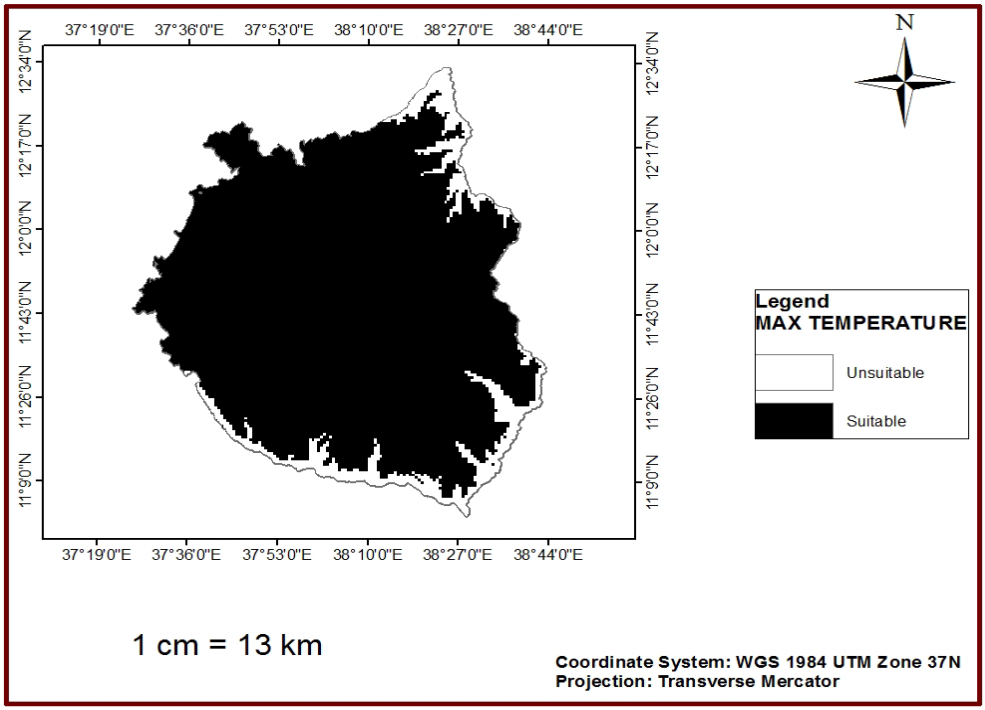

Figure 5: Suitability Map of Wheat Crop Based on Maximum Temperature.

The results in Fig. 5 show that the black color indicate that suitable of the area and white color indicate that unsuitable of the land for wheat crop based on slop, some parts of like simada, misrakeste and mirabeste are unsuitable for wheat crop in terms of maximum temperature

Table 3: Suitability of Wheat Based on Maximum Temperature

Range	Class	Value	Color	Area (km^2)	Percentage
35<	Unsuitable	0	White	1,127.6	8%
25-35	Suitable	1	Black	12,967.3	92%
	Total			14,094.9	100%

The result in table3show that the suitability of wheat crop based on maximum temperature, The resulted from reclassified map and table show that 8% of the study area unsuitable for wheat crop production and the remaining 92% of the area are suitable for wheat crop based on maximum temperature.

Minimum Temperature and Elevation

According to Rasul. .G (2009) the minimum temperature required for wheat crop is 3°-5. If the temperature less than 3° it's unsuitable for wheat production

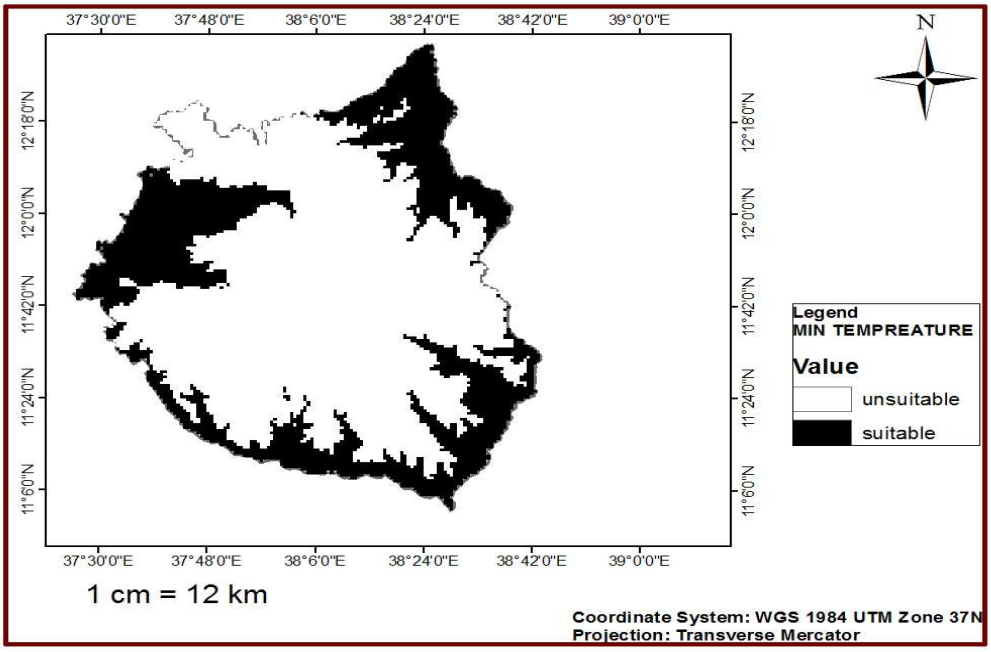

Figure 6: Suitability Map of Wheat Crop Based on Minimum Temperature.

The results in Fig.6 show that the black color indicate that suitable of the area and white color indicate that unsuitable of the land for wheat crop based on minimum temperature, some part of area like southern and norther tip of the area are suitable for wheat crop based on minimum temperature

Table 4: Suitability of Wheat Based on Minimum Temperature

Range	Class	Value	Color	Area (km^2)	Percentage
<3.5	Unsuitable	0	White	9,443.65	67%
3.5-5	Suitable	1	Black	4,651.45	33%
	Total			14,095.1	100%

The result in table 4 show that the suitability of wheat crop based on minimum temperature, show that 67% of the study area unsuitable for wheat crop production and the remaining 33% of the area are suitable for wheat crop based on minimum temperature.

Wheat Suitability Analysis Based on Soil

According to (Kidanu. *S et al*.,2004), (FAO 1993) and (Rhykerd & Ossome, 2007)Soil are affected plant growth, some productivity and yield parameters of crop. Wheat crop grown in major soil clay and loamy soil texture but it also can grow in a soil Nitosols, luvisols and cambisols respectively. This types of soil consider as suitable for wheat crop. The study area reach in different types of soil (Vertisols, Rock surface, Lithosols, Regosols, Lake, Nitosols, luvisols and cambisols) but only three of them are suitable for wheat crop production

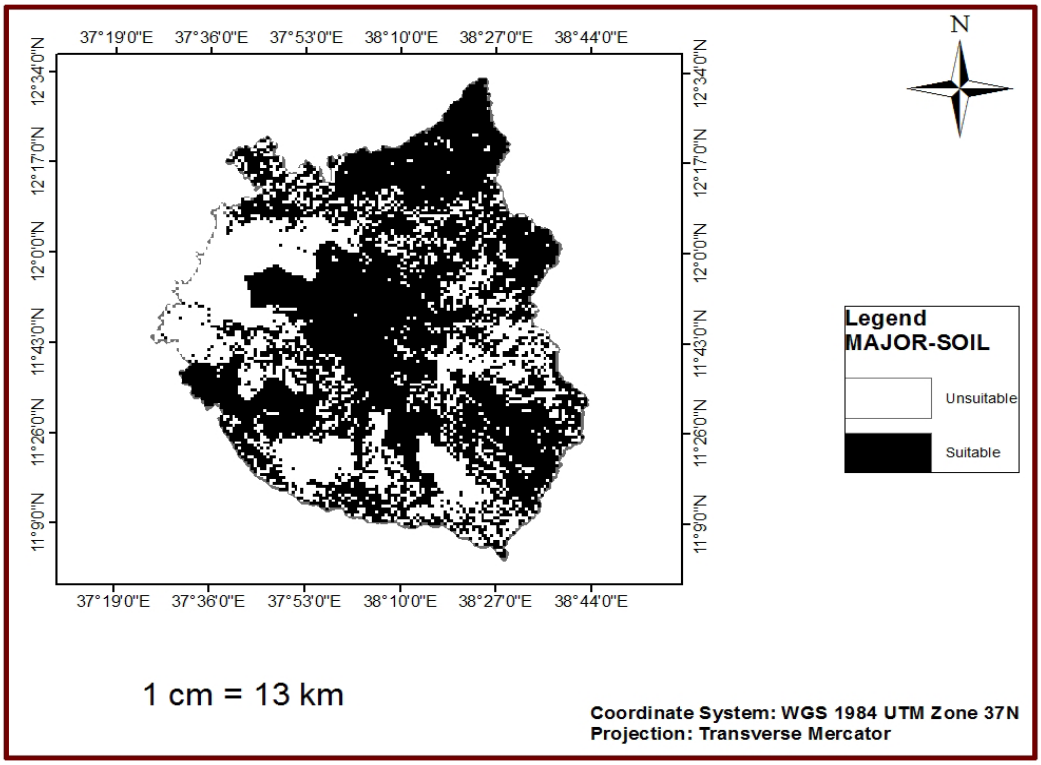

Figure 7: Suitability Map of Wheat Crop Based on Soil.

The results in Fig.7 show that the black color indicate that suitable of the area and white color indicate that unsuitable of the land for wheat crop based on soil type, most parts of western and southern area are unsuitable while the rest are categorized under.

Table 5: suitability of Wheat Based on Soil

Type Of Soil	Class	Value	Color	Area (km^2)	Percentage
Vertisols, Rock surface, Lithosols,Regosols and Lake	Unsuitable	0	White	4,791.96	34%
Nitosols, Luvisols and Cambisols	Suitable	1	Black	9,302.2	66%
	Total			14,094..16	100%

The result in table. 5 show that the suitability of wheat crop based on soil, show that 34% of the study area unsuitable for wheat crop production and the remaining 66% of the area are suitable for wheat crop based on soil.

Interpritation

This study has revealed the potential agricultural land for wheat crop in south Gonder zone. For crops to be matched with the physical conditions variables (soil, slop, altitude and average temperature,) the combination of sub factors was carried out through the weighted sum tool in ArcGIS 10.3.The following overlay of sub factors the final maps show two different classes of suitability and the each class has been displayed consistently in 2 color. This will assist in quick identification and comparison of suitability level.

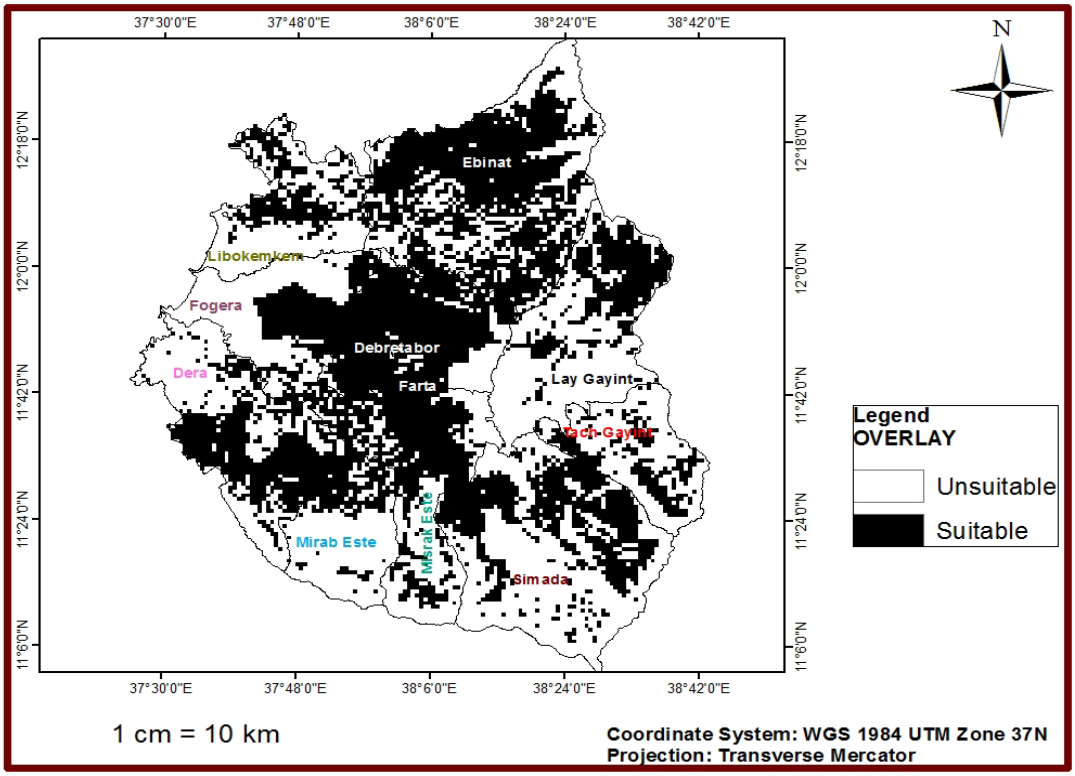

Figure 8: Suitability Map of Wheat Crop Overlay.

Based on the result in fig.8 The Northwestern and northern and central parts (Debre tabor, Derafarta, Ebinat and Farta) of the zone are the most suitable locations for cultivating wheat, whereas some of wester, eastern and southern parts (Simada, Tach gaynt, Lay gaynt, Limokemkem, Merab este and Misrakeste) are found to be unsuitable.

Table 6: Suitability Map of Wheat Crop

Class	Value	Color	Area (km^2)	Percentage
Unsuitable	0	white	7,329.868	52%
Suitable	1	black	6,766.032	48%
Total			14,095.9	100%

Suitability analysis table.6 indicated that total area of study is 14095.19 square kilometers. From the table above, the area identified as suitable for wheat cultivation regardless of the level of suitability is 6766 square kilometers of the area are suitable and the remaining 7329square kilometers are unsuitable.

CONCLUSIONS AND RECOMMENDATION

Conclusions

This study investigated in agricultural land suitability analysis for wheat crop by using multi criteria and GIS technology in case of south Gonder zone, Ethiopia. GIS provides a great advantage to analyze multi-layer of data spatially and quantitatively. Depending on the available spatial data, the accuracy and reliability of the result using GIS Application could be high, with GIS in our experiment proves it is a powerful combination to apply for land-use suitability analysis. In the above research finding Most of land units in the study area fall under the unsuitable (52%) class for wheat crop production, and the rest (48%) are suitable.

Recommendation

The recent times, insufficient agricultural production/ food insecurity as a result of reduction in agricultural investments, increasing costs of production, shortages of agricultural labor, degradation of agricultural resources, water scarcity, climate change and globalization have caused increase pressure on land utilization.

Based on the research finding the researchers provide the following recommendation to the all-stakeholder inthe study area to take some activities to improve agriculture sector

- The study involved one crop and the same process can be applied to other crops.
- The study narrowed the major factors in consideration to four. The exercise can be carried out considering all possible factors affecting the crop.
- The study was carried out in south Gonder district and it is possible to apply the exercise to the whole Amhara region and possibly the whole country too.
- The government should work on areas which categorized under unsuitable class, (Simada, Tach gaynt, Lay gaynt, Limokemkem, Merab este and Misrakeste), in order to minimize the above problem and also the government and local administrator should

REFERENCE

1. *Bodaghabadi, M.B., Martínez-Casasnovas, J.A., Khakili, P., Masihabadi, M.H., Gandomkar, A.,(2015). Assessment of the FAO traditional land evaluation methods, a case study: IranianLand Classification method.*
2. *Boared, (2012), physical and socio-economic data of south Gondar zone, unpublished document.*
3. *Boared, (2014), physical and socio-economic data of south Gonder zone, unpublished document.*
4. *Drone, S. and Lies, A. (2009). Multi-attribute decision analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. Informatics. 33: 459-474.*
5. *EFAP, 1994 Ethiopian forester action program vole ii the challenge for development EFAP secretariat, Addis Ababa.*
6. *FAO (2009). Soil resources, management and conservation service land and water development division, FAO food and agriculture organization of the united nation.*

7. *Hossain M, Rahman SN, Bhattacharya P, Jacks G, Saha R and Rahman M, (2015) sutability of arsenic mitigation interventions an elevation of different alternative safe drinking water options provided in matlab, an arsenic, hotspot in bangladish.*
8. *Kidanu, S.; Mamo, T.; Stroosnijder, L.(2004) Agricultural Systems : Elsevier Science Ltd: Oxford, UKVol.80 No.2 pp.151-170*
9. *Little boy, M., D. M. Smith and BryantM. J (1996). Simulation modeling to determine suitability of agricultural land. EcologicalModeling.*
10. *Malczewski, J. (1999). GIS and Multicriteria decision analysis. Wiley & Sons Inc., New York, USA.*
11. *Malczewski, J. (2006). GIS-based Multicriteria analysis: a survey of the literature. International Journal of Geographic Information Science, 20: 703–726.*
12. *Rhykerd, R.L., OSSOM, E.M, (2007). Effects of Corn (Zea mays L.) and grain legume associationson soil mineral nutrient concentration, soil temperature, crop yield, land equivalent ratio and gross income in Swaziland. In: ZA, K., MAH, M., SL, S., EMA, E.-M., AMI,H. (Eds.), Proceedings of the 8th Afr. Crop Sci. Conf.El-Minia, Egypt.*
13. *Sys c, van Ranst E, Debaveye J. (1991). Land evaluation. Part 1: principle in land evaluation, and crop production calculations. General administration for development cooperation, agricultural publication, no. 7, Brussels, Belgium.*
14. *Teka,k., &haftu, M. (2012). Land suitability characterization for crop and fruit production in midlands of tigray, Ethiopia. Momona Ethiopia journalof science4*
15. *Wang, H., X. Wang and H. Li, (2006). Land utilization situation in Heilonjiang province based on quantitative geography model. Transactions of the Chinese Society of Agricultural Engineering.*