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Suitability Analysis for Enset (*Ensete ventricosum Cheesman* (*Welw*)) Cultivation in Maraka District, Dawuro Zone, Southern Ethiopia

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Abstract

The factor maps like land use /land cover, temperature, rain fall, soil type and altitude were classified based on suitability evaluation methods of FAO and experts' opinion. At final stage these were reclassified and standardized in GIS software extension tools, which led to the preparation of suitability analysis map of the enset plant suitability classes. As part of spatial MCDM, AHP pair wise comparison module was used to derive internal and external weights for each individual factors and parameters respectively. More weight was given for rain fall automatically by AHP algorithm for the reason that enset cultivation needs availability of rain fall more than any other factors. Consequently, suitability analysis was done and weighted overlay suitability map was visualized with integration of GIS. The findings show that among total area of 46,724 hectares, 30.4% is highly suitable for enset cultivation and production. About 53.7% of the study area is moderately suitable, 12.1% is marginally suitable and 3.8% is currently not suitable to enset crop cultivation of study area. The suitability Analysis of criteria evaluation on the study area showed that the area has greatest potential of enset cultivation. The final suitable open area that can be used for enset cultivation is 635.3ha. This accounts for about 1.4% of the total study area and 4.5% of available open area with in highly suitable order. Based on finding, it could be recommended that this work would be used as policy guide for planners; enset investment could be successful in the District, further suitability research works should be carried out in order to optimize the enset crop cultivation and production.

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Keywords

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Enset suitability,
Maraka District,
Suitability analysis,
Spatial MCDM,
Weighted overlay analysis

Introduction

According to MoFED (2010), agriculture is the base for the economy of Ethiopia. Employ 85% of its population, over 43% of the country's gross domestic product (GDP) and over 80% of foreign exchange earnings. Irrespective of this fact, production method is dominated by small-scale subsistence farming system mostly based on low-input and low-output rain-fed agriculture (Gizachew, 2014). *Enset* (*Ensete ventricosum Cheesman (Welw)*) is a perennial crop belonging to the *Musaceae* family. Where *enset* was once domesticated, it has been used as a food crop for long period of years only in Ethiopia (Brandt *et al.*, 1997), in Dawuro and other south and south western

parts of Ethiopia (Mathewos *et al.*, 2015; Alemayehu, 2017) Some researchers and organizations such as Solomon and Mohammed (2016) and FAO (1996) have tried to prepare a standard framework for suitable and optimal agricultural land use and classified into five suitability classes by following Food and Agricultural Organization (FAO) agricultural potential classes. FAO (1996) classifies agricultural potential based on soil and environmental characteristics into five classes including highly suitable, moderately suitable, marginally suitable, currently not suitable and permanently not suitable. Another researcher like Kassa and Mulu (2012), classify crop and fruit producing surface into four suitability classes (highly suitable, moderately suitable, marginally suitable and not suitable) based on its suitability classes or modifying factors. The problem of selecting the correct land for the cultivation of a certain agriculture product is a long standing and mainly empirical issue (Pirbalouti *et al.*, 2011).

Materials and Methods

Study Area Description

The study was conduct in Mareka District, Dawuro Zone that is located in SNNPRS where *enset* crop is a predominant staple food crop. It is situated to the southwest of Ethiopia at a distance of about 445k.m from Addis Ababa across Butajira- Hosana and 510km through Jimma via Tarcha. Astronomically Mareka District extends from $6^0$56' 00" to 7^0 04' 00" North and 37^0 02' 00" up to 37^0 16' 00" East. In its relative location Mareka District is found south west of GenaBosa, North West of Loma, north of Esera and east of Tocha Districts. The total land surface area of the district is about 46.724 square km. The overall elevation of the District ranges between 947 and 2546 m.a.s.l

According to MoA, (2000) traditional classification, agro-ecology of Ethiopia, the agro-ecology of the Mareka District is classified as 8.23% is Kola (500-1500m.a.s. l), 50% Woinadega (1500-2300 m.a.s.l) and 41.77 % Dega (>2300 m.a.s.l). The minimum and maximum temperature ranges between 16^0c to 23.4^0c and the minimum and maximum rainfall amount is about 1314mm to 1516 (MoA, 2000).

Thus a methodology of GIS, SMCDM and AHP based land suitability analysis used to determine the suitability of *enset* crop cultivation in Mareka District by using factors such as LU/LC, climate (temperature and rain fall), altitude and soil type characteristics of the area.

When a given crop suitability was carried out; area coverage, importance of the crops in the livelihood of the concerned community, suitability of soils and agro-climatic conditions of the study region is always considered. The cropland use requirement (LURs) was also selected based on agronomic knowledge of local experts and FAO (1998) guidelines.

The research results evidence that the comparison of current land use highly and moderately suitable land surface for *enset* cultivation are already being used in the area for *enset* and other agriculture cultivation. Multi criteria decision making is defined as a process that combines and transforms a different spatial data inputs into a resultant decision output as described in (Drobne and Lisec, 2009). Spatial MCDM is more complicated and hard in contrast to conventional MCDM, as large numbers of factors need to be identified and considered, with high association of relationships among the factors (Malczewski, 1999).

Being an issue of multi-criteria decision-making process, *enset* suitability demands for visualization of the impact of the alternatives and criteria in the form of maps. This requires can be accomplished effectively by the integration of spatial analysis and conventional multi-criteria evaluation techniques. Moreover, environmental decision problems are characterized of having multiple and often contradictory objectives. When evaluating such a complex phenomenon, the spatial dimension seems to be the big hurdle. Here, the integration of GIS and MCDM techniques becomes useful.

To come up with relative influence of weights of criteria and sub criteria, Analytical Hierarchy Process (AHP) approach in MCDM was used. In order to calculate the weights for criteria and sub- criteria, pair wise comparison matrix was structured by using data obtained from different experts and literatures; each and every factor were compared with the other factors relative to its influence on a scale from 1/9 to 9 in tabular format that was introduced by (Saaty, 2008).

IDRISI software decision wizard software component was used to support multi criteria in which evaluation process multilayer were aggregated to yield a single out suitability overlay map. The weights were developed by providing a serious of pair wise comparison matrix of the relative importance of the factors to the suitability of pixels for the activity was analyzed. The pair wise matrix comparisons were then analyzed to produce a set of weights that sum to one. The procedures by which the

weights were produced follow the logic developed by Saaty under the analytical hierarchy process (AHP). The responses of KII on ordering, weighting and rating the influence of the considered factors were analyzed inform of table under criteria standardization table.

Results and Discussion

Multi Criteria Decision Making (MCDM) and Weighted Overlay Analysis

Criteria standardization

Following the processing and preparation of data, the factors were organized in an order of fit to their weight of importance. In AHP approach, the criteria are standardized, by using pair wise comparison methods. The standardization of factors or criteria brought about in ratings.

In order to make comparison of one criterion with other, all values transformed into the same unit of measurement scale 1 to 4, while the different in put factor maps have dissimilar measurement units. The value of 1represents highly suitable, 2 stands for moderately suitable, 3 represents marginally suitable and 4 are not suitable based on sub suitability classification of the factors.

The reason of weighting is to express the significance or preference of factors in relation to other factor effect on *enset* cultivation and growth. Pair-wise comparisons are relays on making judgments between two given factors rather than trying to prioritize an entire list of elements. A matrix is built, where each factor is compared with the other factors, comparative to its importance, on a scale from 1 to 9.

The weights generated by this module are produced by means of the principal eigenvector of the pair wise comparison matrix. The information gained from experts standardized again by AHP eigenvector weight. Then, a weight calculated approximately and used to derive a consistency ratio (CR) of the Pair-wise comparisons. If the CR > 0.10, then some Pair-wise values required to be reconsidered and the process is repeated till the desired value of CR < 0.10 is reached.

All factors, which were selected for the evaluation of Land suitability in the study area, were weighted using pair-wise comparison. After the Pair-wise comparison matrices were filled, the weight module was used to identify consistency ratio and develop the best-fit weights. The consistency ratio (CR) was 0.05, which was acceptable for weighting of the factors to evaluate the physical land suitability of the area.

The finding reached with this study is in line with different research works done with in different time. Meaning that most of factors analyzed give the result that support the previous research done on *enset* with regards of physical environmental requirements for *enset* cultivation.

This is acceptable

Rainfall is a dominant factor that determines the suitability of *enset* cultivation in the District composing the largest share of the influence which is about 55.8%. The factors including altitude, land use, temperature and soil type has the percentage influence of 21.01%, 4.86%, 6.94% and 11.36% respectively. The ratings value 1,2,3,4 and 5 are given as result of the corresponding weight influences of each and individual factors.

The eventual suitable land decision for *enset* crop capability surface was done by multiplying the pixel value of each provided factors reclassification raster by weight of influence and summing the result of pixel value to get the suitable surface for *enset* cultivation.

Suitability Evaluation

The findings map the Mareka District tells that the District has the suitable potential for *enset* agriculture. The highly and moderately suitable portion of area sums to 39,282.1ha or about 84.1% of the total land surface area. The others marginally and not suitable classes 5,657.12 and 1,844.65 hectare or 12.1 and 3.8 % for *enset* cultivation

Among the whole area of 46,724 hectares of Mareka District, 14,185ha is highly suitable to the *enset* cultivation. This suitable area is distributed to the central part of the District laying from east to west in widening pattern. This is due to the existence of favorable physical environmental conditions like optimum rain fall, temperature, suitable soil type so on.

Suitability of an area for *enset* cultivation is not based on the influence of a given factor. Suitability is function of different factors combined together. That means both suitability and unsuitability of a given plot of an area for *enset* cultivation is result of the combined effects of physical environmental factors.

Table.1 Data types, sources and resolutions

No	Variables	Data type	Resolution (m)	Resample (m)	Data source	Remark
1	Elevation	DEM/raster	30*30	Original	USGS	
2	Soil data	Vector	-	30*30	FAO	
3	Meteorological data	Raster	1km	30*30	Worldclim.com	
4	Landsat8 2016 image	Raster	30*30	Original	USGS	
5	KII	Qualitative description data from Key informants				

Table.2 Description of enset crop suitability (based on experts' knowledge and Gizachew, 2014)

Code	Class	Description
S1	Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
S2	Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
S3	Marginally suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
S4	Not suitable	Land that cannot support the land use on a sustained basis, or land on which benefits do not justify necessary inputs.

Where S1=highly suitable, S2=moderately suitable, S3=marginally suitable, S4=Not suitable

Table.3 Saaty scale of rating influence of factors

No	Intensity of influence	Definition	Explanation
1	1	Equal importance	Two factors influence equally to objective.
2	3	Somewhat more important	Experience and judgment slightly one over the other
3	5	Much more important	Experience and judgment strongly favour one over the other
4	7	Very much more important	Experience and judgment are very strongly to favour one over the other. Its importance is demonstrated in practice.
5	9	Absolutely more important	The evidence favouring one over the other is of highest possible validity
6	2,4,6,8	Intermediate values	When compromise is needed

Table.4 Criteria considered for *enset* suitability analysis (experts' knowledge)

No.	Criteria considered	Ratings	Suitability order	Weight	Source
1	LU/LC	1	S1	5.42	Experts
		2	S2		
		3	S3		
		Restricted	S4		
2	Average annual temperature	1	S1	11.28	Experts
		2	S2		
		3	S3		
		4	S4		
3	Average annual rainfall	1	S1	51.80	Experts
		2	S2		
		3	S3		
		4	S4		
4	Altitude	1	S1	23.96	Experts
		2	S2		
		3	S3		
		4	S4		
5	Soil type	1	S1	7.54	Experts
		2	S2		
		3	S3		
		4	S4		
	Total			100	

Table.5 AHP derivation

Criteria	Altitude	Land use	Rainfall	Soil type	Temperature
Altitude	**1**	3	1/3	3	4
Land use	1/3	**1**	1/7	½	1/3
Rainfall	3	7	**1**	7	5
Soil type	1/3	2	1/7	**1**	½
Temperature	½	3	1/5	2	**1**

Table.6 Eigen vector weight

Criteria	Weight	% influence	Rating
Altitude	0.2396	23.96	2
LU/LC	0.0542	5.42	5
Rainfall	0.5180	51.80	1
Temperature	0.1128	11.28	3
Soil type	0.0754	7.54	4

Consistency ratio= 0.05

Table.7 Over all enset suitability analysis

Suitability class	Area (ha)	Area in %
Highly suitable	14,185	30.4
Moderately suitable	25,097.17	53.7
Marginally suitable	56,57.12	12.1
Not suitable	**18,44.65**	**3.8**

Fig.1 Agro ecological zones of Mareka District (Mareka District office of agriculture, 2014)

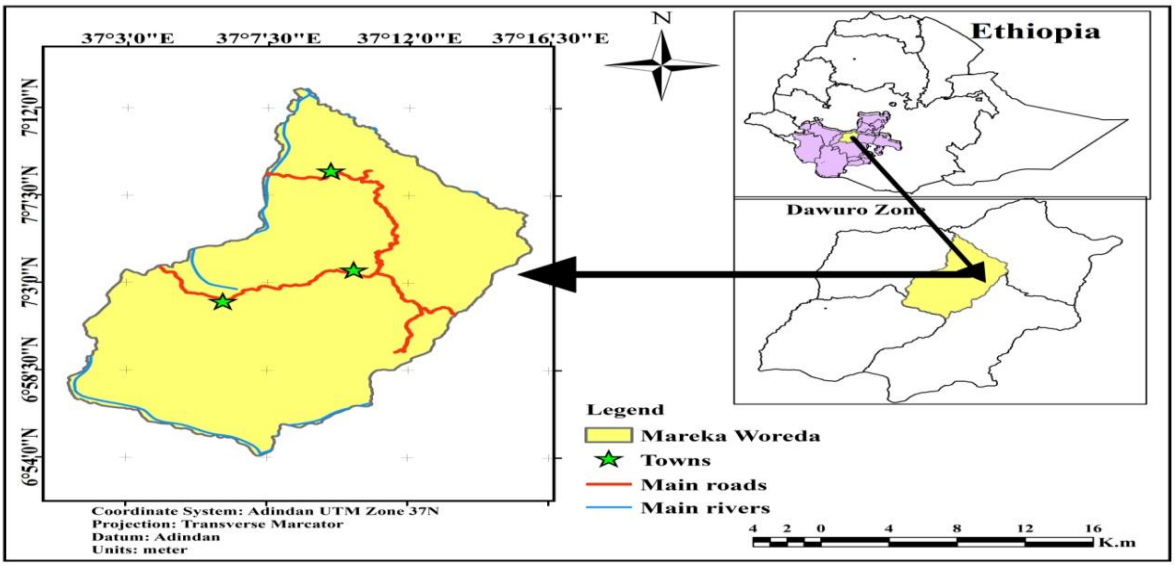


Fig.2 General methodological flow chart

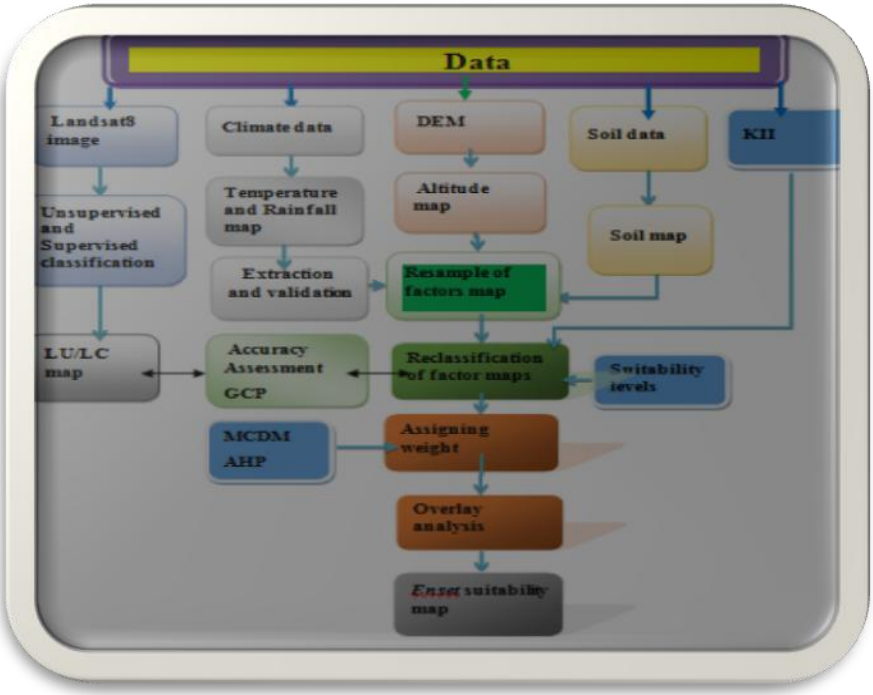


Fig.3 LU/LC suitability of the study area

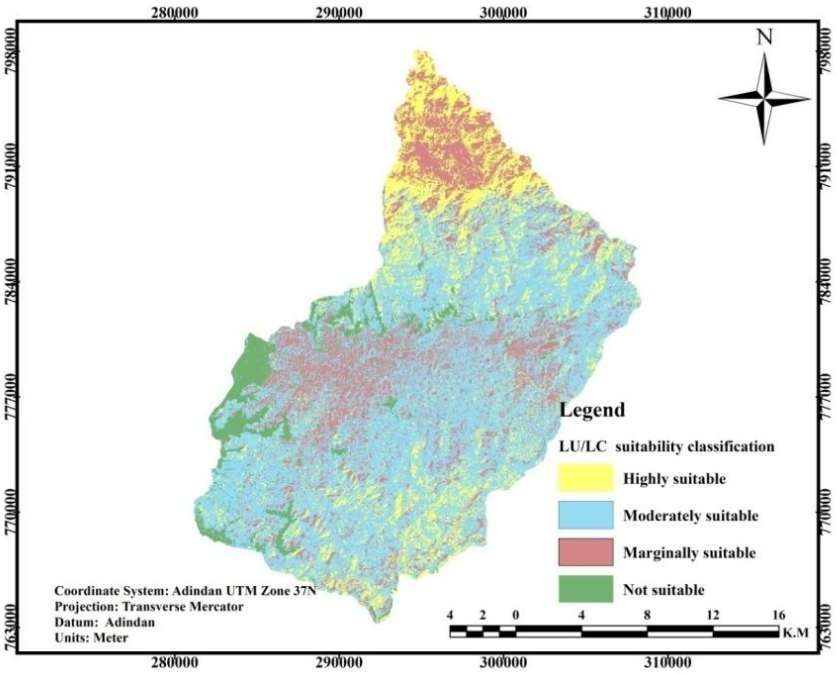


Fig.4 Altitude suitability map of the study area

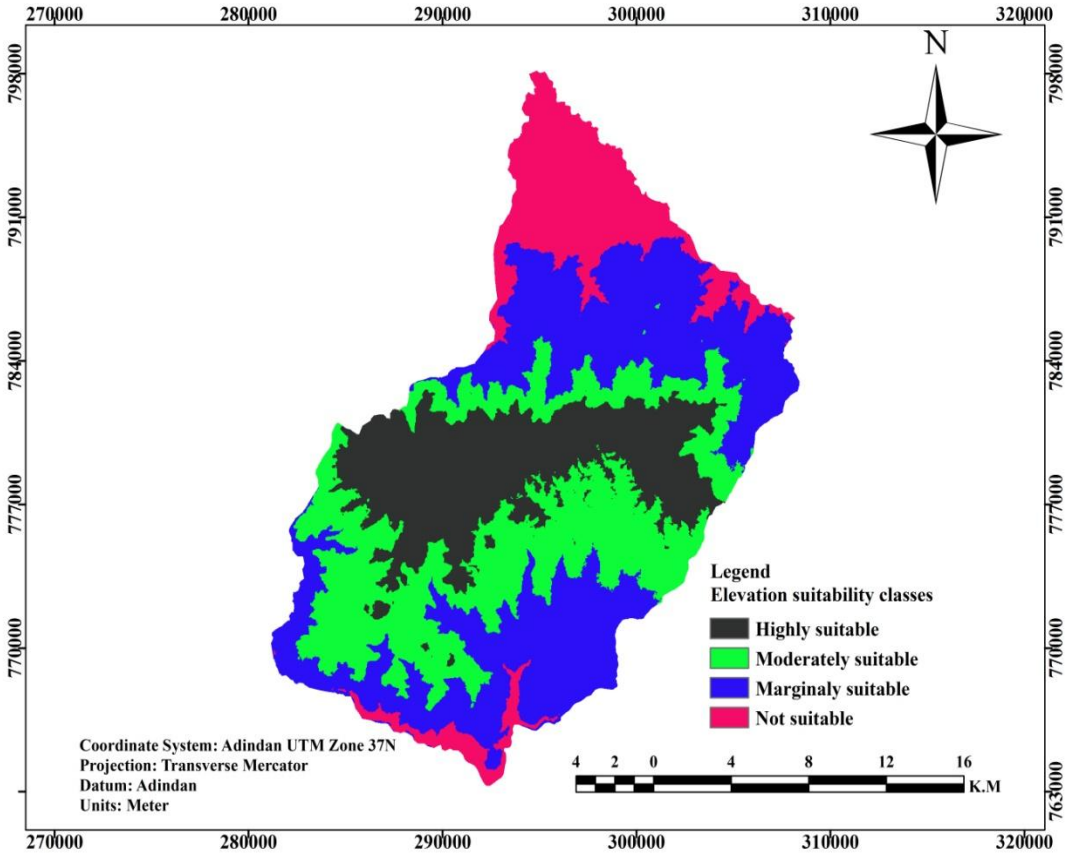


Fig.5 Soil type suitability classes

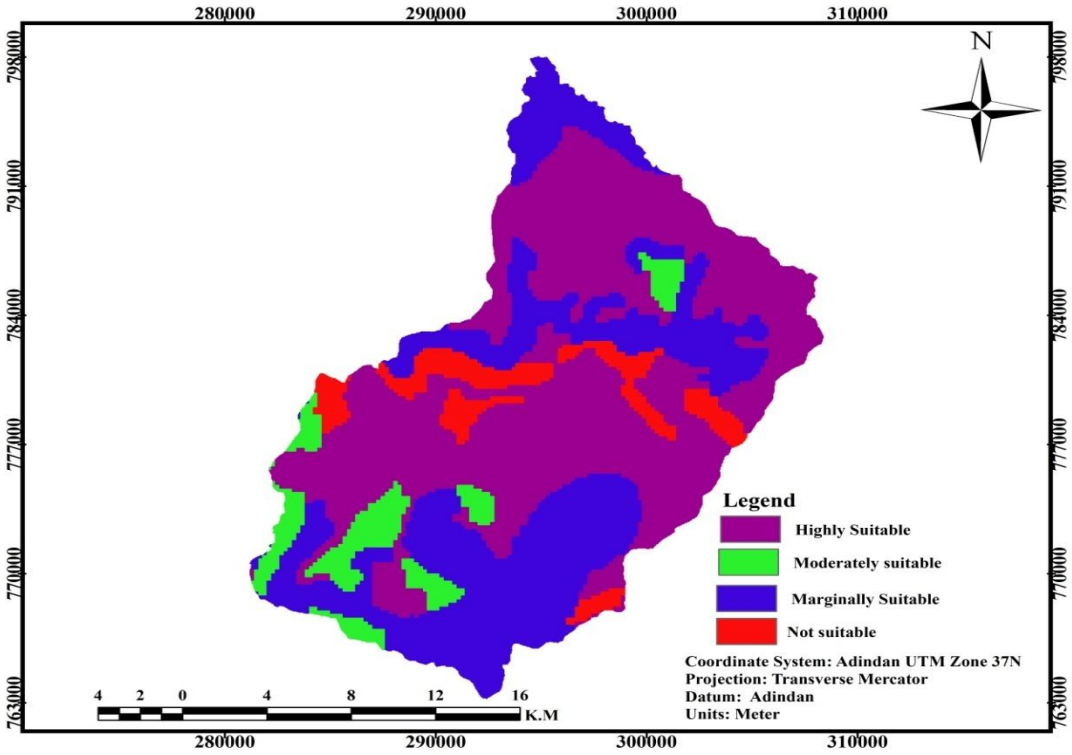


Fig.6 Average temperature suitability of the study area

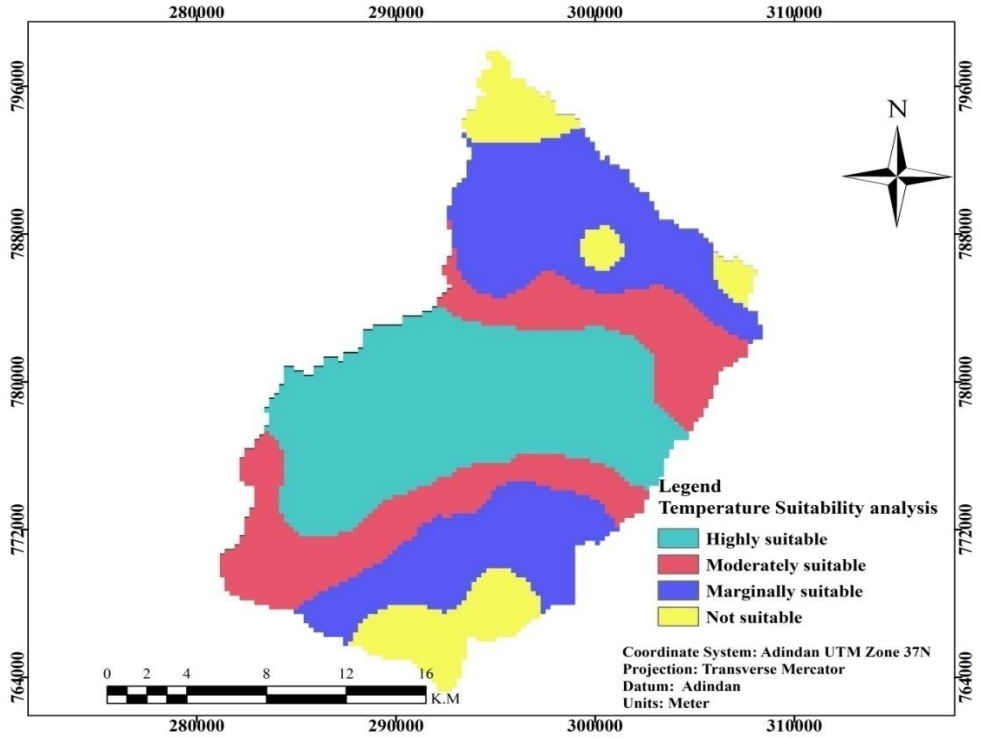


Fig.7 Average rainfall suitability of the study area

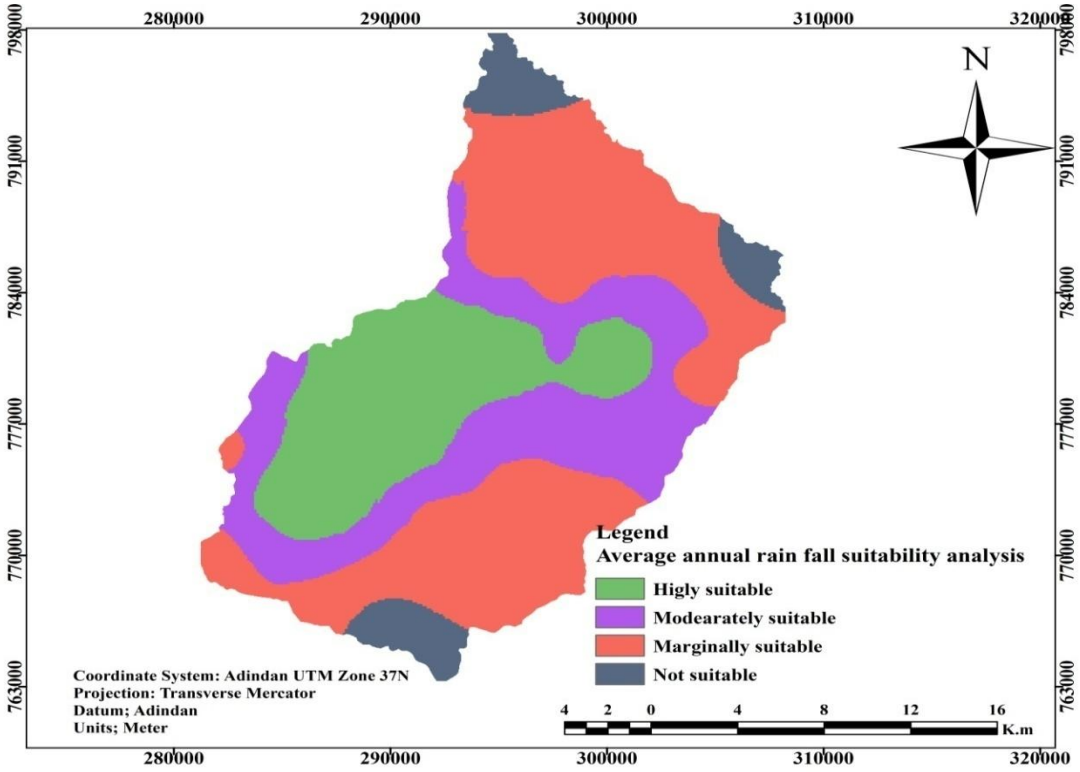


Fig.8 Enset cultivation suitability map of the study area

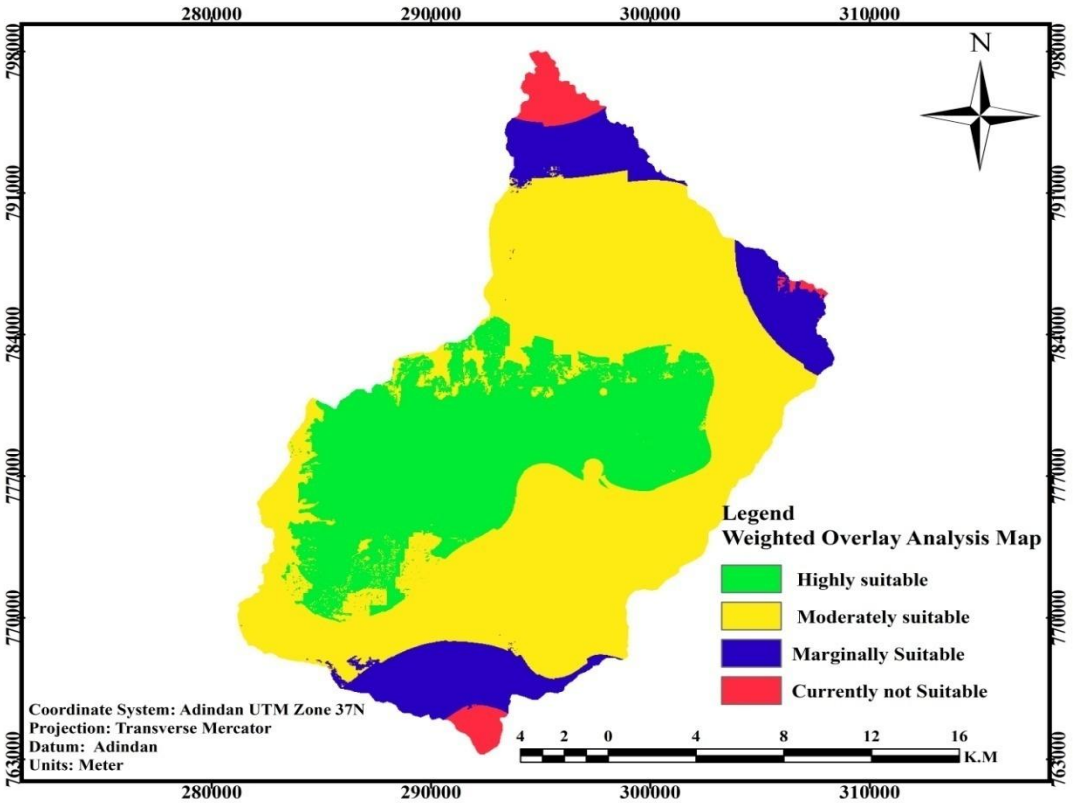
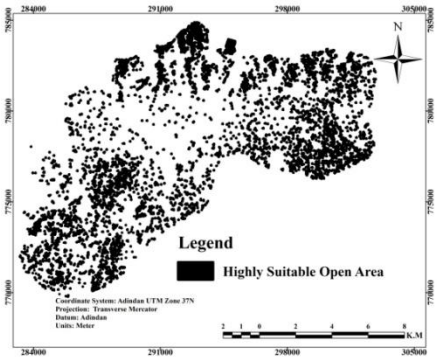


Fig.9 Suitability Model Map



The final suitable area gained in the analysis is still cannot be used to carry out *enset* cultivation without limitation. Due to parcels of land covered with different types of LU/LC. This area is in fact predominated existing cover of *enset* cultivation.

In addition to the above, the study has also come across with open area which is located within potentially cultivated area that can be cultivated *enset* without any limitation identified and displayed on map.

Total highly suitable area is 14,185ha; this is about 30.4% of total study area. Potentially highly suitable open area is 635.3ha. This is about 1.4 % of total study area coverage and 4.5 of area highly suitable for *enset* cultivation. This open area can be utilized for *enset* cultivation without limitation and little economic cost.

The research results evidence that the comparison of current land use highly and moderately suitable land surface for *enset* cultivation are already being used in the area for *enset* and other agriculture cultivation. The result of the study indicated that about 39,282.2 hectares or 85% of the total area 46,724 is analyzed as potentially from highly to moderately suitable for *enset* agriculture in the study area. The final suitability weighted overlay analysis surface map shows that the suitable area for *enset* crop cultivation is situated to the central parts laying from east to west in widening pattern of the study area. This area characterized by higher elevation, receiving higher average annual rainfall, lower temperature, existence of nitosols and fluvisols. While areas having lower altitude, characterized by lower average annual rainfall, higher temperature and cambisols type which situated to the most tips of southeast and north are marginally to currently not potentially suitable for *enset* agricultural practice. These are because of the total biophysical conditions of the surface in the central parts of the study area is favorable for cultivation, but the aforementioned places have harsh agro ecological condition for agricultural practices. This can be understood from the displayed suitability weighted overlay analysis map.

The data produced in the course of this study like land use land cover, altitude, climate and soil type can be used by planners and decision makers to organize suitability analysis for *enset* agriculture investment. This work can also help government to raise awareness concerning *enset* cultivation suitability. Generally, as a finding the existing highly suitable *enset* growing area in Mareka District lies in the central parts from east to west. As the land suitability has been analyzed, Mareka District has much very great potential for *enset* crop cultivation. The study involved *enset* crop and the same process can be applied to other crops. There is more suitable land for *enset* cultivation and production capacity than current utilization of area. Defining the suitability for factors to be considered requires expert knowledge in the subject of interest and consults expert in the specific field.

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