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Land-Site Suitability Analysis for Tea Using Remote Sensing and GIS Technology

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Abstract:- Tea plantation faces wider range of soil fertility issues, this issue include physical,and biologicalissues interactandincludelossof, topsoil due to erosion, acidity, salinity, and deterioration of other physical soilproperties. The aim of this research project was to develop the potential sites map for tea plantation in Twumba sector, Karongi district. Analytic hierarchy processes with a combination of Geographical information System (GIS) techniques were used to analyze eight different criteria which were selected.

To achieve objectives of this study, Landsat8 was used in land use/ land cover estimation in detail to assess their spatial and temporal variability within the area. Reclassification and weighted overlay were used to analyze the important criteria in order to identify the potential sites mapping for tea plantation in Twumbasector. Rainfall, soil PH, soil texture, soil depth, slope, elevation, drainage, and land use land cover were selected as important criteria to identify the potential sites for tea plantation in Twumba sector. 53.6% (532.2 km^2) of the study area be high suitable for Tea plantation,30.4% (301.9 km^2)

Thisstudyhasidentified that 53.6% (532.2 km^2) of the study area are highly potential site for tea plantation and 30.4% (301.9 km^2)is moderately potential for teaplantation. As the results shows, the comparing of thesimulated potential landuseclassestotheexistinglandusepattern the most part of potential and moderate lands were covered by Nyungwe Park which is protected area and taken as the tourist attraction.

Keywords:- *Land Use And Land Cover, Landsat, Slop.*

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ACRONYMS AND ABREVIATION

IST : Institut Supérieur de Technologies
CBD : Central Business District
DDP : District Development Plan
ESRI : Environmental System Research Institute
GIS : Geographical Information System
GPS : Global positioning System
SANET : Spatial Analysis on a Network

I. INTRODUCTION

Land use and land cover change is an important factor responsible for observed global environmental changes(Hanspeter *et al.*, 2011). Although the terms land use and land cover is often exchangeable, they suggest different implications in climate change studies. Land use refers to utilization of land resource by human for various socioeconomic purposes while land cover indicates the type of physical material at Earth's surface. Anthropogenic land use patterns have direct impact on land cover type. Both land use and land cover can be strongly linked with local and regional climate (Hanspeter *et al*., 2011).

Agricultural activity is one of the most important processes driving land use and land cover in a region. During the pre-industrial period, addition of croplands was the primary response to increasing demand for food and

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other agricultural products. With the advent of modern agricultural technology, farmers adopted intensive crop farming to minimize the use of land area and slow down the rate of land cover changes. Nevertheless, globally the fraction of farmland, which comprises cropland and pasture, has been steadily increasing at the expense of forest(Silke & Wolfgang , 2010). The average global greenhouse gas (GHG) emission from agriculture was reported to increase by 1.6 % per year during 1961–2010(Silas, 1984).

Karongi District is one of 7 Districts in Western Province of Rwanda. It is composed with 13 sectors and Twumba sector as case study is one of the 13 sectors composed Karongi District. Its total area is estimated to 993 km^2. Karongi District border in the North Rutsiro and Ngororero, Muhanga and Ruhango Districts in the East, Nyamasheke and Nyamagabe Districts in the South and Lac kivuin the West (Figure2). The total population number is estimated to 331,808inhabitants with a density of 330/km^2 this represents 13.4% of the total population of the Western Provinceand3% of the total population of Rwanda. Females comprise 54% of the population of Karongi district and Males46% of the population of Karongi district(NISR, 2012).

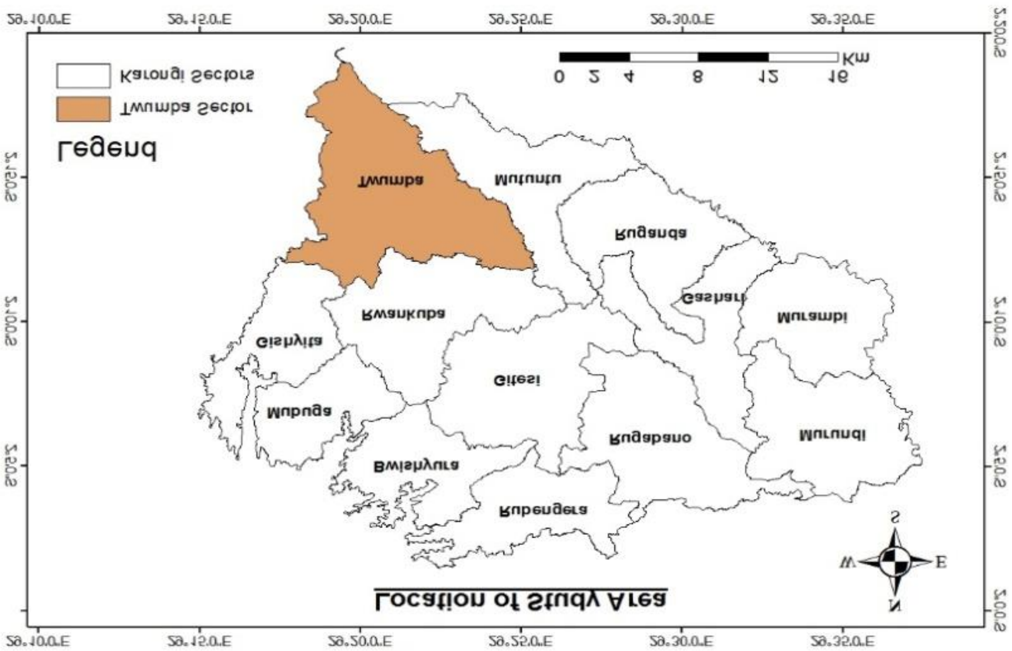

Figure 1: Location of study area

II. METHODOLOGY

Methodology will be includes identifications of the spatial characteristics of the study area, conversion of information into digital form, land sites suitability map within the GIS environment and presenting outputs using a thematic map. Research methods include collection of available and new field work data, data analysis using various tools and techniques. In addition these, data have been collected to assess indicators of land utilization in various altitudinal ranges.

2.1 Research Design

Research Design The study used the experimental andsurvey design. Whereas the experimental design was used in assessing the physical suitability of land, survey was used obtaining data on economic suitability for particularLand Use for Tea.It also talks about the methodology setting in order to present, and to explain some techniques used from data to result and conclusion through data processing, and data analysis. These include primary and secondary sources of data such as GPS data, documentation, satellites images, field observations, and the questionnaire method used in this project.

2.2 Study Population

(Kruger & Casey, 2001)Described a Population as a full set of elements that may include individuals, groups, organizations, human products and events from which a sample can be drawn to generalize results for the entire population". The targeted population of our research was the population of Karongi District exactly Twumba Sector. This implies that the criteria to be part of the sample included being a people living in Twumba Sector.

2.3 Sample size determination

Conducting quantitative research necessarily involves the selection of a population to serve as a sample for further analysis. To select the sample, there are two distinct types of methods: probability and non-probability sampling(Riley *et al.*, 2000). According to these authors, probability sampling is a random selection method in which each unit in the population has a known chance of being selected into the sample. In contrast, non-probability sampling is used when

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the chances of selecting a sample of the population are not random.

Having in mind the suitability of response rates, the researcher took a simple random sample, in which each unit of the population had an equal chance of inclusion(Shore, 1999).Stratified Sampling technique was applied to identify individual to be questioned. The distance of 300m was respected during the selection of households in villages bordered to tea plantation in Twumbasector.

2.4 Sampling techniques and procedure

According to Alain Bouchard, a sample can be defined as set of individuals selected from a universal population and usually is intended to represent the population in a research study(Bluman *et al.,* 2004). Due to financial means, time Constraints and the need of precision of results, it was impossible to study all population.

The population under study is finite with tolerable error "z" equal to 5% and then, the formula is

$n_o = p.q\frac{z^2}{e^2}$ or $n_0 = {}^{1}/_{z^2}$ when p is unknown (Equation $n^0$1)

$$n_0 = {}^{1}/_{(0.05)^2} = 400$$

Then by reducing the error we use a finite population correction factor:

$n' = \frac{n_o.N}{n_o+N}$ (Equation n° 2)

$n'$is simple size from N

N: total number of households in these 7cells is equal to 995

$$n' = \frac{n_o.N}{n_o+N} = \frac{400 \times 995}{400+995} = 285$$

All selected people for interviewer were found in each cells of Twumba sector boarded to tea plantation. The researcher was obliged to determine the sample size of each cell (stratum/ group).

Since we have 7 cells, therefore, we have:

$$Ns1 + Ns2 + Ns3 + Ns4 + Ns5 + Ns6 + Ns7 = n'$$

Then the proportion of number of respondents for each cell was obtained using the following formula:

$N_{s1} = \frac{N1.n'}{N}$ (Equation n°3) (Bluman *et al*., 2004)

Where; Ns_1 is the sample size of the stratum S_1

N is the size of the total population

N_1 is size of population in stratum and n is the total sample size.

The following table indicates the sample size of the population per cell as total sample size of all sector's population.

Table 1: Respondents by cell

Cell	Respondents	$Ns_1 = \frac{N1.n'}{N}$
Gakuta	98	28
Gitabura	152	44
Gisovu	203	58
Bihumbe	135	39
Rutabi	179	51
Kavumu	108	31
Murehe	120	34
Total	995	285

2.5. Data Collection Methods and their source

By using Interview method to ask information on population and remote sensing method Land sat 8 image was downloaded from USGS Website http://earthexplorer.usgs.gov free of charge. Satellite image is of vital importance for land use classification. It can provide updated and detailed land use information, which is very useful in current research. Digitalelevation model (DEM) of 12.5 m spatial resolution was downloaded fromhttps://www.asf.alaska.edu/-free of charge. Additionally, soil data from Rwanda agriculture board and rainfall data from Rwanda Meteorology Agency. The projection type has been used was UTM, Spheroid name was WGS84, Datum Name was WGS84 and UTM zone have been used was 35 south.

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Year	Satellite data	Resolution	source	Purposes
2016	Land sat 8 OLI	30 m	USGS	Mapping of LUC
2016	PAN (landsat8)	15 m	USGS	Resolution merging
	DEM	12.5 m	Alaska Satellite Facility	To generate slope and elevation
	Soil data		Rwanda agriculture board	To generate soil properties

2.6. Pre-testing (Validity and reliability)

In this research some various materials and data were used to achieve the targeted objectives. After delineating the study area, Satellite images especially Landsat 7 ETM+ and Landsat8 OLI images were downloaded from USGS Web platform (www.earthexplorer.usgs.gov/.).

2.7. Measurements of variables (quantitative studies)

The population under study is finite with tolerable error "z" equal to 5% and then, the formula is

$n_o = p.q\frac{z^2}{e^2}$ or $n_0 = 1/_{z^2}$ when p is unknown (Equation n[0]1)

$$n_0 = 1/(0.05)^2 = 400$$

Then by reducing the error we use a finite population correction factor:

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N is the size of the total population

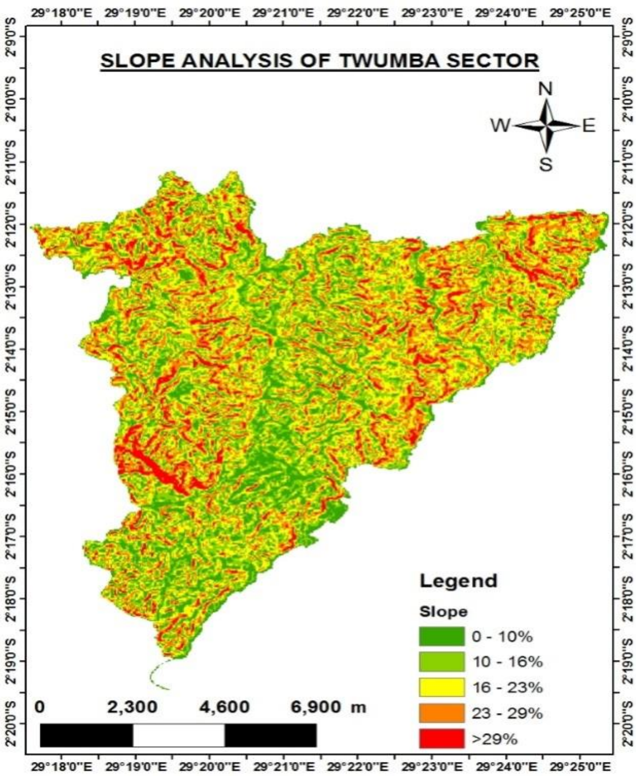
N_1 is size of population in stratum and n is the total sample size.

The following table indicates the sample size of the population per cell as total sample size of Twumba sector's population.

III. RESULTS AND DISCUSSIONS

3.1. Slope of Twumba sector

As it was mentioned earlier, slope gradient has great impact on work efficiency, erosion control practices and crop adaptability. Using FAO guidelines the study area was reclassified into five classes according to its land qualities and characteristics of the slope for the selection of the land for suitability site of tea crop. The classes include high suitability sites (S1), suitability (S2), medium suitability (S3), marginallysuitability sites (S4), and low- suitability sites (N).



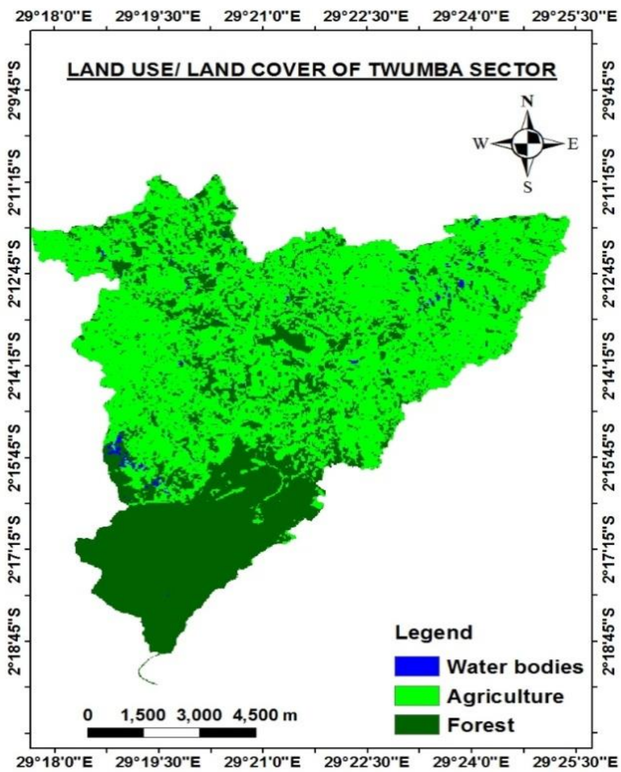


Figure 3: **Reclassified slope map**Figure 4:**Current land use/land cover of study area**

Table 2: Spatial variation of slope

suitability site	Slope range	Count	Area (km^2)	Percentages
S1	(>29)%	21041	202.37	**20.38**
S2	(23-29)%	20344	195.52	**19.69**
S3	16-23)%	23151	222.54	**22.41**
S4	(10-16)%	18840	180.92	**18.22**
N	(0-10%)	19941	191.65	**19.30**
Total		103317	993	**100**

4.2 Land use/ land cover of Twumba sector

The type of land use/land cover in the study area includes water bodies, forest and agriculture land (Table 8). Accuracy assessment resulted from classification is summarized (Table) that the overall accuracy was 94%.The results shown that 0.92% of Twumba land was covered by water bodies, 62.45% was covered by Agriculture and 36.63% was covered by Forest.

Table 3: Current land use/land cover

Land use type	Number of pixel	Area (km^2)	Percentage
Water body	1004	9.14	**0.92**
Agriculture	68479	620.13	**62.45**
Forest	40169	363.73	**36.63**
Total	109652	993	**100**

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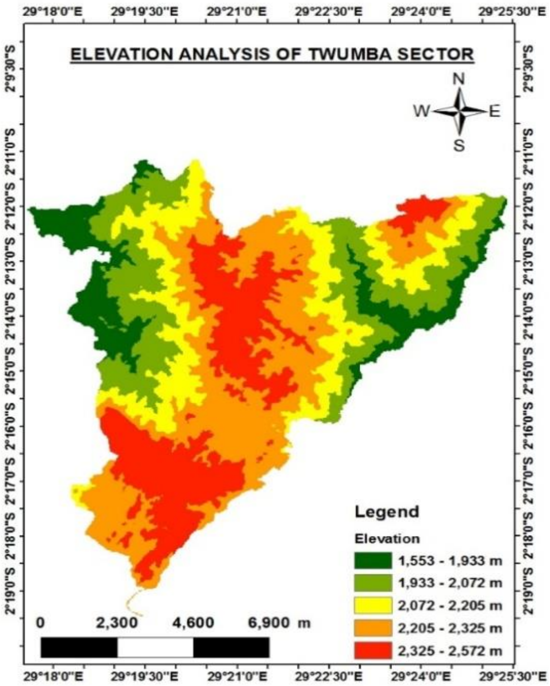
3.3. Elevation of Twumba sector



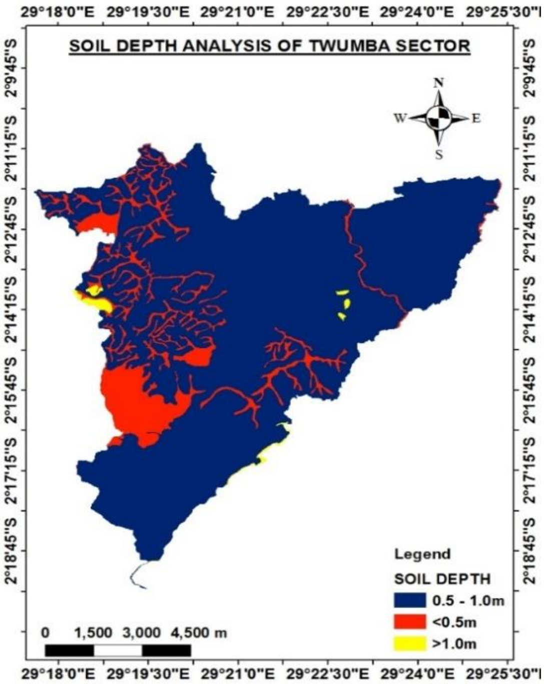


Figure5 : Reclassified elevation map**Figure 6:** soil depth analysis of twumba sector

Elevation data layer (Fig.5), were generated from digital elevation model (DEM) data Since no specific crop suitability is assumed, elevation value lower3000 m is taken to suitable for tea agriculture, for Twumba sector all study area are suitable for tea crop . Elevation above 3000 m is classified as unsuitable for agriculture purposes. Different elevation classes for the study area are defined as in table 5, where 26.35% occupy highly potential, 49.88% occupy moderately potential sites, 21.72% marginally potential sites, 2.01 occupy non potential sites.

Table 4: Spatial variation of elevation

Rating	Elevation range (m)	Number of pixel	Area (km²)	Percentage
Highly suitability	2325-2572	22981	219.55	**22.11**
Moderately suitability	2205-2325	22880	218.66	**22.02**
Medium suitability	2072-2205	17793	170.10	**17.13**
Marginally suitability	1933-2072	20765	198.50	**19.99**
Low suitability	1553-1993	19480	186.19	**18.75**
Total		103899	993	**100**

5.2 Soil depth analysis

A soil depth variation from place to place determines the growth of plants and also affects the growing of plant roots. The thickness of the soil materials, which give structure support, nutrients and water for crops, is referred as soil depth. The soil depth of the study area was classified in to three classes which is shallow (0-0.5m); moderate deep (0.5-1m) and deep (>1m). Based on soil depth required by tea, the reclassified soil depth map reveals that, 68.47% of study area has soil depth (Figure and table)

Table 5: Spatial variation of soil depth

Potential site	Soil depth(m)	Count	Area(km²)	Percentage (%)
S1	>1	7481	71.5	**7.2**
S2	0.5-1	73976	707	**71.2**
S3	0-0.5	22442	214.5	**21.6**
Total		103899	993	**100**

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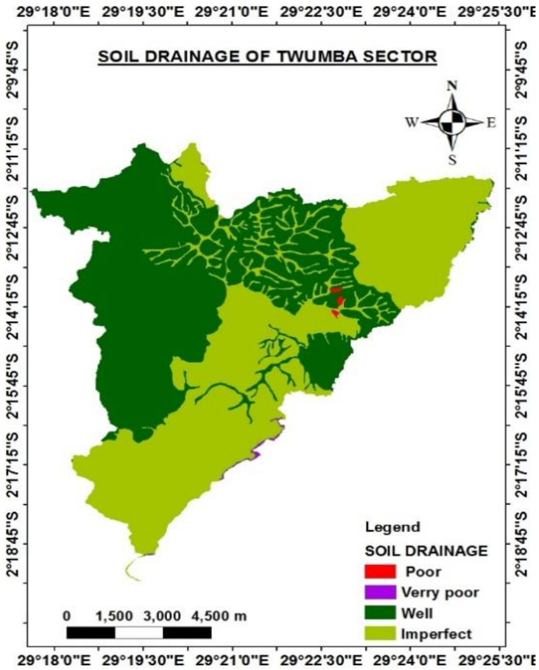
3.4 Soil drainage

Evaluation of the soil drainage requirement is a critical element in selecting land for crop production, because it permits normal plant growth. Adequate soil drainage is essential to ensure sustained productivity and to allow efficiency in farming operations. Soil drainage properties of Twumba sector were classified as well drained, and imperfect, poor and very poor drained soil.



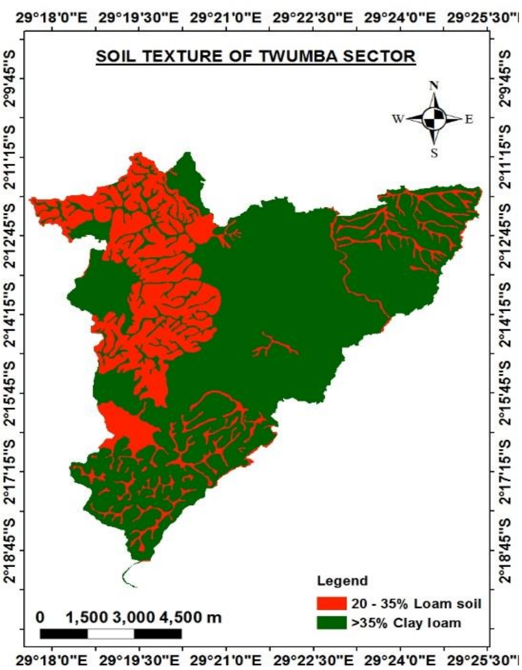


Figure 1: Soil drainage suitability of Twumba sector**Figure 2:**Soil texture suitability

However the soil drainage ensures that the soil is property aerated it help also to reduce the risk of soil slippage, it revealed that 1.6% of study area drainage is not potential (Table).

Table 6: spatial variation of soil drainage

Potential site	Drainage	Count	Area (km^2)	Percentage (%)
S 1	well	56521	540.2	**54.4**
S 2	imperfect	42391	405.1	**40.8**
S 3	poor	3325	31.8	**3.2**
N	Very poor	1662	15.9	**1.6**
Total		103899	993	**100**

3.5 Soil texture

Most of the physical characteristics of the soil depend on texture class (Mustafa *et al*,2011), this study resulted that between 20-35% of study area soil was loam soil and upper to 35% was clay loam. Mean that 100% of study area soil was loamy soil .the whole study area has high suitable soil texture.

3.6 Soil PH

Soil PH is the degree of acidity alkalinity of the soil .PH is the negative logarithm of the H ion activity. This refers to the relative activity of the H ion in the soil solution in present investigation PH value ranges from 3.60 and 5.26. PH of given soil presents an indication of the degree of availability of many soil nutrients and the favorability of soil condition to microbial activity which contributes to the fertility in turn.

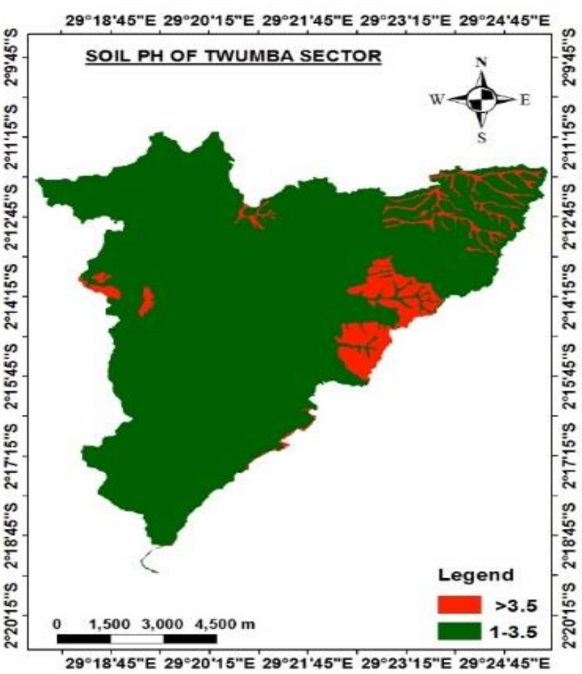


Figure 3: Soil PH analysis of study area

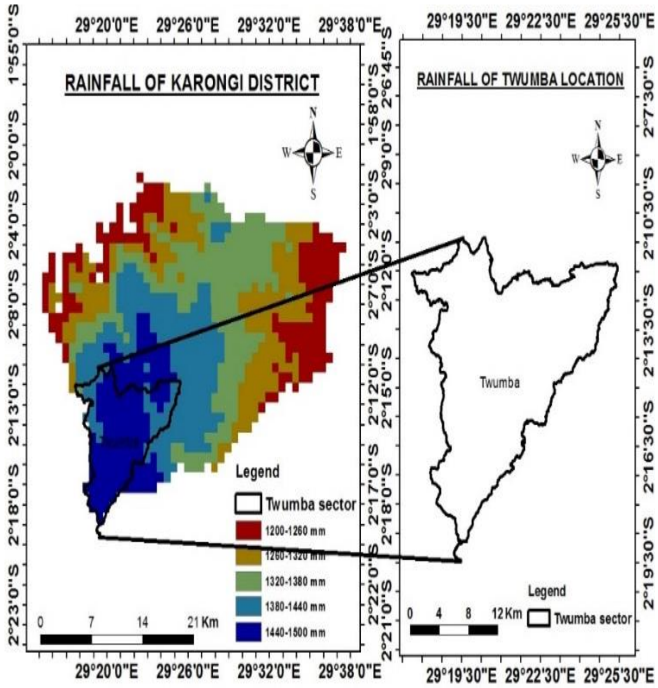


Figure4: Rain fall analysis map

The area which has the soil PH greater than 3.5 is S1, from 1 to 3.5 is S2 (ultra-acidic soil).The resulted PH in study area are summarized.

Table 7: Spatial variation of soil PH

Potential classes	Soil PH (reaction)	Count	Area (km²)	Percentage (%)
S1	>3.5	15793	150.9	**15.2**
S2	1-3.5	88106	842.1	**84.8**
Total		103899	993	**100**

3.7 Mean annual rain fall

The other major elements of climate, which is major requirement for crops production was rainfall, From Inverse Distance Weighted (IDW) interpolation technique rainfall map of the study area were developed.

The results were shown that the whole study area has high potential rain fall required by tea where it range between 1380 to 1500mm, Twumba sector has high rain fall than the others sectors of Karongi District. By using weighted overlay shown that the 100% of study area are high potential site for tea plantation.

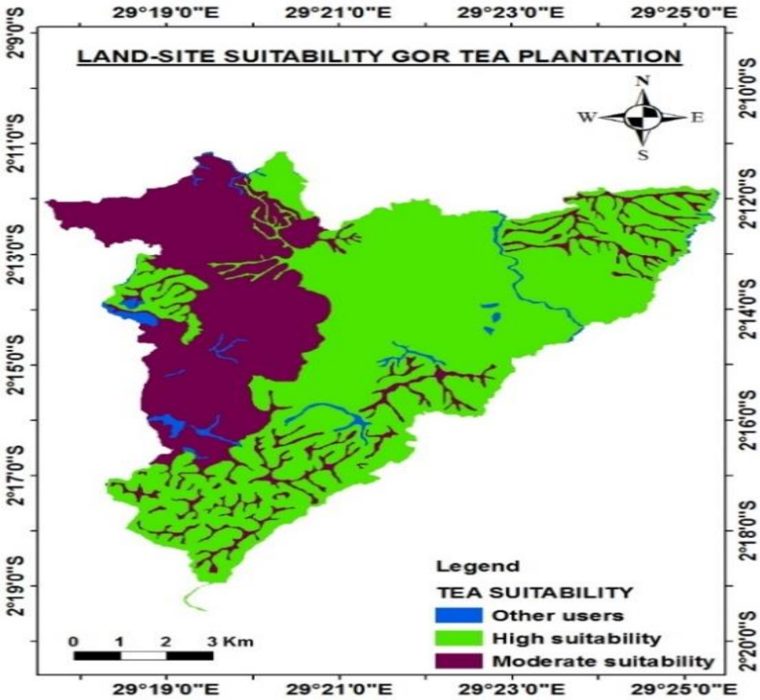


Figure 5: Potential sites map for tea

3.8. Tea suitability land-site map

The result of potential site analysis shows that 45.38% of the agricultural area is highly potential site for tea cultivation, 54.62% is moderately potential sites for tea cultivation. (Fig and Table)

Table 8: Highly and moderately potential sites result

Potential site	Count	Area (km ^{2})	Percentage (%)
High suitability	55690	532.2	**53.6**
Moderate suitability	31585	301.9	**30.4**
Other users	16624	158.9	**16**
Total	103899	993	**100**

According to the results obtained ,the part of study area was high potential for tea due to the best climatic condition resulted in that place where temperature and rain fall of that place was feet the requirements of tea .Not only climatic condition, also soil texture was best feet the requirement. In that place it was observed that was loam and clay loam soil which was best on tea. The soil texture and rain fall has a high influence on the tea production where they contribute more than 50% of all parameters used in this study. Other remained part is moderate of the study area was resulted as moderate potential which was mostly observed in poor drained area and steep sloping area (>25%) locate in east of the study area. All these threats resulted in a limited amount of land in the study area being identified potential sites for agricultural of tea production.

IV. CONCLUSION AND RECOMMENDATION

This study focused on the identification of the potential land for Tea plantation in Twumba Sector. Analytic processes with a combination of GIS were utilized for the evaluation in which nine different criteria were selected. This study has demonstrated that 53.6% (532.2 km ^{2}) of the study area be high suitable for Tea plantation,30.4% (301.9 km ^{2}) is Moderate Suitable and 16% (158.9 km ^{2}) is other users. However, the problems of the low production caused by geographic characteristics, such as very high elevation, a high degree of slope, and less soil moisture. All these threats resulted in a limited amount of land in the study area being identified suitable for Tea plantation.

The local government, land managers and the planning departments shall take into consideration, update and land use policies and regulations associated to avoid all lacks of harmony in land uses. In other words, many efforts should be put in maintaining the agriculture land use and the road network.

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