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Research Article

Land Evaluation and Crop Suitability Analysis – A Case Study on Karachchi Divisional Secretariat, Kilinochchi District, Sri Lanka

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Abstract: Agricultural development in any region needs knowledge about the soils, their properties, and spatial distribution. Crop-land maps created using land evaluation are essential for land management. The research was conducted to develop a crop-land suitability map with "Highly Suitable", "Moderately Suitable" and "Currently Not Suitable" categories for Karachchi Divisional Secretarial Division (DSD) (438.2 square kilometers) by analyzing soil quality. Twelve parameters and 63 sample locations were selected. Weather data such as rainfall, temperature, and relative humidity were collected from secondary sources. A slope map was created using the Digital Elevation Model (DEM) file, and the constructed questionnaire was used to obtain the drainage details. Soil depth was deduced from the wells and soil pits. The collected soil samples were analyzed to determine the parameters such as pH, electric conductivity, the sum of basic cations, base saturation, soil texture, and organic carbon. Each parameter was reclassified using ArcGIS™ 10.4.1 to create parameter maps. After that, an analytical hierarchical process (AHP) was applied to each crop, and then each parameter was reclassified again with reference to FAO's 1993 crop requirement criteria. Finally, the Weighted Overlay Analysis (WOA) was conducted to obtain the crop-land suitability map. The study revealed that 50% of the study area falls under the "Highly Suitable" category for coconut cultivation. Rain-fed paddy shows that 45% of the study area is "Moderately Suitable". Irrigated paddy has a "Moderately Suitable" area of 48%, while nearly 51% is "Moderately Suitable" for onion. 17% of the land is "Highly Suitable" for groundnuts. The pineapple is "Highly Suitable" for 12% of the study area. A crop-land suitability map for Karachchi DSD was created. This map will be a guide for land planning decision-makers.

Keywords: Agriculture, Analytical Hierarchical Process, Land evaluation, Weighted Overlay Analysis.

1. Introduction

The soil is critical for plant growth and anchoring plants (DOA, 2015). Further, Agricultural development in any region needs knowledge about the soils, their properties, and spatial distribution. This knowledge helps in land management decision-making (Walke et al., 2012; Feizizadeh and Blaschke, 2013). Soil represents the only aspect of the land. So, 'land' should not be confused with 'soil'. Vegetation, hydrology, topography, climate, and infrastructure are aspects of land other than soil (Singha and Swain, 2016). Using unsuitable land will result in low production and inefficient utilization of resources. So, land selection is critical for any planning activity (Ambarwulan et al., 2016).

Overpopulation and urbanization have put pressure on natural and agricultural resources. An increased economic return is required to meet the growing world population's economic demands. Unfortunately, the available landmass remains fixed, but the population growth and infrastructural development keep increasing (Ahmed et al., 2015). This increased pressure on the available land resources results in land degradation (Ahmed et al., 2016; Li et al., 2017).

Land evaluation analysis and decisions based on assessment are the means through which we may maximize the use of land resources (Lupia, 2012). Crop suitability of land is assessed considering a sound cropping system to optimize a piece of land for a specific use. Suitability is a function of crop requirements and land characteristics, and it is a measure of how well the qualities of the land unit match the requirements of a particular form of land use (Brink and Young, 1977).

The land suitability evaluation technique is extensively used for land suitability analysis to identify the potential lands for watershed management (Steiner et al., 2000), plantation (Zolekar and Bhagat, 2014), agriculture (Olaniyi et al., 2015, Ahmed et al., 2016, Albaji and Alboshokeh, 2017, Tersteeg, 1993, Bera, 2017, Singha and Swain, 2016, Ghebremeskel, 2003, Ambarwulan et al., 2016, Abdel Rahman et al., 2016, Ahamed et al., 2000, Reshmidevi et al., 2009) etc. A land suitability analysis output is a set of maps, one for each land use, showing which level of suitability characterizes each parcel of land (Hopkins, 2014). Further, with the advances in data collection and processing technology, land suitability evaluation has been gradually applied in various fields (Li et al., 2017), such as Agricultural Land Suitability Evaluation (ALSE), landscape planning, waste

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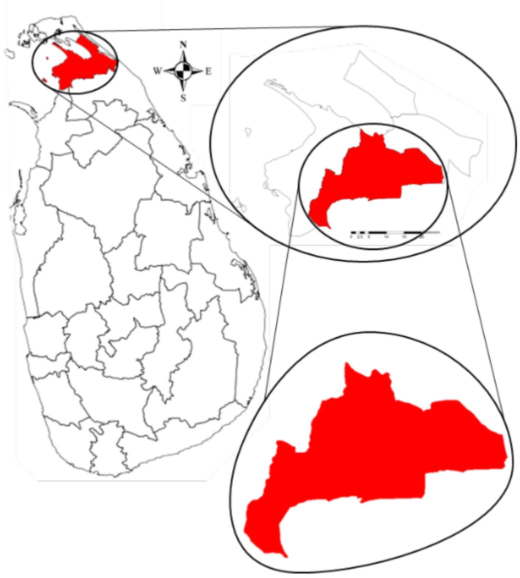

Figure 1: Map of Kilinochchi District and Karachchi DSD

management planning, impact evaluation, land restoration, sustainable urban development, etc.

Food and Agricultural Organization (FAO) had recommended a methodology for evaluating land suitability ratings based on climatic terrain and soil properties (Brink and Young, 1977). Further, the spatial and non-spatial data can be easily handled by Geographic Information System (GIS) (Ahamed et al., 2000). A GIS-based database for land is essential for crop-land suitability analysis. GIS is a promising tool for making an effective decision for land evaluation by employing the methodology of FAO. Ahmed et al. (2016) conducted an agriculture land suitability analysis evaluation based on multicriteria and GIS approach for rubber in Seremban, Malaysia. They used soil texture, rainfall, elevation, and slope as their evaluation criteria. Their main objective was to provide an up–to–date GIS-based ALSE for determining suitable agricultural land for rubber crops in Malaysia. In the Sri Lankan context, Anushiya and Illeperuma (2016) conducted a suitability analysis for paddy cultivation sites using a multicriteria evaluation and GIS in Imbulpe DSD. They used the following parameters such as pH, soil texture, soil depth, drainage, rainfall, slope, aspect, temperature, and relative humidity (RH) as their crop criteria to evaluate paddy suitability. This research was conducted in an area of 225.3 square kilometers.

Olaniyi et al. (2015) conducted a substantial agricultural land-use suitability assessment for Malaysia of 336,745 square kilometers. They evaluated oil palm, cocoa, wetland paddy, and rubber with 12 criteria. They were rural GDP, rural workforce, number of rainy days, average temperature, RH, population density, percentage, rural population, distance to the minor road, distance from the central rail, distance to a major river, slope, and elevation. Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS, and AHP techniques was conducted by Yalew et al. (2016). Slope, elevations, town, river/ water bodies, soil depth, soil stoniness, soil type, soil water content, road, protected area, and land cover are the parameters they selected for the suitability analysis.

In Kilinochchi District, the primary livelihood is agriculture. Many different crops are cultivated throughout the year (NPC, 2017). Further, crop demand is increasing these days while the yield in the many agricultural lands is decreasing. So, cropland maps are essential for land management, farming, and industrialization. However, there are no well-documented maps in Karachchi DSD or Kilinochchi District.

There has been considerable study on land evaluation and, more specifically, agricultural land worldwide. However, in the Sri Lankan context, very few evaluations were conducted. Considering this research gap, the primary focus of this research was to assess the suitability of land for agricultural purposes in the selected site. The ultimate scope of this research is to identify the present status of soil parameters and to find the crop suitability for the land.

2. Methodology

2.1. Study Area

Kilinochchi District is part of Sri Lanka's Northern Province. It contains four DSDs with a total size of 1,349.5 square kilometers (NPC, 2017). Karachchi DSD (Figure 1), one of the four DSDs with an area of 438.2 square kilometers, was selected for the land evaluation analysis. Karachchi DSD is located between latitudes ranging from 9 13'475" N to 9 29'032" N and longitudes ranging from 80 10'045" E to 80 31'033" E. Karachchi

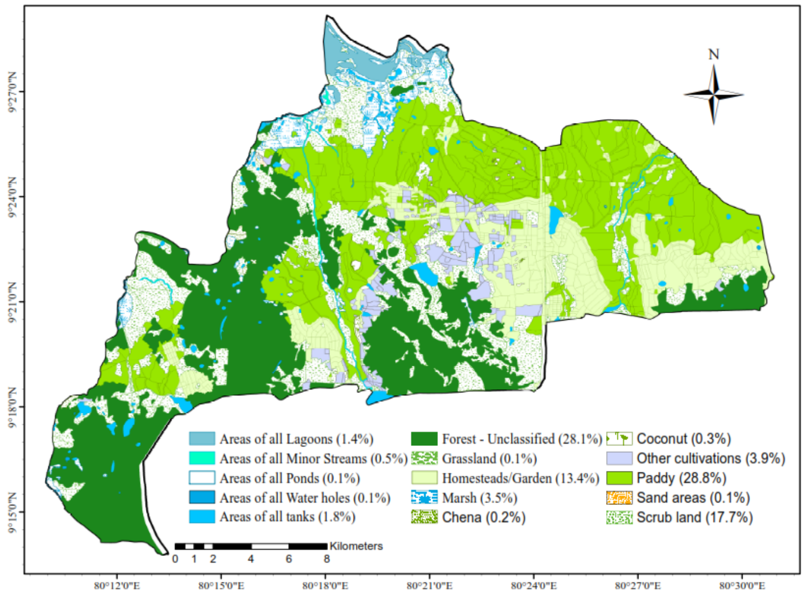

Figure 2: Karachchi DSD land use pattern

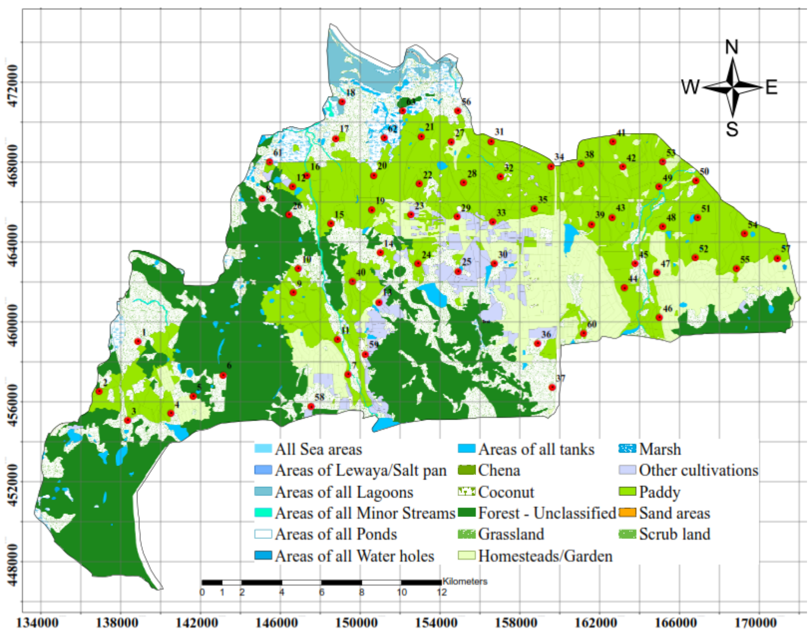

Figure 3: Sampling locations

DSD is further divided into 42 GN Divisions and 115 villages. The total number of families in the DSD is 23,897 (NPC, 2017). The land-use types in Karachchi DSD are shown in Figure 2.

2.2. Sample Location and Sample Collection

The area of 223.4 square kilometers was selected for this study. The remaining area (214.8 square kilometers) was considered Not Suitable (N1) category. The land-use types belonging to the N1 category are all lagoons, areas of all minor streams, areas of all ponds, areas of all tanks, areas of all water holes, forest–unclassified, grassland, homesteads/garden, and marsh. The grid of an area of 4 square kilometers was placed on the land use map using ArcGIS^{TM} 10.4.1. Locations were selected randomly from the areas of land use types that are currently suitable for agriculture. Totally 63 locations were selected. The soil samples were collected as triplicates in each location and aggregated. Each sample was taken up to 30 cm in depth. All the samples were collected during the day for 20 days in June 2019. Figure 3 shows the sample locations with a grid of 4 square kilometers. Figure 4 shows the methodological framework followed in this research.

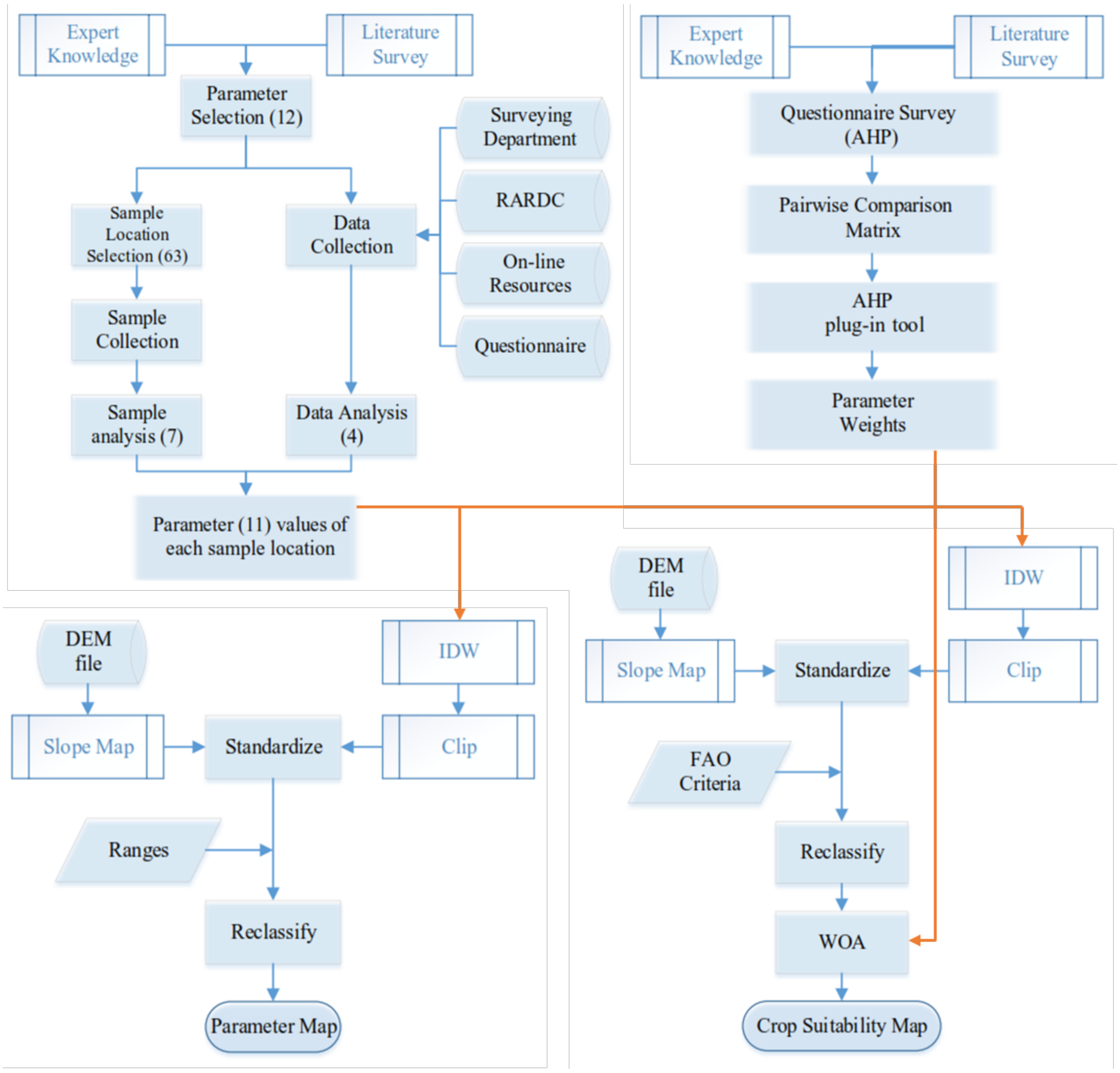

Figure 4: Methodological framework of the research

2.3. Data Collection

Daily rainfall, temperature, and RH were obtained for 17 years (2003-2020). Here, the assumption was made that the rainfall, temperature, and RH do not vary in high deviation within the Karachchi DSD. A questionnaire survey was conducted to find the drainage class of the selected areas. The slope map is directly downloaded from the U.S. Geological Survey (USGS) website.

2.4. Sample Analysis

Soil texture was determined using the ASTM 152H Bouyoucos hydrometer method. Organic carbon content was measured using ASTM D 2974 dry oven method. Electric conductivity was measured by using an EC meter. In order to determine the sum of basic cations, sodium, and potassium content was analyzed using a flame photometer, and calcium and magnesium content was measured with the help of atomic absorption spectrophotometer. pH was obtained from the direct reading from the pH meter. Base saturation was calculated from the sum of basic cations and pH values. Since most agricultural wells are not cemented inside, agricultural wells were used to estimate the soil depth. A soil pit was dug to find the soil depth if no wells were present near the sample location.

2.5. Spatial Mapping

2.5.1 Inverse Distance Weighted (IDW)

The sample points were converted into polygon data, i.e., converted into areas. The "IDW (Spatial Analyst)" tool was used to interpolate a raster surface from points using an IDW technique. The outcome from the IDW would be in a rectangle covering the Karachchi DSD.

2.5.2 Clipping

The outcome from the IDW was clipped to a map of existing agricultural land use. The "Clip (Data Management)" tool was used to achieve this. It crops out a portion of a raster dataset layer.

2.5.3 Reclassification

The clipped map was reclassified according to our value range using the "Reclassify (Spatial Analyst)" tool. It reclassifies the values in a raster. This was done for every 12 parameters, as each crop has a different suitability value range. Further, each parameter was reclassified with a general capacity to create parameter maps.

2.5.4 AHP

Each parameter should be weighed before doing the final analysis because, for each crop, each parameter influences a different percentage. So, to find out the weight for each parameter, an AHP questionnaire was conducted for each crop by experts in agriculture. The final Pairwise Comparison Matrix (PWCM) was created from the surveyed questionnaire. We applied the "AHP plugin tool" to get the weights for each parameter for each crop.

2.5.5 WOA

The "Weighted Overlay (Spatial Analyst)" tool was used to get the final cropland suitability map. This tool overlays several rasters using a standard measurement scale and weights each according to its importance. The reclassified parameters according to the FAO's crop requirement criteria (SYS et al., 1993) were added for each crop, and the corresponding weights were given. This will produce the final cropland suitability map.

3. Results and discussions

3.1. Spatial Variations of Parameters

3.1.1 Soil pH

In the study area, pH ranged from 4.64 to 8.95, indicating that the study area is not firmly acidic or strongly basic. The spatial distribution of pH has been reclassified into four classes with the value range of 4.0 – 5.5, 5.5 – 6.5, 6.5 – 7.5, and 7.5 – 9.5. The area's 189.6 square kilometers (43%) lies within 5.5 to 6.5, indicating that the soil is suitable for many crops. Only 0.9% and 0.6% of the agricultural area lie within 4.0 to 5.5 and 7.5 to 9.5, respectively. Figure 6 in the Appendix shows the spatial distribution of pH in Karachchi DSD.

3.1.2 Soil Texture

Three types of soil texture classes are found in the study area: sandy loam, loamy sand, and sandy clay loam. The study area is laid by sandy loam and loamy sand, extending to 95.2 square kilometers and 122.7 square kilometers. Figure 7 in the Appendix displays the spatial variation of soil texture in the study area.

3.1.3 Drainage

The study indicates that 13% and 35% of the study area are under good and moderate drainage classes, respectively. Figure 8 in the Appendix displays the spatial distribution of drainage classes.

3.1.4 Organic Carbon

The spatial distributions of organic carbon (Figure 9 in the Appendix) show that 33%, 9%, and 0.4% of the total agricultural land is characterized by 0.8 – 1.2, 1.2 – 1.8, and 1.8 – 2.5, which shows high organic carbon availability.

3.1.5 Electric Conductivity

In the study area, the maximum electric conductivity value obtained is 0.421. Some locations near Elephant Pass Lagoon are salty and contain lots of ions. That is why those areas have higher electric conductivity than the other locations. The spatial distribution of soil electric conductivity classes is presented in Figure 10 in the Appendix.

3.1.6 The sum of Basic Cations

The spatial distribution of the sum of basic cations has been reclassified into four classes. An area of only 0.6% lies within the range of 0 to 1.5, which is not suitable for crops (SYS et al., 1993). The spatial distribution of the sum of basic cations is shown in Figure 11 in the Appendix.

3.1.7 Base Saturation

The minimum base saturation is 65% in the study area, which is above the minimum level range. It shows that base saturation does not affect the crops in the study area. Figure 12 in the Appendix shows the distribution of base saturation in the study area.

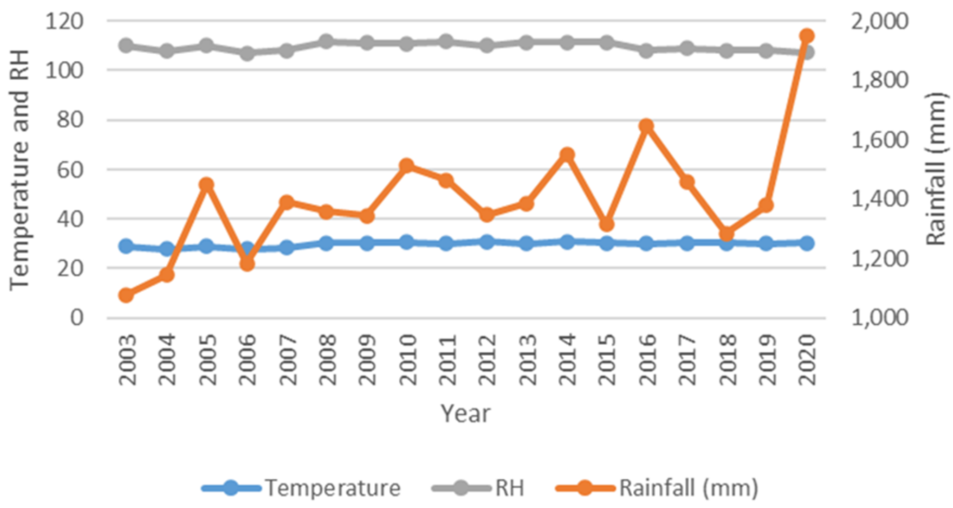

Figure 5: Annual average rainfall, temperature, and RH (2003 – 2020)

3.1.8 Slope

The results indicate that 36% of the agricultural area has less than a 5% slope. Only 0.1% of the total agricultural land has a slope greater than 25%. The distribution of the slope classes is shown in Figure 13 in the Appendix.

3.1.9 Soil Depth

The depth was deduced up to 100 cm. The spatial reclassified variations of soil depth show that about 38% of the total agricultural lands are restricted by the range of 50 to 90 cm. Figure 14 in the Appendix displays the spatial variation of soil depth in the study area.

3.1.10 Rainfall, Temperature, and Relative Humidity

Rainfall, temperature, and RH were assumed to be uniform throughout the study area. This assumption was taken with the help of agricultural experts and indigenous people. This assumption was forced to be made since the weather data for long periods are often unavailable in most rural communities. The average rainfall, mean temperature, and RH are 1375 mm, 29.7 ^{0}C, and 80%, respectively. The annual variation of rainfall, temperature, and RH are shown in Figure 5.

3.2. AHP weights

The results from the AHP for coconut show that it is highly affected by slope, RH, soil depth and organic carbon. The coconut is not growing in hilly areas despite high rainfall because of RH and slope. Since coconut can survive in a wide range of temperatures, the temperature got low weight. The results of the AHP for rain-fed paddy show that drainage, rainfall, and the sum of basic cations have high weights. Since it is rain-fed agriculture, precipitation is the most important factor. pH and soil texture do not affect the rain-fed paddy as they have weights of 0.05 each. The results from the AHP for irrigated paddy showed that pH and soil texture do not significantly affect the crop. Slope plays an essential role with a weight of 0.17. Soil depth weights 0.10.

Since rainfall and temperature are crucial to a small limit, the AHP analysis for onion shows that rainfall and temperature have high weights of 0.16 and 0.13, respectively. The AHP outcome for groundnuts explains that pH, rainfall, and drainage impact groundnuts more than others. RH does not contribute to the high impact on groundnuts as it survives in a wide range of RH. The AHP analysis for pineapple shows RH and Soil Depth do not affect too much on pineapple. Pineapple can survive at depths of 20 cm and RH of 30% and above. Table 1 shows the weights obtained for each crop from the experts' questionnaire survey.

3.3. Spatial variations of crops

3.3.1 Coconut

Coconut (*Cocos nucifera* L.) is the most beneficial palm globally. The coconut palm thrives well under an evenly distributed annual rainfall ranging from 1000 mm to 3000 mm. The mean annual temperature for optimum growth and maximum yield is around 27°C with a periodic variation of 6°C to 7°C. The optimal mean annual relative air humidity is at least 60%. Soil with a minimum depth of 75 cm is "Highly Suitable" for coconut cultivation. It is tolerant to salinity and has a wide pH range from 5.2 – 7.5 for high suitability. The suitability of coconut shows 221.0 square kilometers (50%) of the total Karachchi DSD has fallen in the class of "Highly

Table 1: Weights obtained for each crop

	Weights					
Parameter	**Coconut**	**Rain fed paddy**	**Irrigated paddy**	**Onion**	**Groundnut**	**Pineapple**
Soil Depth	0.0953	NA	0.1022	0.0362	0.0849	0.0283
pH	0.0866	0.0547	0.052	0.0932	0.1194	0.0718
Rainfall	0.0815	0.2076	NA	0.1672	0.124	0.0763
Soil Texture	0.0398	0.0504	0.0464	0.1203	0.0988	0.1337
Organic Carbon	0.1539	0.0943	0.1261	0.0945	0.1059	0.0302
Sum of Basic Cations	0.0314	0.1718	0.1314	0.045	0.0567	0.1708
Base Saturation	0.0239	0.0926	0.1362	0.0455	0.0439	0.0252
Electric Conductivity	0.0506	NA	0.1089	0.0786	0.0706	0.1211
Temperature	0.0431	0.0929	NA	0.1328	0.0881	0.1002
Drainage	0.0285	0.1569	0.1196	0.1186	0.115	0.1369
Slope	0.1799	0.0379	0.1768	0.0677	0.0362	0.0859
Relative Humidity	0.1851	0.0404	NA	NA	0.056	0.019
Total	**0.9996**	**0.9995**	**0.9996**	**0.9996**	**0.9995**	**0.9994**

NA - Not applicable

Suitable". 0.6% (2.4 square kilometers) is categorized as "Moderately Suitable", and 49% of the area falls under "Currently Not Suitable". Figure 15 in the Appendix shows the details of the coconut suitability in the study area.

3.3.2 Paddy

Paddy (*Oryza sativa*) is the staple food and a mainstay for the rural population and their food security. Rain-fed paddy: The primary water source of rain-fed paddy is rainfall. That does not mean that heavy rain is also suitable. The optimal range (for the '"Highly Suitable"' category) of annual rainfall should be between 600 and 1800 millimeters. The weighted overlay analysis results of rain-fed paddy show that 45% (194.9 square kilometers) of the whole study area is "Moderately Suitable", and 7% (28.6 square kilometers) of the area is "Highly Suitable". The land suitability of rain-fed paddy is shown in Figure 16 in the Appendix.

Irrigated paddy: Irrigated paddy cultivation is not affected by rainfall, temperature, and RH. An adequate water supply ensured by irrigation fulfills the water requirement of paddy crops. However, the land slope is an essential factor, especially for irrigated paddy crops. Various types of soils, including sandy soil, silt soil, clay soil, and loamy soil, may be utilized to cultivate paddy under irrigation only if the irrigation is appropriately done. Further, unlike rain-fed paddy, irrigated paddy is affected by soil depth. Water is not always available at the root system because the water table goes down due to the absence of a permanent water source. According to the results, irrigated paddy has the maximum "Moderately Suitable" area with 48% of the total extent. Most areas are "Moderately Suitable" because of drainage, slope, and soil depth. These three are the limiting factors for the irrigated paddy. Figure 17 in the Appendix presents the area and percentage coverage of the different suitability categories of lands for irrigated paddy.

3.3.3 Onion

The onion (*Allium cepa*) crop can be used for flavor and vegetables, which has medicinal value in Sri Lanka. Rainfall should be within 350 mm to 600 mm for "Highly Suitable" onions. The temperature range also should be within the range of 16℃ to 22℃. Onion crop has thin root systems with short lengths and few root hairs. Thus, it is essential to maintain nutrient and soil moisture availability within the shallow rooting zone. The final map of the onion shows that 51% of the landmass area is "Moderately Suitable". As the temperature and rainfall of the study area are not very favorable for onion growth, no area falls under '"Highly Suitable". Figure 18 in the Appendix shows the details of the onion crop suitability.

3.3.4 Groundnuts

Groundnut (*Arachis hypogaea*) is an oil crop. In Sri Lanka, it is mainly used to produce snacks and confectionaries. Groundnuts are ideally grown in well-drained sandy loam or sandy clay loam soil. Deep, well-drained soils with a pH of 6.0 – 7.5 and highly fertile soils with a healthy supply of calcium and moderate organic matter are ideal for groundnut cultivation. Around 17% of the total land extent is "Highly Suitable", while 34% (148.8 square kilometers) of the land is "Moderately Suitable" for groundnut cultivation. (Figure 19 in the Appendix).

3.3.5 Pineapple

Pineapple (Ananas comosus) grows in an area where temperature is between 16°C and 35°C. The results revealed that 12% (54.3 square kilometers) of the total land extent is "Highly Suitable", while 39% (169.1 square kilometers) of the land is "Moderately Suitable" for pineapple cultivation. Soil texture is a limiting factor that makes most of the area "Moderately Suitable". Figure 20 in the Appendix shows the details of the pineapple crop suitability in the study area. Sulaiman (2000) reported that pineapple and coconut crops might be cultivated as intercropping, yielding high income in a limited area.

4. Conclusion

The soil quality of Karachchi DSD was analyzed using twelve parameters. Crop-land suitability maps and parameter maps were created. The FAO framework has remained the vital reference and guiding document for land suitability evaluation in Karachchi DSD. The suitability map of Karachchi DSD will be a guide for decision-makers considering crop substitution to achieve better agricultural production. This study has proved that farmers of Karachchi DSD have an excellent understanding of their biophysical environment because the selected crops fall only in the "Highly Suitable" or "Moderately Suitable" category.

As results showed, irrigated paddy has a "Highly Suitable" category of only 3% of the total land extent; instead of cultivating irrigated paddy, the study recommended that the farmers cultivate highland crops during the *yala season* and intermediate season. Further, the coconut is cultivated only on 1.36 square kilometers in the study area. However, the results showed it is "Highly Suitable" in 221 square kilometers. Hence, the study recommended cultivating coconut with pineapples as intercrop.

5. Acknowledgment

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References

AbdelRahman, M.A., Natarajan, A. and Hegde, R., 2016. Assessment of land suitability and capability by integrating remote sensing and GIS for agriculture in Chamarajanagar district, Karnataka, India. *The Egyptian Journal of Remote Sensing and Space Science*, 19(1):125-141.

Ahamed, T.N., Rao, K.G. and Murthy, J.S.R., 2000. GIS-based fuzzy membership model for crop-land suitability analysis. *Agricultural systems*, 63(2):75-95.

Ahmed, G.B., Shariff, A.R.M. and Idress, M.O., 2015. Adaptation of Land Suitability Evaluation for the Malaysian Agricultural Land Use. *Asian Journal of Applied Sciences*, 3(5).

Ahmed, G.B., Shariff, A.R.M., Balasundram, S.K. and bin Abdullah, A.F., 2016, June. Agriculture land suitability analysis evaluation based multi criteria and GIS approach. In *IOP Conference Series: Earth and Environmental Science* (Vol. 37, No. 1, p. 012044). IOP Publishing.

Albaji, M. and Alboshokeh, A., 2017. Assessing agricultural land suitability in the Fakkeh region, Iran. *Outlook on Agriculture*, 46(1):57-65.

Ambarwulan, W., Setiawan, Y. and Walter, C., 2016. Assessing the suitability and availability of land for agriculture in Tuban Regency, East Java, Indonesia. *Applied and Environmental Soil Science*, 2016.

Anushiya, J. and Illeperuma, I., 2017. Suitability Analysis For Paddy Cultivation Sites Using A Multi Criteria Evaluation And GIS Approach Case Study: Imbulpe DS Division In Sri Lanka. In *37th Asian Conference on Remote Sensing (ACRS 2016), Colombo, Curan Associates, Inc* (pp. 2190-2197).

Bera, S., Ahmad, M. and Suman, S., 2017. Land suitability analysis for agricultural crop using remote sensing and GIS-A case study of Purulia District. *IJSRD-International Journal for Scientific Research & Development*, 5(06):999-1024.

Brink, R., and A. Young. *A framework for land evaluation*. No. 22. ILRI, 1977.

DOA., 2015. *Integrated plant nutrition system - Training Manual*.

Feizizadeh, B. and Blaschke, T., 2013. Land suitability analysis for Tabriz County, Iran: a multi-criteria evaluation approach using GIS. *Journal of Environmental Planning and Management*, 56(1):1-23.

Ghebremeskel, L.A., 2003. *Land suitability evaluation for rainfed agriculture using GIS: the case study of Weenen Nature Reserve, KwaZulu-Natal, South Africa* (Doctoral dissertation).

Hopkins, L.D., 1977. Methods for generating land suitability maps: a comparative evaluation. *Journal of the American institute of planners*, 43(4):386-400.

Li, Q., Huang, J., Wang, C., Lin, H., Zhang, J., Jiang, J. and Wang, B., 2017. Land development suitability evaluation of Pingtan island based on scenario analysis and landscape ecological quality evaluation. *Sustainability*, 9(7):1292.

Lupia, D.F., 2014. Crop/land suitability analysis by ArcGIS tools. *Technica l report*.

NPC., 2017. *Statistical Information 2017, Northern Province Council*.

Olaniyi, A.O., Ajiboye, A.J., Abdullah, A.M., Ramli, M.F. and Sood, A.M., 2015. Agricultural land use suitability assessment in Malaysia. *Bulgarian Journal of Agricultural Science*, 21(3):560-572.

Reshmidevi, T.V., Eldho, T.I. and Jana, R., 2009. A GIS-integrated fuzzy rule-based inference system for land suitability evaluation in agricultural watersheds. *Agricultural systems*, 101(1-2):101-109.

Singha, C. and Swain, K.C., 2016. Land suitability evaluation criteria for agricultural crop selection: A review. *Agricultural reviews*, 37(2):125-132.

Steiner, F., McSherry, L. and Cohen, J., 2000. Land suitability analysis for the upper Gila River watershed. *Landscape and urban planning*, 50(4):199-214.

Sulaiman, S.F.M., 1998, Pineapple production and research in Sri Lanka. In *III International Pineapple Symposium 529* (pp. 89-92).

Sys, C., Van Ranst, E., Debaveye, J. and Beernaert, F., 1993. *Land Evaluation. Part III: crop requirements. Agricultural Publications n° 7, GADC, Brussels, Belgium, 1993, 191 p.*

Tersteeg, J.L., 1993. Land resources and production systems in agricultural land use planning in Botswana.

Walke, N., Reddy, G.O., Maji, A.K. and Thayalan, S., 2012. GIS-based multicriteria overlay analysis in soil-suitability evaluation for cotton (Gossypium spp.): A case study in the black soil region of Central India. *Computers & Geosciences*, 41:108-118.

Yalew, S.G., Van Griensven, A., Mul, M.L. and van der Zaag, P., 2016. Land suitability analysis for agriculture in the Abbay basin using remote sensing, GIS and AHP techniques. *Modeling Earth Systems and Environment*, 2:1-14.

Zolekar, R.B. and Bhagat, V.S., 2014. Use of IRS P6 LISS-IV data for land suitability analysis for cashew plantation in hilly zone. *Asian Journal of Geoinformatics*, 14(3):23-35.

Appendix

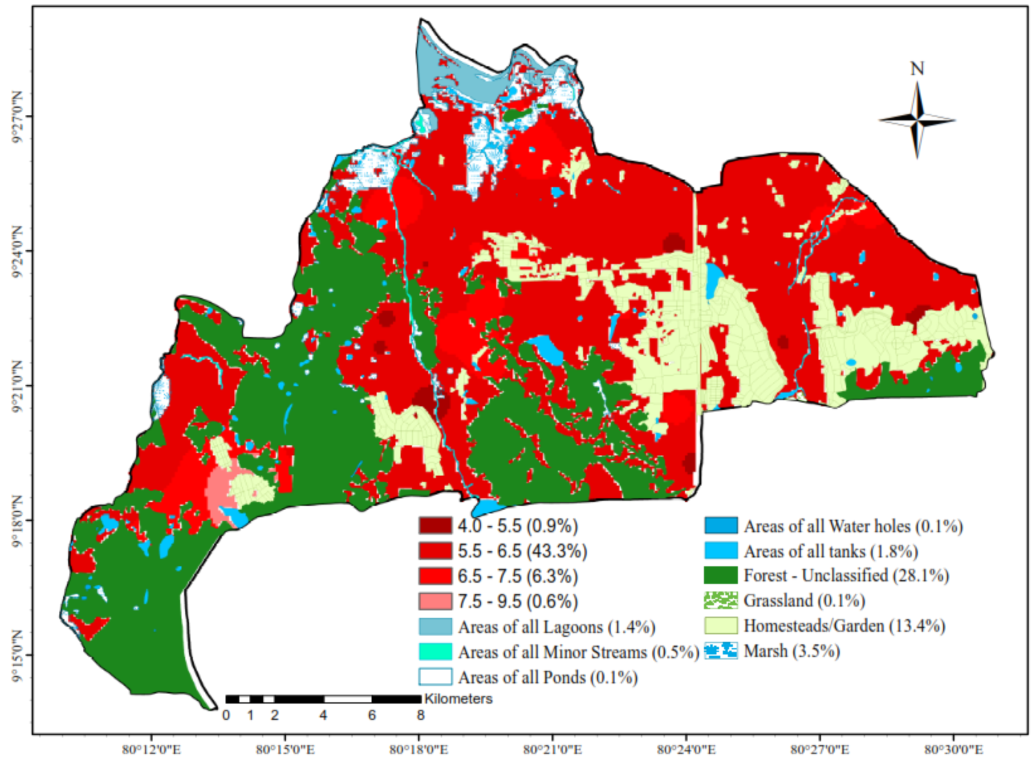

Figure 6: Spatial distribution of pH (NB: Total land extent of 438.2 square kilometers)

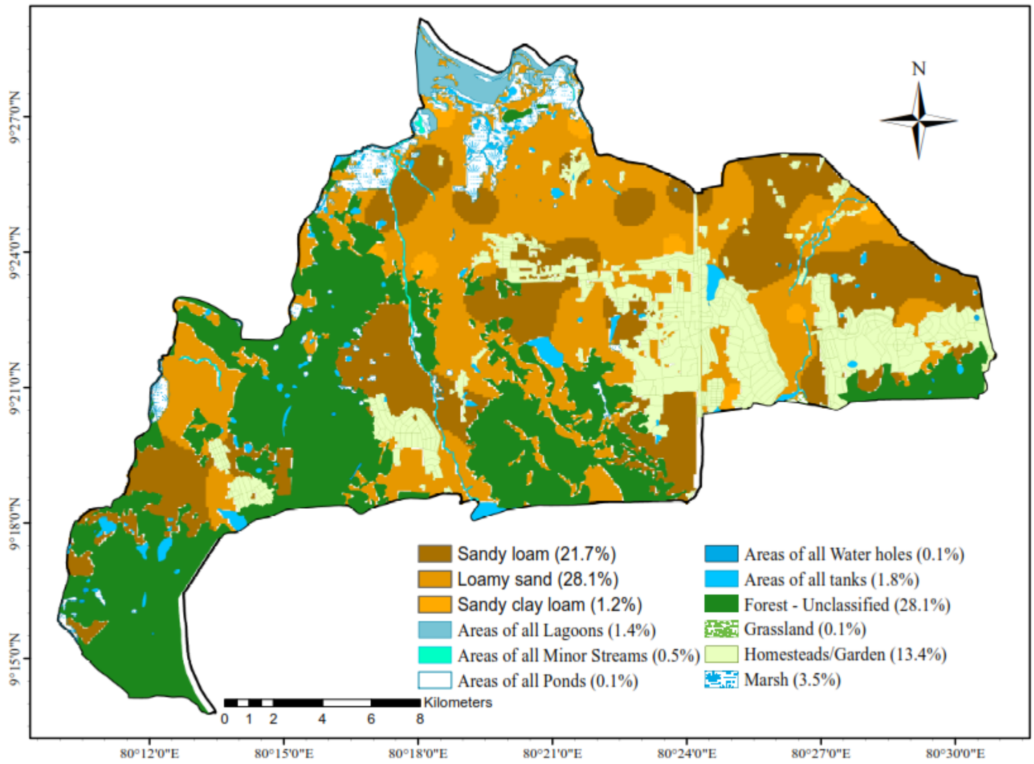

Figure 7: Spatial variation of soil texture

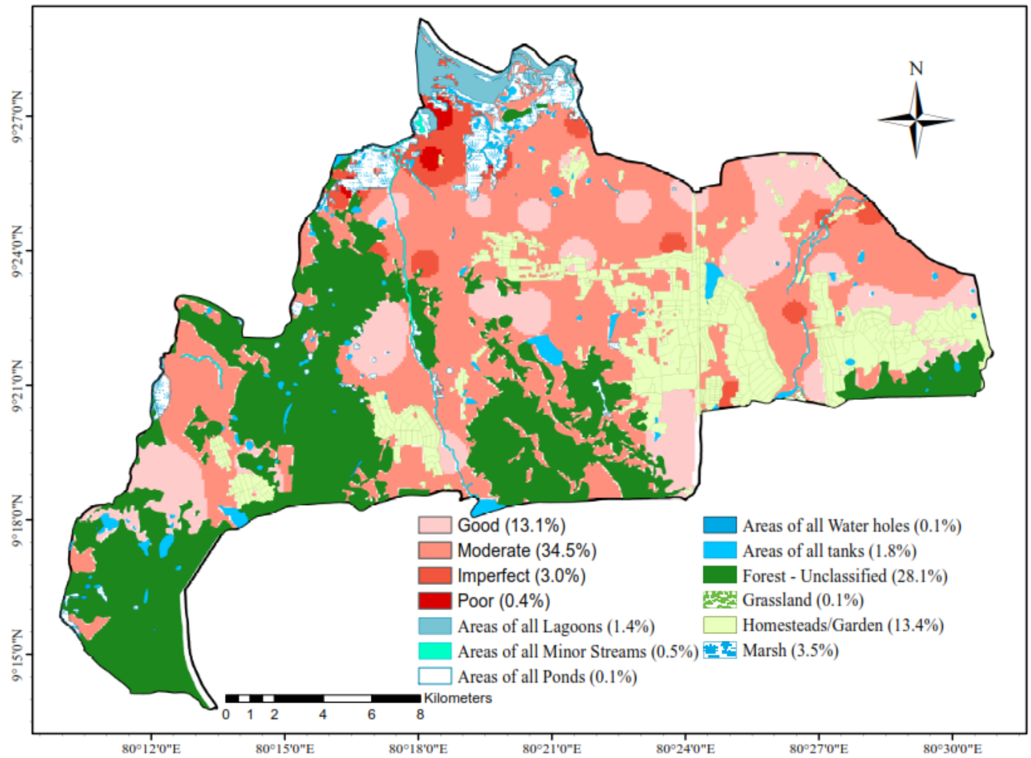

Figure 8: Spatial distribution of drainage

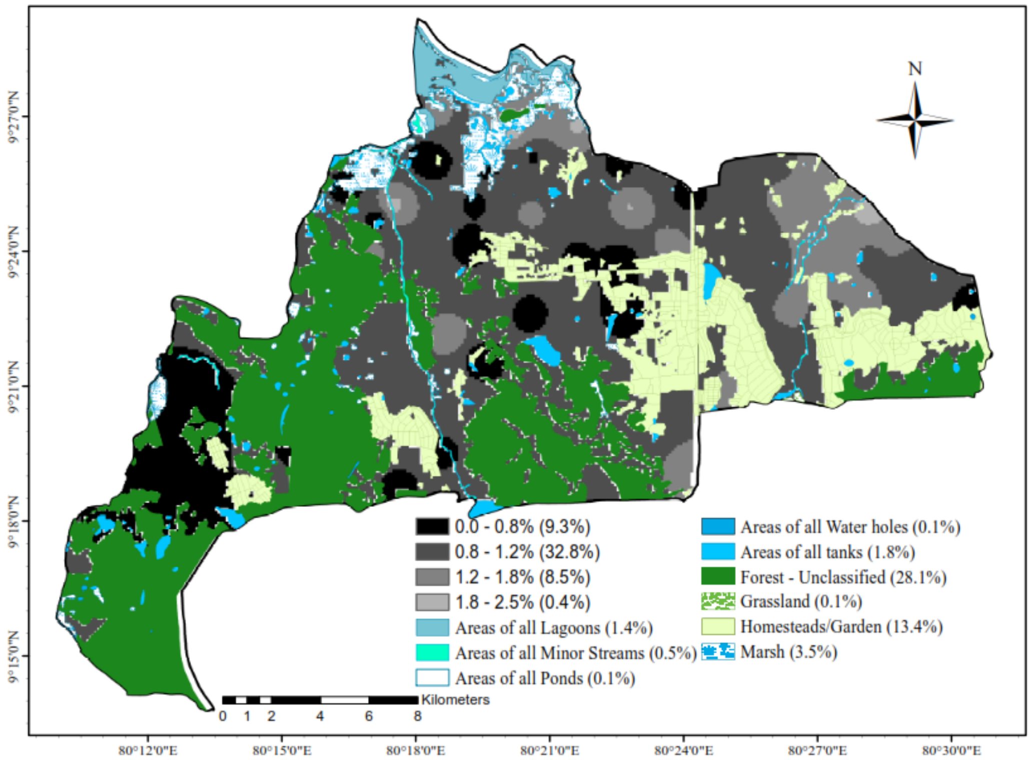

Figure 9: Spatial variation of Organic Carbon

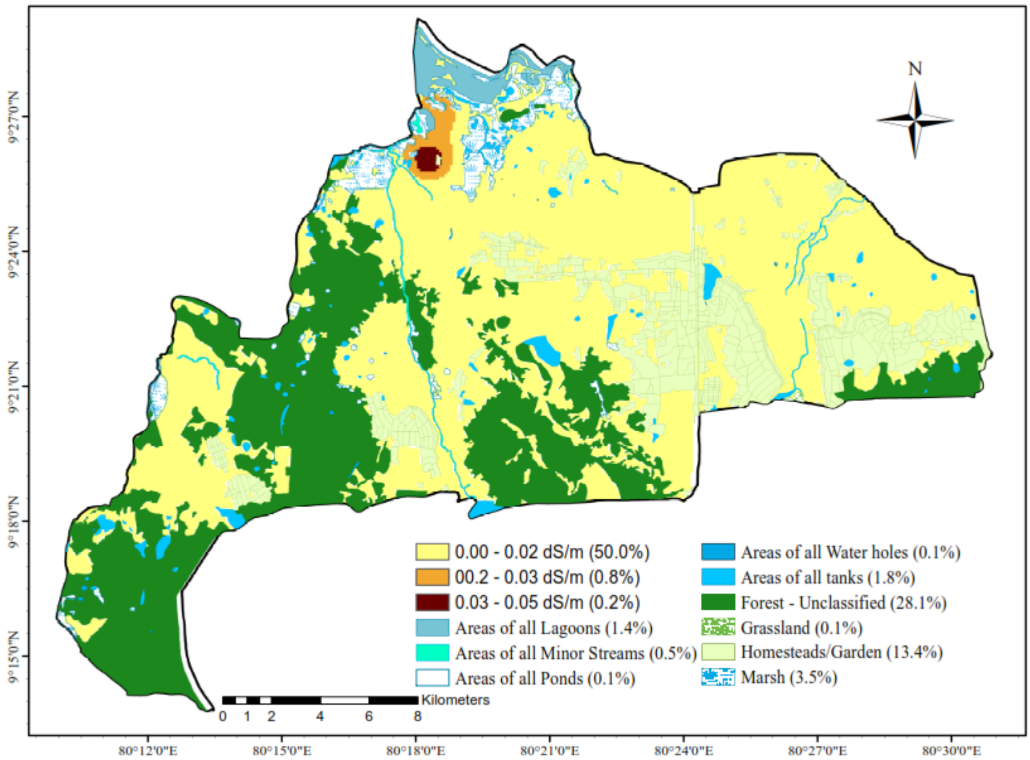

Figure 10: Spatial distribution of Electric Conductivity

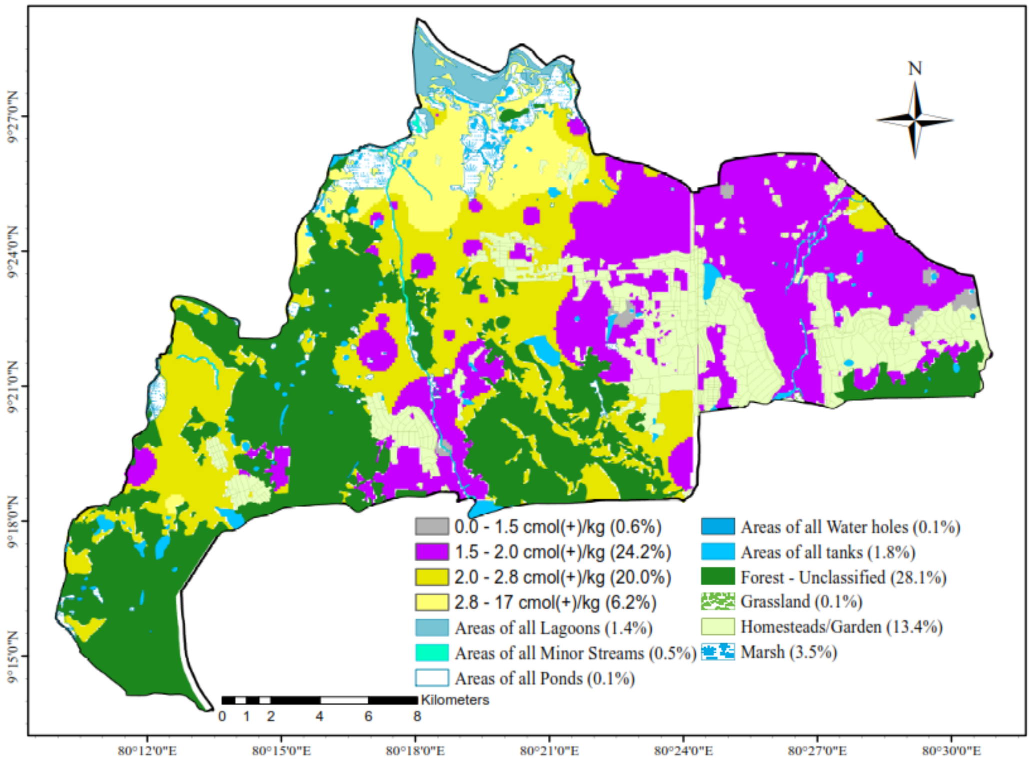

Figure 11: Spatial distribution of Sum of Basic Cations

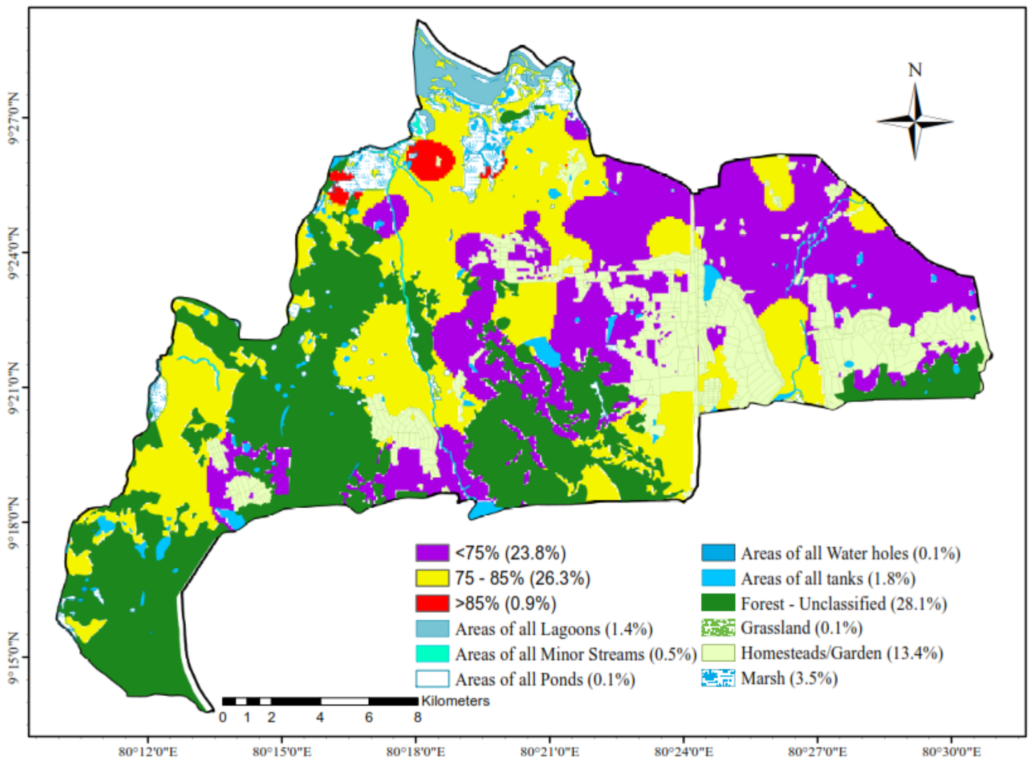

Figure 12: Spatial variation of Base Saturation

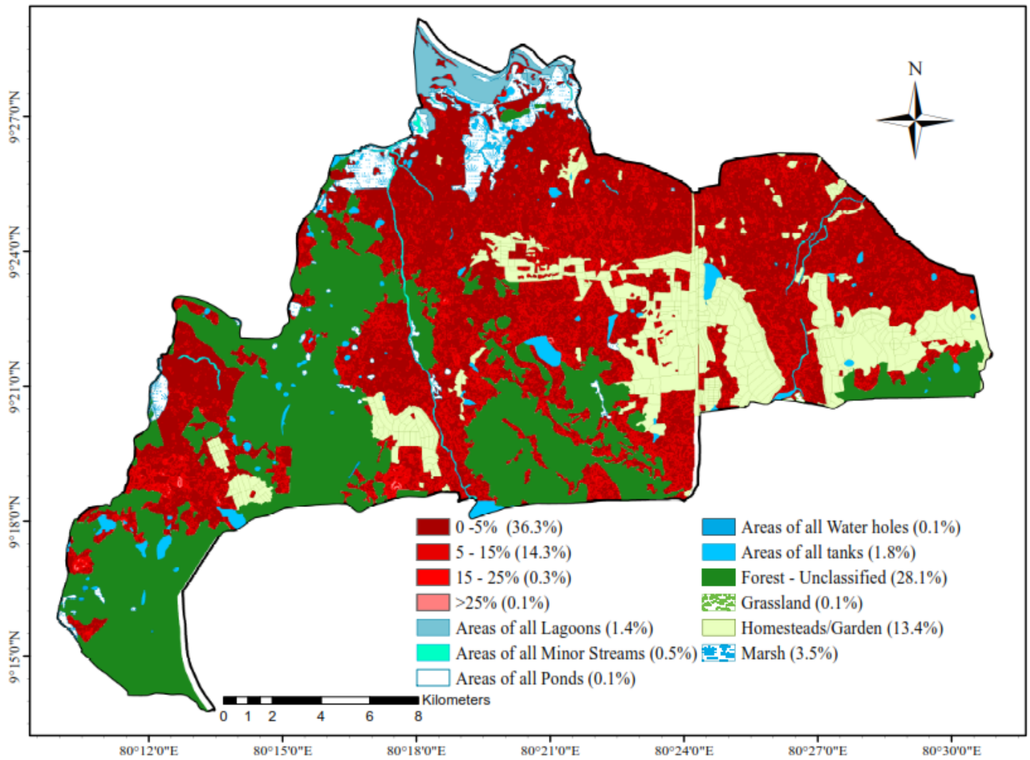

Figure 13: Spatial distribution of slope

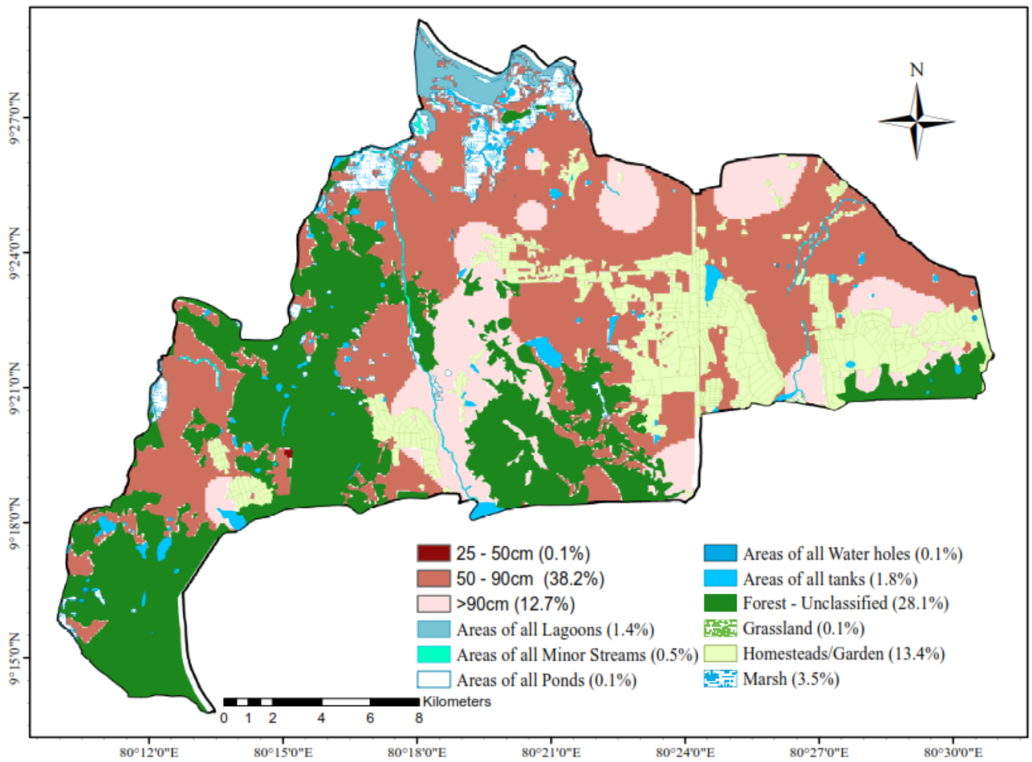

Figure 14: Spatial variation of soil depth

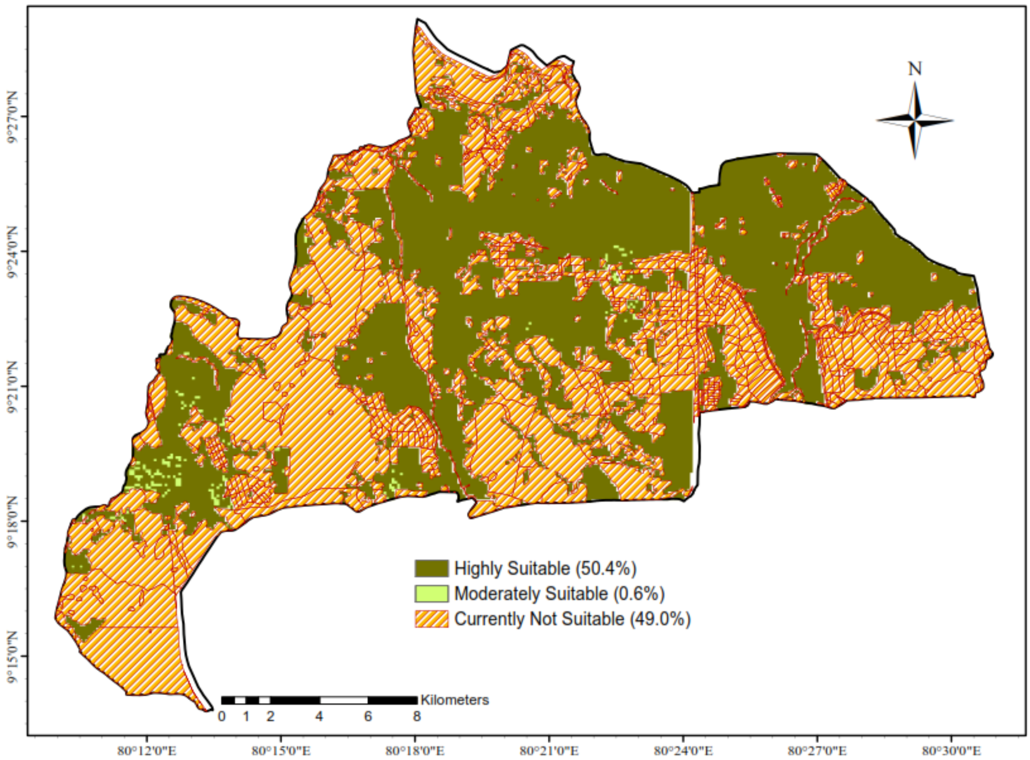

Figure 15: Land suitability of coconut

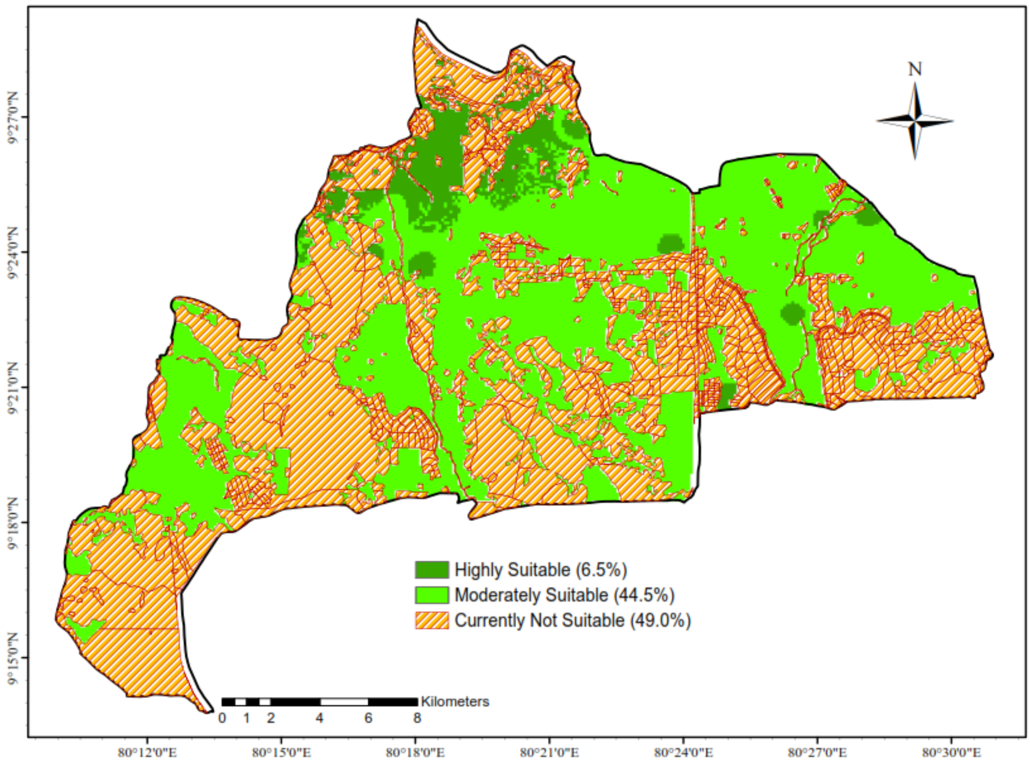

Figure 16: Land suitability of rain-fed paddy

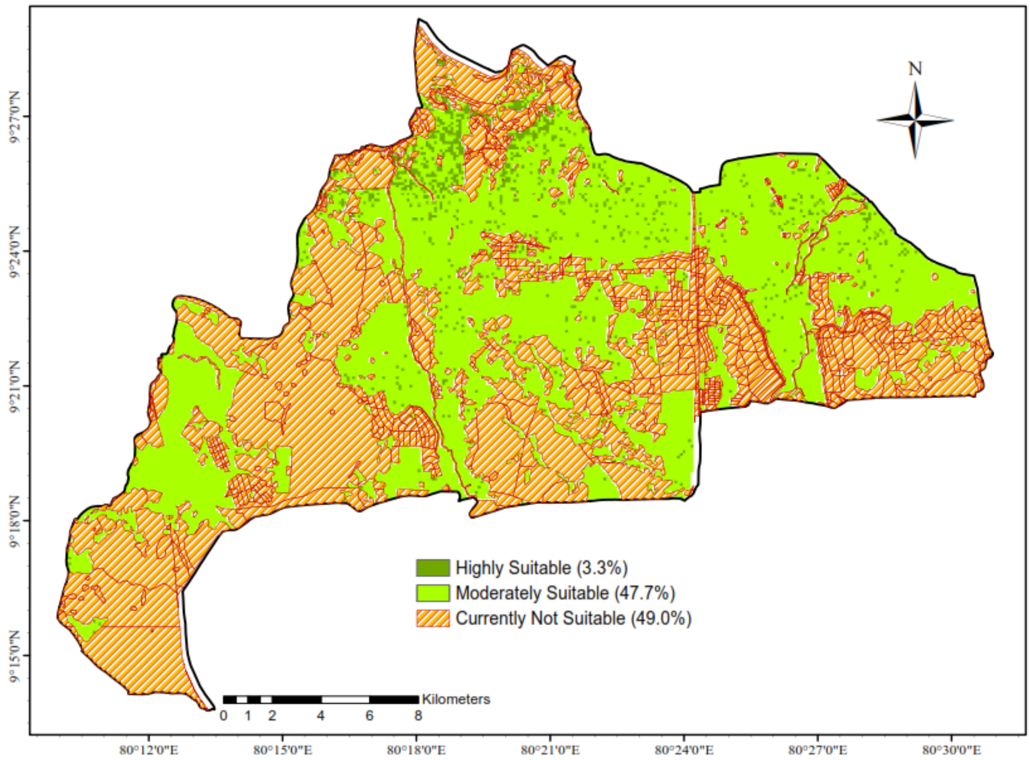

Figure 17: Land suitability of irrigated paddy

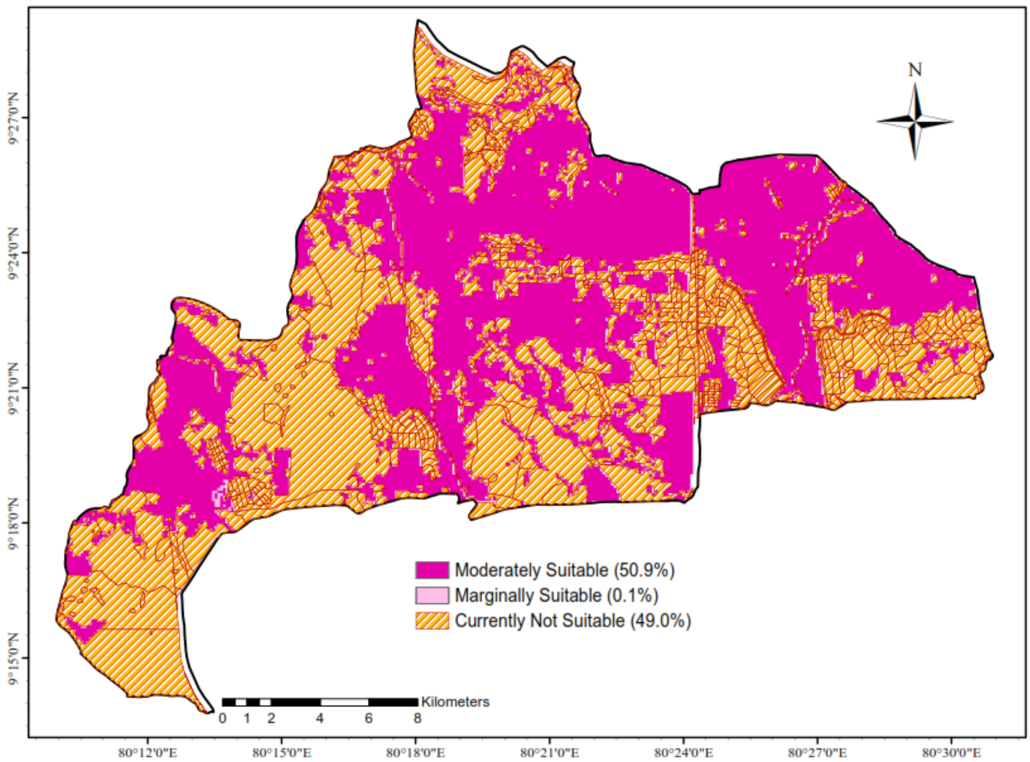

Figure 18: Land suitability of onion

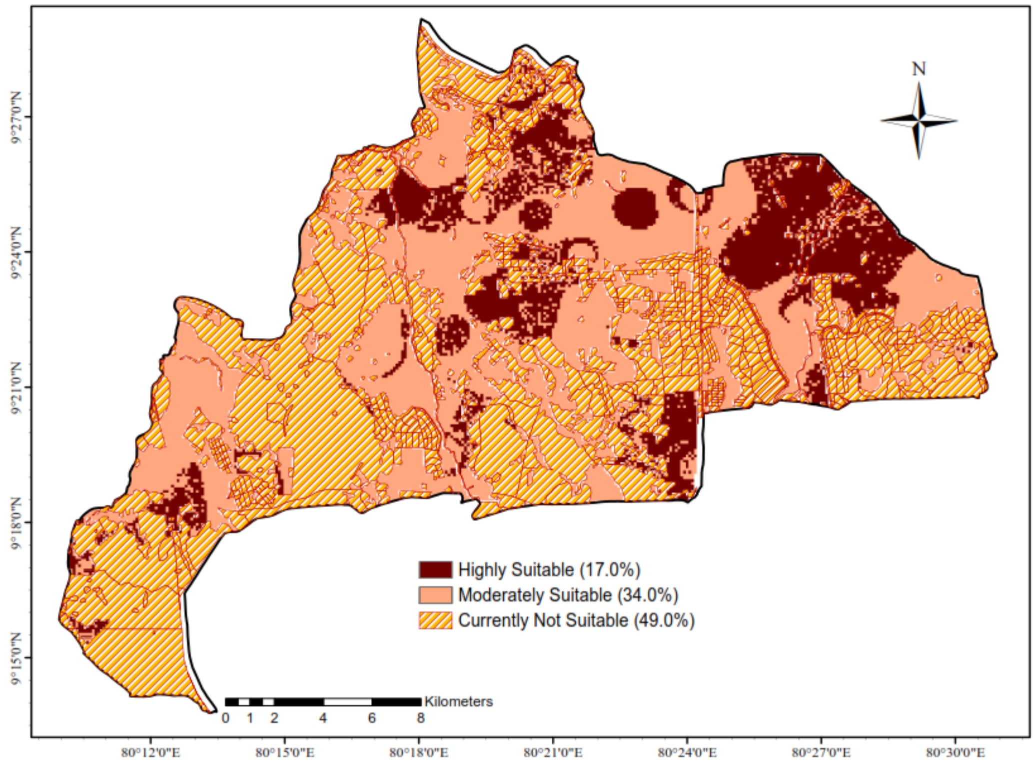

Figure 19: Land suitability of groundnuts

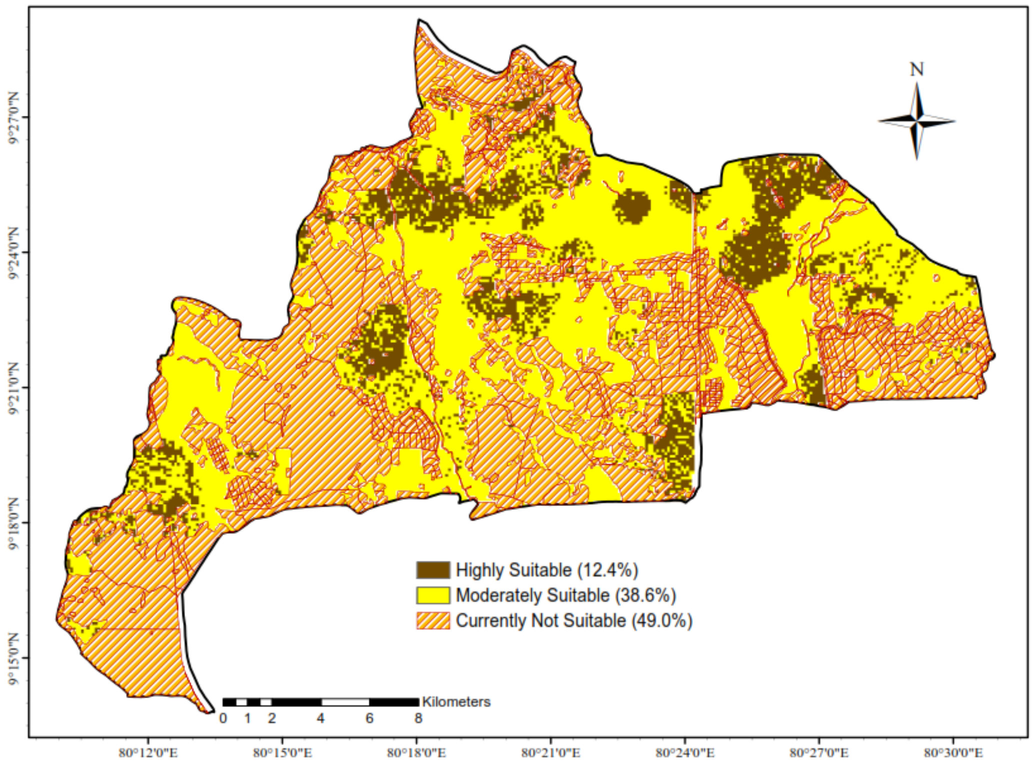

Figure 20: Land suitability of pineapple