Suitability Analysis of Potential Cocoa Cultivation in Southern Highlands and Hela Provinces of Papua New Guinea

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Abstract

Cocoa is the second major cash crop in PNG after coffee. Listed 12th with other top 20 cocoa producing nations in the world, PNG has fairly been in the loop by contributing 41200 tons of cocoa per annual from the recent statistic released in September 2018. With the changing climate conditions, and the increased technology of genetics and hybrid cocoa seedling, there is a possibility of cocoa farming becoming very sustainable in the highlands region of PNG. Karimui of Chimbu province is the first highlands province that has successfully been cultivated and producing cocoa based on the technical support from Cocoa Coconut Research Institute of PNG. For this study, soil test and suitability analysis were carried out to identify, potential if any, of cocoa cultivation in Hela and SHP provinces. The study involves the use of GIS and geo-spatial multi-criteria decision-making approach. A total of nine geographic parameters were considered, such as temperature, rainfall, soil texture, pH, nitrogen, phosphorus, Available Water Holding Capacity (AWC), Base Saturated (BS) and slope. Specific analyses involved were map manipulation and overlay, surface analysis, spatial interpolation, data management and data conversion. Each respective spatial technique was carried out throughout data input, processing and finally to produce output results.The result of the analysis revealed that 25% (6273km²) and 30% (7447km²) of the total area are very highly and highly suitable respectively. 31% (7864km²) of the study area is delimited as moderately suitable for cocoa cultivation. The remaining 11% (2651km²) and 3% (774km²) are low and very low in suitability for cocoa cultivation. This study highly recommends that the concerned government authorities in the provinces should start implementing and planting the trial hybrid cocoa clones at a small scale in some of those areas that are highly suitablefor cocoa farming.

Keywords: *Cocoa, Soil, GIS and Remote Sensing, Suitability Analysis*

1. Introduction

Soil suitability analysis is a scientific approach that provides information on constraints and opportunities for land use that aids in proper decision making for optimal use of land resources. This analytical approach involves processing of soil data including scientific, topographic, physical and chemical properties of soil, climate and land accessibility. These assist farmers, agricultural scientists and other land administrators to fully utilize the land resources for potential cash crop cultivation. Situated near the tropics, PNG has been known for cocoa cultivation and production which has contributed enormously towards the country's GDP. Its contribution to the world market has been well regarded and was rated 12thamong the world's leading cocoa producing countries (The National, 2019, April 18).

Cocoa is a well adopted agro-forestry plantation crop grown in hot, rainy climates with cultivation concentrated in the area between 0 to 20 degrees north and south of the Equator. This area is sometimes called the cocoa belt (Herman, et. al. 2010). In PNG, cocoa is the second most important agricultural cash crop delivering an income of US$96.3 million in 2015. Some 60% of its income goes directly to the growers, 90% of whom are smallholder farmers. Around 14% of the population (more than1 million people) rely on cocoa production and exports for most of their livelihood. The Cocoa Industry Strategic Plan for 2016-2025 (Cocoa-ISP) underlines that investments in cocoa will benefit most of the population in PNG and contribute positively to the nation's Sustainable Development Goals (SDGs). Although there are few plantations of different cash crops from medium to large sales, agriculture's contribution towards the country's GDP is much below its inherited potential at present (Samanta et al. 2011).

Unlike any other agriculture systems adopted by other highlands provinces, Southern Highlands Province (SHP) and Hela Province have yet to develop strong cash cropping components. Cocoa is a well adopted agro-forestry plantation plant. Although it is mainly known as the principal ingredient for chocolate, there are other different products derived from cocoa beans, such as cocoa liquor, cocoa butter, cocoa cake and cocoa powder (Hermann, et al. 2010). The genius Theobroma originated in the Amazon and Orinoca basins and subsequently spread to Central America, particularly Mexico. Whitlock, et al. (2001) suggested that the regional extension from the forests of Amazon to the Orinoco and Tabasco in South Maxicoshould become the centre of production of cocoa. Schulter (1984) predicts that cacao dispersed along two roots, one leading north and the other to the west. Later, Cortés, a Spaniard, carried cocoa to Spain in 1520s and used it as a beverage as well as a crop for cultivation.

It was the Spaniards who also introduced the crop to Equatorial Guinea in the seventeenth century. In PNG, cocoa was introduced by German settlers around 1900. Smallholder blocks were established on the Gazelle Peninsula in East New Britain Province, around Lae in MorobeProvince and Popondetta in Oro Province. The smallholder production was concentrated in ENB and Bougainville Provinces, and these two provinces have continued to dominate the smallholder sector of the 22 provinces, while 14 provinces have planted cocoa at various levels from smallholders to plantations scale (The National, 2019, April 18). The present study is based on multi-criteria decision-making approach for suitability analysis of cocoa cultivation. The study is limited to SHP and Hela Provinces. In this study, the geographical data were combined and transformed into decisions. Topographic analysis was done by extracting Digital Elevation Model (DEM) of the study area from the 90m resolution DEM data for PNG acquired from the Department of Surveying and Land Studies, PNG University of Technology. Here, the spatial topographic analysis tools from ArcGIS 10 were used to analyze the slope and aspects of the study area. Soil database was prepared to analyze chemical and physical properties of the soil from the soil information extracted from the Geobook and PNGRIS. The two climatic conditions - temperature and rainfall data - were also prepared from the PNGRIS database and updated with some existing recent datasets collected so far.

Like any other studies, there are certain limitation factors especially in acquiring/getting data ready. In this study, time, resources, and cost were the limiting factors that were considered. It is very costly to travel all throughout Hela and Southern Highlands Provinces (SHP) to collect soil samples. Laboratory preparation and analysis is also very expensive. Thus, the multi-criteria decision-making approach and GIS were combined to analyse available soil data and other required datasets.

PNG has made its way into one of the top 12 cocoa producing nations in the world. However, since the outbreak of cocoa pod disease in 2015, there has been a drastic drop in its annual production. In PNG, cocoa is grown in only 14 provinces at different scales and provides livelihood for 151,000 households. Cocoa cultivation and production in PNG are well known particularly on Niugini Islands, and in Momase and Papuan regions. To diversify agriculture there has been a growing demand to increase cocoa production in the Highlands provinces. Thus, this study is aimed at investigating soil suitability in Southern Highlands and Hela Provincesand explore its suitability for cultivation and production of cocoa in these two provinces.

With the government's timely support to raise cocoa production and selling, there is a need to investigate and analyse the suitability of the huge unused landmass for proper land resource utilization and management. Karimui in Chimbu province is significantly doing well now with high yield qualitative cocoa produce (Benjamin, 2018). Although there is a potential for cocoa production in other Highlands provinces, qualitative cocoa production can only be achieved through proper analysis of conditions that are required for high yield cocoa production.

2. Methods and Study Area

2.1 Study Area

Hela Province and Southern Highland Province (SHP) are the two provinces that were selected for this study. The whole area was earlier known as SHP (Figure 1), but recently SHP has been divided into two provinces - Hela Province and SHP. The boundary is still under review to be perfectly and clearly identified to be shown or displayed on maps and in figures. The study sites (Hela and SHP) are the two highland provinces further south of other highland provinces and are centred in the mainland of PNG. Bounded within142˚ to 145˚ E longitudes and 5˚ to 7˚ S latitudes, the provinces are located approximately 530 kilometers NW of Port Moresby, the capital city of PNG. The provinces are cold to moderately warm all year around. Districts in the central and close to the foot of Mt Giluwe are extremely cold with temperatures ranging from 4-11 degrees Celsius, while districts bordering provinces of other regions are warm to moderately hot with mean temperature range of 21-26 degrees Celsius. The landmass is approximately 25009km.sq in area.

The two provinces share boundaries with more than four provinces of other different regions. On the north and north east, the study area is bounded by East Sepik and EngaProvinces. Further to the west and south, it is bounded by Western and Gulf Provinces of Papuan region and on the south-east by Chimbu province. Topography is very rugged with fully grown, short vegetation cover of Iceland environment style fauna flanking the top of the mountains. Trending NW-SE, it creates a political boundary with Western Highlands Province to the north east. At the foot lies a huge swampy valley.

The altitudes range from below 600 m to above 2800 m the above sea level. At or above 2800m altitude, there is no land use or any other agricultural activities. Around 14% of the total land is below 600 m altitude and just over 5 percent is above 2800m. Agriculture is concentrated within this altitude range where all other land use activities are also concentrated in this altitude window. Further to the SW is Mt Bosave with an extinct volcanic featured caldera with radial drainage pattern. At the foot is generally swampy vegetation covering Erave and Kutubu to the west and south west respectively. In between Mt Bosave and Mt Giluwe lays a NW-SE trending lowland corridor with pockets of huge valleys and mountain ranges generally at NW direction. This corridor begins from Pangia to the south-east, then to Ialibu and trends all the way from Kagua, Lai valley of Mendi-Munio district, further to Nipa-Kutubu electorate rising further NW in Hela Province.

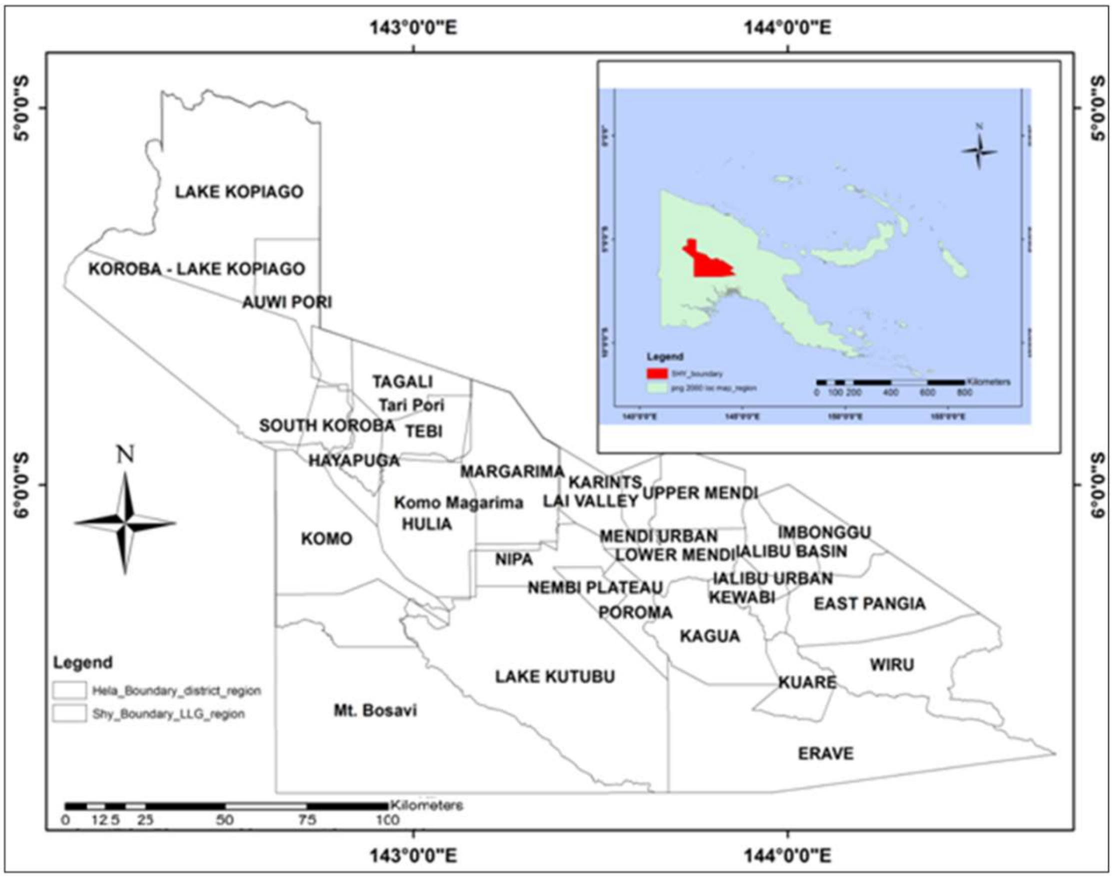

Figure 1: Study Area Locality.

2.2 Materials and Methods

The data set comprises satellite images, climate, topographic and soil data. Different GIS software and their respective functions used to process each respective data set are discussed in detail, section by section. The details of data are given in Table 1. Most of the data especially temperature, and soil data were updated using 2015 Landsat 8 OLI satellite image.

Table1: Data Used and integrated in the study.

No.	Data	Year	Sources
1	Temperature and Rainfall data	2008	PNGRIS
2	Soil Data	2008	PNGRIS, Geobook
3	Topographical data	2003	Surveying & Land Studies, PNG University of Technology
4	LANDSAT 8 OLI of Hela & SHP	2015	libra.developmentseed.org and USGS Earth Explorer

The methodology used in this study was classified into five different steps. The workflow diagram is illustrated in Figure 2.

2.2.1 Extraction of Study Area

An old existing shape file for provincial boundary covering both Hela and SHP (SHP Boundary) was used to mask the study area using the mask function of ArcGIS version 10. All required data sets were first converted into a single datum and projection system of WGS using the projection tool from ArcGIS. Preprocessing of images was performed where all pixel sizes were set to 30m resolutions and classified to single pixel size in order to perform other analyses.

2.2.2 Soil Sample Collection and Analysis

The soil information was obtained from PNGRIS and Geobook databases. The shape files in both raster and vector forms for all different soil characteristics were extracted and analyzed using different ArcGIS functions. In order to perform re-class to assign ratings on individual classes, the shape files in vector forms were first converted into raster form in the process called rasterization. Rasterization was performed using polygon to raster conversion function. The reclassification was performed using re-class tool in ArcGIS. Soil physical and chemical database was prepared from PNG Geobook and PNGRIS. Soil textures were classified by the fractions of each soil particles (sand, silt, and clay) present in the soil database.

2.2.3. Generation of Thematic Maps

The thematic maps of each of the soil properties (pH, Nitrogen, ppm, AWC, Texture) and climate data were generated using inverse distance weighting (IDW) interpolation technique using ArcGIS version10 software. The shape files were used to analyse the class values and perform re-class to assign suitable class ranges. Tables 2,3,4,5,6, 7, 8 and 9 show respective class values with the most suitable class given the highest re-class value that represents the most suitable factor. The re-class values in Tables2-9 below were then used to create the thematic maps.

Table 2: Temperature Suitability Reclassification.

Re-class Value	Mean Temperature (˚C)	Suitability Rating
5	21-26	Very High
4	18-20	High
3	15-17	Moderate
2	12-14	Low
1	4-11	Very Low

Table 3: Showing the rainfall suitability classification of the study area

Re-class Value	Mean Rainfall (mm)	Suitability Rating
5	2300-3400	Very High
4	3500-3900	High
3	4000-4500	Moderate
2	4600-5000	Low
1	5100-5500	Very Low

Table 4: Showing suitability classification of pH of the soil

Re-class Value	pH	Suitability Rating
4	>7	Very High
3	6-7	High
2	5-6	Moderate
1	<5	Low

Table 5: Showing the soil nitrogen suitability classification.

Re-class Value	Nitrogen (%)	Suitability Rating
3	> 0.5	high
2	0.2 - 0.5	moderate
1	<0.2	low

Table 6: Show soil phosphorus suitability classification.

Re-class Value	Phosphorus (ppm)	Suitability Rating
3	> 20	high
2	10 - 20	moderate
1	<10	low

Table 7: Showing the Available Water holding Capacity (AWC) of soil.

Re-class Value	AWC (cm)	Suitability Rating
5	>15	Very High
4	10 - 15	High
3	5 - 10	Moderate
2	3 - 5	Low
1	<3	Very Low

Table 8: Showing the soil Base Saturation in the study area.

Re-class Value	BS (%)	Suitability Rating
3	>60	High
2	20-60	Moderate
1	<20	Low

Table 9: Showing topographic classification for slope suitability.

Re-class Value	Slope (degree)	Suitability Rating
5	<4	Very High
4	4-8	High
3	8-16	Moderate
2	16-20	Low
1	>20	Very Low

2.2.4 Multi Criteria Evaluation

The objective of weighting is to express the importance of each factor relative to other factors that have effects on crop yield and growth rate. The factors and their classes were assigned weightage based on their importance as gleaned from literature review of previous studies, interviews and questionnaire survey. The researchersthen identified and assigned classes based on the relevance of soil texture, the chemical and physical properties, temperature, AWC, base saturation, nitrogen, phosphorus, potassium, rainfall and temperature. The suitability level was defined as classes and these classes were used as basis for constructing the criteria maps for each factor.

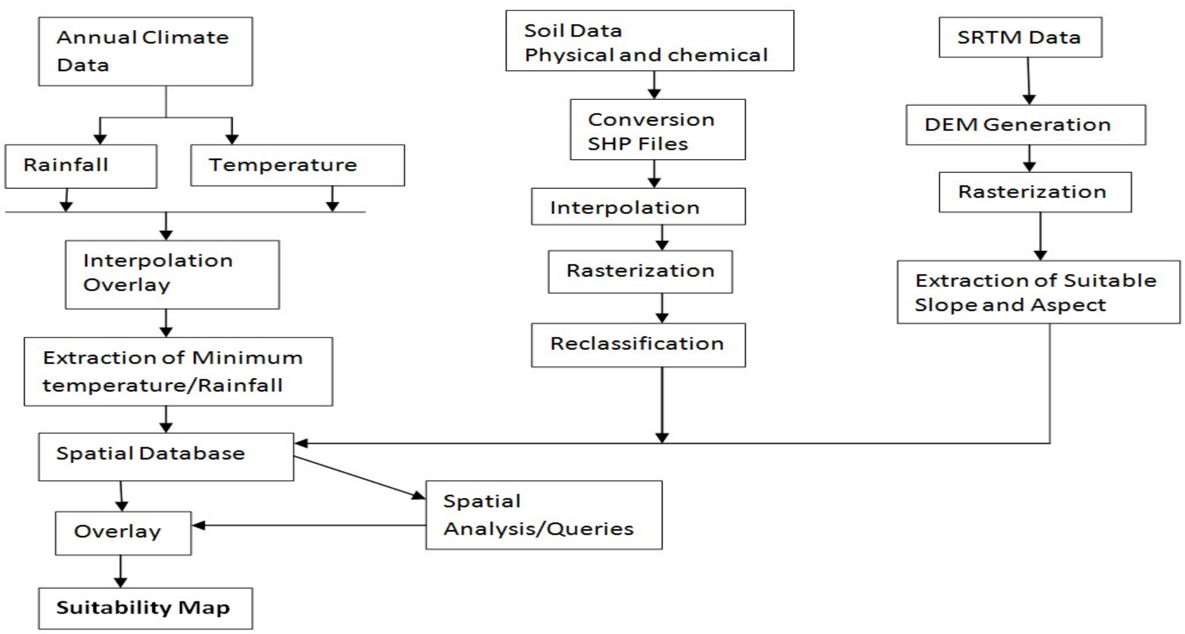

Figure 2: Flow chart showing the multi-criteria approach and methodology carried throughout the study.**Source:** Authors, 2019

3. Results and Discussion

There are several factors that need to be taken into consideration before a land isconsidered suitable for cocoa cultivation. They are soil conditions, which constitute the physical and chemical parameters, the climatic conditions that constitute the annual average temperature and rainfall, and the topographic conditionsthat encompasses mainly the slope. In the multi-criteria approach applied, equal weighted values were assigned to each factor and were considered equally important. The soil physical and chemical conditions have equal importance as the climatic conditions and topographic conditions. All these factors with their suitable ranges were checked and analyzed to be considered suitable for cocoa cultivation and production. For this study, all these factors were integrated into GIS environment and individual thematic map layers were created. The map layers were given ratings up to 5 for very highly suitable range and 1 for very low or unsuitable range. Ranges in between were considered low, moderate or high. A total of nine (9) important factors were studied for Hela and SHP provinces to be considered suitable for cocoa cultivation and production. They are temperature, annual rainfall, soil texture, soil pH, soil nitrogen, soil phosphorous, soil AWC, soil BC and the slope. Each of them is further discussed below.

3.1 Temperature of the Study Area

Air temperature is known to influence various physiological processes of cocoaand world cocoa distribution and is largely determined by the narrow range of temperature conditions under which the plant thrives. Based on studies conducted in South Africa (Erneholm, 1948), it is suggested that 15˚C (60˚F) should be regarded as the lowest mean temperature acceptable for cocoa production with an absolute mean of 10˚C (50˚F).At a temperature below 25.5˚C, flower formation starts to appear to be inhibited and trunk growth is appreciably reduced. The mean temperatures of the study areas generally range from 4-26 degrees Celsius. Temperature decreases with increasing altitude. At higher altitudes, there is a significant drop in temperature. This is clearly observed at Mt Giluwe and other mountainous areas where temperature drops as low as 4 degrees. Temperature range from 21 to26 degrees Celsius is considered best for cocoa cultivation. This suitability window appeared in places with low altitude. Thus, this study has delineated some significant zones with suitable temperature for cocoa cultivation within the entire study area. Figure 3 (A) illustrates the temperature distribution of the study region.

3.2 Rainfall Distribution of the Study Area

An annual rainfall of 2000mm to 3500mm is ideal, but cocoa grows well in areas with 1500mm of rain. According to the ICCO (2013),optimal growth is achieved in areas with well-distributed annual rainfall of 1500mm-3000mm. Other studies have found that most cocoa growing areas enjoy 1500mm-2500mm of rainfall. The distribution of annual rainfall for regions in which cocoa is grown is 1600mm-2500mm (Erneholm, 1948). The rainfall in the study area is very high and well distributed all year around. A range between 2300mm and 3400mm is considered best for cocoa to grow well and healthy. Although there is not much issue given the annual minimum and maximum rainfall, further classification was done by considering several scientific effects it may have on plant development and production of cocoa. Figure 3B indicates the distribution of rainfall in the area showing the clear zoning of the distribution. The mountainous regions tend to experience low rainfall while those further down to the lower altitudes and away from the mountainous regionsexperience high rainfall. Again, cocoa is a tropical rainforest plant and enjoys a wide range of rainfall.

3.3 Soil Texture

Soil texture is one of the most important factors when considering cocoa cultivation for land suitability assessment and management as it provides information about the porosity of the soil and bulk density, thus indicating possible limitation to root growth and penetration (Ayorinde, et al, 2015). Agro-forestry cocoa systems are established on silt and clay loam soils. It provides moderate to adequate infiltration and only a small portion are poorly drained. Soil texture influences the dynamics of the soil organic matter which increases in the clayey soil. Five different soil textures were extracted from the Geobook soil database for this study and the thematic layer was prepared (Figure 3 (C)). The five different soil textures were considered due to their respective physical and chemical properties required for cocoa cultivation. Silty clay is the most suitable soil texture due to its finest texture and water holding capacity. Though, it occurred as patchy at places, it dominates the SW portion of the study area and runs around the old extinct volcanic caldera of Mt.Bosave. The second suitable soil texture is the sandy clay soil which predominantly covers the entire Hela and SHP Provinces. The other sandy clay loam, clay and peat were considered moderate, low and very low respectively in terms of their suitability. They appear to be less abundant and generally occur in the swampy and steep mountainous environment.

3.4 Soil pH

The soil pH is useful in soil suitability evaluation as it provides information about the solubility and toxicity of elements for specific crops. Like any other plants, cocoa has its suitable pH range for it to grow well. The suitable soil pH for cocoa ranges from 6 to 7 on the pH scale which indicates that the soil is near acidic to neutral. This also indicates that the soil has a balanced nutrient level and great suitability for cocoa cultivation. Regions shown with light yellow on the pH map indicate locations with high suitability range from 6 to7. Almost 50% of the study area is also highly acidic with pH less than 5.Figure 3 (D) illustrates a map showing the pH level of the soil under study.

3.5 Soil Nitrogen

Nitrogen is a vital chemical component of chlorophyll, which is required for photosynthesis, the process in which plant leaves use sun energy to make sugar and carbohydrates. They exist in three different forms: the organic nitrogen compound, ammoniums ($NH4+$) and nitrate ($NO3^-$) ions.At any given time, 95 to 99 percent of the potentially available nitrogen in the soil is in organic form. While most of the total percentage of nitrogen is only accessed for the top soil (0-25cm), most of the nitrogen occurs in the surface horizons in combination with the content of organic matter. Nitrogen is poorly correlated with plant growth and subject to rapid changes following forest clearing and cropping. Nitrogen content of the areas under study is generally very high with values greater than 1.5% and it is well distributed through the study area. High content of soil nitrogen may indicate high organic content. Nitrogen in the study area is well distributed throughout, which is fundamental for cocoa to grow well. Low nitrogen content may indicate excess potassium, zinc and magnesium. Figure 3 (E) illustrates the map of soil nitrogen under study.

3.6 Soil Phosphorous

Phosphorous (P) is generally important in farming and it is sometimes called the master key to agriculture (Pierre, 1938). Low crop production is due more often to a lack of phosphorous than to a lack of any other soil nutrients. The amount of phosphorous in the soil generally has a close association with the pH value. Both acidic and basic conditions lower the phosphorus content of the soil. The highest P content is associated with near neutral to neutal (6-7) pH of the soil

(Mark, 2016). In cocoa-agro forestry system, phosphorous content from 7-35ppm is considered suitable for cocoa cultivation. The phosphorus content in the study area higher than 20ppm is concentrated within the lowlands of NW-SE corridor that is bounded by Mt Giluwe and Mt Bosave. The second classes that range from 10ppm-20ppm generally trend at the same direction. These classes have high phosphorous content required to cultivate cocoa. Again, high phosphorous content is in association with the neutral pH condition of the soil under study. The lowest value of less than 10ppm generally occurs at high elevated mountainous areas. Figure 3 (F) illustrates the distribution of soil Phosphorous in the study region.

3.7 Soil Available Water Content (AWC)
Available water content is the maximum amount of plant available water a soil can provide. It is an indicator of a soils' ability to retain water and make it sufficiently available for plant use. Available water capacity is the water held in soil between its field capacity and permanent wilting point. Lack of available water reduces roots and plant growth, and it can lead to plant death if enough moisture is not provided before a plant permanently wilts. The water content in the study area is extremely high and exceptional. There is a positive relationship that exists between the soil texture and AWC. The silty clay and sandy clay soils have higher AWC value of greater than 15cm and have been well distributed. Figure 3 (G) illustrates the soil AWC of the study region.

3.8 Soil Base Saturation (BS)
Analysis of the BS concentration of the area under study shows that the distribution has some relationship with the soil texture types. Areas with high sandy clay soil have high percentage concentration of BS up to >60%. This is notably seen in NW, Central and SE portions of the study area. Areas with clay and peaty soils have less concentration of BS. BS values with less than 20% appear to be occpying the areas where abundance of peaty and clay soils are distributed. Soil textures and their structures are the main factors that influence the distribution and contraction of the soil BS. Figure 3 (H) below illustrates the concentration and distribution of soil BS under study.

3.9 Slope
Slope is the measure of changes in elevation of the terrain surface. It is another important factor that needs to be taken into consideration for a land to be suitable for cocoa cultivation. In agriculture, slope is one of the factors that play important parts in the distribution and selection of which agricultural crop to be planted in a given terrain. Soil erosion, weathering, and landslide are natural hazards that occur due to difference in surface elevation. This natural hazard affects the growth and cultivation of cocoa. Slopes with low slope angles are considered suitable for cocoa cultivation. Slope angles less than 4 degree and below or nearly flat surfaces are highly suitable for cocoa cultivation. Slope angles greater than 4degrees are considered moderate or rated low as it is prone to weathering and erosion. Anything greater than 20 degrees are considered unsuitable for cocoa cultivation as it is highly susceptible to weathering or possible landslide depending on the underlining geology and other factors. Figure 3 (I) illustrates the slope map of the study area. Different slope angles are indicated by different color composites in the slope map below.

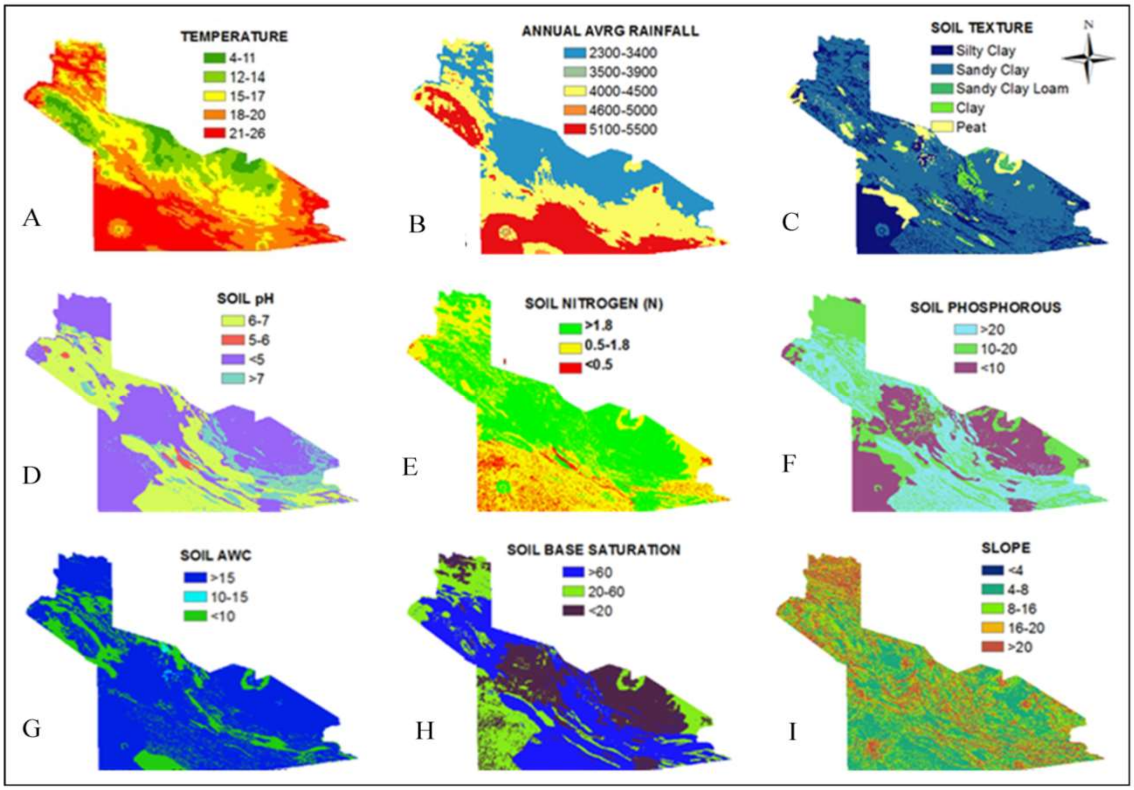

Figure 3: Thematic layers prepared and integrated for cocoa cultivation and production; Temperature (A), Rainfall (B), Soil Texture (C), Soil Ph (D), Soil Nitrogen (E), Soil Phosphorus (F), Soil AWC (G), Soil Base Saturation (H), Slope (I). Source: Fieldwork, 2019

3.10. Assigning of Weighting and Rank

For the thematic layers to be counted into the GIS environment, the factors and the class values must be weighted and fed into the GIS function. The temperature of a location for instance is one of the very important factors that define the area to be suitable for planting cocoa. Temperature for that reason has the highest influence on the suitability and so was assigned 20% of the total parentage. Temperature was also subdivided into different class ranges to analyze and identify specific temperature ranges with its spatial locations best suited to cocoa cultivation and production. Those classes were assigned weighted values with the most suitable range given the highest-class value of 5 as shown in Table 10. This information was fed into the GIS environment through the function called the raster calculator to come up with the final suitability map as shown in Figure 4. Table 10 below summarizes the weighted values and the percentage values assigned for each factor and their classes.

Table 10: Weightage and ranking of each factor for suitability analysis for cocoa cultivation

Factors	Percentage Influence (%)	Class	Weighted Value	Remarks
Temperature		21-26	5	Highly Suitable
		18-20	4	Moderate to High
	20	15-17	3	Moderate
		12-14	2	Moderate to Low

		4-11	1	Unsuitable
Soil Texture	18	Silty clay	5	Highly Suitable
		Sandy clay	4	Moderate to High
		Sandy-clay-loam	3	Moderate
		Clay	2	Moderate to Low
		Peat	1	Unsuitable
Rainfall (mm)	16	2300-3400	5	Highly Suitable
		3500-3900	4	Moderate to High
		4000-4500	3	Moderate
		4600-5000	2	Moderate to Low
		5100-5500	1	Unsuitable
pH	12	6-7	4	Highly Suitable
		5 - 6	3	Moderate to High
		<5	2	Moderate
		>7	1	Moderate to Low
N	10	>1.8	3	High
		0.5-1.8	2	Moderate
		<0.5	1	Low
P (ppm)	8	>20	3	High
		10-20	2	Moderate
		<10	1	Low
AWC (cm)	6	>15	3	High
		10 – 15	2	Moderate
		5 – 1	1	Low
BS (%)	5	> 60%	3	High
		20 - 60%	2	Moderate
		<20%	1	Low
Slope (˚)	5	<4	5	Highly Suitable
		4-8	4	Moderate to High
		8-16	3	Moderate
		16-20	2	Moderate to Low
		>20	1	Unsuitable

3.11 Final Cocoa Suitability Map for Hela and SHP

The final weighted suitability map was created using the raster calculator from the spatial analyst tool. The map was then reclassified into 5 different suitability levels to zoom into the area of interest. The classes were classified as very highly suitable, highly, moderate, low, and very low or not suitable. The results obtained show that 6273km² of land is very highly suitable for cocoa cultivation covering 25% of the project area. The second class has 7447km² of land being highly suitable for cocoa cultivation and covers 30% ofland area. This class has few limitations to fully consider for being highly suitable. Other classes 3 and 2 cover 7864km² and 2651km² respectively covering 31% and 11% of land areas respectively. Class ranked 1 has total area of 774km² covering only 3% of the area. Those places that have been classified as moderate, low or very low have some limitations where the required window of conditions required by cocoa to grow well is lacking. The climate, topography and soil properties in those given locations don't fall in the required window required for cocoa cultivation thus posturing it to be considered moderate or unsuitable which will be provided in Table 11.

Table 11: Suitability table showing actual land area available for cocoa cultivation and production in SHP and Hela Provinces

Rank	Suitability	Area (km²)	Percentage (%)
1	Very Low	774	3
2	Low	2651	11
3	Moderate	7864	31
4	High	7447	30
5	Very High	6273	25
Total		**25009**	**100**

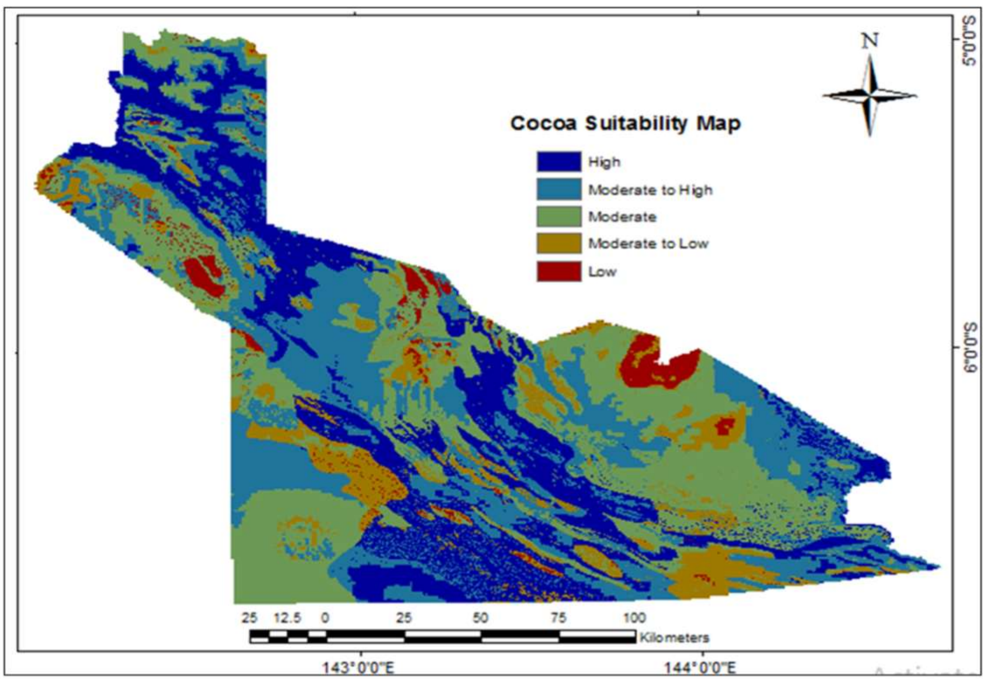

Figure 4: Final Cocoa Suitability map for the two provinces, Hela and SHP

4. Conclusion and Recommendations

Suitability analysis for cocoa cultivation was carried out in Hela Province and SHP. The study involves the use of GIS and geo-spatial multi-criteria decision-making approach. A total of 9 geographic parameters such as temperature, rainfall, soil texture, pH, nitrogen, phosphorus, AWC, BS and slope were considered. Specific analysis involves map manipulation and overlay, surface analysis, spatial interpolation, data management and data conversion, which were applied respectively throughout data input, processing and finally to produce the output results. The result of the analysis reveals that 25% (6273km²) and 30% (7447km²) of the study area are very highly and highly suitable respectively while 31% (7864km²) of the study area is moderately suitable for cocoa cultivation. The other 11% (2651km²) and 3% (774km²) are low and very low or deemed unsuitable respectively. From the results obtained, it is concluded that Hela and SHP have ¼ of the land very highly suitable for cocoa cultivation and production. It is now the responsibility of the concerned authority, district and provincial agriculture boards to make a bold decision to test those places that have high potentials for planting cocoa. Cocoa has never been grown before in these areas and to test out those very high suitability areas, little can be done until the results of the trial plantings are available.Thus, it is recommended that those concerned authorities should start implementing and planting the trial cocoa seeds as experiments in highly suitable areas. This will again open up a room for a new study that can zoom into the areas of interest, whether it would be atthe district, electorate or provincial level to conduct a detailed study in terms of actual land available opportunities for planting trial seeds, and also the social and economic aspects of the project and the constrains and opportunity that may they may present.

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