ENHANCEMENT OF THE FIELD ASSESSMENT PROTOCOLS AND SUITABILITY MAPS FOR COCONUT

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KEY WORDS: Coconut Suitability, Geographical Distribution, Environmental Factors, Multi-Criteria Weighted Overlay Analysis.

ABSTRACT:

The crop suitability assessment particularly in coconut planting has not been revisited in over two decades. An in-depth analysis of the various factors affecting coconut farming was conducted. This involved the utilization of local remotely-sensed data on elevation, slope, soil type, and land cover. Global gridded data on rainfall and land surface temperature were acquired to supplement the local data. Each factor was given its corresponding weight assignments upon consultation with the experts from the Philippine Coconut Authority. Variable factors such as rainfall (15%) and temperature (10%) were given with lower scores than the permanent or nearly unchanging factors on elevation (25%), slope (25%), and soil type (25%). These individual factors were processed for the final multi-criteria weighted overlay analysis. Finally, the land cover map was used to remove areas deemed unsuitable for coconut planting. Results showed that about 20 million hectares of the country's total land area are suitable for coconut planting with varying levels of suitability. Of the total suitable areas, only 3.64 million hectares (18%) were planted with coconuts based on the PSA data for 2021. One important factor to consider is that most of the areas not planted with coconut are devoted to other important land cover types like forests, perennials, and annual crops. The utilization of the open source Quantum GIS (QGIS) software proves to be essential in this kind of enormous data processing and analysis, coupled with the generation of very detailed coconut suitability data and maps on a nationwide scale.

1. INTRODUCTION

Assessment of crop suitability plays a major role in determining productivity to include factors like environmental and climatic changes over the past several years. Likewise, agricultural farms are better evaluated by examining various climatic and edaphic factors to ensure optimum results. Coconuts, in particular, can obtain its optimum potential once proper suitability assessment coupled with the proper application of corrective management practices is considered.

Environmental conditions play major roles in the productivity of coconut crops. By integrating the major factors such as climatic, topographic, and soil properties, the suitability of the land for coconut crop production is better determined. This process reduces the risk of making incorrect decisions in selecting areas for coconut establishment (Magat, 2006).

Pursuant to Presidential Decree 232 dated 30 June 1973, the Philippine Coconut Authority (PCA) is the sole agency mandated by the government to protect and develop the coconut industry in the country. With the recent enactment of RA 11524 – the Coconut Farmers and Industry Trust Fund Act (CFITFA) with the goal of improving the lives of coconut farmers and modernize the coconut industry, it is imperative for PCA to revisit the existing coconut suitability assessments generated more than decades ago. PCA needs to come up with an enhanced protocol that can adapt not only to the current and future agricultural and socio-economic challenges but more so for those brought about by climate change.

This project focused on the determination and acquisition of essential and available geospatial data for the enhancement of existing coconut suitability maps. Data collection and analysis include multiple essential factors on elevation, slope, soil, rainfall, temperature, and land cover obtained from the National Mapping and Resource Information Authority (NAMRIA), the Bureau of Soils and Water Management (BSWM), and the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA). PCA was the source of data on coconut-related industries/companies, and the incidence of coconut pests and diseases. On the other hand, global gridded data from NASA and other international organizations was explored and downloaded through the Google Earth Engine online platform to supplement the national data.

2. MATERIALS AND METHODS

2.1 Essential Data for Generating Coconut Suitability

Gridded data on the five essential environmental factors were collected and used for this study. The datasets are a mix of open data retrieved from public geospatial data archives and data requested from relevant government agencies.

<u>Topographic Data</u>. The NAMRIA provided the Interferometric Synthetic Aperture Radar (IfSAR) data which were used in determining the elevation and computation of the slope data of the entire country.

<u>Climatic Data</u>. Global datasets were acquired from the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) to have the gridded data for every part of the country. These global data were comparable with the PAGASA's weather station climatological data.

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For the rainfall data, the 2021 Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) dataset developed by the National Aeronautics and Space Administration (NASA) and National Oceanic and Atmospheric Administration (NOAA) was used. For the land surface temperature (LST) data, NASA's Terra satellite using its sensor called Moderate Resolution Imaging Spectroradiometer (MODIS) was used.

Soil Data. The BSWM supplied PCA with a soil series vector map consisting of seventy-seven (77) soil classifications.

Land Cover Data. NAMRIA also provided PCA with the 2020 Land Cover Vector Map. This was generated from the 2016-2021 Sentinel 2 satellite data with ground/image validation with a 10-meter high-resolution.

Geographical Boundaries. To delineate the boundaries and extent of the study area (Regional, Provincial, Municipal, up to Barangay delineations), the administrative boundaries shapefiles were acquired from this GitHub repository (GitHub - altcoder/philippines-psgc-shapefiles: High resolution Philippine PSGC administrative boundaries). To update the map with the most recent changes to the administrative boundary, it was synchronized with the Philippine Standard Geographic Code (PSGC) master list issued by the Philippine Statistics Authority (PSA) last December 31, 2022. This PSGC data include the master list of four hierarchy levels namely the administrative regions (17), the provinces (82), the municipalities/cities (1,488/146), and the barangays (42,046).

2.2 Weight Assignments - Suitability Score

Upon consultation with the experts on coconut crop from the Philippine Coconut Authority, each factor was given corresponding weight assignments. Variable factors such as rainfall and temperature were given lesser scores than the permanent or undeviating factors namely elevation, slope and soil types.

- Elevation = 25%
- Slope = 25%
- Soil Type = 25%
- Rainfall = 15%
- Temperature = 10%

Further, the parameters for every component factor were categorized and given their corresponding scores (Table 1).

Factor	Score / Parameter				
	5 (Very High)	4 (High)	3 (Average)	2 (Low)	1 (Very Low)
Rainfall (Total Annual, mm)	1,800 - 3,000	1,200 - 1,800	1,000 - 1,200	500 - 1,000	500 below / 3,000 above
Temperature (Annual Ave., °C)	24-29	22 - 23, 30 - 34	20 - 21, 35 - 38	18 - 19, 39 - 40	18 below, 40 above
Elevation (Meters above Sea Level)	1 - 300	300 - 400	400 - 500	500 - 600	600 above
Slope (in %)	1 - 5	5 - 10	10 - 15	15 - 20	above 20
Soil Types	Loamy	Clayey	Silty	Sandy	Undifferen-tiated

Table 1. Weight Assignments for each Factor

2.3 Coconut Suitability Assessment Classification

The coconut suitability is classified into the Suitable and the Not Suitable areas. The Suitable areas are further classified as *Highly Suitable*, *Moderately Suitable*, and *Marginally Suitable*. On the other hand, the Not Suitable areas are classified into *Currently Not Suitable* and *Permanently Not Suitable* areas. Further, after thorough evaluation of the suitability score ranges, and in consultation with the experts of PCA, the appropriate ranges were finalized and indicated below.

Suitable Areas - The land can support the land use indefinitely and benefits justify inputs.

- S1 *Highly Suitable* (80 – 100)
  Land without significant limitations. Include the best 20-30% of suitable land as S1. This land is not perfect but the best that can be hoped for.
- S2 *Moderately Suitable* (60 – 79.99)
  Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on S1 land.
- S3 *Marginally Suitable* (30 – 59.99)
  Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that the cost is only marginally justified.

Not Suitable Areas - Land that cannot support land use on a sustained basis or land on which benefits do not justify necessary inputs.

- N1 *Currently not suitable* (1 – 29.99)
  Land with limitations to sustained use that cannot be overcome at a currently acceptable cost.
- N2 *Permanently not suitable* - Land with limitations to sustained use that cannot be overcome.

2.4 Multi-Criteria Suitability Analysis

After settling on the weights for each of the factors, the multi-criteria suitability analysis was done using QGIS *Raster Calculator*. The formula presented below was used to compute the suitability scores for the whole country:

$$Suitability = (RF * 0.15) + (T * 0.10) + (E * 0.25) + (S * 0.25) + (ST * 0.25) \quad (1)$$

where RF = Rainfall
T = Land Surface Temperature
E = Elevation
S = Slope
ST = Soil Type

3. DATA PROCESSING AND ANALYSIS

The technical workflow of the project was divided into three major parts: (a) preliminary work, (b) data processing, and (c) suitability analysis. There were two main tasks for the preliminary work. The first one was *Factor Identification*. As with other crops, coconut trees require certain environmental conditions to thrive. These conditions need to be identified first in order to perform a comprehensive coconut suitability analysis. The factors were identified based on existing literature on coconut growing and through discussions with coconut experts of PCA. After having identified the most important factors to be included in the analysis, the next crucial step was to gather machine-readable data that a GIS software can process. The datasets gathered in this study were acquired through requests from different Philippine government agencies and from international public geospatial data archives.

A bulk of the processing was dedicated to *Preprocessing* the acquired geospatial data. The *Preprocessing* step is required because it prepares and transforms the data into something that is useful for suitability analysis. The *Preprocessing* steps included the (1) conversion of raster file format, (2) coordinate system reprojection, (3) resampling, (4) merging, (5) clipping, and (6) reclassifying the datasets. Each dataset generally underwent these steps. However, there were minor differences in how each dataset was treated. The specific *Preprocessing* that each dataset went through is presented in Appendix 1 and discussed in the ensuing sections.

3.1 Elevation Data

The high-resolution 2013 IFSAR-DTM data from NAMRIA were processed to make them suitable for analysis. The original 2013 IFSAR-DTM data consists of 12,951 tiles in BIL file format (band interleaved by line) format image tiles in three projections: Philippine Reference System 1992 UTM Zone 50N, 51N, and 52N with a spatial resolution of 5-meters. The data were divided into 13 groups (e.g., Northern Luzon, Central Luzon, etc.). The initial step was to use the Geospatial Data Abstraction Library (GDAL) command line interface to convert the data (.bil) per group to GeoTIFF file format and reproject it into WGS 84 / UTM Zone 51N (EPSG:32651). The tiled GeoTIFF format data were then merged into a virtual raster by group and then converted into GeoTIFF format. Then, the GeoTIFF file generated for each group was clipped using the regional boundaries. The outputs of the clipped regions were then merged and resampled into a 30-meter spatial resolution DEM using bilinear interpolation. Finally, QGIS's *Reclassify by Table* function was used to reclassify the original elevation data for each region using the determined appropriate elevation for coconut growing (Figure 1).

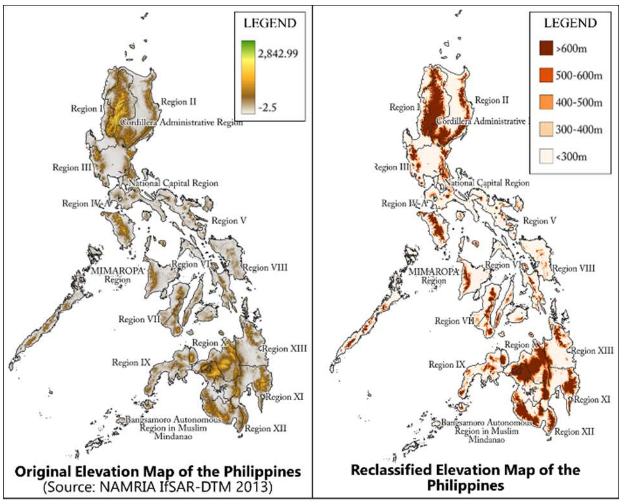

Figure 1. Elevation Map of the Philippines

3.2 Slope Data

The slope data was derived from the 2013 IFSAR-DTM data from NAMRIA. This was accomplished using the GDAL command-line interface. *GDAL's gdaldem slope* function was used to estimate slope in degrees from the reprojected elevation raster data. The tiled slope data were then merged into a virtual raster and then converted into GeoTIFF format. Next, the GeoTIFF file that was generated for each group was clipped using the regional boundaries. The output of the clipped regions was then merged and resampled into a 30-meter spatial resolution slope data using bilinear interpolation. Afterward, QGIS's *Reclassify by Table* function was used to reclassify the slope data for each region using the determined appropriate slope values for coconut growing (Figure 2).

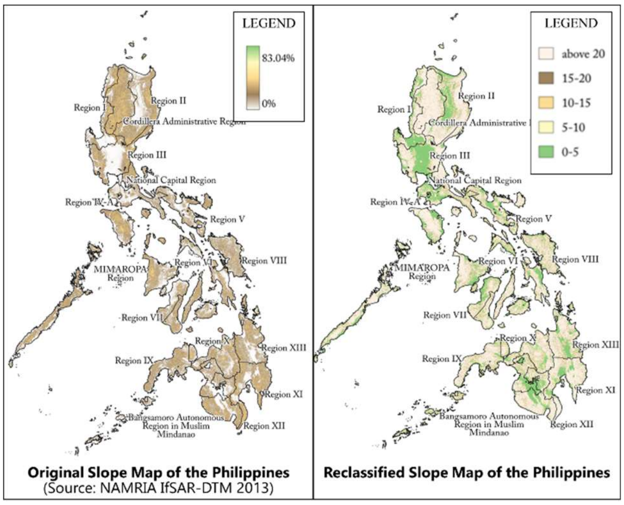

Figure 2. Slope Map of the Philippines

3.3 Soil Type

The soil type data was originally a vector map in a shapefile format that consisted of 77 soil type classifications. The vector data was reclassified into five categories (i.e. Loamy, Clayey, Silty, Sandy, and Undifferentiated). After the reclassification, the data was rasterized into a 30-meter spatial resolution layer using QGIS's *Rasterize* (vector to raster) function. Then, the raster data was reprojected into WGS 84 / UTM Zone 51N (EPSG:32651) using QGIS's *Warp* (Reproject) function. Finally, the 30-meter soil-type raster data was clipped per region for suitability assessment. The original and the final reclassified soil type map of the Philippines are presented in Figure 3.

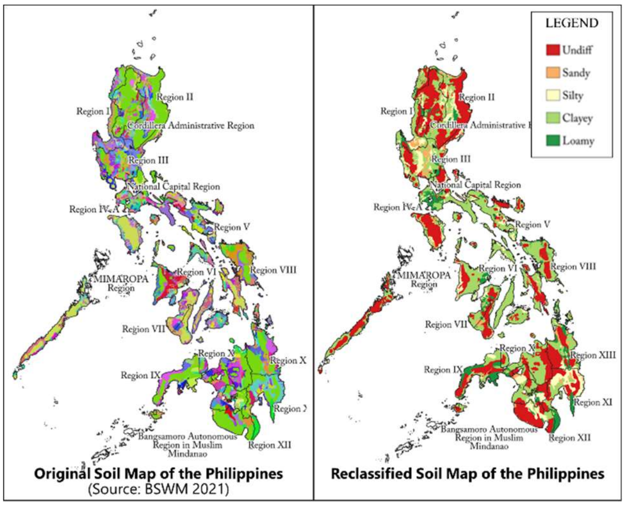

Figure 3. Soil Map of the Philippines

3.4 Rainfall

The 2021 rainfall data from CHIRPS were reprojected into WGS 84 / UTM Zone 51N (EPSG:32651) using QGIS's *Warp* (reproject) function. Then, the data was divided into smaller, more manageable tiles for improved performance and faster rendering using the GDAL's *gdal.retile* function. The resulting tiles were then resampled into a 30-meter spatial resolution layer using nearest-neighbor interpolation before being merged. Once the tiles were merged, it was then clipped per region for the suitability assessment. Figure 4 shows the rainfall layer and the reclassification output.

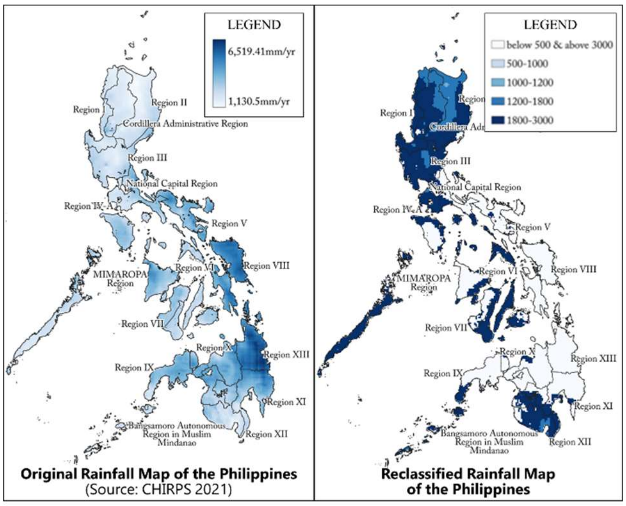

Figure 4. Rainfall Map of the Philippines

3.5 Land Surface Temperature (LST)

The 2021 temperature data from MODIS were reprojected into WGS 84 / UTM Zone 51N (EPSG:32651) using QGIS's *Warp* (reproject) function. Then it was divided into smaller, more manageable tiles for improved performance and faster rendering using the GDAL's *gdal.retile* function. The resulting tiles were then resampled into a 30-meter spatial resolution layer using nearest-neighbor interpolation before merging. Once the tiles were merged, it was then clipped per region for suitability assessment. The original and the final reclassified LST map of the Philippines are shown in Figure 5.

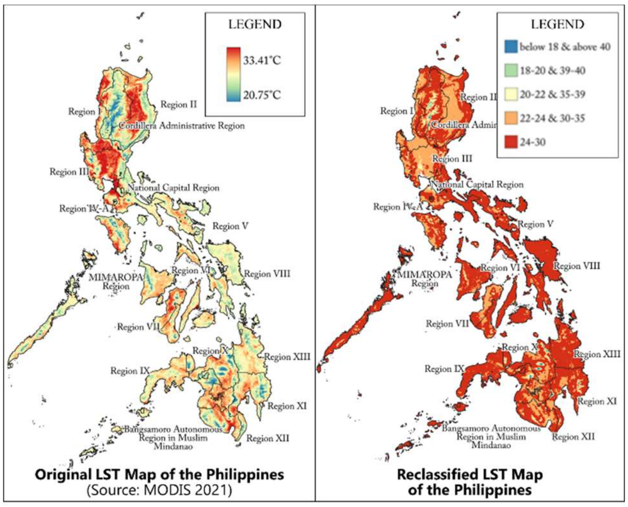

Figure 5. Land Surface Temperature Map of the Philippines

3.6 Land Cover

After reclassifying the resulting coconut suitability layer, masking was done using the NAMRIA Land Cover Map. This is to remove areas deemed unsuitable for tree planting. Since the land cover data acquired from NAMRIA was divided into four (i.e., Luzon, Visayas, Mindanao, and Palawan), they were first merged together. Of the twelve land cover classifications, five (5) were identified as not possible areas for coconut planting, to wit: Built-up, Mangrove Forest, Marshland/Swamp, Fishpond, and Inland Water. These land classifications were only 6.84% of the total land cover.

Using the QGIS *Select by Expression* function, the identified areas were selected and then exported as a new layer. This new layer was used as input on the *Rasterize* (Overwrite with a fixed value) along with the reclassified coconut suitability layer to mask out unwanted areas by setting the fixed value to burn as -9999. This turned the areas overlapped by the *Not Suitable* land cover types into areas of no data value essentially removing them. The original and the final reclassified land cover map of the Philippines is presented in Figure 6.

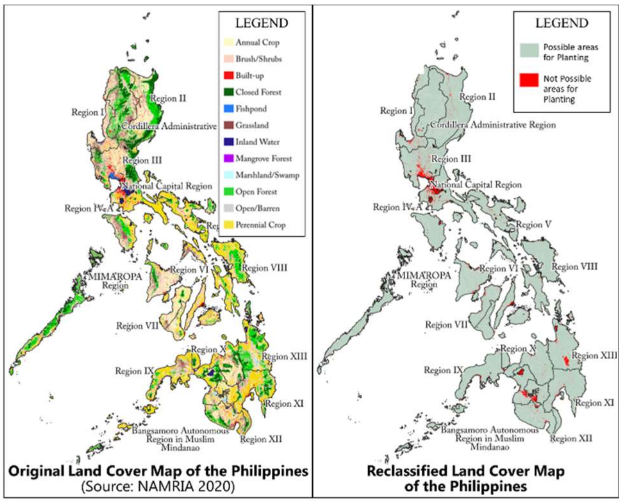

Figure 6. Land Cover Map of the Philippines

4. RESULTS AND DISCUSSION

Statistical functions (i.e., median coconut suitability classification and area per suitability level) were then extracted using the QGIS *Zonal Statistics* and *Raster Layer Unique Values Report* functions to generate a detailed report on the result of the coconut suitability analysis.

Elevation. More than half (about 64%) of the Philippines have an elevation of less than 300 meters which is deemed the best for coconuts while only 18% have an elevation greater than 600 meters where coconuts start to have stunted growth. Among the regions, the Cordillera Administrative Region (CAR) was the least suitable in terms of elevation because it has many high elevation values due to its mountainous terrain. On the other hand, the region with the most suitable elevation values was the MIMAROPA Region.

Slope. Due to the sloping characteristics of land features in the country, many areas registered high slope values thus received low score for this category. After data reclassification, more than half of the country's area (53%) have slopes greater than 20% (equivalent to 11.31°). About one-fourth (24%) has a very high score of five because of its relative flatness. The regions with the highest sloping areas are CAR, Region II, Region IV-B, Region VIII, and Region XI. These are the areas with more than 1,000 hectares of sloping or above 20%.

Soil Type. Roughly 36% of the entire Philippines has an undifferentiated soil type. It is still currently not possible to determine whether these areas are suitable or not for coconuts. The remaining 64% were shared by four different general soil types: loamy, clayey, silty, and sandy. Only 8% of the country was classified as having loamy soils. The majority of the area (about 40%) was classified as having clayey soils. Silty areas had an 11% share while sandy has 5%.

Rainfall. In terms of hectarage, about 45% of the country's area received enough amount of rainfall in 2021. On the other hand, 47% was given a very low score due to either a low amount of precipitation throughout the year or having too much rain that it may oversaturate the soil and affect coconut growth. Areas that received very high scores are mostly in the northern region of the country (e.g., Regions I, II, III, and CAR) while those that scored low can be found in the central, eastern, and southern parts of the country. Among the regions, it was Region III that received a good enough amount of rain while it was Region VII that scored the lowest in the rainfall category.

Land Surface Temperature. About a third of the entire Philippines (about 72%) was given a very high score and deemed suitable in terms of temperature. About 26% were given a high score while only 2% of the country was given an average score. This implies that almost the entire country has temperatures that allow the coconut to thrive. However, it is still the MIMAROPA region that has the most areas with a score of five while Northern Mindanao (Region X) has the most areas which received a score of one implying that it has areas that have unsuitable temperatures which may affect coconut growth.

The final result of the *Multiple Weighted Overlay Analysis* showed that about 20 million hectares of the country's total land area are suitable for coconut planting. The suitable areas were broken down into three suitability classifications. About 3.6 million hectares or 14% of the country's total land area were classified as *Highly Suitable* for coconut planting. About 7.2 million hectares (29%) and about 9.1 million hectares (36%) were classified as *Moderately Suitable* and *Marginally Suitable* respectively. Further, about 5.2 million hectares (21%) were classified as *Currently Not Suitable*. The return on investment might be low should coconut trees be planted in these areas. The enhanced coconut suitability map is presented in Figure 7.

In terms of the regional distribution of suitable areas, the top five regions with varying levels of the most suitable areas for coconut planting are Region II with 1.96 million hectares (or 81% of its total land area), Region III with 1.62 million hectares (or 89% of its total land area), Region IV-B with 1.57 million hectares (or 81% of its total area), Region VIII with 1.56 million hectares (or 87% of its total land area), and Region VI with 1.46 million hectares (or 83% of its total land area). See Figure 8 for details.

Potential Areas for Coconut Planting. Finally, based on the outputs of this study, there are a combined total of 19.9 million hectares of suitable areas for coconut planting. Of this total, there are 3.64 million hectares (18%) planted with coconut based on the PSA data for 2021. Thus, there are about 16.4 million hectares (82%) of potential areas for coconut planting with varying levels of suitability.

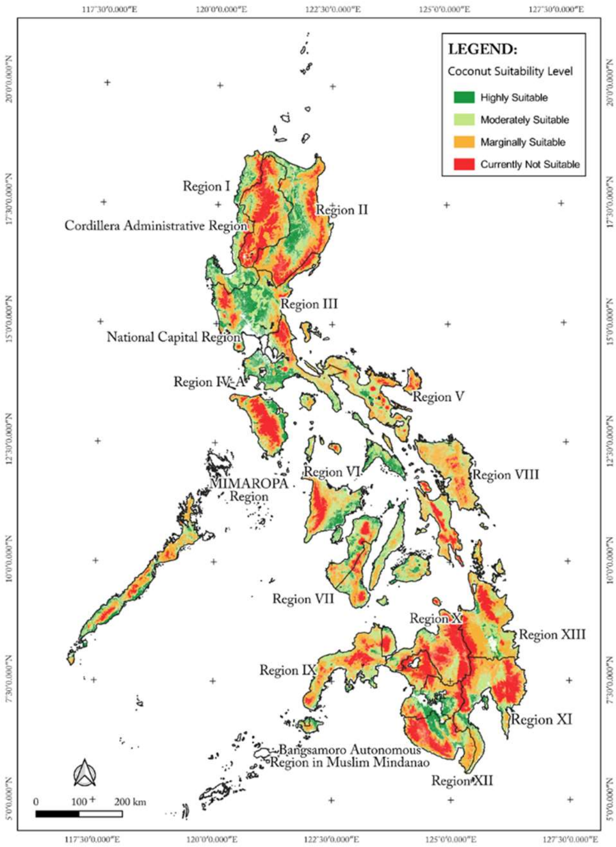

Figure 7. Enhanced Coconut Suitability Map of the Philippines

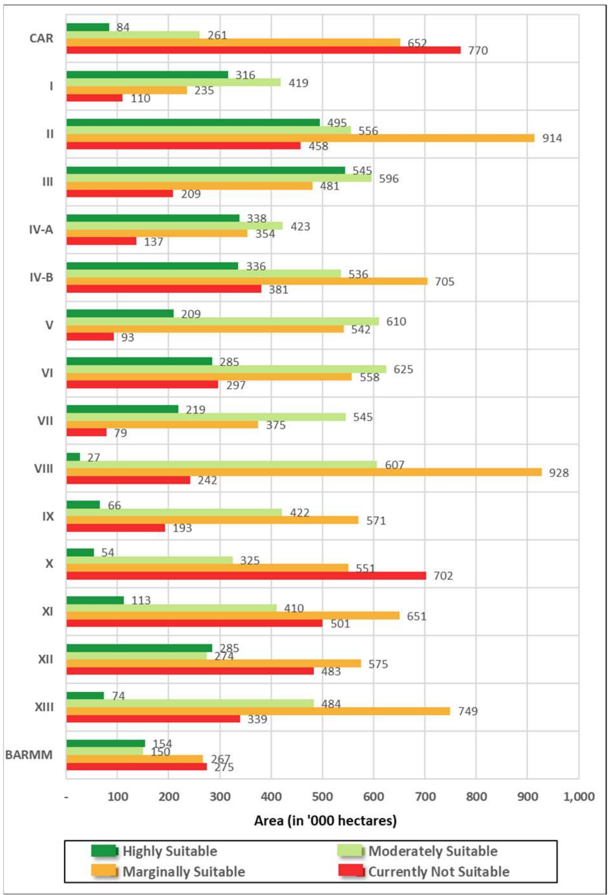

Figure 8. Coconut Suitability Data by Region

Among the regions with the highest potential areas for coconut planting are Region II (with 1.9 million hectares), Region III (1.5 million hectares), IVB (1.3 million hectares), VI (1.3 million hectares), VIII (1.2 million hectares) and XIII (1.1 million hectares). Details are presented in Figure 9.

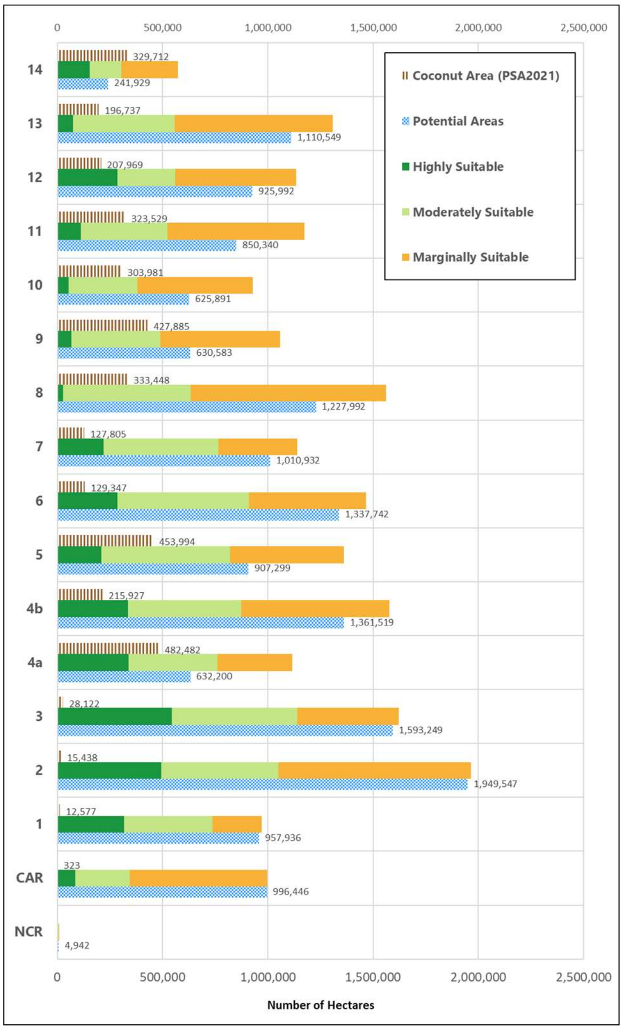

Figure 9. Potential Areas for Coconut Planting

5. CONCLUSION AND RECOMMENDATION

The outputs of this project led to the enhancement of the field assessment protocol in determining the suitable areas for coconut planting. An enhanced form was developed as presented in Appendix 2. Other important factors must be considered for selecting suitable areas besides the topographic and environmental factors. These are the (1) Current Land Cover/Land Use status, (2) Farmer's interest, (3) Participants good standing status with PCA's program implementation, (4) Peace and order situation, (5) Land tenancy disputes, (6) Farm accessibility, and (7) Current pest outbreak management.

With the rapid development of geospatial technologies and increasing accessibility of remotely-sensed data, it is high time that the agriculture sector, the coconut industry included, take advantage of the massive benefit of using geospatial data. Utilizing mapping technologies will enable PCA to make sound and informed decisions to develop the Philippine coconut industry.

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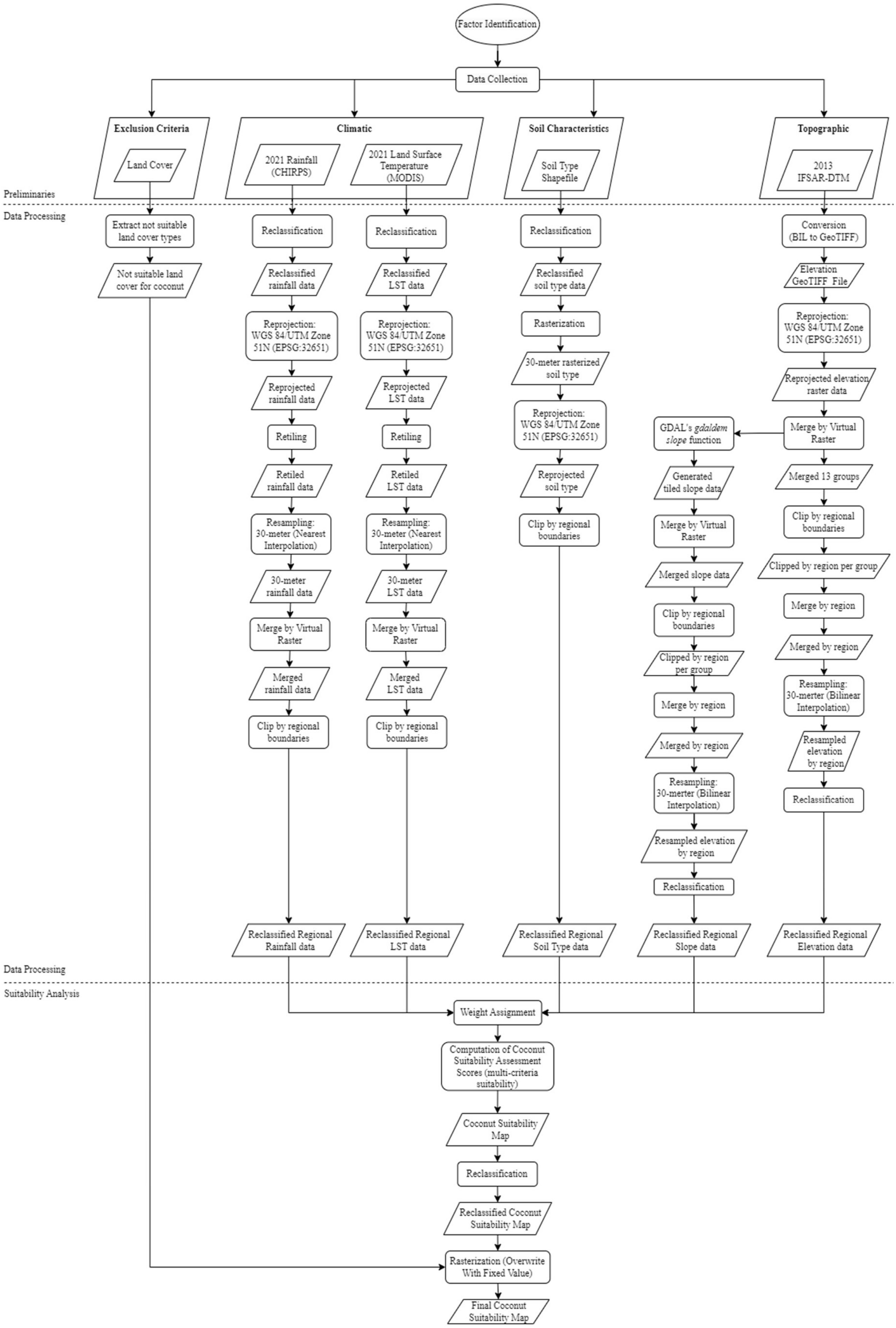
Appendix 1. Technical Workflow on Coconut Suitability Assessment



Appendix 2. Suitability Criteria in Selecting Areas for Coconut Growing

Department of Agriculture
PHILIPPINE COCONUT AUTHORITY
Department of Science and Technology
PHILIPPINE COUNCIL FOR AGRICULTURE, AQUATIC AND NATURAL RESOURCES RESEARCH AND DEVELOPMENT

ISO 9001:2015

SUITABILITY CRITERIA IN SELECTING AREAS FOR COCONUT GROWING

Farmer: 1 First Name ______ Middle Name ______ Last Name ______

Address: 2 Region ______ Province ______ Municipality ______ Barangay ______ Longitude/Latitude ______

Existing Farm Details: 3 Farm Size (in Hectare) ______ No. of Coco Trees ______ Age of Trees ______ Coconut Variety ______ Intercrop ______

REMOTE ASSESSMENT (Coconut Suitability Score)

ENVIRONMENTAL AND SOCIO-ECONOMIC SUITABILITY SCORE (60%):

4 Score ☐

Coconut Suitability Score
Topographic: Philippine Elevation and Slope Data provided by NAMRIA
Soil Characteristic: Philippine Soil Series Data provided by BSWM
Climatic: Global Rainfall and Temperature Data from NASA (CHIRPS and MODIS)

ON-SITE ASSESSMENT (Actual Field Assessment by PCA-Regional Offices)

COCONUT HYBRIDIZATION FIELD ASSESSMENT FACTORS (20%):

5 Score ☐ 6 Yield Index Score: ☐ 7 Varietal Homogeneity: ☐

PARTICIPANT'S INTEREST/CONSENT (10%):

8 Score ☐
9 Willingness to lease own land to PCA for the implementation of OFHPS for a period of two (2) years subject to renewal yearly thereafter? Yes ☐ No ☐
10 Consent of the Owner if Tenant or Administrator of the farm? Yes ☐ No ☐

PARTICIPANT'S GOOD STANDING STATUS (10%):

11 Score ☐
12 Membership standing on Organization/Cooperative if applicable? Good ☐ Bad ☐ Inactive ☐
13 Standing on PCA's projects if recipient? Good ☐ Blacklisted ☐

EXCLUSION CRITERIA ASSESSMENT: Check all factors with issues/concerns

14 Land Cover ☐ Soil Drainage ☐ Peace & Order ☐ Land/Tenancy Disputes ☐ Farm Accessibility ☐ Pest Outbreak ☐

15 **REMARKS (any remarks on the Participant, Farm, Coconut Stands, Peace and Order, and other concerns):**

16 **Attach copy of the Certificate of Land Title for proper documentation and accurate mapping of the farm.**

Total Points 17 ☐

18

SUITABILITY ASSESSMENT	RANGE
S – SUITABLE	
S1 - Highly Suitable	75 – 100
S2 - Moderately Suitable	50 – 75
S3 - Marginally Suitable	25 – 50
N - NOT SUITABLE	
N1 - Currently Not Suitable	1 – 25
N2 - Permanently Not Suitable	

Attested by Participant:
19 ______
Printed Name and Signature / Date

Evaluated by Agriculturist/CDO/PCA Field Evaluator:
20 ______
Printed Name and Signature / Date

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