

Mapping Philippine Agro-Ecological Zones (AEZS) Technical Notes

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I. INTRODUCTION

An agroecological zone is an area of land that has relatively even possibilities when it comes to crop production (Pariyar and Singh, 1994). The process of using the different biophysical attributes (e.g. soil characteristics, physiography, climate, land use/land cover, productivity, etc.) of a certain place to group together homogeneous areas is known as agroecological zoning (AEZ).

Climate, soil characteristics and land forms are factors that determine how productive any piece of land can be. Similarly, these are what can limit the productivity of any land area (Patel, 2003). AEZ in turn uses these factors as a basis for dividing a given area into agroecological zones. The process of AEZ can therefore assist the government and regional planners when it comes to how land use should be utilized in the present and in the future.

Agroecological zoning (AEZ) can be a useful tool for policy and decision makers for appropriate planning, especially in terms of land use and development.

The FAO particularly defined agro-ecological zones as regions with the same agricultural capacity characterized according to homogeneous climatic and edaphic conditions (Barber, 1996). Due to growing interest and efforts in the study of AEZ, in the latter part of 20th century, FAO published a guidebook for AEZ as aid for countries in enhancing land and water resources assessment. After giving a definition of the concepts and terms important in understanding AEZ, this guidebook discusses in detail the AEZ process and its application, the tools used in agro-ecological zoning particularly, GIS, and the ecological-economic zoning (Barber, 1996). Based on this reference, AEZ process has three steps: making a profile of land use, climatic and edaphic data; merging the data on period of crop growth, climate, soil, land use and resources; and finally, assessment of the land for agro-ecological zoning. Due to its flexibility in data manipulation and management, ability to process multi-dimensional operations and fast improvement, focus is given on GIS as a potent instrument in managing and analyzing information for AEZ delineation (Barber, 1996). An alternate to AEZ, the ecological-economic zoning (EEZ) and the proposed process which incorporates social and economic variables in the evaluation of land utilization are also explained (Barber, 1996).

In the past, intersection of mapped sets of data and statistics are used to determine AEZs (de Vries et al, 1993). Significant amount of data could be lost in this method due to inconsistencies in geographical location (Patel et al, 2005). Now, because these climatic and edaphic data have geographic reference, the practice of GIS technology improved the result of AEZ mapping by producing more accurate results because it preserves pieces of information that could be lost using previous methods (Patel et al 2005).

AEZ was done in the Southwest corner of Narayani Zone in Nepal, the Chitwan district (Pariyar and Singh, 1994). The researchers developed a geographic information system (GIS) model to use for agroecological zoning. In short, they gathered data and used temperature, moisture, irrigation and soil characteristics of the area as layers for the GIS based model. They were able to create AEZ maps that could be used for regional planning and development.

However, there was a limitation to agroecological zoning. For instance, mountainous regions lack geospatial data, which make them harder to study using AEZ (Patel, 2003; Quiroz et al., 2001). But, newer tools have made AEZ possible even in data scarce areas such as mountains. Using remote sensing and process-based models and applying them to climate interpolation and crop/livestock production can greatly enhance the AEZ method (Quiroz et al., 2001). Two such case studies will be reviewed briefly.

Patel (2003) used remote sensing and GIS as tools for agroecological zoning in the Kumaon Himalayas. Patel looked at climate variables of different locations (minimum, maximum and average temperature, rainfall) in order to compute for the potential evapotranspiration (PET) and consequently the moisture index (MI). These describe how “wet” a certain area is, wherein those with positive MIs (meaning the area has water) are conducive for crop growth and those with negative MIs (meaning the area is dry) are not conducive for crop growth (Sebastien/ HarvestChoice, 2009). The vegetation biomass variability, land use/ land cover (from satellite data and later incorporated to raster GIS) and soil characteristics data were also collected and compiled and inputted to the model. The researcher concluded that it can indeed be done, and the appropriate land use choices were suggested to the region.

Quiroz et al. (2001) conducted a similar study in the Ilave-Huenque watershed of the Andean high plateau. Similar to Patel, Quiroz et al. looked at soil characteristics, topography, land use/ land cover, biomass and climate. All of the said characteristics were used as layers in GIS and their results show that remote sensing can be used in the analysis. They derived four agroecological zones as their results, and the local professionals with whom the researchers worked with have access to them, making positive changes more likely to occur.

An alternative method of determining AEZs is computation of crop growth period. The duration of crop growth is computed using rainfall and potential evapotranspiration data (de Vries et al, 1993). However, this is not the practice nowadays ever since the application of more advanced agricultural techniques to make crops grow faster although this may not increase crop productivity (de Vries et al, 1993). Calculation of growth period was replaced by models showing the suitability of an area for crop production.

Computer models provided a cheaper alternative for AEZ study. Computer models allow users to create different scenarios and present options that decision-makers could choose from according to their objectives.

Fischer and Anoiné (1994) wrote about the details of a computer program that can be used in delineating AEZ's in Kenya – the Kenya-AEZ. This software includes land and atmospheric data inventory, a programming guide and a planning aid for various circumstances.

Kenya-AEZ is followed by the creation of AEZWIN, a Windows-based computer program that enables the user to classify agro-ecological zones in which multiple scenarios could be made for subsequent analysis. Similar to the Kenya-AEZ, this program includes making an inventory on land and atmospheric data in Kenya. These sets of data are also classified to derive spaces that are suitable for crop production. AEZWIN is simpler to use and more powerful compared with Kenya-AEZ. This program could create scenarios using more criteria. Fischer et al (1999) wrote a handbook for AEZWIN. In this guidebook, they explained the AEZ process, the steps in using this software to analyze agricultural efficiency and to create land use models with different components and scenarios for decision-making.

In recent years, decision support systems are developed to aid in creating policies and choosing directions to address agricultural sustainability. One example is MicroLEIS DSS, a system for evaluating land use applied in the study of de la Rosa et al (2009) in a Southern province of Spain. Boateng (2005) used GIS as decision support system to determine whether the land in Ghana is suitable for planting rice.

AEZ Methodologies

In the study of Patel et al (2005) on the Kumaon region, India, they used monthly rainfall data collected for eight years by rain gauge stations, USGS DEM, temperature from meteorological stations, computed potential evapotranspiration and moisture indicator computed based on method developed by Thornwaite and Mather in 1955, NDVI extracted from NOAA AVHRRR (Advanced Very High Resolution Radiometer), ground validated land use generated from IRS WiFS satellite data as well as soil data from National Bureau of Soil Survey and Land use Planning of ICAR in India. These datasets are used to delineate the agro-ecological zone to increase the efficiency of land utilization. By overlaying these mapped datasets, cells containing agro-ecological data could be extracted. In this study, nine AEZs in Kumaon are identified according to the conglomeration of temperature, moisture and vegetation data (Patel et al, 2005).

In their book, Fischer et al (1999) described the datasets on land and atmosphere inventoried in AEZWIN. These datasets are rasterized. Cross-tabulation was used to derive class combinations. The mean harvest and the predicted harvest exposed to various climate specifications are computed. Rules based on the factors affecting crop growth are formulated. Land productivity is computed based on these rules. This will result on the productivity of various crops planted in different agro-ecological zones. After this, land use layer could be incorporated in AEZWIN for generation of various scenarios (Fischer et al, 1999).

Efforts were also made by the Philippine government to map agro-ecological zones in the past. A collection of maps and data in national scale regarding AEZ was created by Bureau of Soils and Water Management. This collection includes maps on crop growth, map showing temperature, elevation, slope, soil properties and irrigation. These maps could be accessed in the web in JPEG format (Concepcion, 2004). Efforts were exerted to locate shapefiles of fundamental datasets like Philippine soil orders but these were not successful. The FAO soil order map from the CD of the Philippine Biodiversity Conservation Priorities (Ong, P.S. et al, 2002) was found to be the best available shapefile and so was used in generating Philippine agro-edaphic zones through its cross-tabulation with maps of elevation and slope (SRTM version 4, February 2000, NASA-USGS).

Application of AEZs

AEZs are used in studying various environmental, social and economic aspects. Research on soil nutrient in different agro-ecological zones and application of fertilizers, the connection of agro-climatic and agro-edaphic conditions and poverty as well as agro-ecological zoning for fuel production were done in the past. These studies are summarized in this section.

A document reported the research on recommended fertilizer per agro-ecological zone in Bangladesh, land use study in China, agro-ecological zone process in assessing the ability of Palawan province in the Philippines to support its populace, evaluation of the appropriate use of land in Thailand, and AEZ in Sri Lanka. Highlighted in this document is the importance of GIS in agro-ecological zoning (FAO, 1991).

Another study on the appropriate use of fertilizers for various AEZ is also conducted. Smaling (1993) studied how to manage the combination of nutrients such as nitrogen, phosphorus and potassium that affect crop production in Kenya. He related land use with sources of nutrients. He found out that exceeding amounts of nutrients in the land are caused by artificial rather than natural causes. Suggestions on the type of fertilizer for specific agro-ecological zones and crops could be made based on these results. Included in this study is the use of computer model called Quantitative Evaluation of the Fertility of Tropical Soils (QUEFTS). This model aided in the study of combination of various parameters (Smaling, 1993).

Recent studies showed interest in determining arable land suitable for farming of various crops for economic growth. AEZ is delineated to assess regions fit for planting rice in Ghana (Boateng, 2005). Aside from food production, a study on suitable land for planting *Jatropha* for fuel production was done according to agro-ecological provisions (Jingura et al, 2011).

In Bangladesh, a study on the connection of AEZ and Poverty was conducted. The result of this study shows more poor people in regions with less agricultural production. This is due to less number of land owners and more workers. However, the connection between poverty and climatic and edaphic conditions still remains inconclusive (Moral and Rainis, 2011).

II. RATIONALE

It is said that the objective of the 7th PHDR is to determine and verify the implications of geography on human development at the sub-national level, that is, in spatio-temporal terms. Research questions include whether geography has a direct impact on human development and in which ways geography facilitates or hampers development. Another important question deals with whether public policies as well as paradigms of development should be determined by geographical contexts. As such, recommendations for improving the linkage of geography with human development directions are sought (Communication by HDN, 2011).

Among background papers for the 7th PHDR is a research on "*The Creation of an Ecology-Based Spatial Framework for an Alternative HDI Analysis*". The overall goal is to map the agro-ecological zones (AEZs) of the country and to find correlations with human development. This particular study will focus on the merging of agro-climatic with agro-edaphic zones.

The definition of agroecological zones was provided by the HDN, as follows: “Agroecological zones (AEZs) provide consolidated information on climate (including radiation, rainfall, temperature, and humidity) for the particular purpose of assessing the production potential of land for different types of (rainfed) agriculture. Many agricultural production systems, technologies and practices are often associated with specific AEZs, or their performance is relatively uniform within individual AEZs. AEZs therefore provide a useful spatial framework to ... summarize and report other important agricultural measures such as production, population, extent of cultivation, and market accessibility. This provides an ecology-based division of space as opposed to reporting based solely on administrative boundaries.” (Sebastien/ HarvestChoice, 2009)

The main objective of the study is to map AEZs of the Philippines according to a predetermined methodology and a selected set of variables. The study focuses on merging agro-climatic with agro-edaphic zones. A preliminary set of variables for each type of zone was selected and then combined in map form. The choice of this preliminary set of variables was mainly determined by their availability in shapefile format, which is proprietary to ArcView/ ArcGIS. The results are transboundary AEZs spanning the country, which shall then be correlated by the HDN. It is recommended that such correlation be spatial in approach, that is, using multi-temporal maps of HDIs, respectively for 1997, 2000, 2003 and 2006.

III. METHODOLOGY, SCOPE AND LIMITATIONS

Many studies on agro-ecological zones were grid cell-based and variably merged agro-climate zones (i.e. rainfall, moisture/ humidity, temperature), biomass, agro-edaphic zones (i.e. elevation, slope, soils, irrigation) with land resources (i.e. land use/ cover) (e.g. Sebastien/ HarvestChoice, 2009; Pariyar and Singh, 1994; Patel, 2003; Quiroz, 2001). A global AEZ (GAEZ) rule set for combining “major climate divisions”, “warm/ cool distinctions” (i.e. Temperature/ elevation) and “moisture zones”/ humidity were demonstrated in great detail in the case of Sub-Saharan Africa (Sebastien/ HarvestChoice, 2009).

On the other hand, technological tools and another rule set for dynamically defining AEZs were discussed in the research of Quiroz et al. (2001). The difference from previous studies was the inclusion of soils, slope, land use/ cover, biomass (e.g. with NDVI as an indicator for biomass) and rainfall aside from temperature in a watershed context. Two categories of AEZs were developed: Category I was on “soil classes, altitudes and slopes” while Category II encompasses “land use/ land cover, biomass and climate”. For this high-resolution study, “remote sensing”, “process-based interpolation models” as well as “geographic information systems” (GIS) were applied. These tools were highly recommended because these facilitate mapping of AEZs, especially under data poor conditions (Quiroz et al., 2001).

A study by Patel (2003) assessed variables similar to the study of Quiroz et al., (2001), e.g. “soil resources, temperature, rainfall, moisture and biomass as input layers” (p. 231). But in contrast, additional variables for soils were included, such as “physiography, texture, slope and depth” (p.219). Spatial coverage of sub-AEZs was featured in terms of area and percentage area.

Map integration methods in previous studies included logical combination methods (Harvest Choice, 2009) and “unsupervised (pixel-based) classification” (Quiroz et al., 2001). GIS thematic layers as baseline maps were used in the case of unsupervised classification.

An important aspect of this research is to find out if AEZ maps of the Philippines already exist. The FAO map on AEZs was found to be very coarse, such that the whole Philippines is classified as being warm humid tropic (RAEZ 10 and AEZ 3). Locally, the Philippine classification for AEZs are wet, moist and dry, as reported under a “forage resource profile... first prepared in 1998/ 99 and revised in 2005 by: Francisco "Frank" A. Moog, Chief, Research Division, Bureau of Animal Industry, Diliman, Quezon City, Philippines. e-mail< frankmoog@yahoo.com >. He is currently the International Coordinator of the FAO Regional Working Group on Grazing and Feed Resources for Southeast Asia.”. However, the said map could not be found. A map of Philippine AEZs actually exists, which was obtained from the Bureau of Agricultural Research or BAR. However, it is solely climatic, in that it shows general transboundary zones that are classified as being cool tropics, warm humid tropics and warm sub-humid tropics. Here, we sought to improve this map and classification through research and mapping components, whereby climate variables were combined with agro-edaphic variables.

In this study, a limitation considered was that the variables combined cannot exceed 256 classes (= 2⁸ bit). Hence, only fundamental agro-climatic and agro-edaphic zones were cross-tabulated and analyzed, under the premise that land use/ cover depend highly on both. For instance, certain soil orders may be suited not only for agriculture but also for orchards and forests. In order to cross-tabulate parameters two by two or bi-dimensionally, classes of variables needed to be as streamlined as possible yet justified.

The AEZ map, in this case, is not clearly meant to configure development potential, that is, according to the best use of land, as by certain land use (e.g. Residential, commercial, industrial, institutional and mixed use), a nominal variable. Development potential is a very complex parameter, considering not only land cover vs. human settlements, with parameters for best land cover weighed against parameters for the best land use. This evaluation is made more complicated by the need to consider spatial context, that is, specific locations relative to others surrounding it, which in turn may be overlapping. Besides this, development potential would have its push and pulls relative to a location, further complicating the mapping of AEZs if this aspect is considered. Perhaps this may be the subject of future research as time would permit.

In this study, specific crop suitability was not the emphasis but rather general suitability to agriculture or the potential for agriculture. Yet other types of land cover were not discounted, since the description of soil orders puts these into consideration when referred to more closely.

Neither existing land use/ cover nor geology were factored in due to their complexity as variables. It is important to note that land use/ cover are nominal variables, making their combination with other variables very complex. In addition, the Philippines has many versions of land use/ cover maps. Perhaps the inclusion of these previously mentioned variables in AEZ mapping may be considered in future phases of the research as time would permit.

There are other difficulties in AEZ mapping other than the diversity of Philippine landscape and the subsequent need to generalize in view of limits to the number of classes that may be logically

combined. Among these are that maps cannot be perfectly overlaid, having come from different sources. In this study, we used the Geographic Coordinate System Projection. Our Base Map covering Philippine provincial boundaries came from the NAMRIA. A significant amount of time would have to be devoted to edit natural and political boundaries, such that these are reconciled across map themes. In this study, discrepancies in boundaries are recognized as a limitation. The official coastlines and political boundaries of the NAMRIA Base Map are the ones graphically used in the GIS analysis.

The conceptual and methodological framework adopted for this study is illustrated in Figure 1.

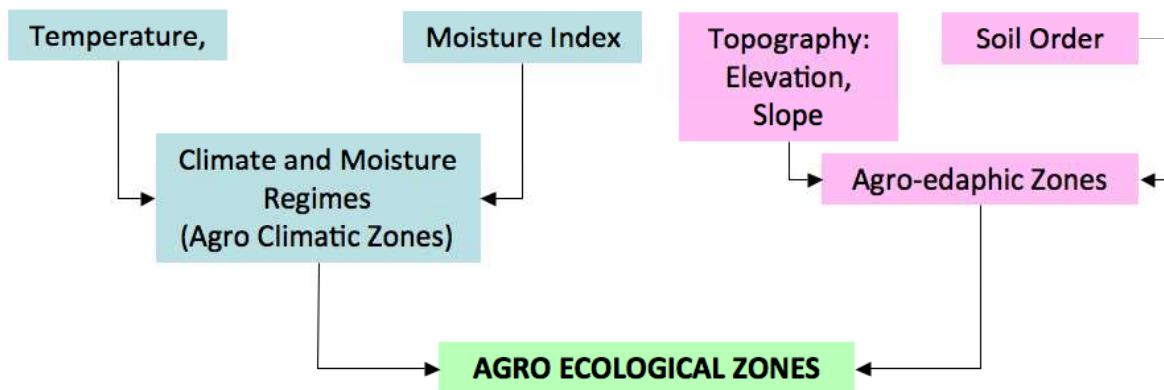


Figure 1. Conceptual framework on developing agro-ecological zones.

In terms of agro-climatic zones, note that data from the meteorological bureau (PAGASA) are not used in this analysis. We used gridded data based on observation stations. This allows the spatial analysis for the whole of the Philippines. The PAGASA stations provide point data in different locations mostly in lowland regions of the country.

The scale of the resulting maps featured in this report in A3 paper is 1:5,500,000 using the Geographic Coordinate System Projection. The graphical scale overrules in A4 format.

A. Philippine Agro-Edaphic Zones

This section discusses the matrix of agro-edaphic zone variables and the methodology for combining these variables. Table 1 illustrates the generalized classifications of elevation, slope, and soil orders. As shown in this table, fundamental datasets were based on reliable sources as follows. Figure 2 shows the method for generating the Philippine agro-edaphic zones after generalization of thematic map layers.

Table 1. Generalized classification of elevation, slope and soil orders. (*FAO [Food and Agriculture Organization of the United Nations]).

Name of Variable	Generalized Elevation		Generalized Slope		Generalized Soils
	Value Elevation (m)	Attribute	Value %	Attribute Angle	
	0-100	Lowland	0-8%	Level - Gently Undulating	Cambisols, Luvisols Fluvisols, Gleysols, Vertisols Acrisols, Arenosols Andosols, Nitisols
	> 100	Upland	8-30%	Rolling – Hilly	
			> 30%	Steeply Dissected to Mountainous	
Source	SRTM version 4 (February 2000), NASA-USGS; Generalized based on DENR and Walpole, Pedro W., Figuring the Forest Figures: Understanding Forest Cover Data in the Philippines and Where We Might be Proceeding, ESSC, July 2010, p. 12, Available from http://download.essc.org.ph/forest/ESSC-PWalpole_Figuring%20forest%20figures_reduced .pdf ; Sustainable Upland Development, Philippines-European Union Development Cooperation, April 2007; Concepcion, R. N., 4.1 The Hierarchy of Soil and Soil Ecological Zones, BSWM; NAMRIA (Base Map)		SRTM version 4 (February 2000), NASA-USGS; Generalization based on World Soil Resources Report: The Digitized Soil Map of the Worlds: Notes, FAO (June 1992); NAMRIA (Base Map)		Ong et al (2002), Philippine Biodiversity Conservation Priorities; World Soil Resources Report: The Digitized Soil Map of the World Notes FAO Release 1.1 (June 1992); Generalization based on Bationo et al, "African Soils: Their Productivity and Profitability of Fertilizer Use" (2006); Encyclopaedia Britannica (2011), USDA and UIDAHO; NAMRIA (Base Map)
Date	2000		2000		1995

The elevation and slope maps were derived from SRTM 90 m. The Encyclopædia Britannica (2011) provided the most readily understandable definition of soil orders. Other sources of soil order definitions were USDA and UIDAHO. BSWM maps are available on-line but only in jpeg format and so could not be immediately processed according to the project time-frame. The soil order map came from a CD of maps accompanying the local report and publication by Ong et al (2002) entitled, “Philippine Biodiversity Conservation Priorities: A Second Iteration of the National Biodiversity Strategy and Action Plan”. DENR-Protected Areas and Wildlife Bureau (PAWB), Conservation

International Philippines (CIP), Biodiversity Conservation Program-University of the Philippines Center for Integrative and Development Studies (BCP-UP CIDS), Foundation for the Philippine Environment (FPE), Quezon City, Philippines. Other references on soil orders came from the World Soil Resources Report: The Digitized Soil Map of the World Notes FAO Release 1.1 (June 1992). The generalization/ combination of soil orders or soil order groupings were guided by Bationo et al, "African Soils: Their Productivity and Profitability of Fertilizer Use" (2006).

Elevation and Slope Analysis

To develop the agro-edaphic zones based on the methodology illustrated in Figure 2, elevation classes, which ranged from -197-2933, based on the SRTM 90m version 4 were used (February 2000). SRTM is the Shuttle Radar Topographic Mission under the NASA (National Aeronautics and Space Administration), which generates a digital elevation model or DEM (Jarvis, et al., 2008). In this study, the 90 m spatial resolution DEM was used and from this, lowland and upland areas were generalized using the criteria of up to 100 m elevation for the lowland areas. This is based on the criteria of the Department of the Environment and Natural Resources, Walpole, P. of the Environmental Science for Social Change (2010), the Sustainable Upland Development, Philippines-European Union Development Cooperation (April 2007) and 4.1 The Hierarchy of Soil and Soil Ecological Zones, BSWM. The generalized map of elevation is shown in Figure 3. Classifying elevation into lowlands (< 100 m) and uplands (> 100 m) was a limitation of the study, which seemed suitable to the intended correlation with provincial HDIs.

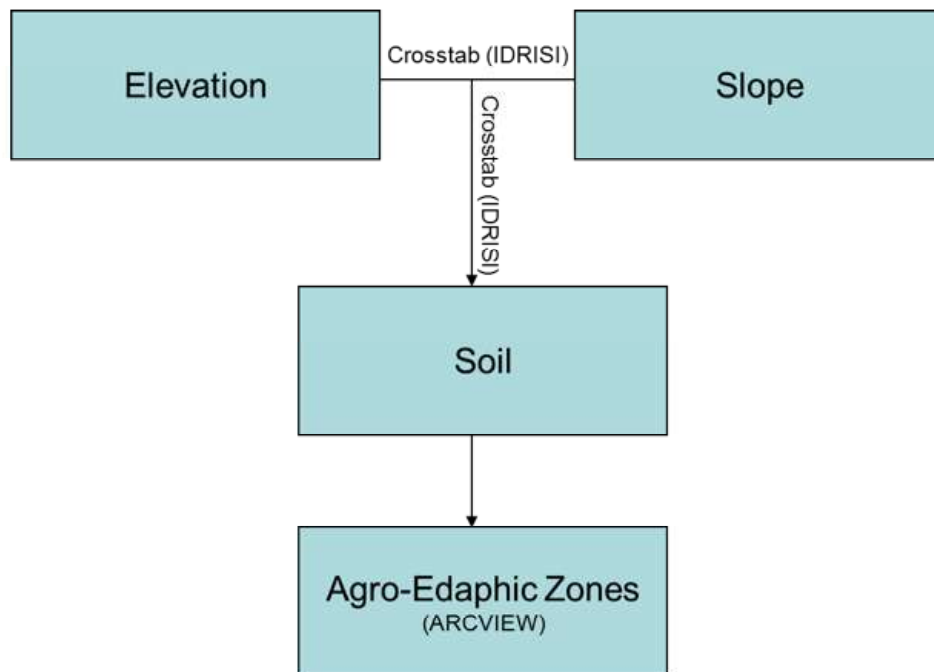


Figure 2. Diagram for generating the Philippine agro-edaphic zones.

Slope classes from the Global Digital Elevation Model (GDEM), a product of the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) (LP DAAC, 2011) were obtained for the slope analysis. There are seven slope classes in GDEM given by:

- 0-4% (level to gently rolling)
- 4-9% (undulating to rolling)
- 9-15% (rolling to hilly)
- 15-21% (hilly to moderately steep)
- 21-31% (moderately steep to steep)
- 31-45% (steep)
- 45-100% (very steep)

These were then reduced to three classes based on the classification of the Food and Agriculture Organization of the United Nations, or FAO, (1991), see Table 1. The three resulting elevation classes are:

- Level to gently undulating (0-8%)
- Rolling to hilly (8-30%)
- Steeply dissected to mountainous (> 30%)

The generalized map of slope is shown in Figure 4.

Generalized Elevation

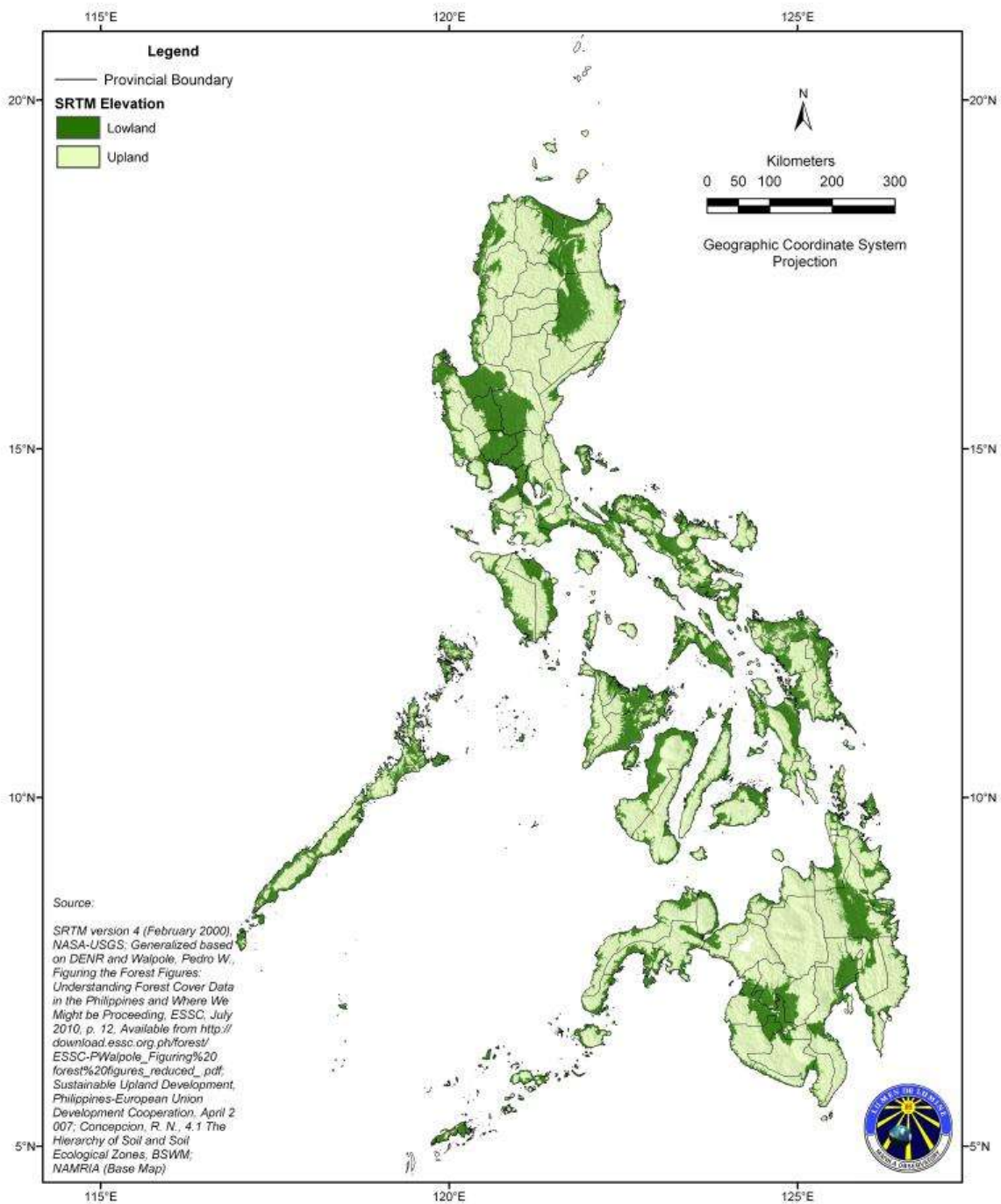


Figure 3. Generalized map of elevation.

Generalized Slope

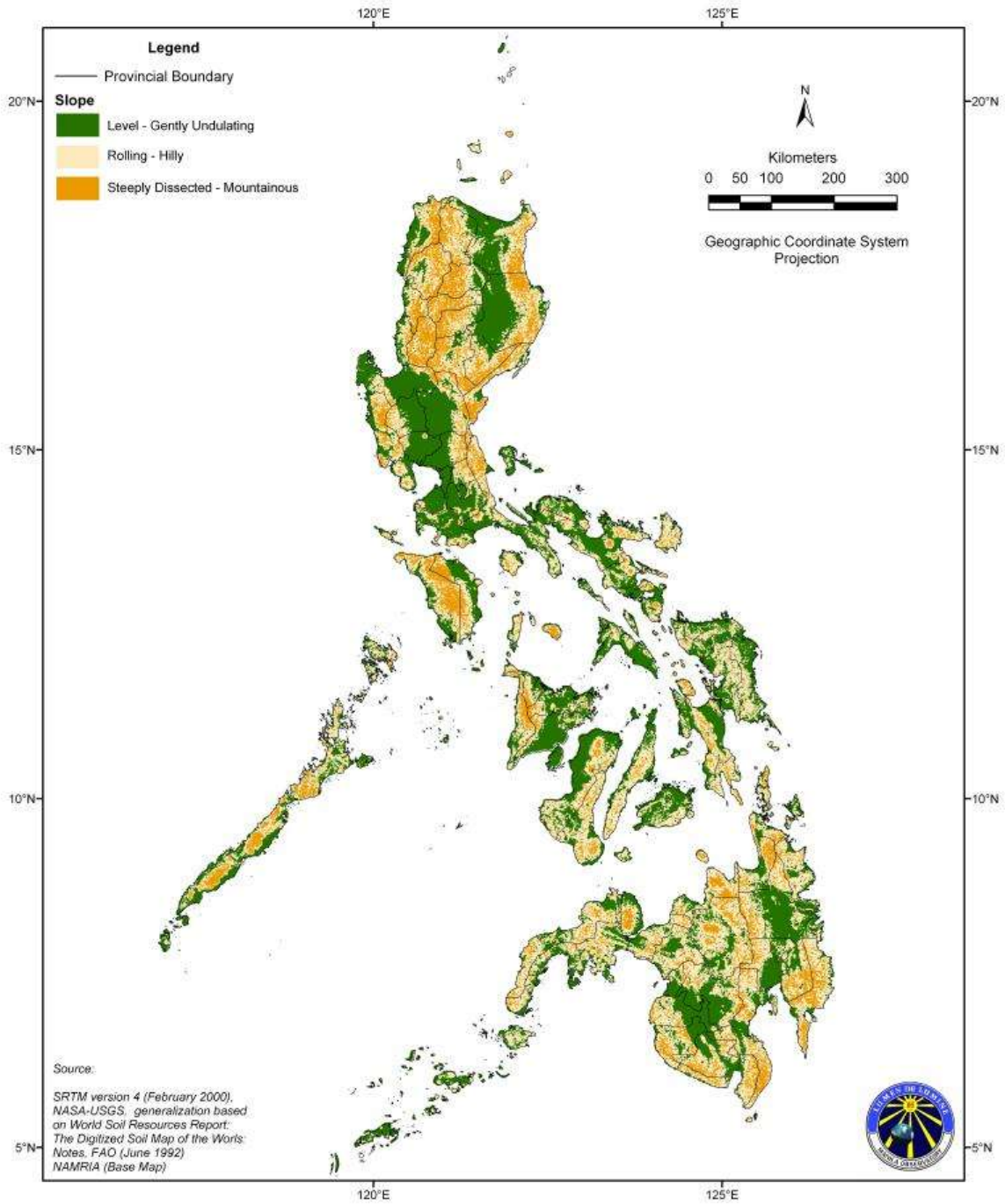


Figure 4. Generalized map of slope.

After having generalized the classes of elevation and slope, the two generalized elevation classes (i.e. lowland and upland) were then cross-tabulated with the three slope classes (i.e. level to gently undulating (0-8%), rolling to hilly (8-30%) and steeply dissected to mountainous (> 30%)). Cross-tabulation is a logical combination method wherein variables representing two different themes are matched two by two or are paired. The cross tabulation between elevation and slope classes, hence resulted in six pairs or combinations representing different elevation and slope classes. These are as follows:

- Lowland/ Level to gently undulating
- Lowland/ Rolling to hilly
- Lowland/ Steeply dissected to mountainous
- Upland/ Level to gently undulating
- Upland/ Rolling to hilly
- Upland/ Steeply dissected to mountainous

Figure 5 shows the resulting map of the cross-tabulation process.

Soil orders or groupings

According to the FAO Guidelines for Land Evaluation (Verheye et al., 2011), the following is the definition of soils (p. 4):

“Soil is a natural body consisting of layers or horizons of mineral and/ or organic constituents of variable thickness, which differ from the parent material in their morphological, physical, chemical and mineralogical properties and their biological characteristics.”

It is also said that the soil classification of FAO is intended for global rather than for local application, in effect, reflecting “dominant soil classes of the world” (Scharenbroch, n.d.).

For the purpose of this study, wherein Philippine AEZs across provinces are to be correlated with corresponding HDIs, the FAO classification is believed to be acceptable. Future studies can, however, explore further the derivation and processing of soil order maps that reflect specific local conditions.

The definition of the Philippine soil orders based on FAO and associated USDA (United States Department of Agriculture) classification are given in Annex A. The detailed soil order map using the FAO classification is shown in Figure 6. The detailed description of soil types then formed the bases for classifying soils as being good or suitable for agriculture as against those problematic for agriculture.

The soils are then grouped according to functional criteria, which are as follows. This grouping is also based on the study of Bationo et al (2006), "African Soils: Their Productivity and Profitability of Fertilizer Use" (p.6).

- 1) Soils good for agriculture:
 - Cambisols and Luvisols
 - Fluvisols, Gleysols and Vertisols

Cambisols are said to be associated with Luvisols. Cambisols are quite suitable for agriculture but according to limits set by topography and climate (Cambisol, 2011). Luvisols possess a “wide range” of suitability for agriculture, “from grains to orchards to vineyards” (Luvisol, 2011).

Fluvisols and Gleysols are closely associated. Fluvisols, found mostly in floodplains, are best devoted to “dryland crops or rice and... grazing” (Fluvisol, 2011). Gleysols are “cultivated for rice or, after drainage, for field crops and trees” (Gleysol, 2011). Vertisols, on the other hand, are suitable for “pastureland and for... plants, such as rice, that thrive in standing surface water” (Vertisol, 2011).

- 2) Soils problematic for agriculture, which means that they require careful management and adaptation practices:
 - Acrisols and Arenosols
 - Andosols and Nitosols

Both having low nutrient levels, Acrisols require “acid-tolerant crops” (Acrisol, 2011) while Arenosols need “careful management” (Arenosol, 2011).

Andosols require the use of fertilizers for agriculture even as they possess good capacity to hold water and nutrients (Andosol, 2011). Nitosols, “especially in monsoonal tropical regions”, are said to “have a tendency to acidify when heavily cultivated, especially when nitrogenous fertilizers” are employed (Alfisols, n.d.).

Figure 7 illustrates generalized soil groupings for the Philippines.

Cross-tabulation of elevation-slope-soil orders

After grouping together associated soil orders, elevation, slope and soil orders were then cross-tabulated. The resulting map of 24 agro-edaphic zones based on the combination of variables is shown in Figure 8. In effect, agro-edaphic zones represent generalized classes of associated soil orders in combination with both elevation and slope.

Elevation - Slope

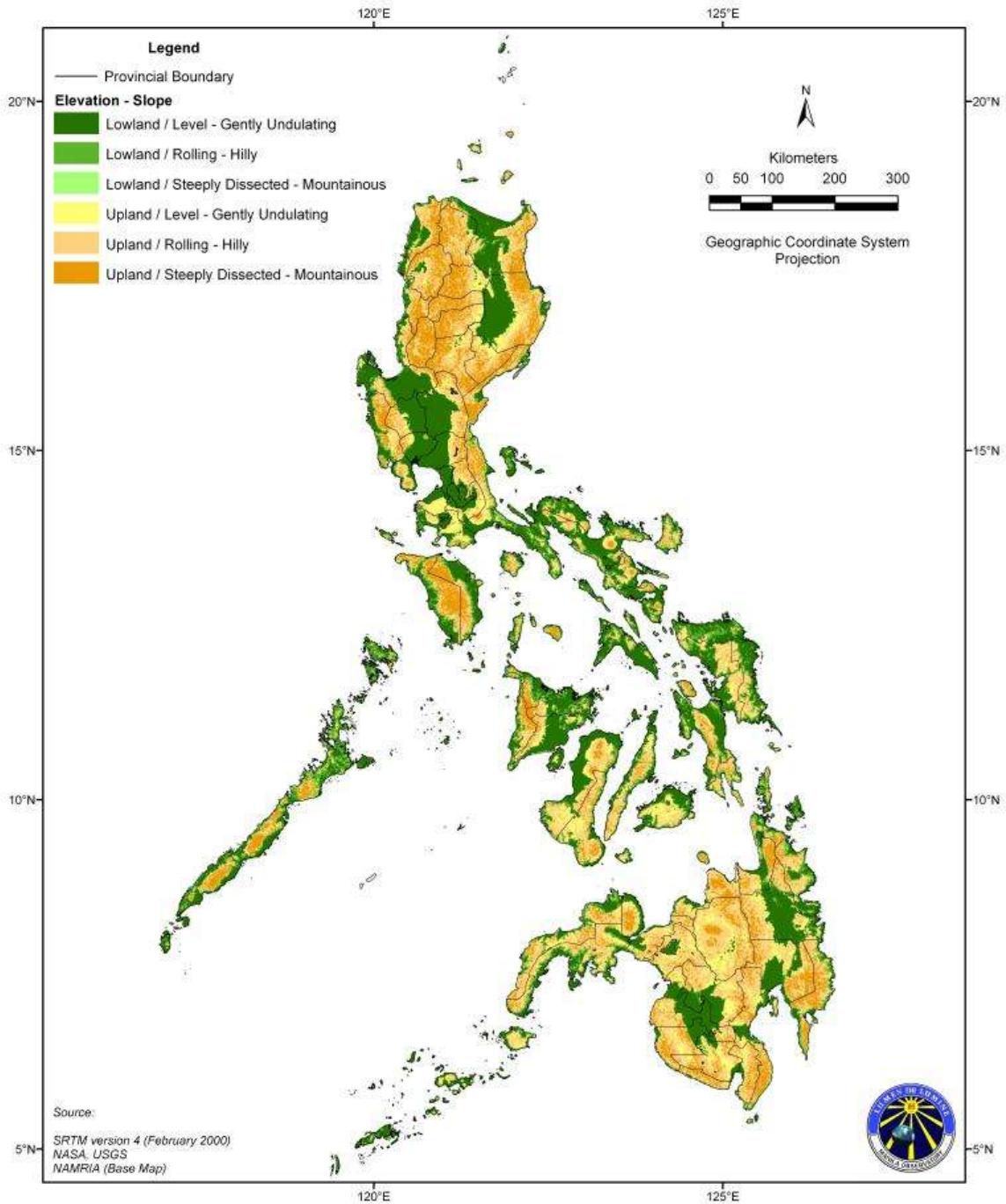


Figure 5. Resulting map of the cross-tabulation between elevation and slope.

SOIL

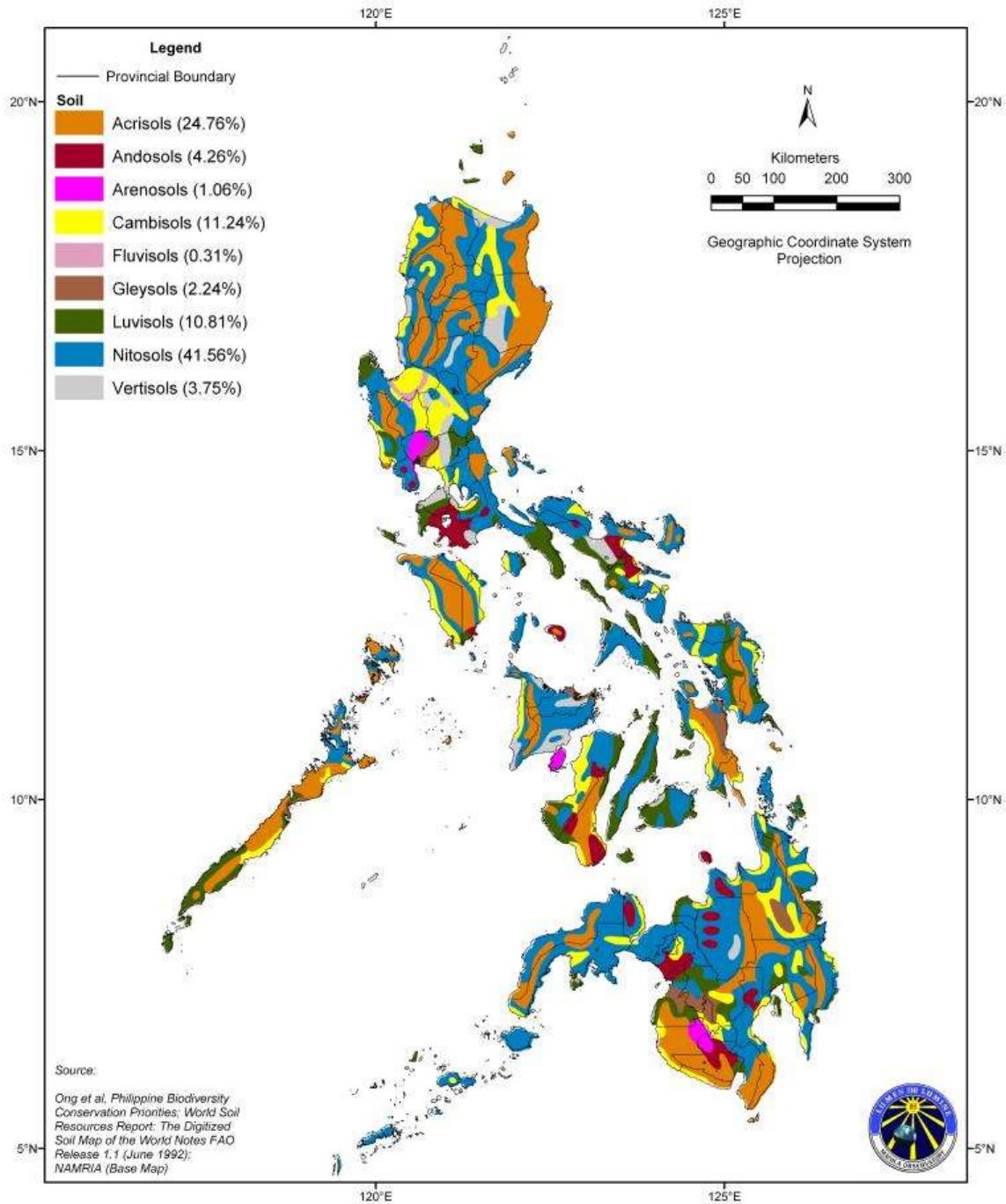


Figure 6. Map of soil orders.

Generalized Soil

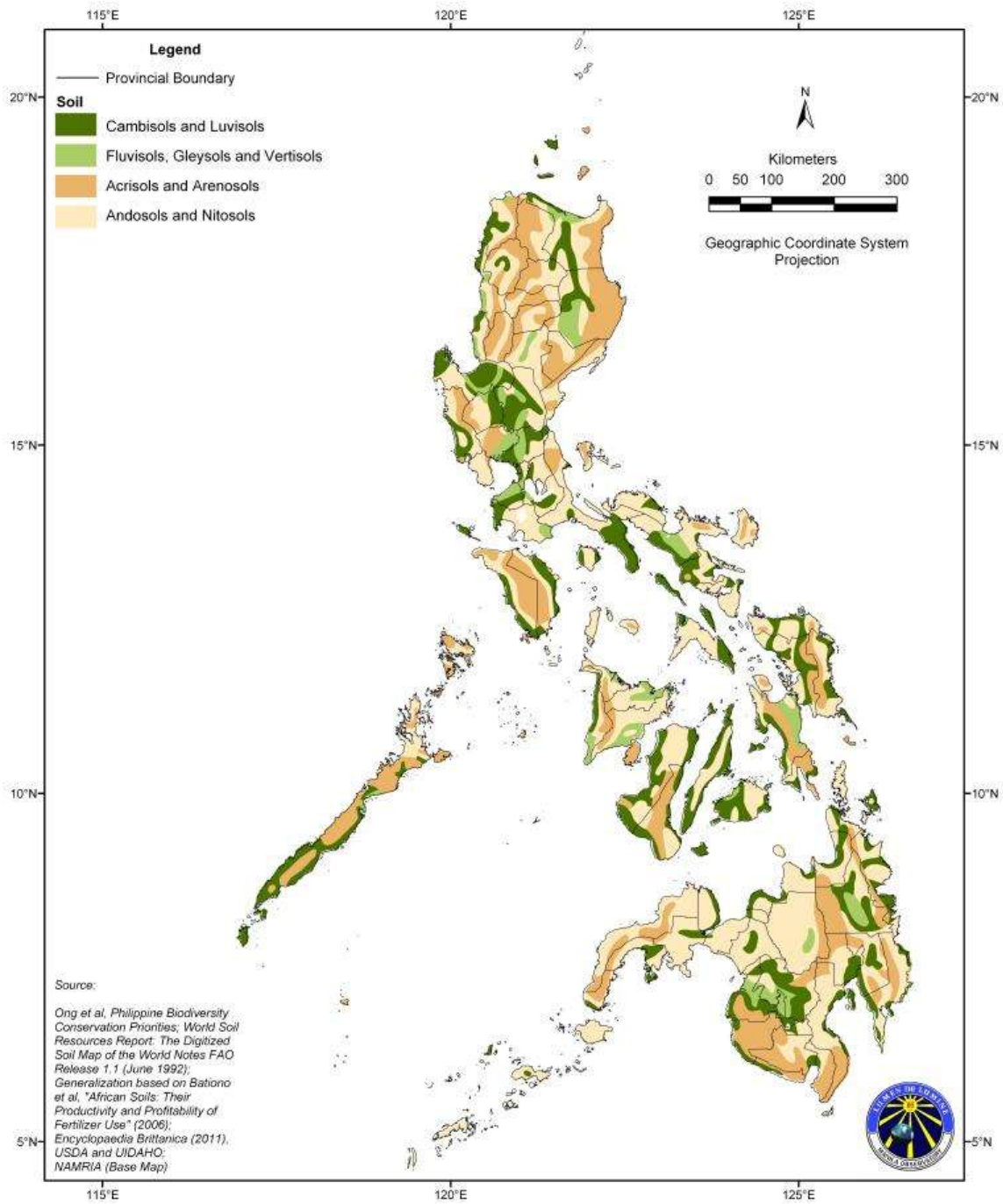


Figure 7. Map of the generalized soil groupings for the Philippines.

Agro-Edaphic Zones

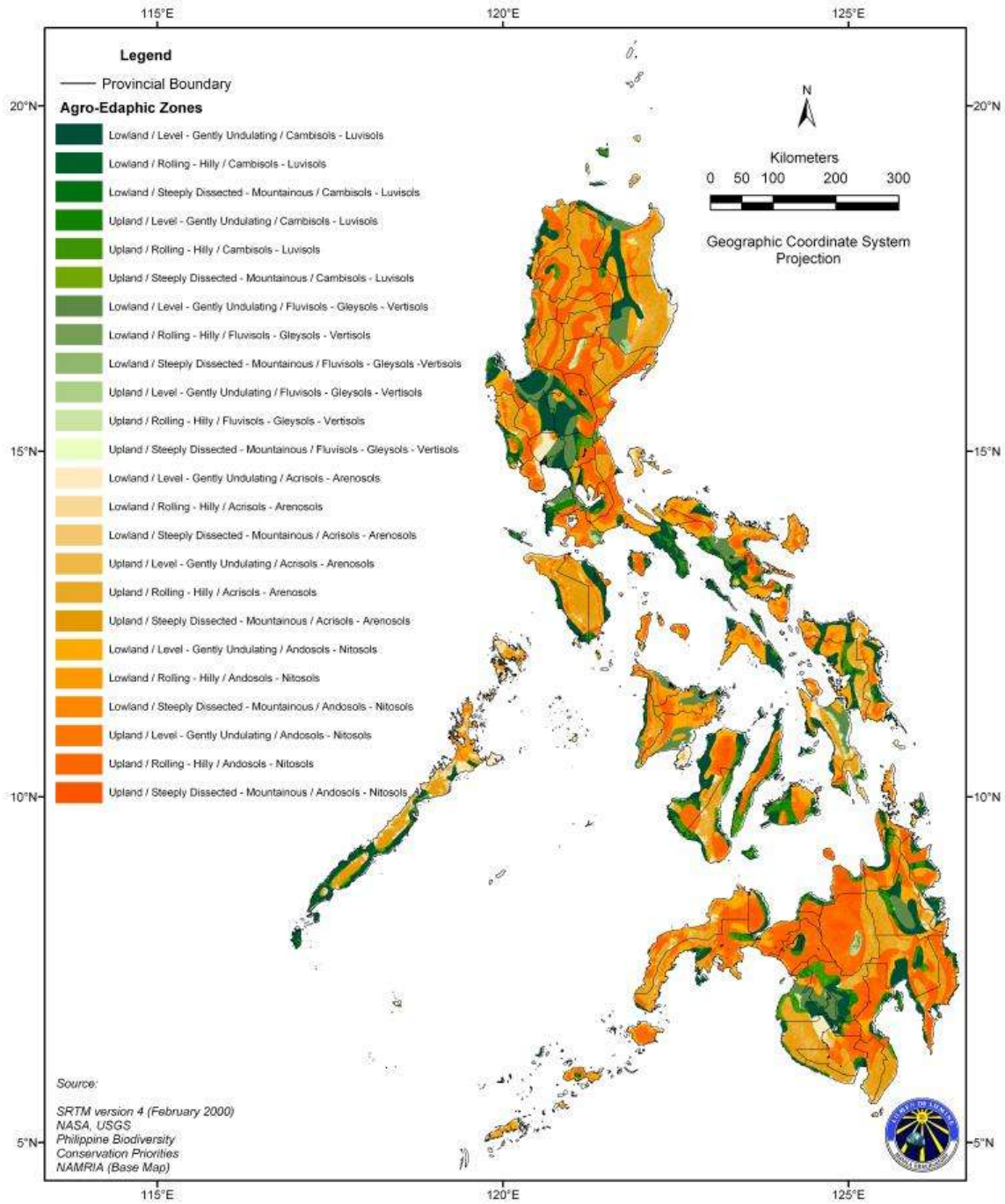


Figure 8. Map of 24 agro-edaphic zones based on resulting combinations of slope, elevation, and soil variables.

Generalization of Agro-Edaphic Zones

The Philippine agro-edaphic zones were then generalized from 24 classes to four broad groupings, see Figure 9. It is important to note that agro-edaphic zones are groupings of soil orders that are made not only on the bases of soil characteristics but also in consideration of their topographic context, the latter specifically including elevation and slope classes.

The broad and relative groupings and their definitions are as follows:

- Soils very suitable for agriculture: These are soils located in lowlands, that is, up to 100 m of elevation, with level to gently undulating (0-8%), rolling to hilly (8-30%) and steeply dissected-mountainous (>30%) regions, belonging to the soil orders of Cambisols-Luvisols and Fluvisols-Gleysols-Vertisols.
- Soils suitable for agriculture: These are soils located in uplands, that is, greater than 100 m of elevation, with level to gently undulating (0-8%), rolling to hilly (8-30%) and steeply dissected-mountainous (>30%) regions, belonging to the soil orders of Cambisols-Luvisols and Fluvisols-Gleysols-Vertisols.
- Soils requiring special management: These are soils located in lowlands, that is, up to 100 m of elevation, with level to gently undulating (0-8%), rolling to hilly (8-30%) and steeply dissected-mountainous (>30%) regions, belonging to the soil orders of Acrisols-Arenosols and Andosols-Nitosols.
- Critical soils requiring intensive management: These are soils located in uplands, that is, greater than 100 m of elevation, with level to gently undulating (0-8%), rolling to hilly (8-30%) and steeply dissected-mountainous (>30%) regions, belonging to the soil orders of Acrisols-Arenosols and Andosols-Nitosols.

Annex A provides a more detailed description of the abovementioned soil orders, which formed the bases for subsequent groupings.

In effect, constraints were considered in classifying management schemes, namely zones suitable and very suitable for agriculture as well as zones requiring special as against those needing intensive management. Again, these classes are based not only on soil characteristics, such as those requiring balanced use of fertilizers, but also their topographic contexts, which, in turn, necessitate slope management. An example of crop management along steep slopes could be SALT or sloping agriculture land technology.

On the matter of forest cover in relation to agro-edaphic zones, most of the remaining forest in the country are located in uplands, in hilly to steep terrain and, therefore, within zones of critical soils requiring intensive management. Soil orders also, by themselves, already take into consideration suitability for the planting of trees.

Grouping of Agro-Edaphic Zones

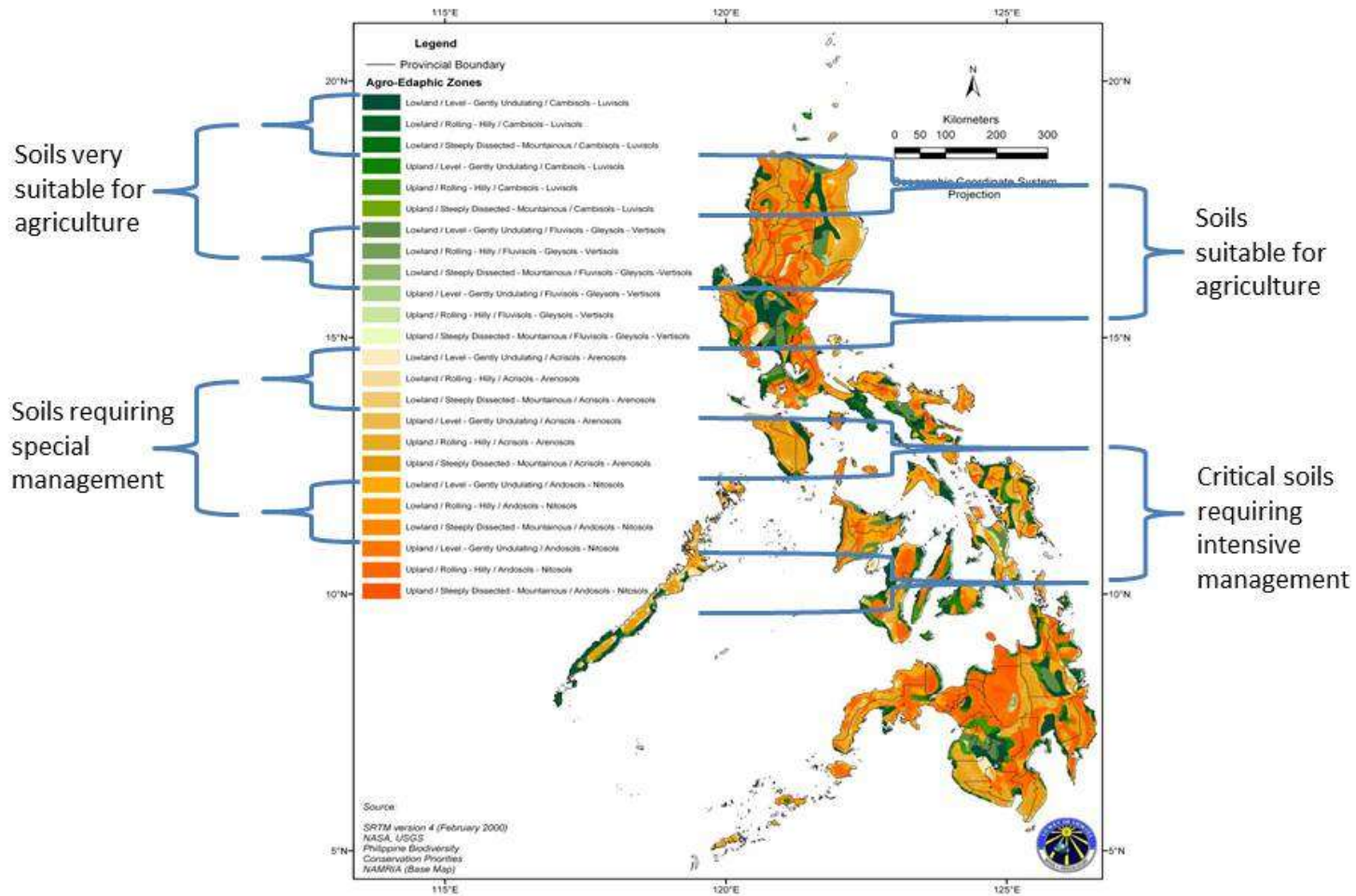


Figure 9. Regrouping of Philippine agro-edaphic zones.

B. Philippine Agro-Climatic Zones

To develop the Philippine agro-climatic zones, monthly mean values for relevant variables from the Climatic Research Unit Time-series dataset version 3.1 (CRU TS3.1) were used to determine climatic means for the Philippine domain which was set to be between 2.25° to 22.25° latitude and 112.25° to 129.75° longitude. The CRU TS3.1 was gridded at a 0.5°x0.5° resolution with climatic data from 1901 to 2009 (Mitchell and Jones, 2005). For this study, two climatic variables were extracted from the dataset for analysis within the decade of 1951 to 2000: Precipitation (mm) and temperature (°C).

A modified moisture index (MMI) was generated for the Philippine domain based on the method established by Thornwaite and Mather (1955). It is noted that the MMI is different from the current modified Coronas Climate Classification for the Philippines. The Coronas Climate Classification is purely based on rainfall and the timing of the onset of different rainfall seasons in the Philippines. A type IV climate for example will have rainfall more or less evenly distributed throughout the year while a type III climate will have seasons not very pronounced and relatively dry periods from December to April & wet during the rest of the year. The moisture categories, on the other hand, take into account more than rainfall as a driver to moisture availability. Hence, it considers that temperature as an additional variable that influences evaporation and transpiration of vegetation and consequently the amount of moisture in a particular area. Based on this, the modified moisture index is then based on both rainfall and the potential evapotranspiration, with the latter incorporating temperature values.

The original method for calculating MMI produced annual moisture index values based on annual accumulated rainfall and potential evapotranspiration (PET). The modified method adopted for this study produced comparable annual moisture index values based on monthly accumulated rainfall and PET instead. By using monthly data in this modified method, monthly moisture index values could be generated for future investigation, if a finer temporal resolution is necessary. Preliminary sensitivity testing showed that, though resulting annual PET values were slightly elevated using the modified method, the difference between the two was statistically insignificant.

This modified moisture index value for a month was calculated as,

$$mMMI = \frac{mP - mPET}{mPET} * 100$$

where,

mMMI=monthly modified moisture index (%)

mP=monthly accumulated rainfall (mm)

mPET=monthly potential evapotranspiration (mm)

The resulting mMMI value represented the available moisture present in each grid cell as a percentage of the mPET of that cell. This mMMI value could range from -100% for areas experiencing months of zero rainfall up to more than 100% for areas where rainfall exceeds their PET completely. The annual

mean of these monthly values were calculated and used to establish an effective moisture index for the Philippine domain as well as to determine the final climatic mean for each grid cell.

For monthly PET values, two methods were identified for potential application for this study. The first method uses the Monthly PET values actually available in the CRU TS3.1 dataset. This CRU Monthly PET was derived from the FAO grass reference evapotranspiration equation (Ekstrom et al., 2007, which is based on Allen et al., 1994), which is a variant of the Penman Monteith method using gridded mean temperature, minimum temperature, maximum temperature, vapor pressure and cloud cover. The second method uses Thornwaite's (1948) equation based on monthly mean temperature. Preliminary sensitivity analysis shows that the CRU PET values are consistently lower than the computed Thornwaite PET values. The latter is used for this study to better represent the effects of temperature extremes in the moisture index.

Thornwaite's equation for potential evapotranspiration takes the form of:

$$mPET = 16 * [10 * T_{ijk} I_{jk} a_{jk}]$$

where,

$$I_{jk} = i = \text{JanDec} (T_{ijk} / 5)^{1.514}$$

T = mean temperature (°C)

i = month of a year (i = Jan, Feb, ... Dec)

j = pixel value of the ith row

k = pixel value of the jth column

$$a_{jk} = 67.5 * 10^{-8} (I_{jk})^3 - 7.71 * 10^{-5} (I_{jk})^2 + 0.01792 I_{jk} + 0.4923$$

To determine a modified moisture index criteria, the deciles method developed by Gibbs and Maher (1967) was adopted. A modification of the "percent of normal" approach to moisture index criteria characterization, this technique divided the distribution of occurrences of all moisture index values (for this study, annual MMI values between 1951 and 2000) into tenths of the distribution. Values falling between the 4th decile (40%ile ceiling) and the 7th decile (70%ile ceiling) were considered "near normal" while those less than the 4th decile were considered "below normal" or "dry" and those greater than the 7th decile were considered "above normal" or "moist". The resultant decile distribution for the Philippines from 1951 to 2000 is given in Table 2 and the criteria determined by this study for a Philippine modified moisture index is given in Table 3.

Table 2. Resultant decile distribution for the modified moisture index used in this study.

1951-2000 MMI Deciles	
1 st (10%ile)	-76.37
2 nd (20%ile)	-48.69
3 rd (30%ile)	-22.18
4 th (40%ile)	3.14
5 th (50%ile)	28.69
6 th (60%ile)	57.60
7 th (70%ile)	93.32
8 th (80%ile)	142.82
9 th (90%ile)	232.17
10 th (100%ile)	5287.31

Table 3. Criteria determined by this study for a Philippine modified moisture index.

1951-2000 Modified MI	
Dry	less than 3.14
Normal	3.14 to 93.32
Moist	more than 93.32

For Temperature, a matrix of growing degree days (GDD) was generated for the Philippine domain. GDD is a measure of heat accumulation used to predict plant development rates in an area with the assumption that plant growth is strongly influenced by ambient temperature in the absence of extreme conditions such as drought or disease. The canonical form for calculating GDD used in this study is given by:

$$\text{GDD} = [(T_{\text{max}} + T_{\text{min}}) / 2] - T_{\text{base}}$$

where,

T_{max} = daily maximum temperature

T_{min} = daily minimum temperature

T_{base} = temperature below which the process of interest does not progress

Though Wang (1960) had established that T_{base} varies among species, cultivars and even growth stages, 10°C, which is the base for corn growth (Cross and Zuber, 1972), was the common base used for generic GDD calculations.

Since CRU TS3.1 only has data for monthly temperature and to simplify matters, monthly Tave values are used as daily mean values instead of $(T_{\text{max}} + T_{\text{min}}) / 2$. Daily GDD values were accumulated for the year to calculate the annual available GDD for each grid point. These annual values were averaged between 1951 and 2000 to establish the climatic GDD available for each grid point in the Philippine domain.

The same deciles method used for the MMI before was used to determine the critical GDD levels for the country. Values falling between the 3rd decile (30%ile ceiling) and the 7th decile (70%ile ceiling) were considered “near normal” or “medium” while those less than the 3rd decile were considered “below normal” or “low” and those greater than the 7th decile were considered “above normal” or “high”. The resultant decile distribution for the Philippines from 1951 to 2000 is given in Table 4 and the criteria determined by this study for a Philippine Growing Degree Day index is given in Table 5.

The resulting maps of the modified moisture index and the growing degree day index are shown in Figures 10 and 11.

Table 4. Resultant decile distribution for GDD for the Philippines from 1951 to 2000.

1951-2000 GDD Deciles	
1 st (10%ile)	4986.23
2 nd (20%ile)	5470.26
3 rd (30%ile)	5732.27
4 th (40%ile)	5865.86
5 th (50%ile)	5956.20
6 th (60%ile)	6030.90
7 th (70%ile)	6102.19
8 th (80%ile)	6182.20
9 th (90%ile)	6293.61
10 th (100%ile)	6787.50

Table 5. The criteria determined by this study for a Philippine Growing Degree Day index.

1951-2000 Growing Degree Days	
Low	less than 5732.27
Medium	5732.27 to 6102.19
High	more than 6102.19

Moisture Index

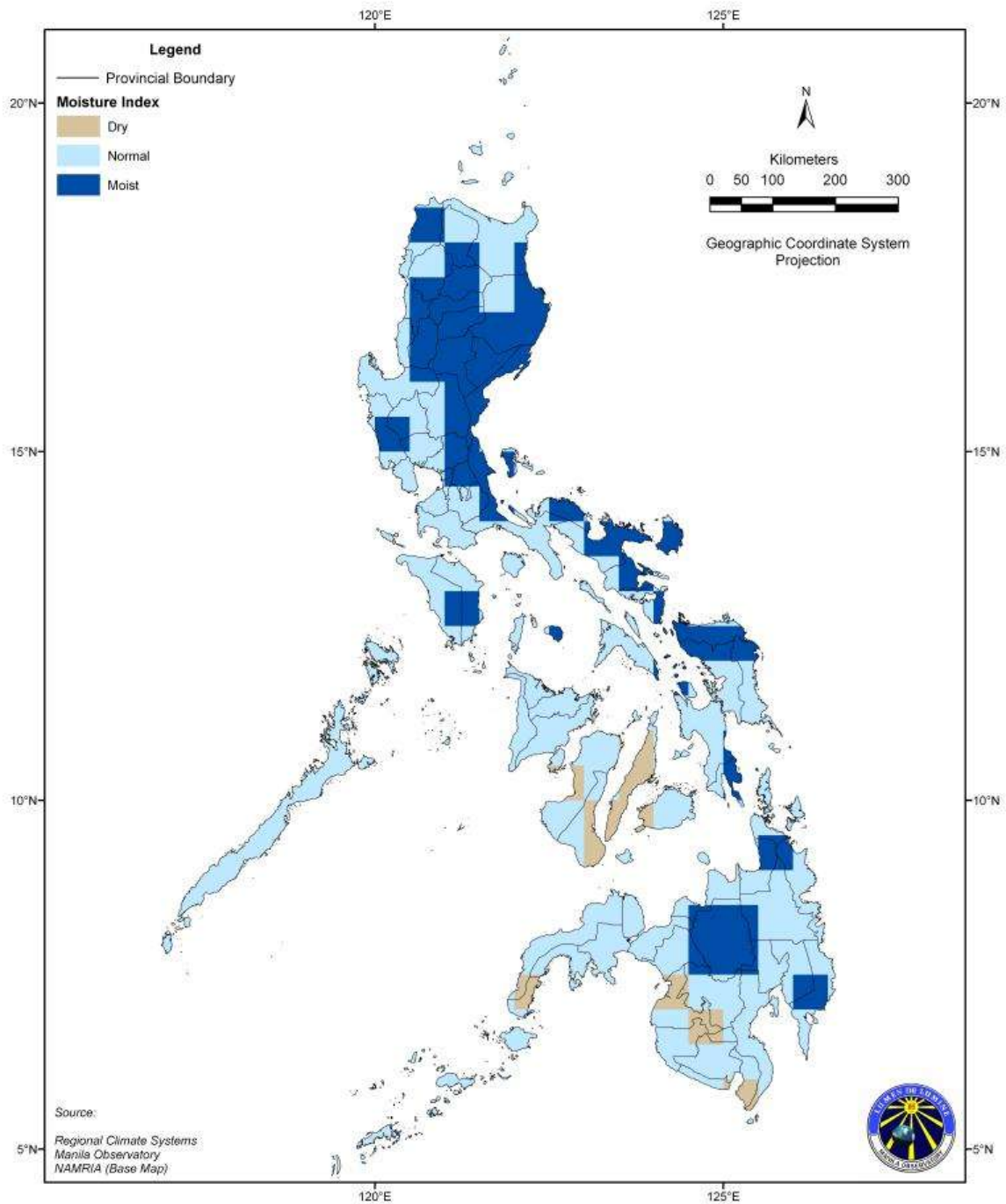


Figure 10. Map of the generalized modified moisture index for the Philippines.

Temperature Index

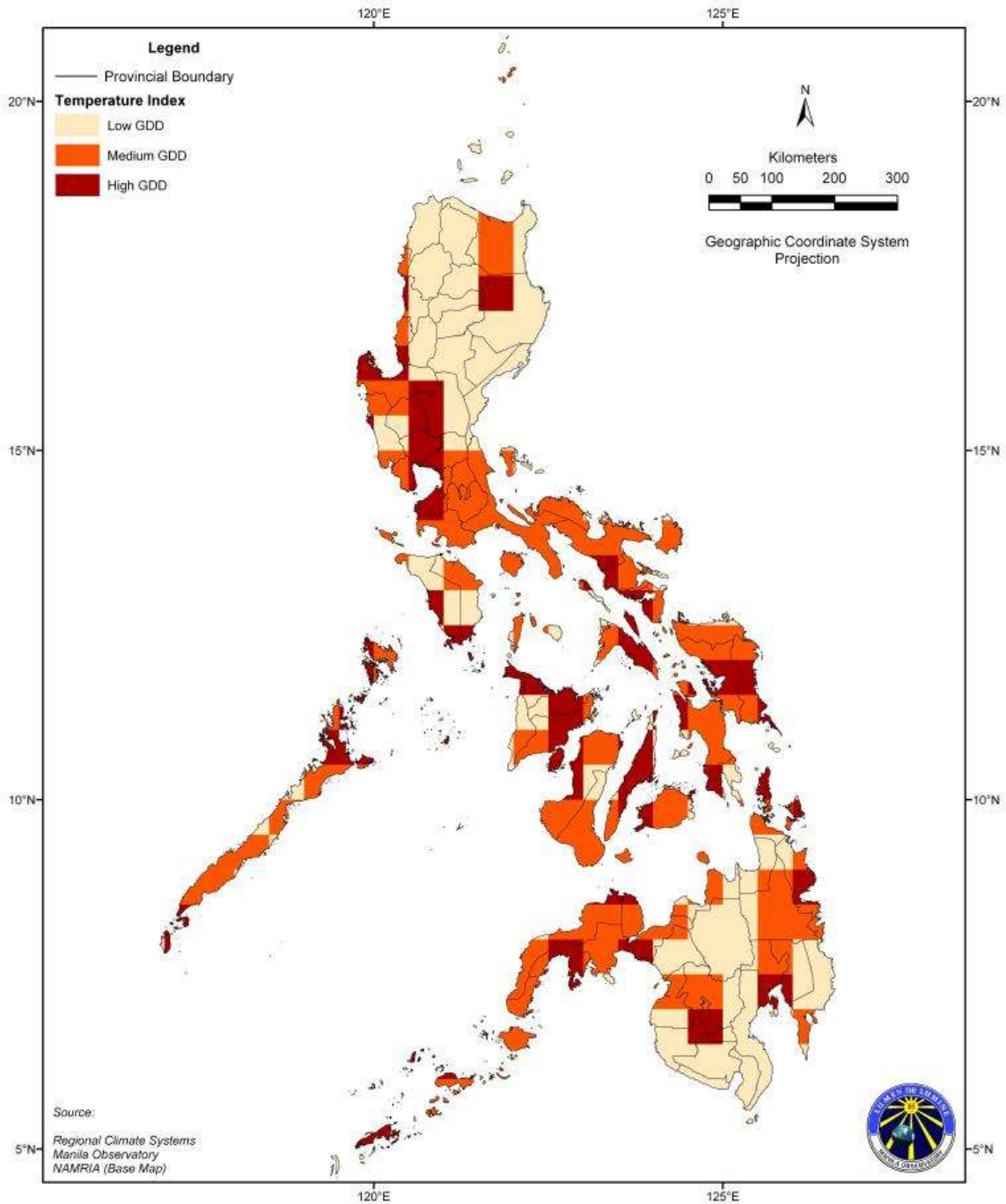


Figure 11. Map of the generalized growing degree day index.

IV. PHILIPPINE AGRO-ECOLOGICAL ZONES

Agro-edaphic zones for the Philippines were developed from the logical combination of elevation, slope and soil orders. These classes were generalized into four groupings for correlation with HDIs. The categories can be distinguished according to soils in the lowlands vs. uplands good for agriculture (i.e., Cambisols-Luvisols and Fluvisols-Gleysols-Vertisols), and soils in the lowlands vs. uplands problematic for agriculture (i.e. Acrisols-Arenosols and Andosols-Nitosols). The latter group refers respectively to soils requiring special management and adaptation strategies attributed to soil characteristics as differentiated from critical soils requiring intensive management on account of topography and the need for slope management.

In summary, results show (see Figure 12 and Annex B for Philippine provinces and regions) that most of the country are critical soils requiring intensive management. The next larger areas are soils very suitable for agriculture. Smaller portions of the Philippines are soils suitable for agriculture or require special management.

Although Philippine agro-edaphic maps are sub-provincial, it was found that the pattern of suitability (or unsuitability) for agriculture tends to be regional in nature. For example, the floodplain of Cagayan Valley in Northern Luzon, which is highly suited for agriculture, is in between highlands problematic for agriculture and needing appropriate management and adaptation measures. Another example in Southern Philippines is the flood plain of ARMM, in the vicinity of the Liguasan Marsh. It is bound by the upland/ steeply dissected-mountainous regions of Central and Northern Mindanao, relatively small portions of which may be used for agriculture, with Cambisols-Luvisols, while the most part requires agricultural management, having Andosols-Nitosols and Acrisols-Arenosols.

By observation, Philippine provinces appear to cluster across and/ or around agro-edaphic zones. It is possible then, based on the said spatial pattern, that regional agriculture, among other possible economic factors, may greatly influence the trends in provincial HDIs. This could be investigated more deeply in the future by correlating statistics across regional to local scales but certainly within the spatio-temporal context.

The Philippine agro-climatic zones, based on the modified moisture index (MI) and the growing degree days (GGD) indices, are given in Figure 13. 9 classes of moisture levels combined with GDD ranges were expected. However, the classes were reduced to 7, the reason being that Dry-Medium GDD and Dry-High GDD were combined into one (1) class: Dry-Medium to High GDD. In addition, there was no Moist-High GDD combination in the cross-tabulation for agro-climatic zones. Results show that most of the country have a normal moisture index (as defined in this study) with GDD ranging from low to high (as indicated by the range of gray shades in Figure 13). There are few areas that are low or dry in moisture index, and these include Cebu and areas in Negros Oriental and Southern Mindanao, including Zamboanga and Maguindanao. Similar to the agro-edaphic zones, there are natural clusters observed in the agro-climatic zones. Northern and Eastern Luzon are noticeably rich in moisture but have a relatively low GDD index. Portions of the eastern seaboard, including Quezon, Camarines Norte, Camarines Sur, Albay, Sorsogon, and Northern Samar, have high moisture indices and medium GDD.

Generalized Agro-Edaphic Zones

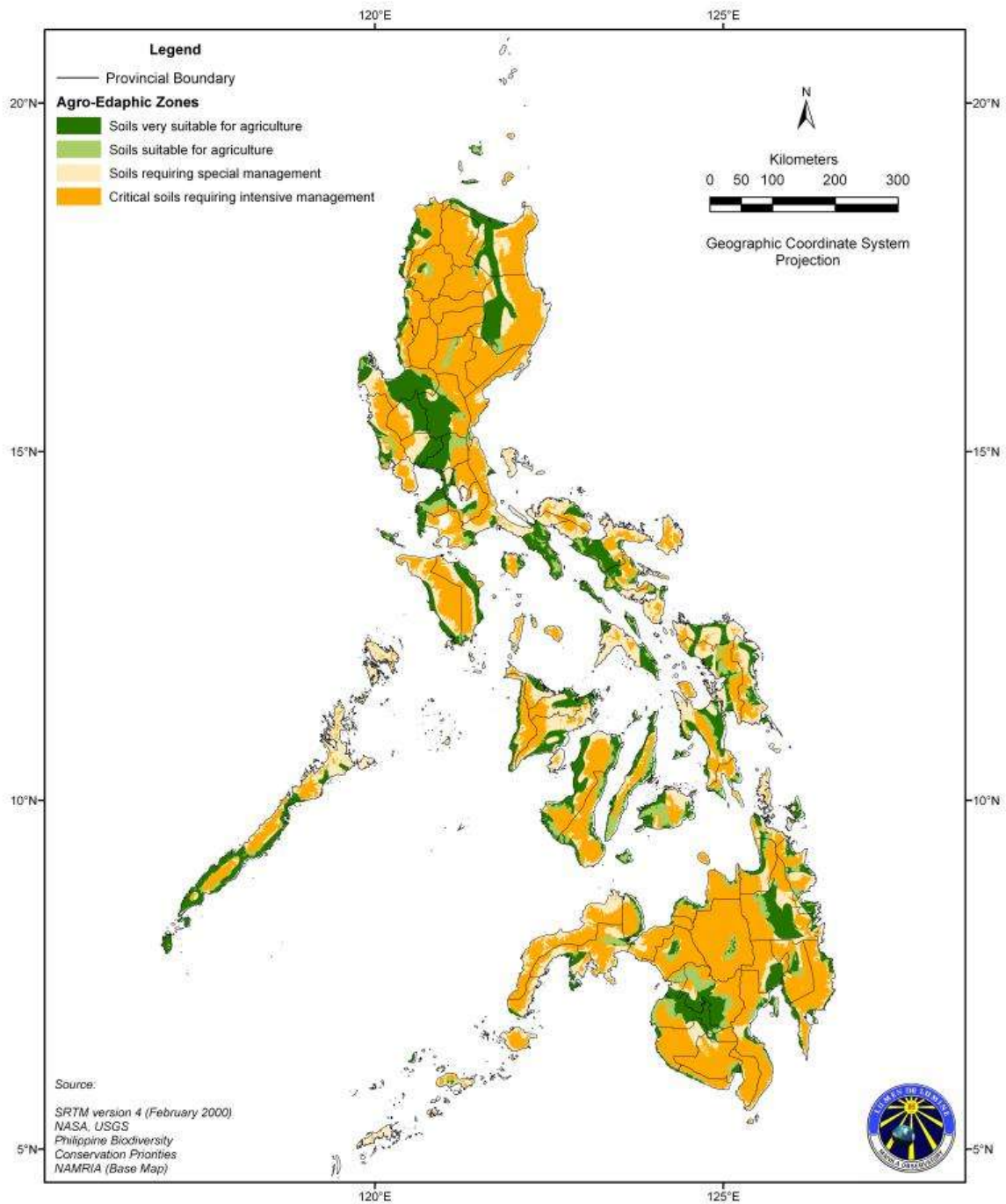


Figure 12. Philippine agro-edaphic zones.

Agro-Climatic Zones

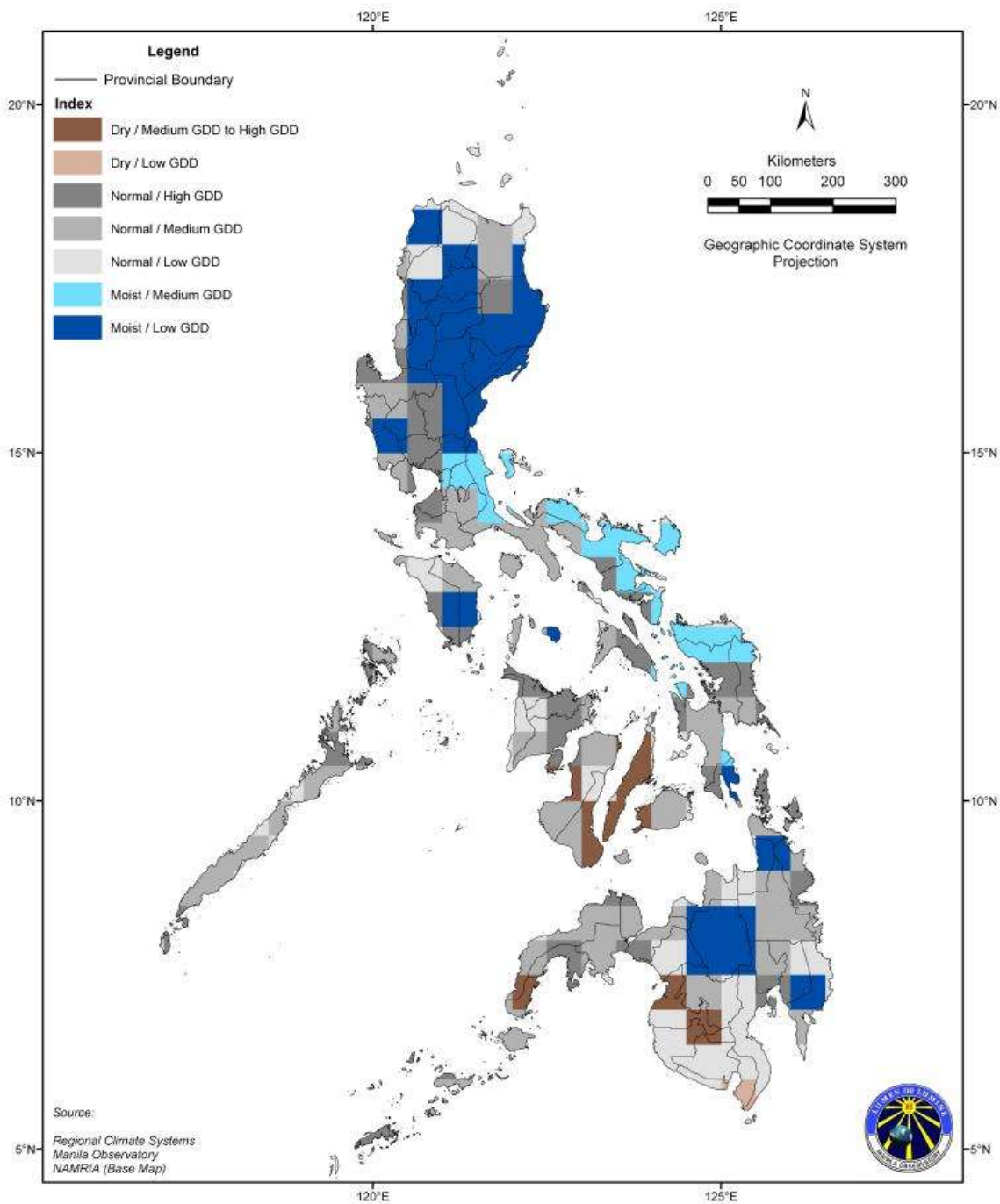


Figure 13. Philippine agro-climatic zones.

The combination of the agro-edaphic and agro-climatic zones produced 26 categories for the Philippine agro-ecological zones (see Figures 14 and 15). In effect, two logical combinations of agro-edaphic and climate zones are not present in the final combined categories: Soils suitable for agriculture-Dry/ Low GDD and Soils very suitable for agriculture-Dry/ Low GDD.

Tables of the agro-ecological zones and their component attributes (e.g. slope, elevation, moisture index, etc.) within provincial boundaries are given in a CD of Annex C. Table 6 provides calculations of areas and percentages of different agro-ecological zones by province. Table 7 gives the same figures but, this time, sorted from highest to lowest.

In general, as shown in Figure 15 and based on calculations, 19.53% of the country belong to critical soils requiring intensive management, is moist and low in GDD. Table 8 shows the 38 top ranking provinces according to the said zones, most of which are in Luzon (white shade) and Mindanao (light grey shade).

On the other hand, again based on Figure 15 and calculations, 13.06% of the country belong to critical soils requiring intensive management, is normal in terms of moisture index and medium in GDD. Table 9 gives 54 top ranking provinces according to the said zones: 27 provinces in Luzon (white shade), 18 provinces in Mindanao (light grey shade) and 9 provinces in the Visayas (dark grey shade).

Moreover, as in Figure 15 and estimates, 11.89% of the country is composed of critical soils requiring intensive management and is normal in moisture index and low in GDD. Table 10 provides 40 top ranking provinces according to the said zones: 16 provinces in Mindanao (light grey shade), 14 provinces in Luzon (white shade) and 10 provinces in the Visayas (dark grey shade). Other remaining types of AEZs are less than 8% in terms of area with respect to the whole country.

It is important to note from all the tables provided that there are differences in the breakdown of total areas of components to and the overall agro-edaphic, agro-climatic and agro-ecological zones by province, especially for coastal provinces. Areas of zonal attributes are more or less consistent for inland provinces.

The aerial discrepancies along the coast are attributed especially to the fact that elevation, slope and soil order maps come from different sources. Moreover, rasterization and resampling of vector maps at .0085 decimal degrees prior to cross-tabulation and then after vectorization of maps to derive areas of zones cause differences in area calculations, again especially in reference to coastal provinces. We also cite that some small islands do not have data on elevation, slope nor soils, thereby reducing aerial estimates of zones further. Other minor aerial discrepancies are attributed to the accuracy of decimal degrees to the third and fourth place using floating point in the GIS of AEZs and their component thematic overlays. Inaccuracies in area estimates between agro-climatic and agro-edaphic zones as well as between agro-climatic zones and AEZs were calculated and range from 0.05 to 0.07 or 5% to 7%, respectively.

Legend

—— Provincial Boundary

Agro-Ecological Zone

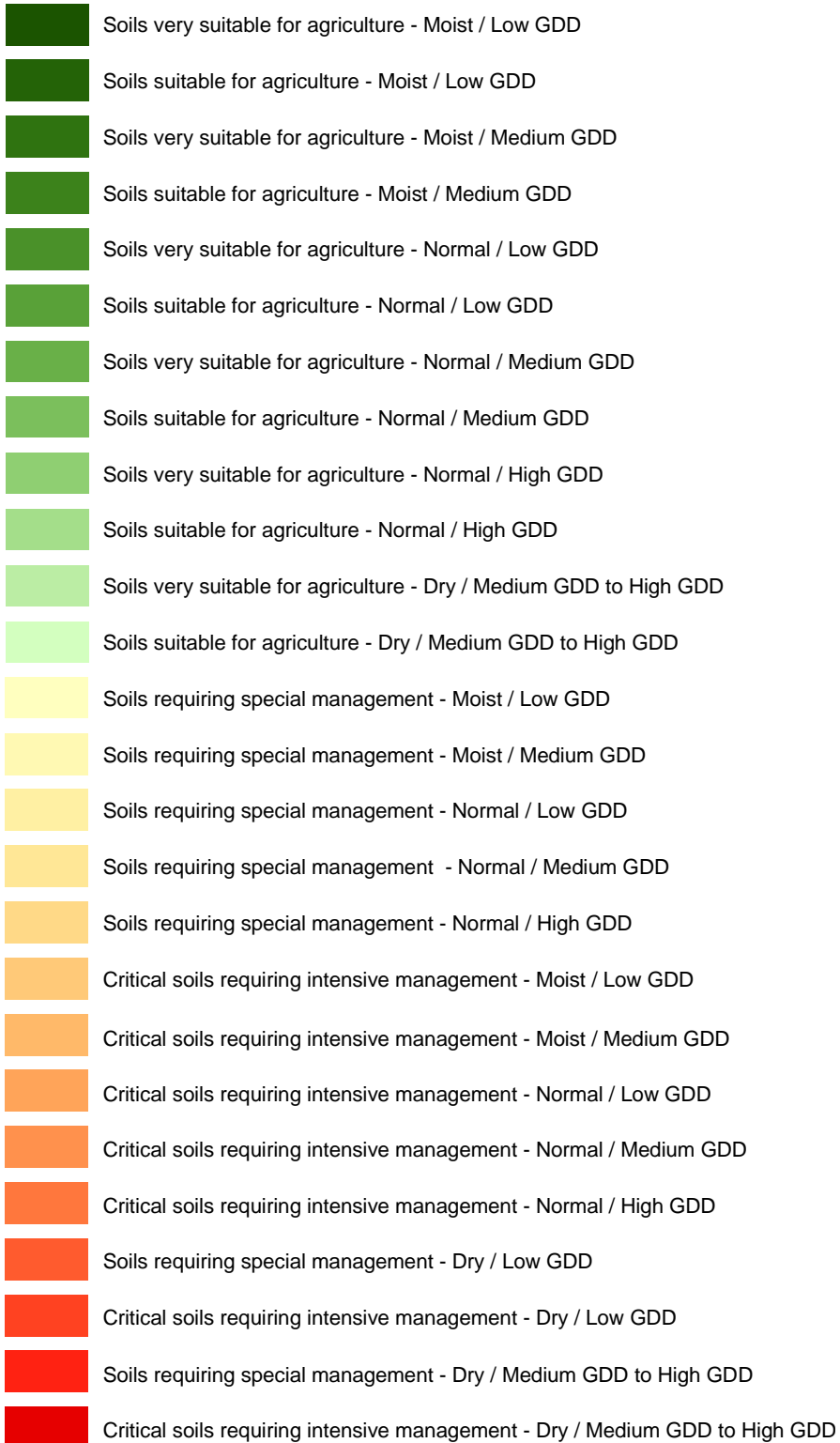


Figure 14. 26 categories defined for the Philippine agro-ecological zones (AEZs).

Agro-Ecological Zones

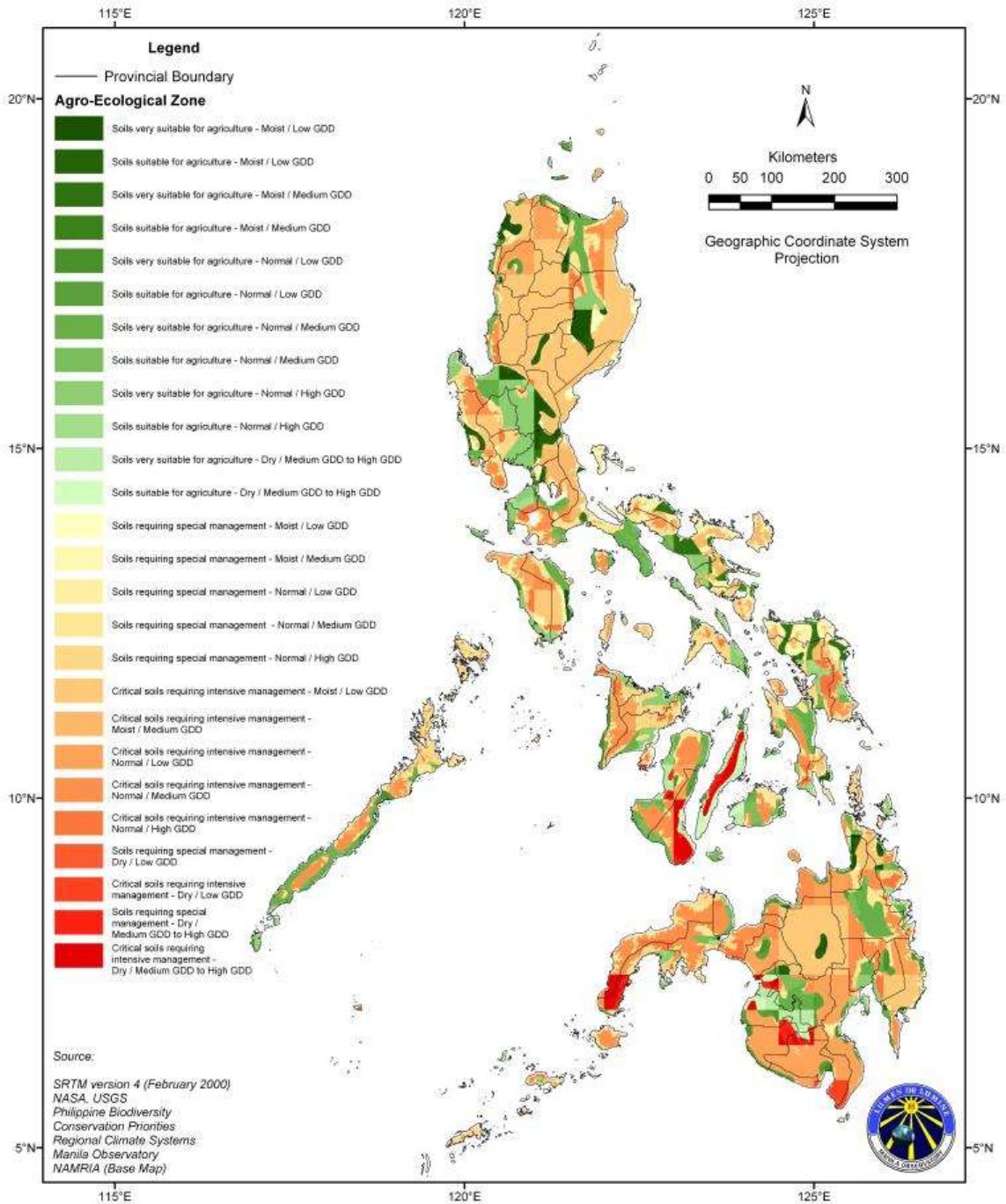


Figure 15. *Philippine agro-ecological zones (AEZs).*

Table 6. *Area and percentage calculations for different agro-ecological zones*

Agro-Ecological Zone	Area	Percentage
Soils suitable for agriculture-Dry/Medium GDD to High GDD	2,265.6687	0.84
Soils suitable for agriculture-Normal/High GDD	2,452.1786	0.91
Soils suitable for agriculture-Normal/Medium GDD	6,314.1737	2.34
Soils suitable for agriculture-Normal/Low GDD	3,362.0262	1.25
Soils suitable for agriculture-Most/Medium GDD	705.4525	0.26
Soils suitable for agriculture-Moist/Low GDD	3,401.3608	1.26
Soils very suitable for agriculture-Dry/Medium GDD to High GDD	4,368.2492	1.62
Soils very suitable for agriculture-Normal/High GDD	16,253.7945	6.03
Soils very suitable for agriculture-Normal/Medium GDD	20,341.1028	7.54
Soils very suitable for agriculture-Normal/Low GDD	4,712.8914	1.75
Soils very suitable for agriculture-Most/Medium GDD	3,540.2899	1.31
Soils very suitable for agriculture-Moist/Low GDD	5,114.0166	1.90
Soils requiring special management-Moist/ Low GDD	3,631.8187	1.35
Soils requiring special management-Moist/ Medium GDD	7,306.4527	2.71
Soils requiring special management-Normal/ Low GDD	4,635.0924	1.72
Soils requiring special management-Normal/Medium GDD	20,926.3599	7.76
Soils requiring special management-Normal/ High GDD	14,685.6184	5.45
Soils requiring special management-Dry/ Low GDD	189.9506	0.07
Soils requiring special management-Dry/ Medium to High GDD	2,475.5934	0.92
Critical soils requiring intensive management-Moist/ Low GDD	52,656.1912	19.53
Critical soils requiring intensive management -Moist/ Medium GDD	8,381.2802	3.11
Critical soils requiring intensive management -Normal/ Low GDD	32,068.7960	11.89
Critical soils requiring intensive management -Normal/Medium GDD	35,214.2870	13.06
Critical soils requiring intensive management -Normal/ High GDD	8,970.8327	3.33
Critical soils requiring intensive management -Dry/ Low GDD	955.6119	0.35
Critical soils requiring intensive management -Dry/ Medium to High GDD	4,679.7916	1.74
Grand Total	269,608.8814	100.00

Table 7. Resorted area and percentage calculations for different agro-ecological zones

Agro-Ecological Zone	Area	Percentage
Critical soils requiring intensive management-Moist/ Low GDD	52,656.19	19.53
Critical soils requiring intensive management -Normal/Medium GDD	35,214.29	13.06
Critical soils requiring intensive management -Normal/ Low GDD	32,068.80	11.89
Soils requiring special management-Normal/Medium GDD	20,926.36	7.76
Soils very suitable for agriculture-Normal/Medium GDD	20,341.10	7.54
Soils very suitable for agriculture-Normal/High GDD	16,253.79	6.03
Soils requiring special management-Normal/ High GDD	14,685.62	5.45
Critical soils requiring intensive management -Normal/ High GDD	8,970.83	3.33
Critical soils requiring intensive management -Moist/ Medium GDD	8,381.28	3.11
Soils requiring special management-Moist/ Medium GDD	7,306.45	2.71
Soils suitable for agriculture-Normal/Medium GDD	6,314.17	2.34
Soils very suitable for agriculture-Moist/Low GDD	5,114.02	1.90
Soils very suitable for agriculture-Normal/Low GDD	4,712.89	1.75
Critical soils requiring intensive management -Dry/ Medium to High GDD	4,679.79	1.74
Soils requiring special management-Normal/ Low GDD	4,635.09	1.72
Soils very suitable for agriculture-Dry/Medium GDD to High GDD	4,368.25	1.62
Soils requiring special management-Moist/ Low GDD	3,631.82	1.35
Soils very suitable for agriculture-Most/Medium GDD	3,540.29	1.31
Soils suitable for agriculture-Moist/Low GDD	3,401.36	1.26
Soils suitable for agriculture-Normal/Low GDD	3,362.03	1.25
Soils requiring special management-Dry/ Medium to High GDD	2,475.59	0.92
Soils suitable for agriculture-Normal/High GDD	2,452.18	0.91
Soils suitable for agriculture-Dry/Medium GDD to High GDD	2,265.67	0.84
Critical soils requiring intensive management -Dry/ Low GDD	955.6119	0.35
Soils suitable for agriculture-Most/Medium GDD	705.4525	0.26
Soils requiring special management-Dry/ Low GDD	189.9506	0.07
Grand Total	269,608.88	100

Table 8. Top ranking provinces with critical soils requiring intensive management-moist/ low GDD

PROVINCE	Critical Soils Requiring Intensive Management - Moist / Low GDD (sq km)
Bukidnon	7,819.6184
Isabela	4,710.0541
Nueva Vizcaya	3,422.1393
Quirino	2,971.2231
Benguet	2,611.2540
Ifugao	2,369.6525
Kalinga	2,220.8407
Aurora	2,136.9000
Nueva Ecija	2,057.4762
Mountain Province	1,987.9815
Abra	1,698.0617
Davao Oriental	1,669.1504
Apayao	1,461.6472
Ilocos Norte	1,444.1472
Ilocos Sur	1,431.7368
Occidental Mindoro	1,257.1053
Agusan del Sur	1,237.5890
Cagayan	1,034.9785
Compostela Valley	1,024.2184
Oriental Mindoro	881.0568
Zambales	873.4959
Tarlac	828.1733
Lanao del Sur	785.5393
Agusan del Norte	646.8357
Surigao del Sur	514.2866
North Cotabato	502.6056
Davao del Norte	498.9550
Pangasinan	369.6905
Bulacan	275.7471
Misamis Oriental	273.3128
Southern Leyte	269.7241
Davao del Sur	268.1283
Pampanga	219.3145
La Union	211.2024
Romblon	206.6985
Quezon	181.4658
Surigao del Norte	172.2622
Lanao del Norte	111.9226

Table 9. Top ranking critical soils requiring intensive management-normal/ medium in GDD

PROVINCE	Critical Soils Requiring Intensive Management - Normal / Medium GDD (sq km)
Zamboanga del Norte	3,144.7946
Palawan	2,597.6802
Negros Occidental	2,508.6715
Agusan del Sur	2,165.1092
Zamboanga del Sur	2,012.1465
Cagayan	1,337.9048
Misamis Oriental	1,296.9926
Davao del Norte	1,244.1048
Lanao del Norte	1,203.1049
Leyte	1,153.6281
Negros Oriental	1,080.1379
Zambales	1,013.6794
Batangas	994.1764
Misamis Occidental	957.7933
Bohol	803.5974
Compostela Valley	783.7741
Iloilo	640.1724
Basilan	632.3705
Lanao del Sur	573.6275
Eastern Samar	537.3683
Antique	511.1185
Zamboanga Sibugay	509.9113
Occidental Mindoro	509.1089
North Cotabato	496.9619
Bataan	479.2916
Davao Oriental	476.6054
Pangasinan	466.3397
Oriental Mindoro	444.4138
Laguna	437.8890
Surigao del Sur	406.8417
La Union	381.2492
Marinduque	346.1705
Bukidnon	334.6549
Tarlac	314.5800
Camarines Sur	303.5801
Quezon	279.1901
Samar	272.9296
Surigao del Norte	228.3539
Romblon	225.7924
Agusan del Norte	189.2738
Camiguin	136.1413

Masbate	132.0314
Camarines Norte	115.8398
Isabela	94.9173
Ilocos Sur	90.1049
Kalinga	78.8440
Sulu	72.5755
Cavite	54.5160
Rizal	53.1424
Southern Leyte	30.4507
Abra	19.5077
Capiz	16.3315
Davao del Sur	14.9355
Benguet	9.8585

Table 10. Top ranking provinces according to critical soils requiring intensive management-normal/ low GDD

PROVINCE	Critical Soils Requiring Intensive Management - Normal / Low GDD (sq km)
Davao del Sur	3,836.9890
South Cotabato	3,388.9706
Sultan Kudarat	2,848.7793
Apayao	2,041.5762
Sarangani	1,861.5509
Abra	1,803.4544
Lanao del Sur	1,678.8141
North Cotabato	1,540.1497
Cagayan	1,316.6356
Davao Oriental	1,261.7657
Occidental Mindoro	1,124.9733
Maguindanao	989.9601
Agusan del Norte	851.1972
Misamis Oriental	745.8764
Antique	721.4362
Compostela Valley	711.4338
Negros Occidental	678.0123
Capiz	615.1362
Ilocos Norte	567.2695
Palawan	536.5621
Agusan del Sur	505.3359
Iloilo	477.6441
Negros Oriental	454.8965
Bukidnon	418.1569
Oriental Mindoro	394.2946
Aklan	223.2656
Lanao del Norte	196.8821
Ilocos Sur	72.8497
Zamboanga del Norte	52.8177
Cebu	34.1054
Zamboanga del Sur	30.8489
Catanduanes	25.8971
Quezon	23.2075
Albay	14.7226
Leyte	5.2404
Surigao del Norte	5.0349
Camarines Norte	4.3148
Eastern Samar	3.5017
Romblon	3.4758
Northern Samar	1.7386

The various inter-related environmental-biophysical maps constructed in the report provide fundamental bases for relating economic and human development within specific ranges of ecological conditions in various part of the country. These, likewise, serve as the basic platform for integrating biophysical and socio-economic databases that influences human development and for the formulation of area/ ecology-specific poverty alleviation policies and infrastructure development. The overall methods, given the appropriate spatial database, information and training, can be downscaled to reasonable planning levels within the province and municipalities.

As regards to the correlation of AEZs with HDIs, the most appropriate approach seems to be comparison of both types of maps in order to determine spatial correlation. It is important then to recognize that AEZs reflect agricultural potential and management requirements of terrain and lands. On the other hand, HDI is a composite index from 0 to one that reflects:

“... a country's average achievements [or capacity] in three basic aspects of human development: longevity, knowledge, and a decent standard of living. Longevity is measured by life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrollment ratio; and standard of living is measured by GDP per capita. The Human Development Index (HDI), reported in the Human Development Report of the United Nations, is an indication of where a country is development wise.... Countries with an index over 0.800 are part of the High Human Development group. Between 0.500 and 0.800, countries are part of the Medium Human Development group and below 0.500 they are part of the Low Human Development group.” (Economic Glossary, Available from <http://glossary.econguru.com/economic-term/HDI>, Accessed 7 March 2011)

The above descriptive qualifications of what AEZs and HDIs are help to determine the extent of necessary investments, in crop production or management and supportive infrastructure, to match or bridge both agricultural potential and human development capacities in a spatial sense. One needs to mention that potentials of the fisheries sector were not included in this study.

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ANNEX A: DEFINITION OF PHILIPPINE SOIL ORDERS



“Acrisol. One of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Acrisols form on old landscapes that have an undulating topography and a humid tropical climate. Their natural vegetation is woodland, which in some areas has given way to tree savanna maintained by seasonal burning. The age, mineralogy, and extensive leaching of these soils have led to low levels of plant nutrients, excess aluminum, and high erodibility, all of which make agriculture problematic. Nevertheless, traditional shifting cultivation of acid-tolerant crops has adapted well to the conditions found in Acrisols. They occupy just under 8 percent of the continental land surface on Earth, covering areas throughout central and northern Latin America, Southeast Asia, and West Africa.

Acrisols are defined by the presence of a subsurface layer of accumulated kaolinitic clays where less than half of the ions available to plants are calcium, magnesium, sodium, or potassium and also by the lack of an extensively leached layer below the surface horizon (uppermost layer). They are related taxonomically to the Oxisol soil order of the U.S. Soil Taxonomy. Related FAO soil groups originating in tropical climates and also containing layers with clay accumulations are Lixisols and Nitisols.”

(SOURCE: “Acrisol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707275/Acrisol>)

“Alfisols are a soil order in USDA soil taxonomy. Alfisols form in semiarid to humid areas, typically under a hardwood forest cover. They have a clay-enriched subsoil and relatively high native fertility. “Alf” refers to Aluminium (Al) and Iron (Fe). Because of their productivity and abundance, the Alfisols represent one of the more important soil orders for food and fiber production. They are widely used both in agriculture and forestry and are generally easier to keep fertile than other humid-climate soils, though those in Australia and Africa are still very deficient in Nitrogen and available Phosphorus. Those in monsoonal tropical regions, however, have a tendency to acidify when heavily cultivated, especially when nitrogenous fertilizers are used.

In the FAO soil classification, most Alfisols are classified as Luvisols or Lixisols, but some are classed as Nitisols.

Alfisols occupy around one tenth of the Earth's ice-free land surface. They are dominant in many areas, such the Ohio River basin in the United States, southern and unglaciated Western Europe, the Baltic region and central European Russia, the drier parts of Peninsular India, Sudan in Africa, and many parts of South America.

Alfisols have undergone only moderate leaching. By definition, they have at least 35% base saturation, meaning that Calcium, Magnesium, and Potassium are relatively abundant. This is in contrast to Ultisols, which are the more highly leached forest soils having less than 35% base

saturation. In eastern North America, Alfisols are commonly found in glaciated areas while Ultisols are restricted to the areas south of the limit of maximum glaciation.

The fossil record of Alfisols begins in the Late Devonian. Alfisols, probably owing to their fertility, are the oldest forest soils: vegetation on weathered Oxisols, by contrast, is not known earlier than Middle Permian. Fossil Alfisols remain common from the Carboniferous and all periods since the Eocene.”

(SOURCE: “Alfisols.” (n.d.). Retrieved from <http://en.Wikipedia.org/wiki/Alfisols>, External links: <http://soils.usda.gov/technical/classification/orders/alfisols.html>, <http://soils.cals.uidaho.edu/soilorders/alfisols.htm>)



“Andosol, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Andosols are highly porous, dark-coloured soils developed from parent material of volcanic origin, such as volcanic ash, tuff, and pumice. They are found from Iceland to Indonesia, but they typically occur in wooded highland areas of the continental lands bordering the Pacific Ocean. Their worldwide extent is estimated at less than 1 percent of the total soil area on Earth.

Andosols have high aluminum content, and their reactions with inorganic phosphate render the phosphate essentially insoluble and unavailable for uptake by plants. Although the soils have excellent water-holding and nutrient capacity (unless leached extensively), their strong reaction with phosphate makes agriculture without fertilizing problematic. Andosols are similar to the Andisol order of the U.S. Soil Taxonomy.”

(SOURCE: “Andosol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.britannica.com/EBchecked/topic/707289/Andosol>)



“Arenosol, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Arenosols are sandy-textured soils that lack any significant soil profile development. They exhibit only a partially formed surface horizon (uppermost layer) that is low in humus, and they are bereft of subsurface clay accumulation. Given their excessive permeability and low nutrient content, agricultural use of these soils requires careful management. They occupy about 7 percent of the continental surface area of the Earth, and they are found in arid regions such as the Sahel of western Africa and the deserts of western Australia, as well as in the tropical regions of Brazil. Arenosols are related to the sandy-textured members of the Entisol order of the U.S. Soil Taxonomy.”

(SOURCE: “Arenosol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707505/Arenosol>)



“Cambisol, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Cambisols are characterized by the absence of a layer of accumulated clay, humus, soluble salts, or iron and aluminum oxides. They differ from unweathered parent material in their aggregate structure, colour, clay content, carbonate content, or other properties that give some evidence of soil-forming processes. Because of their favourable aggregate structure and high content of weatherable minerals, they usually can be exploited for agriculture subject to the limitations of terrain and climate. Cambisols are the second most extensive soil group on Earth, occupying 12 percent of the total continental land area—mainly in boreal polar regions, in landscapes with high rates of erosion, and in regions of parent material resistant to clay movement. They are not common in humid tropical climates.

In order for a soil to qualify as a Cambisol, the texture of the subsurface horizons must be sandy loam or finer, with at least 8 percent clay by mass and a thickness of 15 cm (6 inches) or more. These soils naturally form on medium- to fine-textured parent materials under any climatic, topographic, and vegetative-cover conditions. They differ from Leptosols and Regosols by their greater depth and finer texture and are often found in conjunction with Luvisols.”

(SOURCE: “Cambisol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707510/Cambisol>)



“Fluvisol, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Fluvisols are found typically on level topography that is flooded periodically by surface waters or rising groundwater, as in river floodplains and deltas and in coastal lowlands. They are cultivated for dryland crops or rice and are used for grazing in the dry season. They occupy about 2.8 percent of the continental land area on Earth, mainly in the great river basins and deltas of the world (e.g., the Amazon basin and the Nile delta).

Fluvisols are technically defined by a weak or nonexistent surface horizon (uppermost layer) and by parent material derived from river, lake, or marine sediments that have been deposited at regular intervals or in the recent past. These soils exhibit a stratified profile that reflects their depositional history or an irregular layering of humus and mineral sediments in which the content of organic carbon decreases with depth. Wide variations in texture and mineral composition are observed. Fluvisols are related to the Inceptisol and Entisol orders of the U.S. Soil Taxonomy, wherever the

latter occur on floodplains and deltas. Fluvisols are sometimes found in conjunction with Gleysols, a related FAO soil group formed under the influence of water.”

(SOURCE: “Fluvisol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707616/Fluvisol>)



*“**Gleysol**, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). Gleysols are formed under waterlogged conditions produced by rising groundwater. In the tropics and subtropics they are cultivated for rice or, after drainage, for field crops and trees. Gleysols found in the polar regions (Alaska and Arctic Asia; about half of all Gleysols) are frozen at shallow depth and are used only by wildlife. These soils occupy about 5.7 percent of the continental land area on Earth, including the Mississippi valley, north-central Argentina, central Africa, the Yangtze River valley, and Bangladesh.*

Gleysols are technically characterized by both chemical and visual evidence of iron reduction. Subsequent downward translocation (migration) of the reduced iron in the soil profile is associated with gray or blue colours in subsurface horizons (layers). Wherever oxidation of translocated iron has occurred (in fissures and cracks that may dry out), red, yellow, or brown mottles may be seen. Gleysols are related to the Entisol and Inceptisol orders of the U.S. Soil Taxonomy, wherever the latter occur under waterlogged conditions sufficient to produce visual evidence of iron reduction. In warm climatic zones these soils occur in association with the FAO soil groups Fluvisol and Cambisol.”

(SOURCE: “Gleysol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707618/Gleysol>)



*“**Luvisol**, one of the 30 soil groups in the classification system of the Food and Agriculture Organization (FAO). The mixed mineralogy, high nutrient content, and good drainage of these soils make them suitable for a wide range of agriculture, from grains to orchards to vineyards. Luvisols form on flat or gently sloping landscapes under climatic regimes that range from cool temperate to warm Mediterranean. Occupying just over 5 percent of the total continental land area on Earth, they are found typically in west-central Russia, the United States, central Europe, the Mediterranean basin, and southern Australia.*

Luvisols are technically characterized by a surface accumulation of humus overlying an extensively leached layer that is nearly devoid of clay and iron-bearing minerals. Below the latter lies a layer of mixed clay accumulation that has high levels of available nutrient ions comprising calcium, magnesium, sodium, or potassium. Luvisols are often

associated with Cambisols. Albeluvisols are a related FAO soil group also exhibiting clay migration.”

(SOURCE: “Luvisol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/707930/Luvisol>)



*“**Vertisol**, one of the 12 soil orders in the U.S. Soil Taxonomy. Vertisols are clay-rich soils that undergo significant vertical cracking during the dry seasons. Typically forming under grassland vegetation in basin or rolling hill landscapes, they are best suited for use as pastureland and for the cultivation of plants, such as rice, that thrive in standing surface water. Their very low water permeability when wet and unstable structure make them unsuitable for most other commercial uses. Although broadly distributed on every nonpolar continent, they occupy just over 2 percent of the land area on Earth, primarily in subtropical or tropical zones of Australia, India, and Africa and in parts of the western United States (California and Texas) and Europe (Austria and the Balkans).*

Vertisols are characterized by a content of 30 percent or more by mass of clay-size particles throughout the upper half-metre (1.6 feet) of the soil profile, by centimetre-size (0.4-inch) cracks open to the land surface during the dry season, and by distinct evidence of strong vertical mixing of the soil particles through shrinking and swelling processes accompanying drying and rewetting periods. A definite annual dry season and a parent material conducive to alkaline pH and to the formation of swelling smectite-type clay minerals are believed to be essential to the development of these soils. The topographic setting for Vertisols usually has a crumpled look created by a complex array of mounds and depressions known as gilgai microrelief—the direct result of shrink-swell cycles over long periods of time.”

(SOURCE: “Vertisol.” (2011). Encyclopædia Britannica. Encyclopædia Britannica Online Academic Edition. Encyclopædia Britannica. Web. 02 Aug. 2011. <http://www.brittanica.com/EBchecked/topic/626731/Vertisol>)

The soil orders mentioned in the text were grouped together based on common characteristics:

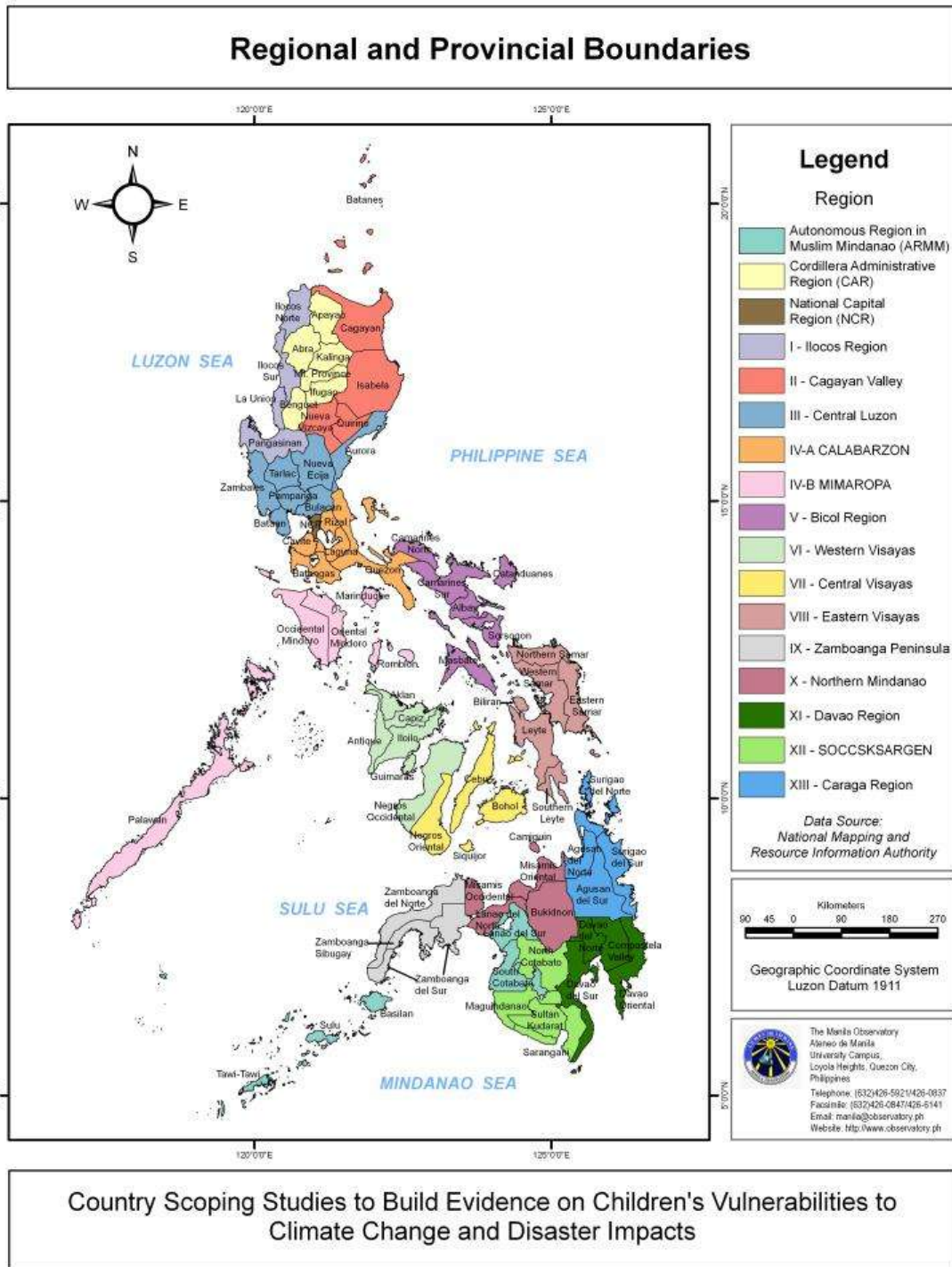
Cambisols and Luvisols were grouped together because they contain minerals and nutrients that can be exploited for or are highly suited to a broad range of agriculture depending on limitations of climate and topography.

Fluvisols, Gleysols and Vertisols are found in waterlogged areas such as river basins/ floodplains and deltas and are best suited for the cultivation of rice other than field crops, the latter when well-drained.

Acrisols and Arenosols have low nutrient levels and are characterized by permeability/ leaching, which, being problematic for agriculture, necessitate careful/ special management.

Andosols and Nitosols have aluminum content, are suited to forested highlands apart from agriculture/ food production but, for the latter purpose, require careful/ balanced

ANNEX B: MAP OF THE PHILIPPINES



ANNEX C: TABLES OF AEZS AND COMPONENTS

PROVINCE	Suitable For Agriculture - Dry / Medium GDD to High GDD (sq km)	Suitable For Agriculture - Normal / Medium GDD (sq km)	Suitable For Agriculture - Normal / Medium GDD (sq km)	Suitable For Agriculture - Normal / Low GDD (sq km)	Very Suitable For Agriculture - Moist / Medium GDD (sq km)	Very Suitable For Agriculture - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Medium GDD (sq km)	Requires Careful Management - Normal / Low GDD (sq km)	Requires Careful Management - Normal / Medium GDD (sq km)	Requires Careful Management - Normal / High GDD (sq km)	Requires Very Careful Management - Dry / Low GDD (sq km)	Requires Very Careful Management - Dry / Medium GDD to High GDD (sq km)
Abra	0.0000	0.0000	0.0000	333.7409	0.0000	0.0000	1701.4784	0.0000	1918.1249	19.5076	0.8158	0.0000	0.0000
Agusan del Norte	0.0000	0.0000	30.1165	108.3247	0.0000	516.1491	774.7654	0.0000	864.9220	556.2358	0.0000	0.0000	0.0000
Agusan del Sur	0.0000	1.6269	3221.7709	80.8778	0.0000	15.1260	1237.7605	0.0000	540.1490	3434.7824	65.4056	0.0000	0.0000
Aklan	0.0000	262.9072	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	303.8694	0.0000	844.4139	0.0000	0.0000
Albay	0.0000	566.2277	0.0000	0.0000	388.1878	0.0000	0.0000	1012.1307	43.5191	0.0000	129.9067	0.0000	0.0000
Antique	0.0000	67.2376	121.4172	464.8077	0.0000	0.0000	0.0000	0.0000	854.9866	701.8839	328.5516	0.0000	0.0000
Apayao	0.0000	0.0000	0.0000	124.5817	0.0000	12.4319	1467.4711	0.0000	2309.6016	0.0000	0.0000	0.0000	0.0000
Aurora	0.0000	0.0000	0.0000	0.0000	0.0000	99.6854	2610.1361	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Basilan	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1040.0366	0.0000	0.0000	0.0000
Bataan	0.0000	2.9516	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	857.5881	370.7845	0.0000	0.0000
Batanes	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Batangas	0.0000	333.3911	513.5625	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1678.9326	262.9618	0.0000	0.0000
Benguet	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	2612.1086	0.0000	0.0000	9.8585	19.1414	0.0000	0.0000
Biliran	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	241.5309	0.0000	0.0000	131.4596	0.0000	0.0000
Bohol	596.6612	0.8761	1115.2931	94.4258	0.0000	0.0000	0.0000	0.0000	0.0000	1533.8655	21.0251	0.0000	4.3834
Bukidnon	0.0000	0.0000	0.0000	0.0000	0.0000	491.0832	7851.3269	0.0000	418.1567	344.0026	0.0000	0.0000	0.0000
Bulacan	0.0000	802.4809	0.0000	0.0000	179.8247	743.8110	276.0770	531.8487	0.0000	0.0000	10.4520	0.0000	0.0000
Cagayan	0.0000	0.0000	1717.9997	652.6709	0.0000	119.1778	1077.4631	0.0000	1708.6658	2784.5704	0.0000	0.0000	0.0000
Camarines Norte	0.0000	0.0000	0.0000	10.7371	342.1739	0.0000	0.0000	1057.3473	26.7496	350.7080	0.0000	0.0000	0.0000
Camarines Sur	0.0000	562.0433	340.4738	0.0000	1060.7489	0.0000	0.0000	1848.7272	70.2161	820.2333	29.4057	0.0000	0.0000
Camiguin	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	179.7302	0.0000	0.0000	0.0000
Capiz	0.0000	745.5993	28.1790	13.6165	0.0000	0.0000	0.0000	0.0000	743.4814	36.9979	884.9929	0.0000	0.0000
Catanduanes	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1131.7260	105.1420	0.0000	0.0000	0.0000	0.0000
Cavite	0.0000	847.8370	76.0912	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	54.5160	183.5942	0.0000	0.0000
Cebu	1820.1171	38.3642	0.0000	352.3073	0.0000	0.0000	0.0000	0.0000	69.9583	0.0000	0.0000	0.0000	1558.4732
Compostela Valley	0.0000	227.0177	190.9024	445.2510	0.0000	2.6514	1030.4075	0.0000	926.0065	1019.1799	394.7959	0.0000	0.0000
Davao Oriental	0.0000	31.7778	271.4608	260.9434	0.0000	126.0471	1806.0915	0.0000	1582.8565	633.7643	1.1321	0.0000	0.0000
Davao del Norte	0.0000	556.2156	429.9488	30.5419	0.0000	0.0000	498.9550	0.0000	0.0000	1561.2167	287.3221	0.0000	0.0000
Davao del Sur	0.0000	195.3604	0.0000	443.2585	0.0000	0.0000	268.1286	0.0000	4203.4527	14.9355	192.3388	196.1202	0.0000
Eastern Samar	0.0000	410.6244	180.7086	0.0000	376.7552	0.0000	0.0000	798.2048	20.4539	828.5373	899.3301	0.0000	0.0000
Guimaras	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8742	314.5449	0.0000	52.5424
Ifugao	0.0000	7.0125	0.0000	0.0000	0.0000	45.4473	2385.5518	0.0000	0.0000	0.0000	65.5794	0.0000	0.0000
Ilocos Norte	0.0000	0.0000	26.8664	156.8487	0.0000	669.1982	1679.4146	0.0000	728.9648	0.0000	0.0000	0.0000	0.0000

PROVINCE	Suitable For Agriculture - Dry / Medium GDD to High GDD (sq km)	Suitable For Agriculture - Normal / High GDD (sq km)	Suitable For Agriculture - Normal / Medium GDD (sq km)	Suitable For Agriculture - Normal / Low GDD (sq km)	Very Suitable For Agriculture - Moist / Medium GDD (sq km)	Very Suitable For Agriculture - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Medium GDD (sq km)	Requires Careful Management - Normal / Low GDD (sq km)	Requires Careful Management - Normal / Medium GDD (sq km)	Requires Careful Management - Normal / High GDD (sq km)	Requires Very Careful Management - Dry / Low GDD (sq km)	Requires Very Careful Management - Dry / Medium GDD to High GDD (sq km)
Ilocos Sur	0.0000	175.6165	197.9378	2.9570	0.0000	59.5270	1511.6297	0.0000	86.4267	253.0348	113.2041	0.0000	0.0000
Iloilo	0.0000	541.9403	506.6189	22.9307	0.0000	0.0000	0.0000	0.0000	559.9114	1110.9283	1463.1832	0.0000	0.0000
Isabela	0.0000	1187.7969	37.2502	0.0000	0.0000	1681.2653	5554.3009	0.0000	0.0000	118.3105	1283.9494	0.0000	0.0000
Kalinga	0.0000	0.0000	0.0000	0.0000	0.0000	194.1669	2241.2220	0.0000	0.0000	188.7146	273.7185	0.0000	0.0000
La Union	0.0000	88.7173	267.0882	0.0000	0.0000	0.0000	212.1662	0.0000	0.0000	492.7283	325.3862	0.0000	0.0000
Laguna	0.0000	0.0000	591.9429	0.0000	15.9114	0.0000	0.0000	548.1798	0.0000	702.3513	0.0000	0.0000	0.0000
Lanao del Norte	0.0000	22.0112	59.6603	0.0000	0.0000	0.0000	111.9226	0.0000	196.8825	1299.9398	933.4691	0.0000	0.0000
Lanao del Sur	0.0000	0.0000	59.0039	460.7560	0.0000	0.0000	786.4489	0.0000	1864.6078	582.4347	67.2711	0.0000	38.5367
Leyte	0.0000	199.3833	1692.8121	86.8901	19.0618	0.0000	0.0000	230.1047	8.7339	1811.2947	885.5851	0.0000	0.0000
Maguindanao	2137.9201	0.0000	248.1350	662.9039	0.0000	0.0000	0.0000	0.0000	1036.9482	1.1955	0.0000	0.0000	544.1955
Marinduque	0.0000	0.0000	248.9299	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	522.1991	0.0000	0.0000	0.0000
Masbate	0.0000	932.9286	109.6222	175.2718	80.2968	0.0000	0.0000	0.0000	52.0511	960.7698	935.6695	0.0000	0.0000
Metropolitan Manila	0.0000	93.3120	57.4349	0.0000	133.9114	0.0000	0.0000	231.0205	0.0000	0.0000	5.0494	0.0000	0.0000
Misamis Occidental	0.0000	103.7422	377.6367	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	982.5135	206.7494	0.0000	0.0000
Misamis Oriental	0.0000	0.0000	162.0623	308.6428	0.0000	69.5138	281.2324	0.0000	758.9886	1351.3805	0.0000	0.0000	0.0000
Mountain Province	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1987.9812	0.0000	0.0000	0.0000	141.0583	0.0000	0.0000
Negros Occidental	668.7335	328.6502	1852.1125	167.0601	0.0000	0.0000	0.0000	0.0000	813.5938	3132.8241	1.7477	0.0000	324.8904
Negros Oriental	381.1579	0.0000	467.8868	349.0941	0.0000	0.0000	0.0000	0.0000	457.5230	1302.2135	0.0000	0.0000	1686.5244
North Cotabato	658.0835	0.0000	1997.2988	548.2165	0.0000	250.4244	502.6062	0.0000	1545.4493	722.9175	0.0000	0.0000	134.9475
Northern Samar	0.0000	0.0000	0.0000	186.4244	532.6766	0.0000	0.0000	1904.2887	124.7002	0.0000	0.0000	0.0000	0.0000
Nueva Ecija	0.0000	2042.6314	0.0000	0.0000	0.0000	1025.4590	2176.7251	0.0000	0.0000	0.0000	232.4659	0.0000	0.0000
Nueva Vizcaya	0.0000	0.0000	0.0000	0.0000	0.0000	458.6960	3465.2729	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Occidental Mindoro	0.0000	633.3405	119.4949	140.6003	0.0000	24.3341	1466.5065	0.0000	1742.8527	593.8677	780.8279	0.0000	0.0000
Oriental Mindoro	0.0000	135.2032	722.3982	60.4749	0.0000	239.4754	1206.8192	0.0000	428.0708	912.5313	238.5276	0.0000	0.0000
Palawan	0.0000	396.3847	3293.7219	384.3752	0.0000	0.0000	0.0000	0.0000	778.0126	4948.6365	2071.8471	0.0000	0.0000
Pampanga	0.0000	997.2573	0.0000	0.0000	0.0000	0.0000	257.1828	0.0000	0.0000	28.4637	961.5985	0.0000	0.0000
Pangasinan	0.0000	1615.0707	863.7050	0.0000	0.0000	622.2782	379.9612	0.0000	0.0000	808.8982	540.6137	0.0000	0.0000
Quezon	0.0000	0.0000	2071.1468	0.0000	173.0733	0.0000	277.3193	2838.2817	164.5742	1724.7833	0.0000	0.0000	0.0000
Quirino	0.0000	0.0000	0.0000	0.0000	0.0000	56.4864	3041.3226	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Rizal	0.0000	0.0000	0.0000	0.0000	144.4844	0.0000	0.0000	996.9547	0.0000	91.2822	0.0000	0.0000	0.0000
Romblon	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	321.3381	0.0000	99.2797	485.7109	0.0000	0.0000	0.0000
Samar	0.0000	837.1730	219.0772	0.0000	662.3740	0.0000	0.0000	1463.6164	0.0000	577.3824	1324.3458	0.0000	0.0000
Sarangani	0.0000	0.0000	0.0000	230.3662	0.0000	0.0000	0.0000	0.0000	1941.9292	0.0000	0.0000	921.2793	0.0000
Siquijor	10.4100	0.0000	212.1396	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sorsogon	0.0000	16.2662	0.0000	78.9738	136.2618	0.0000	0.0000	718.2737	10.4007	0.0000	709.7206	0.0000	0.0000

PROVINCE	Suitable For Agriculture - Dry / Medium GDD to High GDD (sq km)	Suitable For Agriculture - Normal / Medium GDD (sq km)	Suitable For Agriculture - Normal / Medium GDD (sq km)	Suitable For Agriculture - Normal / Low GDD (sq km)	Very Suitable For Agriculture - Moist / Medium GDD (sq km)	Very Suitable For Agriculture - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Low GDD (sq km)	Requires Careful Management - Moist / Medium GDD (sq km)	Requires Careful Management - Normal / Low GDD (sq km)	Requires Careful Management - Normal / Medium GDD (sq km)	Requires Careful Management - Normal / High GDD (sq km)	Requires Very Careful Management - Dry / Low GDD (sq km)	Requires Very Careful Management - Dry / Medium GDD to High GDD (sq km)
South Cotabato	27.2906	0.0000	0.0000	283.4534	0.0000	0.0000	0.0000	0.0000	3502.7087	0.0000	0.0000	3.8525	485.8026
Southern Leyte	0.0000	221.5821	0.0000	0.0000	0.0000	165.2234	381.8916	135.4972	0.0000	40.3682	329.3037	0.0000	0.0000
Sultan Kudarat	331.7781	0.0000	0.0000	349.0797	0.0000	0.0000	0.0000	0.0000	2879.3161	0.0000	0.0000	0.0000	815.8780
Sulu	0.0000	89.5846	37.1674	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	379.2360	207.0380	0.0000	0.0000
Surigao del Norte	0.0000	200.3550	334.8628	3.5117	0.0000	51.1774	205.8250	0.0000	12.1191	621.3238	439.1688	0.0000	0.0000
Surigao del Sur	0.0000	345.6644	606.8396	0.0000	0.0000	282.2540	604.9194	0.0000	7.8339	756.9874	894.2726	0.0000	0.0000
Tarlac	0.0000	1151.3511	160.1731	0.0000	0.0000	0.0000	882.2888	0.0000	0.0000	558.3052	266.0121	0.0000	0.0000
Tawi-Tawi	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	406.6048	24.3105	0.0000
Zambales	0.0000	47.7901	323.9466	0.0000	0.0000	494.2884	1153.9877	0.0000	0.0000	1450.4424	52.4249	0.0000	0.0000
Zamboanga													
Sibugay	0.0000	542.9448	25.4879	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	860.5506	1041.7849	0.0000	16.3895
Zamboanga del Norte	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	110.0364	4248.9357	860.8444	0.0000	480.1580
Zamboanga del Sur	1.7650	99.7226	466.8904	0.0000	0.0000	0.0000	0.0000	0.0000	81.6621	3055.2338	225.0527	0.0000	1012.6629

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