CMU Journal of Science
The Official Scientific Journal of Central Mindanao University
ISSN Print: 0116-7847 js.cmu.edu.ph ISSN Online: 2704-3703

Research Article

A Review of the Characteristics, Distribution, and Degradation Risk of Soils in Misamis Oriental, Philippines

Guadalupe M. Dejarme-Calalang

Agricultural and Biosystems Department, College of Agriculture, Xavier University, 9000 Cagayan de Oro City, Philippines;

* Correspondence: guadalupe.dejarme.calalang@gmail.com ; guadacalalang62@yahoo.com ; Phone: +63 975 621 9169

Citation: Calalang, G.M. (2025). "A Review of the Characteristics, Distribution, and Degradation Risk of Soils in Misamis Oriental, Philippines." CMU Journal of Science. 29(2), 46

Academic Editor: Dr. Constancio Asis Jr.

Received: November 19, 2025
Revised: July 4, 2025
Accepted: November 11, 2025
Published: December 26, 2025

ABSTRACT

This paper presents the characteristics, distribution, and degradation risks of soils in Misamis Oriental. The influence of parent rock materials on soil formation, soil morphology, chemical characteristics, and the associated soil degradation risks are discussed. This article describes the soil morphological, and physical characteristics, mineralogical, and chemical characteristics, and the areal soil distribution in Misamis Oriental. Furthermore, the article postulates the soil degradation risks, the land use conversion to other uses, and their potential implications for the socio-economy of the province. Sources of information, directly or indirectly relevant to Misamis Oriental soils, were government reports, journal articles, monographs, books, thesis manuscripts, development planning documents, and maps. Available soil information for the municipality of Claveria is extensive. Information from other municipalities and cities of the province is lacking. The recommendations formulated based on this review are: (1) conduct pedological and other soil research and establish a soil reference system in other areas where volcanic parent materials are located, particularly in the eastern side of the province; (2) conduct pedological research in calcareous soils and establish a soil reference system in the western side of the province; (3) investigate the occurrence of soil salinization and other forms of soil chemical degradation in the lowland areas; and (4) conduct soil erosion studies in cultivated sloping areas, and (5) investigate the impacts of land use to the socio-economy and food security of Misamis Oriental.

Keywords: Calcareous soils, land use change, soil erosion, soil morphology, soil salinization and volcanic soils

1. INTRODUCTION

The most critical land degradation issue in the Philippines is soil erosion [1], which has caused fertility decline in soils. There is less attention to issues of soil salinization in coastal agricultural areas. With the increasing utilization of lands for agriculture, it is necessary to conduct pedological studies to obtain a detailed analysis of soil and its relationship to the environment [2]. Environmental resource managers will be able to determine the soil's resilience during climate and land use disruptions and evaluate its capabilities to support vegetation. The soil is the foundation of essential ecosystem functions, and crop production depends on it. There is a connection between the conditions of agricultural soils with the society's food security and the stability of an agrarian economy. Misamis Oriental, Philippines, is one of the five provinces of Northern Mindanao. Although its municipalities are along the coastlines, except for Claveria, which is landlocked, the province is predominantly agricultural. The population of the province with the three cities namely; Gingoog, El Salvador, and Cagayan de Oro, as of 2020 population census is 1,685,302 [3]. From 2015 to 2020, the annual growth rates of Misamis Oriental and Cagayan de Oro City are 1.57% and 1.58%, respectively. With the increasing population of the province, development planners, decision-makers, and other stakeholders must use and manage their land resources effectively to cope with the present and future demands for more food. Appropriate and adequate soil data and information are crucial for effective soil governance to develop science-based policies on land utilization and management [4]. Soil characteristics are essential information when planning for the use and management of the natural resource. Among other factors, the physical and chemical characteristics are indicators of soil health and suitability. Study results in a small watershed in the rural areas of southern Brazil showed that soil properties characterization was pivotal in delineating agricultural soils for family farming [5]. Characterization of soils is vital for crop production in the Philippines because the country's average farm size is 1.29 hectares, and of the total 5.56 million land holdings, 38% of the area is under half a hectare [6]. Continuous cultivation for crop production in small areas will easily exhaust the capabilities of the soil [7]. Identifying the respective locations of different soil classifications is an essential initiative for land resource conservation and management. Soil resource managers, researchers, extension workers, and land users would be able to spot those areas that are susceptible to degradation. Larger parts of agricultural areas in Misamis Oriental are located in rolling areas, high uplands, and mountains, which are susceptible to soil erosion if soil conservation and management are absent. Soils along the coastline are vulnerable to saline water intrusion because of the rising sea tides and excessive groundwater abstraction. Moreover, there are areas in Misamis Oriental, particularly in the western part of the province that have limestone parent materials. Salts may have been embedded in the soil parent rock materials because these formations were submerged in seawater in the past.

Empirical pedological data generation are principal information for science-based decisions in land use planning and management. Knowing the existing soil information within Misamis Oriental will enable the researchers to be strategic in selecting research topics and the parameters to be studied for the furtherance of the province's soil resource use. The results of pedological studies will serve as bases for sustainable land management [8]. Pedological studies in Mindanao are few [9]. Claveria is the only municipality of Misamis Oriental in which data on soil characteristics and management are available. These evidences, among others, are found in the works of [10-14]. Other municipalities have none, or if there are, have inadequate soil information; although Misamis Oriental is an agricultural province and contributes to crop production and the agrarian economy of the Philippines. Data gathered for this article were from the compilations of agricultural research reports on soils and crops in the area; government documents and statistical reports, graduate student theses on soils and water, and articles from peer-reviewed journals, monographs, and books. This article points out potential research topics to heighten soil studies for Misamis Oriental. This paper considers the existing facts on the soils of Misamis Oriental. Its contents are: (1) geography, topography, and climatic conditions; (2) geological background, associated rocks, and the soil parent material; (3) discussions on Misamis Oriental soils, related mineralogical properties, location and distribution of soils in the province, morphology, physical and chemical characteristics of soils, and their potentialities and constraints; (4) the development for other uses of land and water that triggers geo-environmental related problems such as soil erosion and soil salinization; (5) the author's recommendations for researchable topics for Misamis Oriental, and the conclusions for the subject that include the author's arguments for the sustainable development of land resources for the province.

2. METHODOLOGY

2.1. Data and relevant information gathering

This literature review utilizes the data and other relevant information for the province of Misamis Oriental. Sources of information come specifically from international geological reports, national soil survey reports, provincial and municipal land use plan documents, postgraduate theses, and articles published in scientific journals.

2.2. Structure of the review paper

This review paper discusses the salient data and information on Misamis Oriental soils which are useful in identifying potential research topics for crops and soil. The following sections are shown the paper discussions:

- The geography, topography, and climate of Misamis Oriental which point out the geographical locations, the watersheds of the two major rivers, and the climate type of the province,
- The geological background, associated rocks, and soil parent materials which discuss the geological formation and parent rocks that influence soil development,
- The characteristics of Misamis Oriental soils topic which presents the morphological, physical, clay mineralogy, chemical characteristics, and the areal soil distribution in the province,
- The geo-ecological issues on soil erosion, toxic elements in agricultural soils, soil salinization risks, land use conversion, and
- The recommendations to conduct soil studies and address the scarcity of soil information in the province.

3. RESULTS AND DISCUSSION

3.1. Geography, topography, and climate of Misamis Oriental

Misamis Oriental, with coordinates of 8°12′24″ to 9°5′25″ N and 124°15′4″ to 125°14′26 E, is one of the five provinces of the Northern Mindanao region. Geographically, thus including Cagayan de Oro City, the province has a total land area of 3,544.32 km^2. Figure 1 shows the map of Misamis Oriental. The province has 25 municipalities with which Claveria is the only landlocked, and the rest are in the coastal areas. According to the four types of Modified Corona Classification; Misamis Oriental has a Type III climate, with no very pronounced maximum rain period and has a short dry season lasting only for one to three months, either from December to February or from March to May [15]. Parts of two major river basins, the Cagayan de Oro River Basin and the Tagoloan River Basin of Northern Mindanao, are in Misamis Oriental [16]. The catchment area of Cagayan de is 1,471 km^2, and one-third of this is geographically part of Cagayan de Oro City. The Tagoloan River Basin has a catchment area of 1,577 km^2 in which a small portion of the catchment is geographically included in Misamis Oriental. The two major rivers terminate their flow at the Macajalar Bay of Cagayan de Oro City. Aside from the aforementioned significant rivers, Misamis Oriental has rivers and creeks that are useful for agriculture, domestic, commercial, industrial, and power generation.

3.2. Geological background, associated rocks, and soil parent materials

Misamis Oriental is an ancient arc that was covered by igneous materials from volcanic activities during the Quaternary period [17]. The province is part of the Central Mindanao Volcanic Field, which encompasses Cagayan de Oro and Iligan in the north, to Cotabato in the south [18]. Pliocene-Quaternary lavas and pyroclastic materials abundantly covered the eastern side of the province. The western side of the province has sediments at various ages from the Pliocene-Pleistocene, late Miocene-Pleistocene, and Paleogene with ultramafic basement.

The Central Mindanao Belt is a magmatic response to the collision between the western and eastern Mindanao about 5Ma ago; whereas the Cotabato Belt results from the subduction of the Celebes Sea Plate along the Cotabato Trench [19]. Rock samples taken from Kinoguitan and Talisayan were high K calc-alkaline basalt; while from Mt Balingoan were calc-alkaline andesite [18]. The term "calc-alkaline" refers to island-arc/subduction zone rocks [20]. The presence of the aforementioned rock infers that Misamis Oriental is within the location where tectonic plates collide.

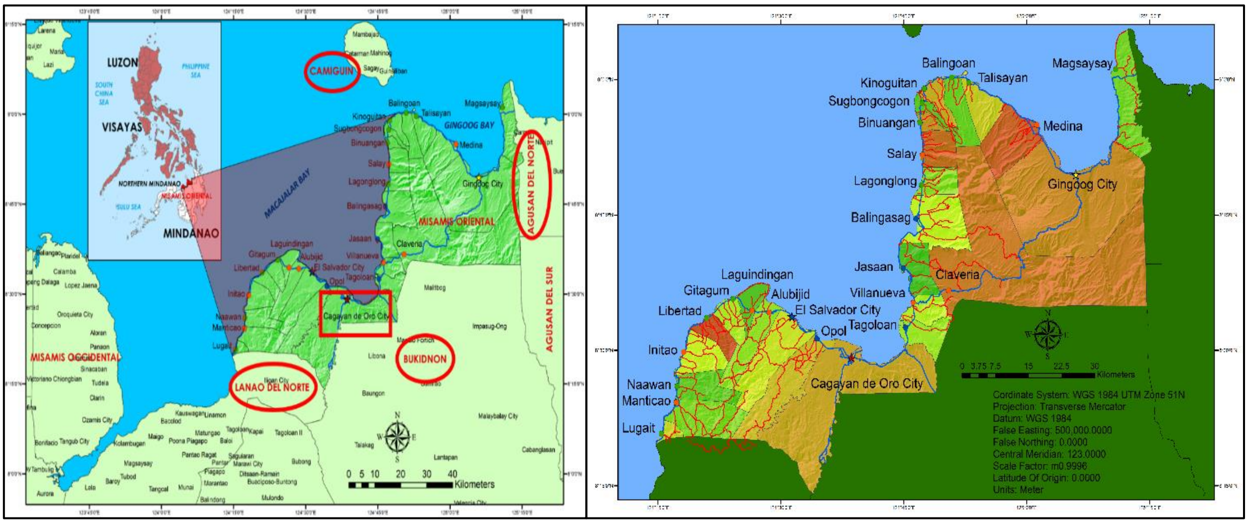

Figure 1. Map of Northern Mindanao; inset the Philippines, and Misamis Oriental Province (Courtesy of Provincial Agriculture Office, Misamis Oriental)

Rock formations from parts of Jasaan to Gingoog City are homogenous and are of quaternary volcanic and pyroclastics. From Magsaysay towards the boundary of Misamis Oriental and Agusan province, are primarily sandstone and clay conglomerates. Rock formations in the western section, from parts of Jasaan to Lugait are heterogeneous; with sedimentary rocks of coralline limestone, sandstone, claystone, and conglomerates. The stratigraphy of the western part of Misamis Oriental mentions the igneous formations; such as ultrabasic rocks, metavolcanic, and undifferentiated volcanic rocks. The stratigraphy further noted the presence of Cretaceous Tago schist, Awang Ultramafic complex, Eocene Himalyan formation, late Oligocene to early Miocene Balongkot limestone and Tuod formation, late Miocene Opol formation, Pliocene Indahag limestone, and Iponan formation, Pleistocene Bukidnon formation and Pleistocene to Holocene gravel formation as the geological formations of Misamis Oriental [17]. Limestone in Opol is among those limestone formations in the Philippines that were submerged in seawater and then raised as coral reefs from the Pleistocene to recent periods [21]. The Report of Geology of the Philippines briefly mentioned the rocks and mineral resources found in Misamis Oriental [22]. According to this report, serpentine is found on the east coast of Mindanao Island including Misamis Oriental, and quartz veins in talcose schists at Pighulogan, Cagayan de Oro. Pighulogan can be the same place as Himolugan or Huluga [23], which may be linguistically similar. Becker's report explicitly mentioned the gold-bearing deposits along the courses of the Bigaan, Cutman, Iponan, and Cagayan Rivers. Cutman could be the old name of Cugman because the watershed map of Cagayan de Oro City shows that the Cugman catchment is adjacent to the Bigaan catchment [22]. Moreover, diorite and serpentine broke through the sandstones and conglomerates of Iponan valley, dipping at 12°. Furthermore, diorite, augite-porphyry, serpentine, jasper, and marble were noted in the conglomerate pebbles. Serpentine is from hydrated magnesium silicate that are relicts of olivine and pyroxene from rocks of origin [24].

3.3. Misamis Oriental soils

The Soil Survey Report 20 presents the primary soil information of Misamis Oriental [25]. The methodology adopted in examining the soil profiles consisted of borings by soil auger, digging of pits, and examining road cuts. The naming of soils uses the USDA classification.

3.3.1. Characteristics of Misamis Oriental soils

Morphological characterization uses standard terminologies in describing the in-situ properties of a soil profile. The physical and chemical characteristics of soil are important information in knowing the status of its fertility and physical conditions that influence crop growth.

3.3.1.1. Morphological and physical characteristics

The soil distribution in Misamis Oriental shows that most of the soil types are clayey; others range from sandy, as for the hydrosols and soil in beach areas; to loam in alluvial formation [25]. Furthermore, the predominant color of soil is reddish; although others have shades of light gray, yellowish gray, brownish gray, reddish brown, red, and black. Organic matter which has undergone decomposition in soils in depressed surfaces and with excessive moisture content is dark brown to black (hue 7.5YR), and hematite which is a common iron oxide causes the red color (hue 7.5R, 10R) of soil [26]. Additionally, dehydrated forms of iron oxide cause brown color to yellowish brown (hue 10YR, 2.5Y, 5Y) in soil. Likewise, the low silica content of the parent material, iron oxide with highly soluble organic matter produces chocolate brown color (hue 2.5YR, 5YR) soil. The soil description presents a consistency that varies from loose to friable, slightly compact to sticky, and plastic; thus, the internal drainage of the soil varies [25].

3.3.1.1.1. Clay mineralogical information

Clay mineral information is vital in knowing the potential presence of elements in the soil to conserve and manage. The presence or absence of elements in the soil that are vital to crops can be due to its mineralogical characteristics as well as the degree of its nutrients' availability during the stage of the parent rock weathering process. The significance of mineral investigations in soil studies is rarely taken importance when studying soil fertility and nutrient dynamics in agroecosystems. This is because of its tedious process and, in developing countries, the absence of the technology and equipment [27]. Less attention is given to soil mineralogical studies in Misamis Oriental. Young islands of the humid tropics have very few pedological studies [28]. However, there are conducted clay mineralogical studies in the presented soil types of Misamis Oriental from different locations in the Philippines using X-ray diffraction techniques. Table 1 shows the clay minerals present in soil types from other places that are also found in some soil types of Misamis Oriental. The clay mineralogical analysis on Claveria found that the soil samples from Hinaplanon exhibited dominant kaolinite, minor goethite/hematite, and traces of feldspar. Soil samples from Tamboboan have gibbsite, minor kaolinite, hydroxyl-AL vermiculite, minor goethite/hematite, and traces of feldspar. The data mentioned earlier are the only information available for clay mineralogical studies in Misamis Oriental soils.

3.3.2. The chemical characteristics

The geological map of the Misamis Oriental shows that the eastern section including Claveria is primarily of volcanic formation. Pyroclastic materials covered the eastern part of the province during volcanic activities in the Pliocene-Quaternary periods. The soil great group Andosol occurs in volcanic regions all over the world including the Philippine archipelago [30]; which accommodates soils from volcanic glass-rich ejecta under almost all climates except for hyper-arid conditions. Andosol is a soil great group classification of the International Union of Soil Sciences – World Reference Base (IUSS-WRB) for soil reports published by the Food and Agriculture Organization [30], and is equivalent to Andisol of the Keys to Soil Taxonomy of the United States Department – Natural Resources Conservation Service (USDA-NRCS) [31]. Andosol is an immature soil and could quickly evolve with time. Radical transformation alters soil mineralogy and chemistry [32-33] except if thick vegetation and higher elevation locations protect the soil [34]. The disturbance of the ecosystems because of anthropogenic activities can be a factor in the fast transformation of Andosol into other soil groups [35]. Soils with andic properties have high organic matter (OM) content [36], because of allophanic substances in volcanic soils that delay the mineralization of soil organic carbon [37]. Soils of volcanic heritage have naturally low pH, have low phosphorus (P), and have high-risk levels of aluminum (Al) toxicity [2]. The volcanic characteristics are among the reasons for low soil pH. Moreover, the presence of allophanic substances causes the slow release of inorganic P in soil [37]. A high risk of Al toxicity occurs when the soil pH is <5.5 [38]. Several coconut trees in Linabu, Balingasag suffered mild to severe boron (B) deficiency [39]. The presence of short-order range minerals in volcanic soils influences the availability of B in soils [40]. The soils in the western part of the province are calcareous. Sedimentary rocks are of sandstone, claystone, conglomerates, and limestone form calcareous soils. Ultrabasic metamorphosed igneous rocks are present in patches. Parent materials influence most chemical properties of soils originating from limestone [28]. Calcareous soils usually are high in pH, high in calcium (Ca), but have the risk of B toxicity [38]. Soils originating from ultrabasic rocks are less fertile, which is a constraint to crop production [41]. The conditions for plant growth are not favorable in soils with serpentinite parent materials because they are depleted in essential nutrients such as Ca, potassium (K), and P, and contain high levels of magnesium (Mg), iron (Fe), and trace elements such as nickel (Ni), chromium (Cr), cadmium (Cd), cobalt (Co), copper (Cu), and manganese (Mn) [42].

Table 1. The clay mineralogical analysis of some soil types that can be found in Misamis Oriental province.

Misamis Oriental Soil type	Location of soil types studied	Minerals	Location of soil type in Misamis Oriental [25]
Jasaan Clay	Claveria, Misamis Oriental	Kaolinite, goethite/hematite, gibbsite, vermiculite, and feldspar [11]	Claveria, Jasaan, Balingasag, Cagayan de Oro
Bolinao clay	Negros Occidental	Chlorite, quartz, alkali feldspar, montmorillonite [29]	Alubijid, El Salvador, Initao, and small portions of Cagayan de Oro, and Lumbia, bordering Bukidnon
Faraon clay	Negros Occidental	Montmorillonite, kaolinite, meta halloysite, chlorite, hydrobiotite, and gibbsite [29]	The western part of Initao and the rolling hills of Manticao from the coast to the border of Lanao province
San Manuel loam	Negros Occidental	Kaolinite, montmorillonite, cristobalite, halloysite, goethite, and attapulgite [29]	Along the banks of the Iponan, Tagoloan, and Cagayan Rivers
Rough mountain lands	Negros Occidental	Kaolinite, goethite [29]	Found in rough and hilly lands bordering Bukidnon, Lanao, and Agusan

The disturbance of the ecosystems because of anthropogenic activities can be a factor in the fast transformation of Andosol into other soil groups [35]. Soils with andic properties have high organic matter (OM) content [36], because of allophanic substances in volcanic soils that delay the mineralization of soil organic carbon [37]. Soils of volcanic heritage have naturally low pH, have low phosphorus (P), and have high-risk levels of aluminum (Al) toxicity [2]. The volcanic characteristics are among the reasons for low soil pH. Moreover, the presence of allophanic substances causes the slow release of inorganic P in soil [37]. A high risk of Al toxicity occurs when the soil pH is <5.5 [38]. Several coconut trees in Linabu, Balingasag suffered mild to severe boron (B) deficiency [39]. The presence of short-order range minerals in volcanic soils influences the availability of B in soils [40]. The soils in the western part of the province are calcareous. Sedimentary rocks are of sandstone, claystone, conglomerates, and limestone form calcareous soils. Ultrabasic metamorphosed igneous rocks are present in patches. Parent materials influence most chemical properties of soils originating from limestone [28]. Calcareous soils usually are high in pH, high in calcium (Ca), but have the risk of B toxicity [38]. Soils originating from ultrabasic rocks are less fertile, which is a constraint to crop production [41]. The conditions for plant growth are not favorable in soils with serpentinite parent materials because they are depleted in essential nutrients such as Ca, potassium (K), and P, and contain high levels of magnesium (Mg), iron (Fe), and trace elements such as nickel (Ni), chromium (Cr), cadmium (Cd), cobalt (Co), copper (Cu), and manganese (Mn) [42].

3.3.3. Areal soil distribution in Misamis Oriental

The soil survey report of Misamis Oriental was published in 1954, and at present, is used as the primary soil information of the province. Soils are classified according to; (1) soil series, (2) soil type, (3) soil phase, (4) a complex, (5) miscellaneous land types, and (6) undifferentiated soils [25]. A soil series is a group of soils with similar profile characteristics and parent materials under the same climatic conditions and vegetation. The soil type is the least soil-mapping unit in the Philippines. The soil phase is the variation within the soil type in some minor features. A complex is an association or intimate mixture of different soil types; which is difficult to separate the types in the map. The name of the complex is after the soil type of the dominant member(s). Miscellaneous land types do not have true soil such as riverbeds, bare rocky mountains, and beaches. Undifferentiated soils do not have information because of their inaccessibility, like mountains and forests. Soil types in the Misamis Oriental are predominantly clay, while others range from loam to clay loam. Hydrosols and beaches have sandy soils. Table 2. presents the distribution locations of soils in the province. Soil groupings are based on their topographic locations. Soils in rolling areas and high uplands constitute about 55.79% of the total land area of Misamis Oriental. Soils in the plains and valleys that occupy 28.56% of the total land area are suitable for crops. Undifferentiated soils that are the locations of slash-and-burn agriculture take up 14.09%. Miscellaneous lands which have insignificant agriculture value cover 1.56% of the total land area of the province.

Table 2. Distribution and locations of soils in Misamis Oriental, Philippines [25, 43].

Topographic groups	Soil type	Parent materials	Soil order/soil great group	Location
Soils in rolling areas, high uplands, and mountains	Jasaan clay	Volcanic rocks such as basalt and andesite	Ultisols Hapludults	The largest areas are mapped in Claveria, Jasaan, and Balingasag. Others are on Gingoog-Claveria Road and in Cagayan de Oro along Bugo-Malaybalay Road. Soil type covers 34,967 ha or 8.94% of the province.
	Jasaan clay, stony phase	Volcanic rocks such as basalt and andesite	Ultisols Hapludults	This soil is in the upland and rolling areas of Cagayan de Oro, and the rolling and hilly areas above the coastal plain from Jasaan to Cagayan de Oro. The mapped area is 18,864 hectares.
	Jasaan clay loam	Volcanic rocks such as basalt and andesite	Ultisols Hapludults	This soil occurs in the southern part of Lumbia; along the Cagayan de Oro River up to the border of Lanao province. Soil type covers 18,816 ha or 4.80% of the mapped areas in the province.
	Jasaan-Bolinao complex	Volcanic and sedimentary rocks	Ultisols Hapludults Alfisols Hapludalfs	This soil is an association of Jasaan and Bolinao soils. This occupies the hills east and west of Jasaan. The area covered 4,593 ha.
	Lourdes clay loam	Weathering of undifferentiated metamorphic rocks, and sedimentary rocks; such as sandstone and shale		The soil is found in Lourdes, Alubijid, in the western part of Lumbia, and the southwestern part of Cagayan de Oro. The area occupied is 35,227 ha or 8.99% of the total area of the province.
	Camiguin clay	Volcanic sands and rocks; such as basalt and andesite	Inceptisols Eutropepts	The soil is widely distributed in Camiguin Island and Kinoguitan, which have giant boulders and rock outcrops. The area occupies 67,102 ha.
	Bolinao clay	Coralline limestone residues	Alfisols Hapludalfs	The soil occupies particularly the whole municipality of Alubijid and El Salvador and a large portion of Initao. Small portions occur in Cagayan de Oro and Lumbia that border Bukidnon. The total area is 23,953 ha.
	Faraon clay	Coralline limestone	Ultisols Hapludults	The soil occupies the western part of Initao and the rolling hills of Manticao along the coast to the border of Lanao province. The total area is 5,265 ha.
	Alimodian clay	Stratified shales and sandstone	Alfisols Haplustalfs	The soil is found mainly in the eastern part of the province to the border of Agusan province. It occupies a total area of 9,730 ha.
	Mountain soil undifferentiated	This soil is found in the high mountains of the province, and the rough hilly mountain ranges bordering Lanao, Bukidnon, and Agusan. It occupies a total area of 111,883 ha or 28.56% of Misamis Oriental		
	San Manuel loam	Alluvium	Inceptisols Dystropepts	The soil is found along the banks of the Iponan, Cagayan, and Tagoloan Rivers,

Soils on plains, valleys, and undulating areas				and the plain in Medina. It occupies 13,463 ha or 3.44% of the total area of the province.
	Umingan loam	Alluvium	Inceptisols Eutropepts	The soil is found in Balingasag-Lagonglong and the Alubijid plains. The total area is 5,577 ha or 1.42% of the total provincial area.
	Umingan clay loam	Alluvium	Inceptisols Eutropepts	The occupied areas are small and scattered; and are associated with Umingan loam and San Manuel loam. The mapped area is 2,502 ha.
	Bantog clay	Alluvium	Vertisols Pellusterts	The largest areas of the soil are the plain in Gingoog City proper, and along the coastal plain from 143 km to 160 km going to Agusan province. This soil is also found in the eastern parts of Cagayan de Oro, and parts of the plains in Opol and Alubijid. The total mapped area is 5,045 ha.
	Matina clay	Alluvium		The soil is found along the plain of Lourdes, the coastal plain of Manticao, and the rice fields between the Cagayan de Oro and Iponan Rivers, from 7 km to Opol. The total mapped area is 4,709 ha.
	Mambajao clay	Recent alluvium	Ultisols Hapludults	The soil is scattered in Camiguin island and the eastern part of the province. The largest identified area is between Gingoog and Medina, and between Talisayan and Kinoguitan. The area occupies approximately 23,877 ha or 6.10%.
Miscellaneous land types	Hydrosol	Alluvium	Entisols Hydraquents	The soil is usually found at the mouths of the rivers and some bays. The area occupies 2,115 ha or 0.54% of the total area of the province.
	Beach sand	This is a narrow strip of sand along the seashore that occupies 3,993 ha.		

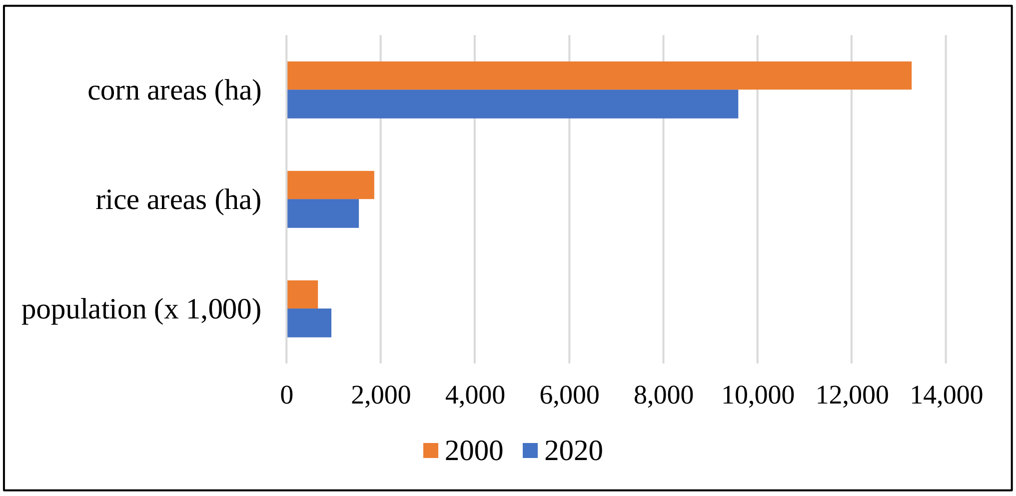

Figure 2. Population versus land areas planted with rice and corn in 2000 and 2020, Misamis Oriental, Philippines [3]

3.4. Soil degradation risks

This section takes up the problems associated with the geo-ecological environment of Misamis Oriental: soil erosion, soil salinization, and decline of soil productivity.

3.4.3. Soil erosion

Rainfall intensity, soil characteristics, topography, vegetative cover, land use, and management affect soil erosion [44]. Removal of soil particles from the ground surface by the impact of a falling raindrop is the onset of the soil erosion process. The greater the rainfall intensity, the more soil particles are dislodged. Runoff tends to carry more soil particles with textures ranging from fine sand to silt, and those with low organic matter. A major part of agricultural lands is located in rolling areas, high uplands, and mountains. Soils located on high-degree slopes are susceptible to soil erosion.

3.4.4. Toxic elements in agricultural soils

The identified problems of soil toxicity in rice production areas of the Philippines are; soil salinity, acid sulfate soil conditions, excess organic matter, and deficiencies in nitrogen (N), P, zinc (Zn), sulfur (S), and Fe [45]. Misamis Oriental is among the provinces in Mindanao with Zn deficiency in soils [46]. Furthermore, a total of 35,839 hectares of irrigated areas in Northern Mindanao have soil N and P deficiency. The said soil problems exist at present and could be contributing factors to the insufficiency of rice production in the province.

3.4.3. Soil salinization risks in agricultural areas along the coastlines

Crops do not tolerate high amounts of salts in soil; thus, an accurate assessment of salinity level is essential in crop production management. Soil salinization includes saline, sodic, and alkaline soils. Drivers of soil salinization are both natural and anthropogenic. Natural factors are due to the kind of soil parent materials and the soil characteristics. Submerged geological formations in seawater have salts embedded in them and when these rocks are uplifted and eventually form the soil, they release the salts during the weathering process [47]. Limestone rocks of Opol are among those submerged formations in the Philippines [21]. The geomorphology of Opol, for instance, hills and plains of limestone formation account for 89% of the total municipal area [48]. Large areas in the western municipalities of the province are on limestone formation.

Sea level rise, which is now a critical issue due to climate change, causes widespread flooding of seawater on land; affecting particular areas that are near the shoreline. Misamis Oriental has identified flooding areas in the municipalities as part of its disaster risk reduction and management initiatives [16]. Opol has identified agricultural areas with soil salinization problems [48] however, their exact locations and severity are not indicated. Studies in seawater intrusions through rivers in the coastal municipalities of Medina, Opol, and El Salvador in Misamis Oriental were conducted by profiling their respective electrical conductivities [49-50]. Seawater intrusion through the Digot River along Poblacion, Medina has already been noted [49]. Plausible seawater intrusion through the Buncalalan River in Opol reaches about 1.9 km, and the Amoros River, El Salvador City to about 1.5 km inland [50]. The electrical conductivity values of seawater are 50,000 $\mu s\text{-}cm^{-1}$ while typical drinking water ranges from 200 $\mu\text{-}cm^{-1}$ to 800 $\mu s\text{-}cm^{-1}$. Electrical conductivities higher than drinking water in wells along coastal areas can be signs of salinity. Saline water intrusion through rivers may not be isolated to Medina, Opol and El Salvador only but may also occur in all coastal municipalities of Misamis Oriental which have rivers that terminate to the Macajalar Bay. The presence of saline groundwater can contaminate agricultural soils if the aquifer characteristics favor the conditions [47]. Anthropogenic drivers of soil salinization are inland fisheries development and groundwater mining. Fishponds pave the way for inland seawater intrusion. Excessive groundwater abstraction in coastal areas causes saline water intrusion into the groundwater aquifers. Soil electrical conductivity characterizes the soil salinity of agricultural soil [51]. Indicators of saline soil are white crust formation on soil; and the glossy, black color of paddy soil at saturated field conditions [52]. Additionally, when the soil is drying, if Na-saturated, micro-cracks appear, and if Ca-saturated macro-cracks develop.

3.4.4. Land use conversion from agriculture to other uses

Misamis Oriental has declining areas planted with rice and corn. Conversion of agricultural lands to industrial and residential uses is apparent but there is no report about its impacts on the food security of the province. Figure 2 shows the comparison of 2000 and 2020 data on population vis-a-vis areas planted with rice and corn. The population of the province is increasing while the hectarage of staple food production areas is declining. The impacts of land use conversion to food security and the agricultural economy of Misamis Oriental are not known. This situation should be studied and understood because this can threaten the staple food supply for the province. Suitability assessments on rice-based cropping systems on the Bantog series conducted by [53] generated pertinent information that is helpful when deciding to change land use. Misamis Oriental has Bantog clay in the coastal plains of Gingoog, Opol, and Alubijid, which are also at risk of conversion to industrial and residential uses. Researchers may conduct similar studies in [53] for Misamis Oriental.

4. RECOMMENDATIONS

Recommendations based on the findings of this literature review are the following:

4.1. Conduct soil research in other areas of volcanic parent materials

Claveria is a highland municipality that has volcanic parent materials and its soils are relatively well studied. The city of Gingoog and the municipalities of Balingasag, Medina, Magsaysay, and Talisayan of the province have agricultural areas greater than 10,000 ha, respectively [16]. It is recommended to conduct soil studies in these agricultural areas of relatively low elevations to have balanced information about the soils of Misamis Oriental. It is recommended to develop a soil information system for the province that will serve as the database on essential parameters that indicate soil health and land suitability.

4.2. Detailed examination of soil with limestone parent materials

It is recommended to conduct a detailed examination of soils with limestone parent materials which provide useful information in formulating strategies for calcareous soils and crop management in the western part of Misamis Oriental. Alubijid, Opol, Manticao, and El Salvador have agricultural areas greater than 5,000 ha [16]. Since limestone parent materials may produce soils that are different from volcanic parent materials, it is also recommended to develop a soil information system dedicated to this part of the province.

4.3. Survey of areas that are on the verge of salinization

It is recommended to investigate the occurrence of soil salinization and other soil degradation issues in rice areas along the coastal municipalities. As reported in some municipalities, seawater inundation and flash floods happen in coastal municipalities. Municipalities to study are those that have significant contributions to the rice and corn production of the province. Studies should include soil degradation risks and parameters to investigate, among other essential data for crop management, which are soil electrical conductivity, soil pH, soil salinization, soil sodication, and cation exchange capacity.

4.4. Conduct of soil erosion studies

As there is no substantial data on soil degradation, it is also recommended to conduct soil erosion investigations to see the severity of land degradation in Misamis Oriental watershed areas. The methodology may range from reconnaissance, point measurements, volumetric measurements, field plots, and remote sensing techniques, depending on the applicability of the procedure and the peculiarity of the research.

4.5. Conduct land use change studies in Misamis Oriental

It is essential to study the land use change of the province to account for the decline of areas for staple food production. Socioeconomics should be the leading component of the study. The investigation shall include the triggers of land use change, the quantity of food lost because of land use shift, and the subsequent impacts on the food security of the province. The province should come up with adaptation strategies and mitigating measures to buffer the losses of food production because of increasing land use shifts.

5. CONCLUSION

The review paper presents the background of Misamis Oriental's geology and associated rocks, soil morphology and physico-chemical characteristics, and the geo-ecological issues, and concerns behind using soil resources. Soil information dates back to 1954 but until now this is the basis for agricultural development planning of the province. The majority of the soil parent materials in the eastern part of Misamis Oriental are volcanic in origin. The western part of the province has sedimentary rocks of different ages with ultramafic basement. Soil mineralogy information in the province is limited. Most of the soil types in Misamis Oriental are clayey. Sandy and loam are also found in beach areas and alluvial formations. Soil drainage is variable because of different soil consistencies. Soil mineralogical studies are very limited. Signs of soil quality decline and increasing soil toxicity problems were noted. Warnings of saline water intrusion are already evident in wells and surface waters along the coastal areas in the province. The production areas for rice and corn are decreasing while the population is increasing over time.

Available information from soil studies in Misamis Oriental is insufficient. There are soil, crop, and farming community studies in the municipality of Claveria but there is no information, or if there is, still not adequate in other municipalities and cities of the province. It is recommended to develop soil information systems for Misamis Oriental. It is further recommended to study soil degradation risks specifically on soil erosion and soil salinization. The government of Misamis Oriental should look into the impacts of land use changes on the food security of the province and the socio-economic conditions of the rice and corn farmers.

Author Contributions: This paper is solely the work of the author.

Funding: Writing of this paper was supported by the Madigan Award of Xavier University.

Data Availability Statement: There is no new data generated in this paper. All information contained are from secondary sources.

Acknowledgments: The author acknowledges the comments and recommendations of the unknown reviewers to improve this paper.

Conflicts of Interest: The author declares "no conflict of interest".

6. REFERENCES

Asio, V.B.; Cabunos, C.C. Jr.; Chen, Z.S. Morphology, Physiochemical Characteristics, Fertility of Soils from Quaternary Limestone in Leyte, Philippines. *Soil Science*. Lippincott Williams and Wilkins Inc. 2006; 0038-075X/06/17108-648–661

Bacatio, C.D.; Kubotera, H.; Nanzyo, M; Yamada, I. Partial rejuvenation of the soil of Intavas Demo Farm, Bukidnon, Mindanao, Philippines by volcanic ash materials. Special Review, *Journal of Integrated Field Science,* 2005; 2:19-27.

Baumeister, J.L.; Hausrath, E.M.; Olsen, A.A.; Tschauner, O.; Adcock, C.T.; Metcalf, R.V. Biogeochemical weathering of serpentinites: An examination of incipient dissolution affecting serpentine soil formation. *Applied Geochemistry* 2015; 54, 74-84.

Becker, J.F. *Report on the Geology of the Philippine Islands*. Department of the Interior – US Geological Survey, Washington, 1895.

Boniao, R.; Van Ranst, E.; Shamshuddin, J.; Baert, G. Impacts of Agriculture on Chemical Properties of Soils on Basalt from Mindanao, the Philippines. *Malaysian Journal of Soil Science*, 1995; Vol 2: 19-29.

Briones, R.M. Addressing Land Degradation: Benefits, Costs, and Policy Directions. *Philippine Journal of Development,* 2010; Vol. 37 Iss. 1.. 41-79.

Calalang, G.; Bock, L.; and Colinet, G. Establishing a soil reference system for fertility assessment and monitoring at plot level in the highlands of Mindanao, Philippines. *Eurasian Journal of Soil Science*, 2014; 3 189 – 196.

Calalang, G.D; Bock, L.; Colinet, G.; Hallet, V.; Walpole, P. Natural and Anthropogenic Factors Affecting the Development of Two Highland Agricultural Soils of Bukidnon, Philippines. *Philipp Agric Scientist,* 2023; Vol. 106 No. 2, 116-130.

Canete, S.D; Collado, W.B.; Badayos, R.B.; Sanchez, P.B.; Sta Cruz, P.C. Suitability Assessment of Bantog Soil Series for Potential Enhancement of Rice-Based Cropping Systems. *Philippine Journal of Science*, 2016; 145 (3): 237-247.

Carating, R.; Flores, A. *Extent of Zinc deficiency in Philippine rice soils*. A paper presented during the Zinc Workshop. Bureau of Soil and Water Management, Manila. August 2015.

Daliakopoulus, I.N.; Tsanis, I.K.; Kotroulis, A.; Kourgialis, N.N.; Varouchakis, A.E.; Karatzas, G.P.; Ritsema, C.J. The threat soil salinity: A European scale review. *Science of Total Environment*, 2016; 573, 727-739.

De Selys Longchamps, F. Hydrogeological Study and Groundwater Modelling of Molugan and Buncalalan Watershed, Misamis Oriental, Philippines, MSc Thesis, Université Libre de Bruxelles, Belgium, 2020.

Dejarme-Calalang, G.M.; Colinet, G. A review of soils and crops in the Bukidnon Highlands of Northern Mindanao, the Philippines. *Biotechnol. Agron. Soc. Environ,* 2014; 18 (4). 544-557.

Demetrio, J.F. *Clay Mineralogy of Fifteen Philippine Soil Profiles.* MSc Thesis, Kansas State University, 1968.

Dorner, J.; Dec, D.; Peng, X.; Horn, R. Effect of land use change on the dynamic behaviour of structural properties of an Andisol in southern Chile under saturated and unsaturated hydraulic conditions. *Geoderma.* 2010; 159, 189-107.

Fernando, A.G.S; Tangunan, D. N.; Fernandez, A.R.C.; Lucero, E.S., Manzano, J.A.Jr.; Collantes, M.G.B; Manzano, L.S. Calcareous Nannofossil Biostratigraphy of Indahag Limestone (Western Misamis Oriental, Northern Mindanao). *Journal of the Geological Society of the Philippines,* 2013; 12-21.

Garrity, D.P.; Agustin, P.C. Historical land use evolution in a tropical acid upland agroecosystem. *Agriculture, Ecosystems, and Environment*, 1995; 53 83-95.

Gonzaga, A.P. Jr. Soil Properties and Nutrient Uptake of Corn-legumes Intercropping Under Conservation Agriculture Practice Systems (CAPS) in a Sloping Upland Oxisol. *Journal of Multidisciplinary Studies*. 2015; Vol. 4, No. 1, pp. 25-49.

Heneffe, M. Seawater Intrusions in the Coastal Area of Medina, Misamis Oriental, Philippines. MSc Thesis. Faculté Polytechnique, Université de Mons, Belgium, 2019.

International Union of Soil Sciences Working Group (IUSS WRB). *World Reference Base for Soil Resources 2014, update 2015* International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome, 2015.

Kome, G.K.; Enang, R.K.; Tabi, F.O.; Yerima, B.P.K. Influence of Clay Minerals on Some Soil Fertility Attributes: A Review, *Open Journal of Soil Science*, 2019; 9, 155-188.

Landon, J. R., 1991, *Booker Tropical Soil Manual* – A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics, Longman Scientific and Technical, New York, 474p.

Lantin, R.S.; Quijano, C.C.; Reyes, R.Y.; Neue, H.U. Rice and problem soils in the Philippines and the humid tropics: Past development and strategies for the 21st century. *Philippine Journal of Crop Science,* 1990; 15 (1) 41-47.

Lao, M.M. *History of Cagayan de Oro*, Bustamante Pressand Publishing House, Cagayan de Oro City, Philippines, 1980; 1622 – 1901.

Lesch, S.M.; Rhoades, J.D.; Lund, L.J.; Corwin, D.L. Mapping soil salinity using calibrated electromagnetic measurements. *Soil, Sci. Soc. Am. J.,* 1992; 56, 540-548.

Lobry de Bruyn L.; Prager, K. How can soil data and information become actionable knowledge to advance sustainable land management? *Soil Use Manage,* 2024; 40., e13115.

Lopez, F.B.; Yñiguez, T.M.; Villegas, E.K. *Soil classification and erosion survey of Misamis Oriental Province, Philippines*. AD Bureau, Manila, Philippines, 1954.

Mac Kenzie, W.S.; Adams, A. E. *A Colour of Rocks and Minerals in Thin Sections*, Manson Publishing Ltd, 73 Corringham Road, London NW11 7DK, UK; 1994, 132p.

Magat, S.S; Cruz, L. G. Boron Deficiency of Coconut (Cocos nucifera Lin.): A Field Note. *CORD 17,* 2001; 01, 34.

March 24, 2021. https://www.cropsreview.com/climate-types.html. Climate types in the Philippines, annual rainfall, and typhoon frequency by region. cropsreview.com

Mercado, A. Jr.; Tulin, A.B; Dorahy, C. Soil management and crop nutrition for tomato in acid soil of Claveria, Philippines. In Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia, 1 – 6 August 2010.

Mileti, F.A.; Langella, G.; Prins, M.A., Vingiani, S.; Terribili, F.

The hidden nature of parent material in soils of Italian mountain ecosystems. *Geoderma*, 2013; 291-309.

Municipal Land Use Committee. *Comprehensive Land Use Plan 2014-2022*. Municipal Development and Planning Office, Opol, Misamis Oriental. 2016.

Navarrete, I.A.; Asio V.B.; Jahn, R.; Tsutsuki, K. Characteristics and genesis of two strongly weathered soils in Samar, Philippines. *Australian Journal of Soil Research*, 2007; 45, 153–163.

Navarrete, I.A.; Tsutsuki, K.; Asio, V.B.; Tani, M; Sueta, J. Chemical, mineralogical, and morphological characteristics of a late quaternary sedimentary rock-derived soil in Leyte, Philippines. *Technical Article Soil Science*, 2011; Vol. 176, No. 12. Lippincott Williams and Wilkins, 699-708.

Philippine Council for Agriculture Resources Research and Development (PCARRD). *The Philippine Recommends for Soil Fertility Management*. Philippine Recommends Series No- 36 – D. Philippine Council for Agriculture, Forestry, and Natural Resources Research and Development, Department of Science and Technology. Los Banos, Laguna, Philippines, 2006; 201p.

Philippine Rice Research Institute (Philrice). Management of salt-affected soils for rice production. *Rice Technology Bulletin,* Philippine Rice Research Institute, Department of Agriculture, Philippines. 2001; No. 40.

Philippine Statistics Authority (PSA) Region X. Highlights of Northern Mindanao Population: 2020 Census of Population and Housing (2020 CPH), Philippine Statistics Authority Region X – Northern Mindanao. Republic of the Philippines, 2021.

Philippine Statistics Authority (PSA). Special Report – Highlights of the 2012 Census for Agriculture (2012 CA). Philippine Statistics Authority, Government of the Philippines, 2012.

Pira, M.F.T.; Sumner, M.; Cabrera, M.; Thompson, A. Boron adsorption and desorption of volcanic ash–derived soils. *Soil Science Society of America Journal*, 2018; 82(1).

Plice, M.J. Factors affecting soil color (Progress Report). *Proceedings of the Oklahoma Academic of Science for 1942*, 1942; pp 49-57.

Poudel, D. D.; West, L. T., Soil development and fertility characteristics of a volcanic slope in Mindanao, the Philippines. *Soil Science Society of America Journal*, 1999; Volume 63: 1258-1273.

Province of Misamis Oriental. Disaster Risk Reduction, Climate Change Adaptation, Enhanced Provincial Development Physical Framework Plan. Provincial Government Office, Misamis Oriental, Philippines for 2013-2018, 2013.

Reichert, J.M.; Gubiani, P.I.; Rheinheimer dos Santos, D; Reinert, D.J.; Aita, C.; Giacomini, S. Soil Properties Characterization for Land Use Planning and Soil Management in the Watersheds Under Family Farming. *International Soil and Water Conservation Research*, 2022; 10 119-128.

Renard, K.G.; Foster, G.R.; Weesies, G.A.; Porter, J.P. 1991. RUSLE Revised universal soil loss equation. *Journal of Soil and Water Conservation*, 1991; 46(1): 30-33.

Sajona, F.G.; Bellon, H.; Maury, R.C.; Pubellier, M.; Quebral, R.D.; Cotton, J.; Bayon, F.E.; Pagado, E.; Pamatian, P. Tertiary and quaternary magmatism in Mindanao and Leyte (Philippines): geochronology, geochemistry, and tectonic setting. *Journal of Asian Earth Science*, 1997; Vol. 15, Nos 2-3. pp. 121-153.

Sandoval, M.A.; Stolpe, N.B.; Zagal, E.M.; Mardones, M. The effect of crop-pasture rotations on the C, N, and S contents of soil aggregates and structural stability in the volcanic soil of south-central Chile, *Acta Agriculturae Scandinavica*, Section B-Soil and Plant Science, Taylor and Francis. 2007; 57:255-262,

Sheth, H.C.; Torres-Alvarado, I.S.; Verma, S.P. What is "Calc alkaline" Rock Series? *International Geology Review*, 2002; Vol. 44, p.686 – 701.

Soil Survey Staff. *Keys to Soil Taxonomy*. Twelfth edition. United States Department of Agriculture-National Resources Conservation Service, 2014.

Tsui, C.C.; Tsai, C.C.; Chen, Z.S. Soil organic carbon stocks in relation to elevation gradients in volcanic ash soils of Taiwan. *Geoderma*, 2013; 201, 119-127.

Tulin, A.B.; Quinones, C. M.; Rallos, R.; Mercado, A. Jr.; Salvani, J.; Lapoot, C.; Justo, V.; Dorahy; F. Evidence-based nutrient management strategy in identifying fertility status and soil constraints for vegetable production in the Southern Philippines. In Proceedings of the 19th World Congress of Soil Science, Soil Solutions for a Changing World, Brisbane, Australia, 1 – 6 August 2010.

Yabe, H.; Sugiyama, T. *On Some Reef-building Corals of a Raised Coral Reef of Mindanao, Philippine Islands.* Communication by H. Yabe, December 13, 1937.

Yumul, G.P.Jr.; Dimalanta, C.B.; Maglambayan, V.B.; Marquez, E.J. Tectonic setting of a composite terrane: A review of the Philippine Island arc system. *Geosciences Journal*, 1997; Vol. 12, No. 1. p. 7-17.