REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
MANILA

Soil Report 5

REVISED EDITION OF

SOIL SURVEY OF PAMPANGA PROVINCE PHILIPPINES

Manila
Adbureau
1956

DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

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SOIL SURVEY OF PAMPANGA PROVINCE PHILIPPINES

BY

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WITH A DISCUSSION ON THE CHEMICAL CHARACTERISTICS AND FERTILIZER REQUIREMENTS OF THE SOILS OF PAMPANGA PROVINCE

BY

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HOW TO USE THE SOIL SURVEY REPORT

Soil Surveys provide basic data for the formulation of land-use programs. This report that the accompanying map present information both general and specific about the soils, the crops, and the agriculture of the area surveyed. The individual reader may be interested in the whole report or only in some particular part thereof. Ordinarily he will be able to obtain the information he needs without reading the whole report. Prepared for both general and detailed use, the report is designed to meet the needs of a wide variety of readers under three general groups: (1) Those interested in the area as a whole; (2) those interested in specific parts of it; and (3) students and teachers of soil science and related agricultural subjects. An attempt has been made to meet the needs of all three groups by making the report comprehensive for purposes of reference.

Readers interested in the area as a whole include those concerned with general land-use planning—the placement and development of highways, power lines, urban sites, industries, community cooperatives, resettlement projects, and areas for forest and wildlife management and for recreation. The following sections are intended for such users (1) Description of the Area, in which physiography, relief, drainage, vegetation, climate, water supply, history, population, industries, transportation, markets, and cultural developments are discussed; (2) Agriculture, in which a brief history of farming is given with a description of the present agriculture; (3) Productivity Ratings, in which are discussed and presented the productivity of the different soils; (4) Land Use and Soil Management and Chemical Characteristics of the Soils, in which the present uses of the soils are described, their management requirements discussed and suggestions made for improvement; and (5) Water Control on the Land, in which problems pertaining to drainage and control of runoff are treated.

Readers interested chiefly in specific areas, such as particular locality, farm, or field, include farmers, agricultural technicians interested in planning operations in communities or on individual farms, and real estate agents, land appraisers, prospective purchasers and tenants, and farm-loan agencies. These readers should (1) locate on the map the tract concerned; (2) identify the soils on the tract by referring to the legend on the margin of the map and seeing the symbols and colors that represent them; and (3) locate in the table of contents under the section of Soils the page where each type is described in detail, giving information on its suitability for use and its relations to crops and agriculture. They will also find useful specific information relating to the soils in the section on Productivity Ratings, Land Use and Soil Management, Chemical Characteristics of the Soils, and Water Control on the Land.

Students and teachers of soil science and allied subjects, including crop production, animal husbandry, economics, rural sociology, geography, and geology, will find interesting the section on Morphology and Genesis of Soils and Mechanical Analysis. They will also find useful information in the section on Soils and Agriculture, in which are presented the general scheme of classification of the soils of the province and a detailed discussion of each type. For those not familiar with the classification and mapping of soils, these subjects are discussed under Soil Survey Methods and Definitions and Mechanical Analysis. Teachers of other subjects will find the sections on Description of the Area, Agriculture, Productivity Ratings and the first part of the section on Soils of particular value in determining the relation between their special subjects and the soils of the area.

—Adapted from the U.S.D.A.

ILLUSTRATIONS

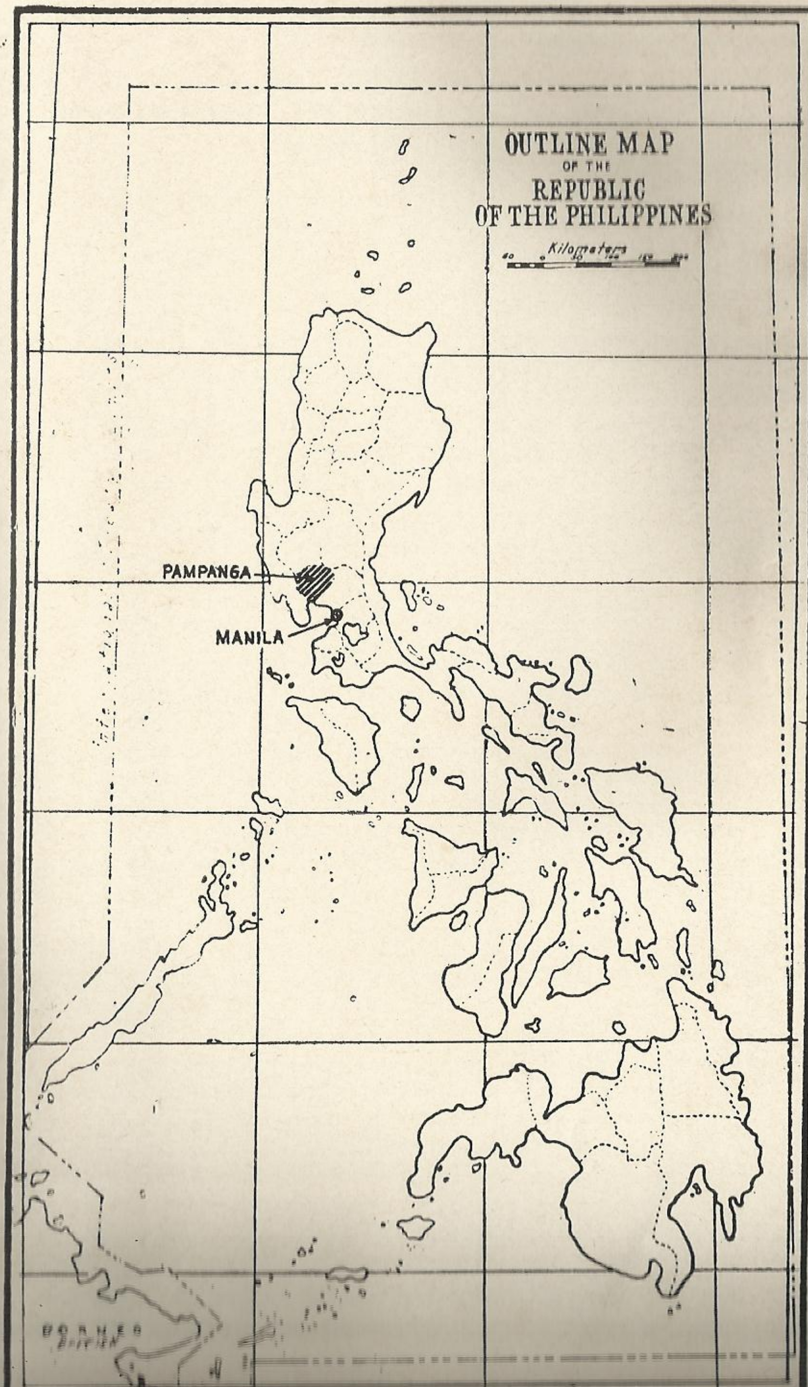

Fig. 1.—Outline map of the Philippines showing the location of Pampanga Province.

SOIL SURVEY OF PAMPANGA PROVINCE, PHILIPPINES

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CHEMICAL CHARACTERISTICS OF THE SOILS OF PAMPANGA PROVINCE

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SUMMARY

Pampanga Province lies in the heart of the Central Plain of Luzon covering approximately 214,193 hectares. San Fernando, the capital, is 67 kilometers north of Manila.

This province constitutes five physiographic sections, namely, the low plain; the narrow strip of land along the western border with several high peaks, among which are Mounts Pinatubo and Negron; the delta of the Pampanga River and its tributaries bordering Manila Bay where nipa palms and mangroves grow; the Candaba Swamp on the Pampanga-Bulacan boundary; and Mount Arayat, an extinct volcano rising solitarily on the northeastern part of the province.

The province is drained by several rivers and their tributaries which empty into Manila Bay. The most important of these are the Rio Grande de Pampanga, Pasig, Porac, and Gumain Rivers.

The natural vegetation consists of non-commercial and commercial forests on the higher hills and mountains; cogon dominates the rolling and hill areas; talahib is found along the riverbeds. Cultivated areas are mostly planted to rice, sugar cane, corn and other locally grown crops.

The province as presently constituted was created in 1901. It consists of 21 towns with San Fernando, Guagua, and Angeles being the biggest towns and the centers of business in the province.

The population of Pampanga was 256,022 in 1918, 371,400 in 1938, and 416,583 in 1948.

Transportation and communication facilities are easily available in the province. All towns are connected with first and second class roads. Regular bus transportation service is maintained by several transportation

companies throughout the province. The Manila Railroad line to the North passes through the province.

Mail, telegraph, and telephone services are available in all towns. Communication by radio and air transportation are exclusively used by the Armed Forces of the Philippines and the United States Armed Forces. Both the Philippines Air Base and the United States Air Base in Pampanga are equipped with first class radio stations.

Public and private schools are available in all towns. Schools of Collegiate level are found in San Fernando, Angeles and Guagua. The Magalang Farm School is located in Magalang and the Pampanga Trade School is in Bacolor. Both schools offer vocational courses.

The sanitary condition of the province is well taken care of by the Bureau of Health which maintains clinics in various parts of the province. The provincial hospital is located in San Fernando. There are also private hospitals in the province and the Philippines and United States Armed Forces have also their own hospitals.

The Roman Catholic Church has a church in all the towns. Churches of other faiths are also found in some towns.

Farming is the most important industry of the province. Fishing is an important industry along Manila Bay and the marshy areas. The most common manufactured articles are sawali, hats, pots of various kinds, nipa shingles, shoes, wooden shoes, and household furniture.

The climate of Pampanga Province falls under the first type of rainfall of the Philippines—two distinct seasons, the dry and the wet season. The dry months are from November to May while the wet months are from May to October. July, August, and September are the months of high precipitation, while March, April, and May are the dry and hot months. December, January, and February are the cool months.

Pampanga is an agricultural province. As of June, 1951, the total area cultivated to different crops was 123,643 hectares or 57.72 per cent of the total area of the province. The total value of the ten leading crops produced in 1948 was ₱32,835,680 and the fruit production of five leading fruit trees was valued at ₱809,900.

Agricultural practices have shown improvement especially in the sugar cane farms, but have not been improved much in the rice farms. Farm machinery and fertilizers are used in the sugar cane farms, while in the rice farms there is a trend towards the application of commercial fertilizers. Rice, sugar cane, and corn are the principal crops. Watermelon, cassava, camote, tomato, eggplant, peanut, and gabi are the secondary crops. Banana, mango, pomelo, chico, and papaya are the five leading fruit trees in the province.

Livestock raising goes hand in hand with crop production. Carabao and cattle are raised for work animals in the farm. Livestock in the province was valued at ₱14,163,100 in 1949. In Angeles, there are few big poultry farms.

The total number of farms in Pampanga, according to the 1948 census, was 19,621, of which 11,063 or 56. 39 per cent, are operated by share-tenants and 1,694, or 8.64 per cent, are operated by owners.

The soils of Pampanga Province are classified and mapped into three groups based on the relief, namely, (1) soils of the flat lowlands, (2) soils of the hills and uplands, and (3) miscellaneous land types.

The soils of the plains comprising a total area of 146,744 hectares consist of seven soil series with thirteen individual soil types of which Angeles fine sand, La Paz fine sand, Quingua silt loam, Bigaa clay loam, and San Fernando clay loam are the more important. They are principally cultivated to rice and sugar cane. The first three types named are the more extensive. The Candaba silt loam and Candaba clay loam and part of the Bantog clay loam are under water during the rainy season to a depth of from 2 to 5 meters. Portions of them are cultivated to watermelon during the dry season when they become dry.

The soils of the hills and uplands have a total area of 11,288 hectares, or 5.27 per cent, of the total area of the province. They comprise three soil series with four soil types. The lower portions of these soils, especially the Buenavista silt loam and Prensa silt loam, are terraced and planted to lowland rice varieties. Some of the upper areas are grown to upland rice, fruit trees and vegetables. Arayat clay loam is covered with non-commercial and commercial forest while Arayat sandy clay loam is partly cultivated to upland rice and vegetables. A greater portion is being reforested.

The miscellaneous land type is composed of the hydrosol and the soils, undifferentiated, each covering an area of 24,011 and 32,150 hectares, respectively. They have no agricultural value. The hydrosol is under water throughout the year where nipa palms and mangroves grow. The fishponds of Pampanga are located in the hydrosol area. The rolling, hilly and mountain regions on the western part of Pampanga are mapped under soils, undifferentiated. Cultivation of these areas is not practicable, but some portions can be used for grazing.

The mechanical analysis of each soil type was performed in the laboratory and the result is presented elsewhere in this report to show the relative quantities of sand, silt, and clay fractions that compose the soil. It serves as a check to the feel method used in the field for the determination of the soil texture.

The productivity ratings of the major soil types of Pampanga are shown in Table 11. The table indicates the comparison between the productivity of the soil types based on the productive capacity of soils under similar conditions of management without the use of fertilizers and amendments.

The soils of Pampanga are classified into land capability classes as guides for their use and management. Under Pampanga conditions, the soils are grouped into seven classes shown in Table 12. Ordinarily, Class A and B soils are croplands on level or nearly level relief and suitable for continuous cultivation of seasonal crops with slight danger of soil erosion. Class D soils are on greater slopes and their suitability for cultivation is limited with complex management and conservation practices. They are preferable for pasture land. Class DA soils are level land but they are imperfectly drained and are under water during the rainy season. They are cultivated during the dry season. Class M, X, and Y soils are not physically suited to farm crops. They include lands best for fishponds and lands best for forest and wildlife.

The different soil series of Pampanga Province are classified into five profile groups, namely, profile groups II, III, IV, VI, and VII, based on the origin, parent materials, degree of profile development, and general relief.

INTRODUCTION

The Philippines is an agricultural country and the greater bulk of the population is engaged in agriculture or its allied industries. The export items to the foreign markets are farm products like sugar, abaca, copra, and oils, but one of the import items worth million pesos is rice, the staple food. This is because the country is not self-sufficient in this important food crop.

Pampanga Province has a very little room for agricultural expansion in proportion to the increasing population. Only about 7,235 hectares are potential lands for possible agricultural extension. And because it is quite extremely difficult to allocate more agricultural lands for the people to ward off the danger of insufficiency of food supply it becomes necessary and essential to look into the problem of how crop yields can be increased per unit area. A re-survey of the soils of the province has, therefore, been conducted in order that the different soil types could be evaluated for their proper uses and systems of farm management and cultivation. Soil samples for each soil type mapped in the province were collected and analyzed for chemical characteristics to determine their fertilizer requirements for the different crops. It is hoped that the results here presented would be considered and attended to in their proper light so that the farmers of the province would have a greater chance to improve their production.

DESCRIPTION OF THE AREA

Location and extent.—The Province of Pampanga, with an area of 214,193 hectares, lies in the heart of the vast Central Plain of Luzon (Fig. 1). It is bounded by Tarlac Province on the north, Nueva Ecija on the northeast, Bulacan on the east and south, and Zambales and Bataan on the west.

Geology.—The province consists of five physiographic sections, namely, (a) the low plain comprising by far the larger part of the province; (b) the narrow strip of highland along the western border consisting of several high peaks, prominent among which are Mount Pinatubu, 1,781 meters high, and Mount Negron, 1,890 meters high; (c) the nipa and mangrove swamps on the deltas of several tributaries of the Pampanga River and other small rivers in the southern part bordering the Manila Bay; (d) the Candaba Swamp on the eastern part between the Pampanga River and Pampanga-Bulacan boundary; and (e) Mount Arayat, an extinct volcano rising solitarily in the Central Plain (Plate 1, Fig. 1).

The soils in the Candaba Swamp and the nipa and mangrove swamps of the hydrosol areas consist of silt and clay

TABLE 1—*Approximate area of the actual soil cover of Pampanga Province* [1]

Kinds of cover	Area in hectares		Per cent	
Commercial forest				
Potential forest	2,655		1.24	
Production forest	3,995		1.86	
Total		6,650		3.10
Forest protection		8,050		3.76
Non-commercial forest				
Potential forest	——		——	
Production forest	860		0.40	
Total		860		0.40
Forest protection		1,400		0.66
Cultivated land		123,643		57.72
Open land				
Potential forest		4,580		2.14
Production forest				
Pasture	12,070		5.66	
Reforestation	11,870		5.54	
Total		23,940		11.18
Swamp				
Fresh marsh	21,040		9.82	
Mangrove	24,030		11.22	
Total		45,070		21.04
Total				
Agricultural land				
Cultivated	123,643		57.72	
Potential	7,235		3.38	
Total		130,878		61.10
Timber land				
Production forest	73,865		34.48	
Protection forest	9,450		4.42	
Total		83,315		38.90
Total soil cover		214,193		100.00

[1] Prepared by the Bureau of Forestry, Department of Agriculture and Natural Resources, June 30, 1951.

materials deposited by water. The plain consists of recent deposits of sandy materials. The elevated highlands on the western border consists of a narrow strip of tuffaceous material. Mount Arayat, on the northeastern part, consists of Tertiary and later effusive rocks, mostly rhyolites, dacites, andesites, and basalts. Figure 2 shows the physiographic map of Pampanga Province.

Drainage.—Drainage is a serious problem in the lower parts of the province, particularly along the Pampanga River and its tributaries. This river often floods the surrounding areas and causes tremendous damage to crops and properties. Because of the disastrous effects of yearly floods, a dike from Arayat to Apalit was constructed and maintained by the Pampanga River Control Project. A river course was also dredged from Apalit by-passing the usual course of the river tributaries to make a direct and short route of the flood waters to Manila Bay. This project has saved millions worth of property and crops since it commenced functioning.

Several rivers drain Pampanga Province. The Rio Grande de Pampanga, with headwaters from Bulacan, Nueva Ecija, and Tarlac Provinces drains the Candaba Swamp and vicinities. This river, before reaching Manila Bay, branches into several tributaries forming the delta occupied by the nipa and mangrove swamps and fishponds. The Pasig River, with headwaters from Mount Cumino, drains the rectangular area of Porac-Angeles and Sta. Rita-San Fernando. The course of this river changes every year. The Porac River from the mountains of Dorts and Cumino passes through Porac, Del Carmen, Floridablanca, and then to Lubao. The Gumain River, which irrigates a number of rice fields in San Pablo and Sta. Cruz, barrios of Lubao, empties into the swamps. The abovementioned rivers carry sand and silt materials and deposit them on the plain.

Vegetation.—The province of Pampanga is not naturally endowed with bountiful forest resources. The productive forest area is only 3,995 hectares or 1.86 per cent of the total soil cover of the province. It is mostly found in the eastern slopes of the Zambales mountain ranges. The most important forest product is boho, (*Schizostachyum lumampao* (Blanco) Merr.) which is used for the manufacture of sawali, a very important home industry of Angeles. Rattan ranks second in importance,

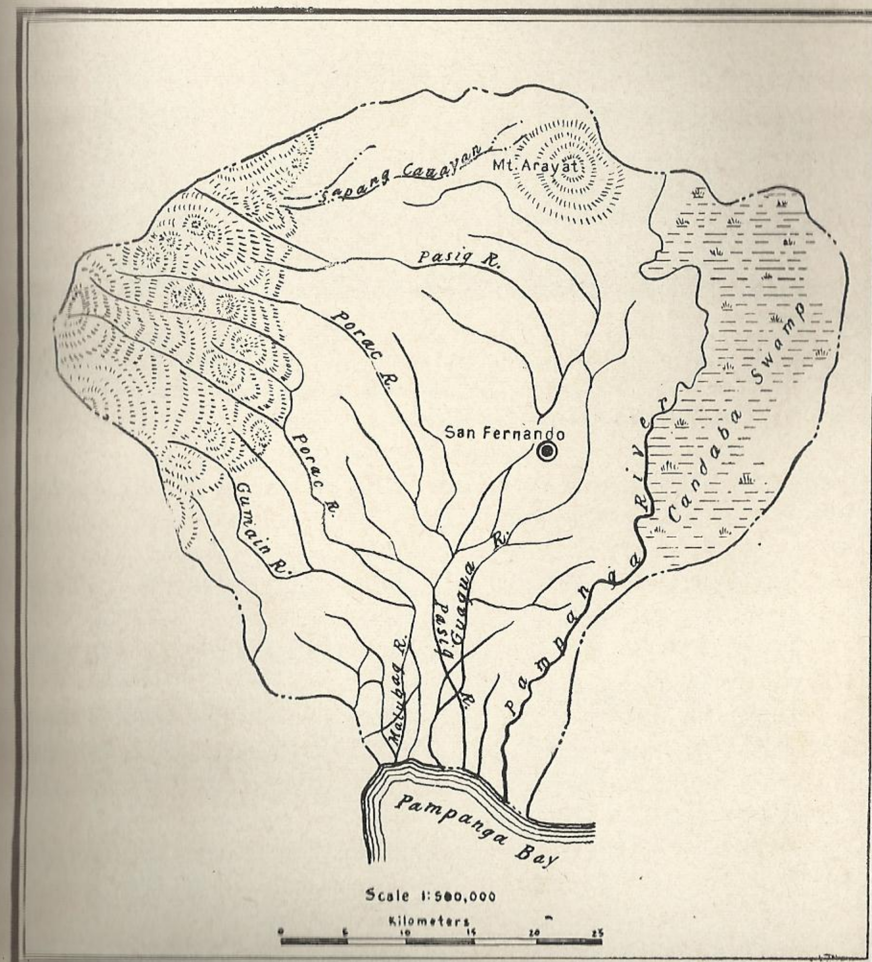


Fig. 2.—Outline map of Pampanga Province showing drainage and general relief.

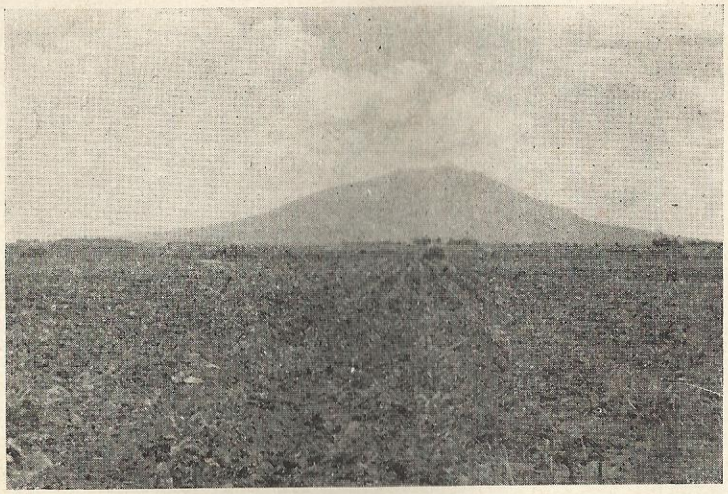


Fig. 1.—Mount Arayat, an extinct volcano rising solitarily amidst the central plain located in the northeastern part of the province. The surrounding areas are all plains cultivated to sugar cane, rice and corn as principal crops.

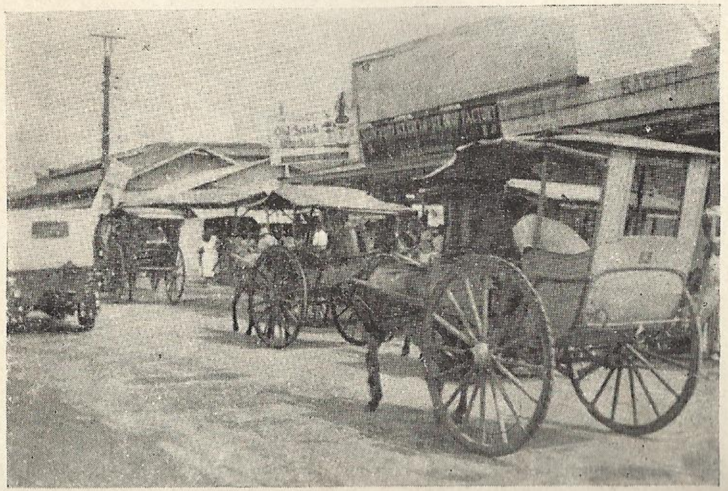


Fig. 2.—A business section of Angeles. Angeles is one of the most progressive towns in the province of Pampanga.

it being used commercially in the manufacture of rattan furniture sets.

Before the last war, the grasslands of the Zambales mountain ranges were devoted to pasture lands but during the Japanese occupation, the industry was wiped out. The present condition of peace and order in the province does not warrant the rehabilitation of the industry hence at present the area is mostly cogonal.

The plain is mostly cultivated to crops such as rice, sugar cane, corn, root crops, vegetables, fruit trees, and legumes.

Settlement and history.—The region north of Manila Bay along the Pampanga River had already been populated before the Spaniards occupied the City of Manila in 1571, and native settlements had already been existing and flourishing in the towns of Lubao, Macabebe, Bacolor, Candaba, and Arayat. Pampanga Province was formally created with Bacolor as its capital. This province occupied a big territory including Bataan, Tarlac, and Nueva Ecija Provinces. However, its area was reduced from time to time. In 1754, Bataan Province was created, and the towns of Dinalupihan, Hermosa, and Orion were included in it. In 1848, the towns of Gapan, San Isidro, Cabiao, San Antonio, and Aliaga were given to the province of Nueva Ecija, and in 1860, the towns of Bamban, Capas, Concepcion, Mabalacat, Magalang, and Porac were given to Tarlac. But in 1873, the towns of Mabalacat, Magalang, Porac, and Floridablanca were returned to Pampanga Province.

In 1901, Pampanga Province with its present boundaries and San Fernando as the capital, was established. This province has an area of 214,193 hectares (Table 1) with a population of 256,022 in 1918, 371,400 in 1939, and 416,583 in 1948. There are 22 towns in this province, the majority of which have modern facilities, such as electricity, telephones, telegraph service, good roads, and other conveniences. The towns of San Fernando, Guagua, and Angeles are the biggest in the province and are the centers of most activities (Plate 1, Fig. 2). This is attributed to the fact that the Clark Air Force Base is in Angeles, the Philippine Army base is in San Fernando, and the presence of sugar centrals, bus transportation terminals, and schools.

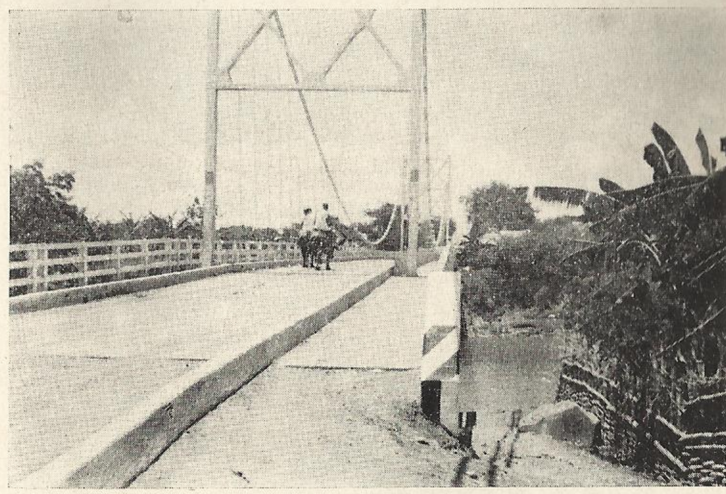
Transportation and communication.—There is in the province a network of first, second, and third class roads connecting all towns (Plate 2, Fig. 5). The first concrete road, a part of the Manila-Baguio road, was constructed in this province (Plate 3, Fig. 1). It passes thru Apalit, San Fernando, Angeles, and Mabalacat. The main line of the Manila Railroad Company to the North passes through this province. There are several railroad lines connecting the sugar cane regions owned and operated by the sugar centrals. Busses to various parts of the province with San Fernando as a terminal are available. The largest bus company operating in the province and to Manila and other provinces is the La Mallorca-Pambusco. There are several smaller companies with few buses operating within the province and to Manila with either San Fernando or Angeles as terminal stations. Water transportation by bancas (Plate 3, Fig. 2) and small motor boats is very common in the western towns especially among dwellings in the hydrosol areas. This is also a popular means of transportation in the eastern part during the rainy season.

Guagua is the only port of entry in the province. Barges and launches of the Luzon Stevedoring Company call at this port to ferry sugar products from Pampanga Sugar Development Company and Pampanga Sugar Mill to Manila via the Pampanga River and Manila Bay. U.S. Army and Airforce supplies from barges coming from Manila for the Clark Air Force Base in Angeles are also unloaded in this port.

Mail and telegram facilities are available in every town. The provincial government maintains a telephone system connecting all towns, some haciendas, and sugar centrals. The Philippine Long Distance Telephone Company operates in San Fernando and other big towns connecting the province with other provinces in Luzon, including Manila.

There are three airfields in the province, two of which are owned by the Armed Forces of the Philippines, one is in San Fernando and the other is the Basa Air Base in Floridablanca. The Clark Air Force Base located in Angeles is a property of the United States Government. These air bases are equipped with first class radio stations.

Schools, public health, and churches.—The province of Pampanga has public schools giving primary, intermediate, and secondary high school instruction in all municipalities. The Pampanga Trade School in Bacolor and the Magalang Farm School offer vocational courses. The latter is an agricultural



Candaba bridge, one of the numerous bridges that span the wide rivers of Pampanga. Recently constructed in order to envigorate the flow of farm products into the markets from the outlying towns otherwise separated by rivers.

PLATE 2

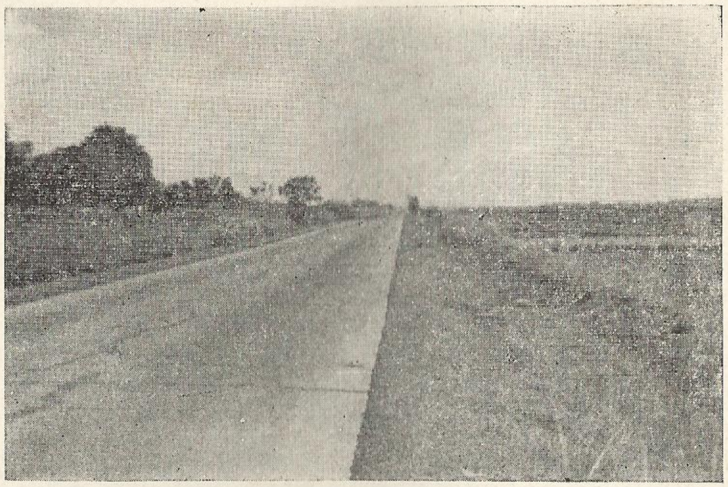


Fig. 1.—The San Fernando-Angeles national highway. These cemented roads were the first to be constructed in the Philippines. A net work of good roads connects all towns to the capital.

Fig. 2.—Bances are popular means of transportation of the barrio people near the river and hydrosol areas. Water transportation is very indispensable especially to those engaged in the bangus and fishing industries of western Pampanga.

high school. Private colleges recognized by the government are maintained in the towns of Angeles, Guagua, and San Fernando. The Catholic Church also maintains parochial schools in almost all towns.

The sanitary conditions of the province are well taken care of by the Bureau of Health which maintains medical clinics in various parts of the province. The provincial hospital is located in San Fernando. Besides, there are private hospitals in some towns aside from the United States Air Force hospital in Mabalacat and the Philippine Army Station hospital in San Fernando. The first class towns have good and sanitary drinking water system while the other towns are adequately provided with artesian wells or water pumps as source of drinking water. The sugar central companies have their own water system for the exclusive use of their personnel.

A Catholic church is available in every municipality. Chapels of different denominations may also be found in small towns. Sunday schools or religious instructions are conducted mostly by the Catholic fathers and sisters in addition to the church services. A non-Christian tribes reservation is found within the jurisdictions of Angeles, Floridablanca and Porac. The reservation is mostly populated by Negritos.

Industries.—Pampanga is mainly an agricultural province. As of 1951, the total cultivated area for agricultural purposes was 123,643 hectares or 57.72 per cent of the total soil cover of the province. Rice is the principal crop. The total area planted to rice is 88,005 hectares with an annual production of 2,585,330 cavans. Second to rice in importance is sugar cane with a total cultivated area of 29,541 hectares. The total production for 1953 was 1,181,640 tons of sugar cane.[1] The greater part of the sugar industry is found in western Pampanga and incidentally the two sugar centrals in operation are located in this region.

The culture of *bañgos* is one of the biggest industries of Pampanga Province (Plate 4, Fig. 1). This industry is located in the towns bordering the deltas of the Gumain, Guagua, and Rio Grande de Pampanga Rivers. The hydrosol in this area is suited for the culture of *bañgos* because the soil conditions favor the growth of the different lower forms of plant life, which are good food for *bañgos*. The young fish, or frys, are import-

[1] Data supplied by the Office of the Provincial Agriculturist of Pampanga.

ed from Quezon, Zambales, Ilocos region, and the Visayan Islands. They are cultured in the fishponds for a number of months before they are brought to the market for sale. *Bañgos* from these fishponds are sold in the different markets in Manila and the neighboring provinces. The estimated total capital invested in the fishing industry of Pampanga is about 94,672,200 pesos.[1] This industry is being developed under modern cultural methods, and adjoining lowland rice areas have been converted into fishponds.

Before World War II, 2,000,000 pesos were invested in the fishing industry in the province. Ayala Company located in San Esteban, Macabebe and the National Food Products Corporation, a subsidiary of the National Development Company, a government corporation were the big corporations engaged in the fishing industry.

Sawali manufacture is a very important home industry in the province. (Plate 4, Fig. 2). *Sawali* is a native name for woven or matted boho which is used for walling and ceiling of houses. Boho is found in the uplands of Pampanga, particularly in Porac. It is also used in various constructions, such as temporary bodegas and warehouses and woven into big baskets for the storing of palay and corn by the farmers.

Hat making is very popular in the barrio homes of San Simon and Apalit, while pot-making which includes the manufacture of cooking pots, drinking pots, and flower pots is a home industry in San Matias and Sto. Tomas.

CLIMATE

Climate refers to the general or average condition of a place in relation to various phenomena of the atmosphere, as temperature, rainfall, humidity, cloudiness, wind direction and velocity as they affect animal and vegetable life. There are four general types of climates in the Philippines based upon the distribution and amount of annual precipitation in the area. To a great extent, the climate of a province has something to do with the cropping system and methods of farming. The most important element of climate that affects the people of Pampanga is rainfall. Heavy rains during the rainy season cause the flooding of the Rio Grande de Pampanga and its tributaries, causing damage to crops and properties.

[1] Data supplied by the Office of the Bureau of Fisheries.

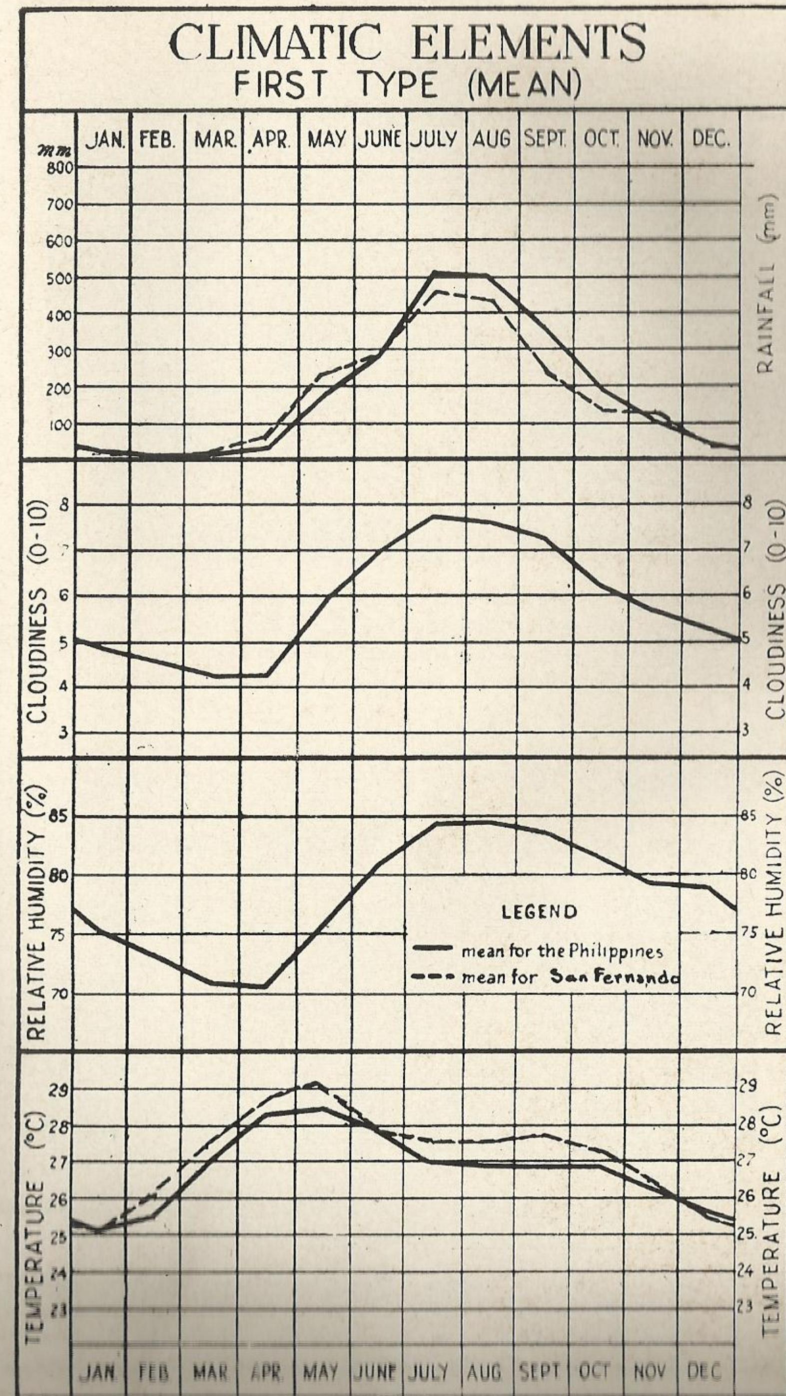


Fig. 3.—Graph of the First Type of climate of the Philippines and of San Fernando, Pampanga.

Fig. 1.—Bangus fishponds in Guagua. The bangus industry is the most important industry associated with the hydrosols. The bangus fry is reared for about a year in these fishponds before they are ready for market. The bangus are shipped to Manila and other provinces.

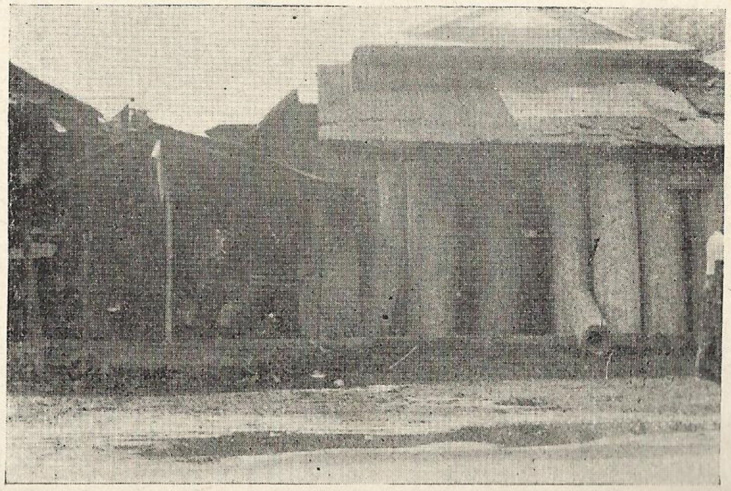


Fig. 2.—Sawali making in Angeles. Woven boho locally known as sawali is a very important industry in Angeles. Sawali is used as ceilings and house walls or woven into big baskets for storage of grains. Boho is obtained in the uplands of Porac and Floridablanca.

The climate of Pampanga falls under the first type, characterized by distinct wet and dry seasons. The dry months are from December to April while the wet months are from May to November. The hottest part of the year is during March, April and May while the heavy rains come in June, July, August, and September, with July registering the heaviest precipitation. Destructive typhoon seldom occurs. Damage to crops and properties due to floods are confined to the lowland areas particularly along the Candaba Swamps and the nipa and mangrove swamps along Manila Bay. The average monthly temperature and rainfall of the four towns of Pampanga are shown in Table 2. Figure 10 shows the graph of the mean of the climatic elements of the first type of climate of the Philippines as compared with that of San Fernando, Pampanga Province.

AGRICULTURE

Agriculture is the most important industry in Pampanga. Pampanga is commonly referred to as the sugar belt of the Central Plain of Luzon and is ranked as the sixth richest province of Luzon. Its actual cultivated area for the different crops as of June 30, 1951 is 123,643 hectares or 57.72 per cent of the total area of the province. Rice, sugar cane, and corn are the main crops.

TABLE 2—*Average monthly rainfall and temperature of four towns of Pampanga Province* [1]

Month	San Fernando			Pampanga Sugar Mills, Del Carmen		
	Rainfall 1920-1932	Temperature 1920 to 1932		Rainfall 1919-1936	Temperature 1924 to 1936	
		Max.	Min.		Max.	Min.
	mm.	°C.	°C.	mm.	°C.	°C.
Jan.	16.3	31.0	19.8	8.2	31.7	20.3
Feb.	7.8	32.2	20.1	16.3	33.0	20.5
March	17.2	33.7	21.0	14.5	34.7	21.4
April	41.1	35.1	22.4	39.1	36.1	22.9
May	224.5	34.5	23.6	203.3	35.3	23.7
June	282.7	32.2	23.6	322.1	32.9	23.6
July	467.3	31.6	23.4	602.4	31.4	23.3
Aug.	481.3	31.5	23.4	609.7	31.5	23.2
Sept.	288.2	32.0	23.4	318.8	31.7	23.0
Oct.	143.9	31.9	22.7	181.9	31.7	22.6
Nov.	132.8	31.2	21.7	120.7	31.5	22.0
Dec.	32.3	30.7	20.6	46.6	31.3	21.3
Total	2,035.8	....	....	2,478.6	....	....

Month	Porac			Arayat		
	Rainfall	Temperature		Rainfall	Temperature	
	1902-1907	1902 to 1907		1902-1907	1902 to 1907	
		Max.	Min.		Min.	Max.
	mm.	°C.	°C.	mm.	°C.	°C.
Jan.	10.2	31.4	19.7	14.8	31.0	20.4
Feb.	5.5	32.7	19.5	5.6	31.8	19.5
March	25.1	34.2	20.1	7.0	34.6	20.6
April	57.3	35.8	22.0	32.4	36.0	23.0
May	261.8	34.7	22.5	131.2	35.2	23.6
June	301.7	32.7	22.5	264.4	32.6	23.8
July	385.0	31.6	22.5	364.5	31.2	23.4
Aug.	329.9	31.2	22.2	201.0	30.8	23.4
Sept.	393.2	31.0	21.9	307.0	31.9	22.9
Oct.	200.5	31.9	29.9	223.0	31.9	22.8
Nov.	80.6	31.2	20.5	95.5	30.9	21.4
Dec.	36.0	31.4	20.5	38.0	30.9	20.5
Total	2,286.8	....	....	1,630.4	....	....

[1] Data supplied by the Philippine Weather Bureau.

The Candaba Swamp, (Plate 5, Fig. 1) is one of the biggest swamps in the Philippines. It is a big body of water during the rainy season, but it is dry from the months of November up to June, when the people utilize the area for the growing of muskmelon and watermelon. These are important crops in the eastern part of the province during summer, when truckloads of watermelon are marketed to Manila and other provinces. The minor cash crops of the people especially in the western part are peanuts, tomatoes, sweet potatoes, cassava, eggplants, and ampalaya. Table 3 shows the ten leading crops of the province.

Rice.—Rice is the principal crop of the province. The census of 1948 shows that the total area planted to both upland and lowland rice was 80,190 hectares or 64.85 per cent of the total cultivated area of the province. A total production of 2,162,400 cavans was obtained and valued at ₱28,217,880. The seasonal occurrence of floods of the Rio Grande de Pampanga have caused yearly destruction to the lowland rice crop of the province. The farmers have adjusted their schedule of planting rice so as not to coincide with the time of floods and heavy rains to minimize the loss of crops due to flood hazard. In the extremely lowland rice fields, planting is done after the heavy rains of September.

There are about 16,000 hectares of irrigable land in the province where two plantings of lowland rice could be possible.

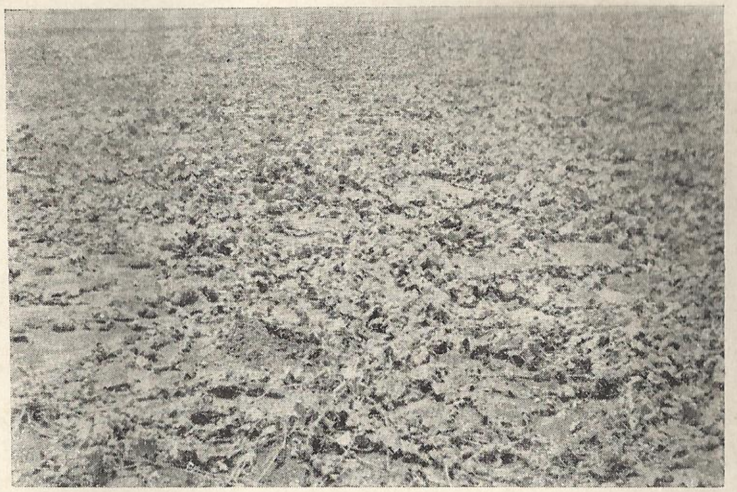


Fig. 1.—Candaba swamp during the dry season. It is principally devoted to watermelons, muskmelons, and vegetables. Dry in November to June but it is a big body of water during the rainy season.

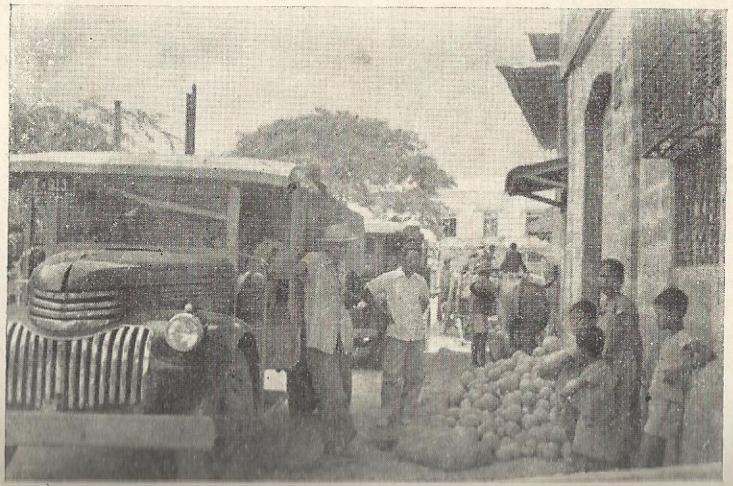


Fig. 2.—Watermelon at harvest time. Truckloads of water and muskmelon are shipped to Manila and the neighboring provinces.

TABLE 3—*Area planted, total production and value in pesos of ten leading crops in 1948.*[1]

CROP	Area planted in hectares	Production (kilos)	Value (pesos)
Rice, rough	80,190	92,162,400	28,217,8880
Sugar cane	3,600	*a* 93,870,000	——
Centrifugal	*a* 4,400	9,483,070	2,374,810
Muscovado and Panocha	*a* 200	548,470	191,960
Molasses	——	2,044,380	58,450
Watermelon	920	3,717,900	743,580
Cassava	680	4,760,000	714,000
Corn, shelled	2,380	1,406,760	246,000
Camote	180	1,080,000	162,000
Tomato	304	336,000	100,800
Eggplant	90	276,000	55,200
Peanut, unshelled	200	120,000	48,000
Gabi	60	120,000	24,000
TOTAL			32,835,680

[1] Data obtained from Facts and Figures about the Economic and Social Conditions of the Philippines, 1948-1949; Bureau of the Census and Statistics, 1950.

a Excluded from total area, production, and value.

This area is located in Bacolor, Sta. Rita, Guagua, and Lubao in the western part of the province, and in Arayat, Mexico, Magalang, Sta. Ana, Candaba, San Luis, San Simon, and Apalit in the eastern part. The eastern towns are irrigated by the Angat Irrigation System, a government owned project, while the western towns are irrigated by private irrigation systems, from the Gumain and Caulaman Rivers. The installation of irrigation pumps along the Rio Grande de Pampanga by the Irrigation Service Unit of the Department of Agriculture and Natural Resources has increased the irrigated riceland area of the province.

The important upland rice varieties planted in the province are Binato, Kinawayan, and Pinursigue with productions ranging from 9 to 15 cavans per hectare. The common lowland varieties are Elon-elon, Raminad, Vencer, and Wagwag. The irrigated areas give an average production of about 45 cavans to a hectare while the unirrigated areas produce an average of about 30 cavans to a hectare. The production of rice in the irrigated areas are much higher than in the nonirrigated areas. This is due to the fact that the nonirrigated areas being rain fed, are often affected by uncertain weather conditions. Sometimes the planting is delayed and in other cases the growing rice plants suffer from drought.

The production of rice per hectare in the province is comparatively low. However, this can be improved and easily in-

Watermelon.—During summer, the Candaba Swamp is dry and is utilized by the people for planting watermelon. In 1948, about 920 hectares of the swamp were planted to watermelon and muskmelon which gave a total production of 3,717,900 kilos valued at ₱743,580. Watermelon and muskmelon by the truck loads from this swamp are marketed to Manila and to other provinces every year. (Plate 5, Fig. 2).

Root crops.—Root crops that are principally grown in Western Pampanga are sweet potato, cassava, and gabi (Table 4). These are usually planted after the harvest of rice and corn. Root crops are used as substitute for rice during the months of food scarcity. Cassava is the most important of these root crops. It used to be an export crop of the province to foreign markets in Europe before World War II. Warner Barnes Company operated a cassava mill in Porac before World War II. At the present time, due to nonoperation of this mill the farmers are reluctant to plant cassava since there is no mill to manufacture flour out of their produce. Table 4 shows the area, yield, and value of each kind of root crop planted in 1948.[1]

TABLE 4—*Area planted, production and value of produce of different root crops in Pampanga.*[1]

Root Crop	Area in hectares	Production in kilograms	Value in pesos
Cassava	680	4,760,000	714,000
Camote	180	1,080,000	162,000
Peanut (unshelled)	200	120,000	48,000
Gabi	60	120,000	24,000

Legumes.—The important legumes planted after the rice and corn harvests are peanut, mongo, beans, and soybeans. The common bean varieties, such as sitao, batao, and patani are planted in scattered and small patches. The towns of Porac, Floridablanca and Sta. Rita in western Pampanga excel in the production of the legume crops.

Vegetables.—Eggplants, tomatoes, ampalaya, onions, and radishes are commonly planted in small areas in various parts of the province. The western towns lead in vegetable production (Plate 6, Fig. 2). The products are marketed in Manila aside from the local markets of the province. Other vegetables

[1] From Facts and Figures about the Economic and Social Conditions of the Philippines, 1948-1949, Bureau of the Census and Statistics, 1950.

Fig. 1.—Eggplants abound in the farm. After the rice harvest, the fields are prepared and planted to vegetables. Vegetable products are shipped to San Fernando and Manila.

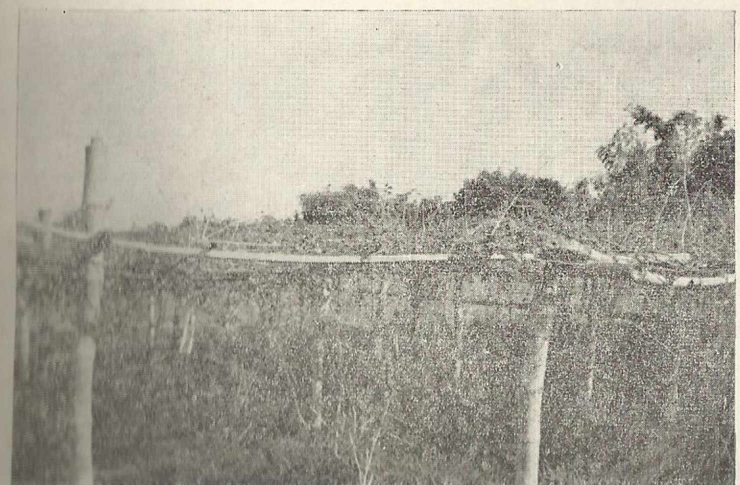


Fig. 2.—Ampalaya in trellises are common in the western towns after the harvest season. Aside from ampalaya, other vegetables like tomatoes, pechay, lettuce, radish, and root crops are raised as cash crops. Crop diversification is limited to vegetables and few fruit trees.

PLATE 6

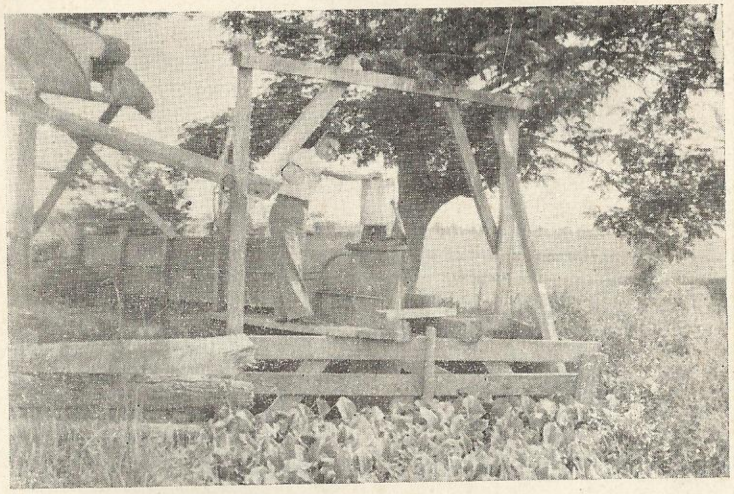


Fig. 1.—A 16-inch pump. This can irrigate a 200-hectare lowland rice farm. Most of the irrigation pumps in Pampanga are installed along the Pampanga River.

Fig. 1.—Irrigation canal from a 16-inch pump. Irrigation water is regulated and brought to the fields by a system of laterals.

grown are pechay, lettuce, cabbage, patola, upo, squash, mustard, garlic, and ginger.

Fruit trees.—The five important fruit trees planted are banana, mango, pomelo, chico, and papaya (Table 5). Banana is extensively grown and is considered the most popular fruit in the markets. This is usually planted along the borders of plantations and in backyards. The common varieties planted are Latundan, Saba, Boñgolan, Lacatan, and Ternate. The fruits are marketed locally or shipped to Manila.

TABLE 5 — *The five leading fruit trees and their area planted, production and value in pesos.*[1]

Kind of Fruit	Area in hectares	Production in kilos	Value in pesos
Bananas	550	546,000	409,500
Mango	450	272,500	261,000
Pomelo	150	178,500	71,000
Chico	30	33,710	35,400
Papaya	60	110,000	33,000

[1] From Facts and Figures about the Economic and Social Conditions of the Philippines, 1948-1949, Bureau of the Census and Statistics, 1950.

Other fruit trees grown in the province aside from those listed in table 5 are orange, jackfruit, atis, lanzones, cashew, guayabano, calamansi, caimito, and avocado. The total production of fruit trees in 1948 was 1,709,500 kilos valued at 942,700 pesos.

AGRICULTURAL PRACTICES

Crop rotation is an important farm practice which, when properly followed, would help in the natural control of weeds, insect pests and diseases, and would maintain soil fertility. This is a practice where a legume crop such as mongo, beans, or soybeans, is rotated with the principal crops—rice, corn, and sugar cane. However, this practice is not common in the lowland irrigated areas and in the sugar cane regions of the province. This is because the lowland irrigated areas of the province are planted to rice twice a year while the sugar cane fields have cane plants for at least ten months a year. Simulated crop rotation is practiced to some extent in the upland areas in the western towns of Pampanga. Different crops are planted but without regard to the kind of crops grown in succession. Peanut, camote, cassava, vegetables, and root crops are planted after the principal crops have been harvested.

This simulated crop rotation offers a good source of farm income and also a distribution of farm labor the year round.

Crop diversification is not a common practice in the province where lowland rice and sugar cane are the principal crops. The climate, which is distinct wet and dry seasons, is not conducive to crop diversification. The dry season is too long and hot for many crops while during the wet season, flood is a common occurence. In the western towns, however, root crops and vegetables are planted, and there are few orchards in the backyards.

There are a number of small private irrigation systems used in irrigating the rice and sugar cane farms (Plate 7, Fig. 1). The biggest of these irrigation systems is found in Arayat and its vicinity. The Angat River Irrigation System, owned and operated by the government is located in the eastern part of the province. This irrigation system irrigates an area of about 16,000 hectares of lowland rice. The area of irrigated lands in the province was greatly increased with the installation of irrigation pumps by the Irrigation Service Unit of the Department of Agriculture and Natural Resources (Plate 7, Fig. 2). These pumps are mostly located along the Rio Grande de Pampanga in the eastern towns.

Previously, the farmers of Pampanga had been giving little attention to the application of commercial fertilizers and lime in their farms. However, the results of the chemical analysis of the soils of the sugar cane districts and some of the lowland rice fields of the province have revealed some interesting facts. The soils of the province have been depleted of plant nutrients after long years of cultivation without proper soil conservation measures and rational fertilization. This fact is shown by the decline of crop yields or the tendency of the yields to go down every year. The farmers now realize that in order to improve or increase the production of their farms, rather than allow them to deteriorate further, the application of commercial fertilizers and lime is of immediate necessity. During the resurvey of the soils of the province, it was found that this agricultural practice has spread extensively especially in the sugar cane districts.

Ammonium sulfate and Ammophos are the common fertilizers used in the province at the rate of 200 to 300 kilograms to the hectare. For the heavily depleted soils about 600 kilograms of fertilizer and 8 tons of lime are applied to the hectare.

Sugar cane planters usually get their fertilizer allocation from the sugar central where they mill their canes, while the rice planters generally get their fertilizers from the Fertilizer Administration of the Department of Agriculture and Natural Resources.

LIVESTOCK

Livestock raising in the province is associated with farm life. Carabaos and cattle are raised mostly as work animals on the farm; horses for transportation; and the rest, such as swines, chickens, sheep, goats, etc., are for table purposes. Poultry and swine raising are very popular among the farmers because they are salable with good profit. The presence of army camps in the province, besides its proximity to Manila a ready market for swine and poultry is assured.

Before World War II, poultry raising was very promising. Big poultry farms were found in Hacienda Pabanlag in Floridablanca, and in Angeles and Mexico. During the Japanese occupation, however, this industry was practically wiped out and the rehabilitation of the industry has been confined mostly to backyard poultry raising. In Angeles, there are few big poultry farms. In 1948-1949, the total value of livestock in the province was ₱14,163,100.

TABLE 6 — *Number and value of livestock and poultry in Pampanga as of January 1, 1948.*[1]

Kind of Livestock	Number	Value in pesos
Carabaos	43,300	10,500,900
Cattle	810	114,210
Horses	3,960	399,960
Hogs	48,240	2,267,280
Goats	8,190	114,660
Sheep	350	5,950
Chickens	232,920	559,010
Ducks	62,850	169,700
Geese	1,250	3,410
Turkeys	2,780	28,020
TOTAL		14,163,100

[1] Facts and Figures about the Economic and Social Conditions of the Philippines, 1948-1949. Bureau of the Census and Statistics.

FARM TENURE

In 1948, there were 19,621 farms of different sizes with a total farm area of 67,405.40 hectares. Table 7 shows the number and percentage of the farms based on different sizes.

TABLE 7 — *Size, number of farms, and percentage distribution in Pampanga Province.*

Size of farms	Number	Per cent
Less than 1 hectare	1,161	5.92
1 to 4.99 hectares	14,730	75.07
5 to 9.99 hectares	3,394	17.28
10 to 24.99 hectares	287	1.49
25 to 49.99 hectares	41	0.16
50 to 99.99 hectares	9	0.04
More than 100 hectares	9	0.04
TOTAL	19,621	100.00

The farms are further classified under different systems of management based on cropping system of the area or productivity of the land.

TABLE 8 — *Number of farms operated by owners, part owners, share-tenants, share-cash-tenants, cash-tenants, and farm managers and other tenants in Pampanga Province.*[2]

Farms operated by:	Number	Per cent	Area (Ha.)	Per cent
Owners	1,694	8.64	4,349.16	6.45
Part-owners	625	3.18	2,624.05	3.89
Share-tenants	11,063	56.39	38,917.47	57.74
Share-cash-tenants	144	0.73	836.10	1.24
Cash-tenants	364	1.86	1,015.03	1.50
Managers	37	0.19	1,922.57	2.86
Other tenants	5,621	29.01	17,741.02	26.32
TOTAL	19,621	100.00	67,405.40	100.00

[2] Census of the Philippines, 1948.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of (a) the determination of the morphological characteristics of soil; (b) the grouping and classification of soils into units according to their characteristics; (c) their delineation on maps; and (d) the description of their characteristics in relation to agriculture and other activities of men.

The soils, their landscapes and underlying formation are examined in as many sites as possible. Borings with the soil auger are made, test pits are dug, and exposures, such as road and railroad cuts are studied. An excavation or road cut exposes a series of layers called collectively the soil profile. These horizons of the profile as well as the parent material beneath are studied in detail, and the color, structure, porosity, consistency, texture, and content of organic matter, roots, gravel,

and stones are noted. The reaction of the soil and its contents of lime and salts and other plant food constituents are determined in the laboratory. The drainage, both external and internal, and other features such as the relief of the land, climate, natural and artificial features are taken into consideration, and the relationship of the soil and the vegetation and other environmental features are studied.

On the basis of both external and internal characteristics, the soils are grouped into classification units, of which the three principal ones are (1) soil series, (2) soil type, and (3) soil phase. When two or more of these mapping units are in such intimate or mixed pattern that they cannot be clearly shown on a small-scale map, they are mapped or grouped into a (4) complex. Areas of land that have no true soil, such as river beds, coastal beaches, or bare rocky mountainsides are called (5) miscellaneous land types. Areas that are inaccessible, like mountain and great forest areas, the classification of which is of no agricultural importance for the present, are classified as (6) undifferentiated soils.

A series is a group of soils that have the same genetic horizons, similar important morphological characteristics, and similar parent material. It comprises soils having essentially the same general color, structure, consistency, range of relief, natural drainage condition, and other important internal and external characteristics. In the establishment of a series, a geographic name is selected, taken usually from the locality where the soil was first identified. For example, the Angeles series was first found and classified in the vicinity of Angeles, Pampanga.

A soil series has one or more soil types, defined according to the texture of the upper part of the soil, or the surface soil. The class name such as sand, loamy sand, sandy loam, silty clay loam, clay loam, or clay is added to the series name to give the complete name of the soil. For example, Angeles silt loam is a soil type within the Angeles series. The soil type therefore has the same general characteristics as the soil series except for the texture of the surface soil. The soil type is the principal mapping unit. Because of its certain specific characteristics it is usually the unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, differing from the soil type only in some minor features, generally external, that may be of special practical significance. Differences in relief, stoniness, and extent or degree of erosion are shown as phases. A minor difference in relief may cause a change in agricultural operation or change in the kind of machinery to be used. The phase of a type with a slight degree of accelerated erosion may need fertilizer requirement and cultural management different from those of the real soil type. A phase of a type due mainly to degree of erosion, degree of slope and amount of gravel and stones in the surface soil is usually segregated on the map if the area can be delineated.

A soil complex is a soil association composed of such intimate mixtures of series, types, or phases that cannot be indicated separately on a small-scale map. This is mapped as a unit and is called a soil complex. If in an area there are several series such as Bigaa, La Paz, Angeles and others that are mixed together, the two dominant series must bear the name of the complex, as Bigaa-La Paz complex or Bigaa-Angeles complex, as the case may be. If there is only one dominant constituent, that series or type bears the name of the complex as Bigaa complex or Angeles complex.

Surface samples for chemical and physical analyses are collected from each soil type or phase, the number being determined by the importance and extent of such soil type or phase. Profile samples are also obtained for further morphological studies of important soil types.

A soil survey party, composed of two or three soils men, maps the area and delineates the various soil types, phases, complexes and miscellaneous land types. All natural and cultural features found in the area are indicated on the soil map. These are trails, roads, railroads, bridges, telephone and telegraph lines; barrios, towns, and cities; rivers and lakes; prominent mountains and many others.

THE SOILS OF PAMPANGA PROVINCE

The soils of Pampanga Province are generally light colored and manifest all shades of colors from light gray, light brown, light reddish brown, yellowish brown and dark brown to nearly black. The light colored soils are mostly found in the well drained plains of sandy texture, while the darker colored soils predominate the lowland areas having poor drainage. On the other hand, the reddish colored soils prevail in the higher, well drained areas of the province. These soils have developed in a climate of long dry and long wet seasons of moderately high rainfall. The heavy precipitation resulted in the leaching of soluble bases, such as calcium, magnesium, potassium, and sodium, thus the surface soils have pH values below pH 7.

The soils of the province have been grouped into two general kinds based on relief: (1) The soils of the flat lowlands, and (2) The soils of the hills and uplands. A third group (3) is the miscellaneous land types. This third group includes the non-agricultural soils. It has been differentiated into hydrosol and undifferentiated soils.

The soils of the first group occupy the plains of the province and have a total area of approximately 146,744 hectares or 70.51 per cent of the total area of the province. They are formed from recent alluvial deposits and have generally level relief with adequate to poor natural drainage conditions. The texture of the surface soil ranges from sand to clay loam or clay. The subsoil varies in consistency from loose and friable to moderately compact and plastic.

Agriculturally, these soils are suited to both specialized and general farming purposes. Due to the fact that they are almost level to very slightly undulating, they can be farmed with a minimum of effort and the problem of conserving their fertility is relatively simple. Any type of farm machinery can be used with good results especially in the sugar cane areas. They respond to good management and become productive when liberally and properly fertilized. The soils have a fair content of organic matter and are well suited for the raising of locally grown crops. Most of the soils are now irrigated. There are, however, low areas especially those that comprise the Candaba Swamps which are under water during the rainy season. These areas are cultivated after they become dry enough—generally after the rainy season.

The soils of the second group comprise approximately 11,288 hectares or 5.27 per cent of the total area of the province. They are formed either from older alluvial deposits or from the weathered products of the underlaying rocks or the weathering of beds of sand. The soils of this group differ in color, texture, consistency, and chemical composition because of the influence of the underlying parent materials. Areas of this group of soils have relief ranging from nearly flat uplands, sloping, undulating, rolling and strongly rolling or hilly. Each of the soils in this group requires one or more special conservation practices to make it more favorable for the production of the common cultivated crops. Their best use depends on the type of soils, type of farm unit, and economic consideration.

This is the group of soils in the province where sheet erosion and gullying are very noticeable. In the strongly rolling areas and steep slopes considerable surface wash and gullying have taken place. The strongly rolling and steep slopes are sometimes grown to clean cultivated crops. These should be retired to permanent vegetation to minimize erosion losses. The undulating and sloping areas should be farmed under terracing, strip cropping, contour cultivation, green manuring, and crop rotation so as to prevent severe losses of soil from erosion and conserve the soils therein.

The two general groups of soils in Pampanga Province have been subdivided into soil series based on the morphological and chemical characteristics of the profile and origin or mode of formation. Each series has been further subdivided into soil types and their phases according to the texture of the surface soil. The soils of the flat lowlands are composed of seven soil series consisting of thirteen soil types, while the soils of the hills and uplands are made up of three soil series comprised of four soil types. The miscellaneous land type group is composed of the hydrosol and the soils undifferentiated.

DESCRIPTION OF THE SOILS

In the following pages are discussed in detail the description and agricultural importance of the soils of the province. Table 9 shows the hectarage, proportionate extent, and the important uses in the province of each of the soil types classified and mapped. The soil map in pocket indicates the distribution of the soil types and land types. The soils of the province are as follows:

I. Soils of the lowlands
   1. Bigaa series
      (a) Bigaa clay loam (3)
   2. Quingua series
      (a) Quingua silt loam (5)
   3. Bantog series
      (a) Bantog clay loam (16)
   4. San Fernando series
      (a) San Fernando clay (68)
      (b) San Fernando clay loam (67)
   5. Candaba series
      (a) Candaba silt loam (69)
      (b) Candaba clay loam (70)
   6. Angeles series
      (a) Angeles coarse sand (71)
      (b) Angeles sand (72)
      (c) Angeles fine sand (73)
   7. La Paz series
      (a) La Paz sand (76)
      (b) La Paz fine sand (77)
      (c) La Paz silt loam (78)

II. Soils of the uplands and hills
   1. Buenavista series
      (a) Buenavista silt loam (9)
   2. Prensa series
      (a) Prensa silt loam (66)
   3. Arayat series
      (a) Arayat clay loam (80)
      (b) Arayat sandy clay loam (79)

III. Miscellaneous land types
   1. Hydrosol (1)
   2. Soils undifferentiated (75)

SOILS OF THE LOWLANDS

The soils of the lowland are the most prized soils of the province because of their relatively higher productivity than the soils of the upland. They are of recent alluvial deposits influenced by the geologic formation of Bulacan, Nueva Ecija, Tarlac, and Zambales Provinces from where most of the soil materials come. The relief is nearly flat to slightly undulating with poor to fairly adequate surface drainage. Internal drainage is good to very poor especially in the Candaba Swamp. These soils occupy the plains of the province covering a total area of 146,744 hectares, or 70.51 per cent, of the total area of the province. Rice, sugar cane, corn, muskmelon and watermelon are the important crops. Seven soil series with thirteen soil types have been identified and mapped.

TABLE 9 — *Area in hectares, percentage and present use of each soil type in Pampanga Province.*[1]

Type No.	Soil type	Area in hectares	Per cent	Present use
1	Pampanga hydrosol	24,011	11.21	Fishponds, nipa and mangrove swamps, and wildlife.
3	Bigaa clay loam	8,953	4.18	Corn, lowland rice, vegetables, and watermelons during dry season.
5	Quingua silt loam	21,569	10.07	Lowland rice, corn, tobacco, tomatoes, & vegetables, fruit trees, like mangoes and bananas.
9	Buenavista silt loam. ..	.364	0.17	Lowland and upland rice and watermelons during dry season.
16	Bantog clay loam	3,855	1.80	Lowland rice and watermelons during dry season. Small amount of corn.
66	Prensa silt loam	2,592	1.21	Lowland and upland rice, corn, vegetables, and watermelon. Few sugar cane and bananas.
67	San Fernando clay loam	6,362	2.97	Lowland rice, sugar cane mangoes, vegetables, and corn.
68	San Fernando clay	2,527	1.18	Sugar cane, lowland rice and corn.
69	Candaba silt loam	3,963	1.85	Slightly elevated areas planted to lowland rice; watermelons during dry season.
70	Candaba clay loam	11,524	5.38	Slightly elevated areas are planted to corn and sugarcane. Watermelons during dry season.
71	Angeles coarse sand ...	8,161	3.81	Vegetables during dry season. Few bananas.
72	Angeles sand	11,609	5.42	Fruit trees, such as mango, citrus, chico, sugar cane, lowland rice, and vegetables, etc.
73	Angeles fine sand	32,279	15.07	Sugar cane, corn, lowland rice, camote, cassava, vegetables, and fruit trees, such as citrus, mangoes, lanzones, coffee, & cacao.
75	Soil, undifferentiated ...	32,150	15.01	For pasture and forest.
76	La Paz sand	4,477	2.09	Lowland rice, sugar cane, cassava, and fruit trees.
77	La Paz fine sand	26,110	12.19	Sugar cane, coconut, lowland rice, cassava, camote, vegetables, and fruit trees.
78	La Paz silt loam	5,355	2.50	Sugar cane, corn, upland and lowland rice, cassava, camote, and vegetables.
79	Arayat sandy clay loam	1,264	0.59	Upland rice and fruit trees.
80	Arayat clay loam	7,068	3.30	Forest and wildlife.
		214,193	100.00	

[1] The area of each soil type was obtained by the use of a planimeter. No deductions were made for areas occupied by roads, buildings, and rivers. Data on total area was obtained from a report of the Bureau of Forestry as of June 30, 1951.

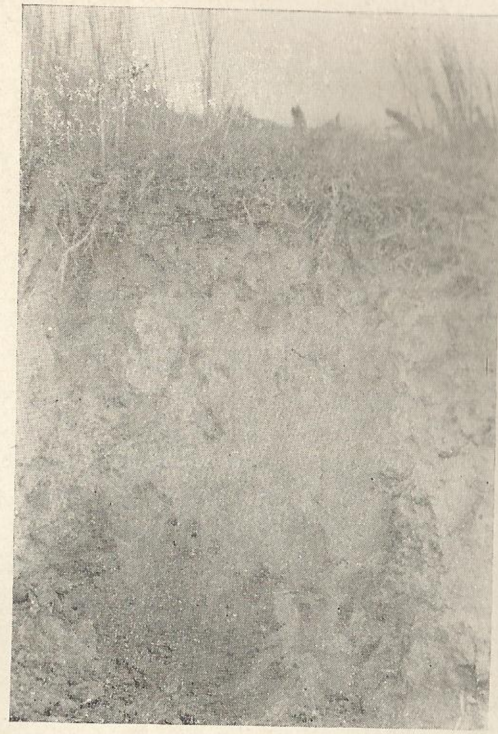


Fig. 1.—This is a typical profile of the Quingua series. It has been formed from recent depositions of soil materials from the surrounding lands.

Fig. 2.—Characteristic of the Quingua series is its level topography. In some cases, it is slightly undulating. It is generally planted to corn, upland rice and sugar cane.

PLATE 8

BIGAA SERIES

The soils of the Bigaa series are formed thru the deposition of alluvial materials from the higher uplands. The relief is nearly level with poor drainage condition and is located along the Pampanga-Bulacan boundary. The surface layer is brown to dark brown with notable reddish brown or dark yellowish brown streaks, compact in some places and loose to slightly compact in other sections. The subsoil is light gray to dark brownish gray mottled yellowish and reddish brown. Concretions are present in both the surface soil and subsoil. Bigaa clay loam is the only soil type mapped under this soil series.

Bigaa clay loam (3).—This soil type is the continuation of the Bigaa clay loam established in Bulacan Province. As it is mapped in Pampanga, this soil type occupies a portion of the Candaba Swamp comprising a total area of 8,953 hectares. The surface soil with a depth of 25 to 40 centimeters is brown to dark brown clay loam with some brick red streaks. It is fine granular is structure, sticky and sometimes plastic in consistency. The subsoil has a depth of from 40 to 60 centimeters from the surface. The texture is clay loam to clay ranging in color from light gray to dark gray and yellowish brown. Iron concretions are present. Below the subsoil is the substratum that reaches to a depth of 120 centimeters. It is light gray clay loam to clay with occasional concretions.

Agriculturally this soil is principally devoted to lowland rice and a limited area is grown to corn, although it is adapted to most of the crops grown in the locality. The soil is not generally fertilized and the production of rice is 45 cavans to the hectare while corn gives 12 cavans to the hectare. Under proper soil management and fertilization this soil will produce a relatively high yield of rice and corn. A small area of this soil is flooded during the rainy season while the other portion is irrigated by the Angat River Irrigation System.

QUINGUA SERIES

Quingua series was first established and mapped in Bulacan Province. Like the Bigaa soil, the Quingua soil is alluvial, formed from recent depositions of soil materials from the surrounding uplands (Plate 8, Fig. 1). However, it differs from the former in that the later has generally a lighter texture from the surface down to the substratum. The relief is level to slightly undulating with fairly adequate drainage conditions (Plate 8, Fig. 2). The soil consists of brown to light brown in the surface layer underlain by a brown to light reddish brown heavier materials. Quingua silt loam is the soil type mapped.

Quingua silt loam (5).—This soil, being almost level to slightly undulating, can be farmed with a minimum of effort. Farm machinery can be used satisfactorily in the sugar cane fields and with some modifications in land preparation it can be used for lowland rice-fields. It is presently planted principally to rice and sugar cane, but the soil is suited to all locally grown crops and would give high production when under good management and properly fertilized. It has a good drainage condition and is easily tilled. A total area of 21,569 hectares is mapped in Arayat, Sta. Ana, Candaba, San Luis, San Simon, Apalit, Masantol, and Macabebe. This soil has the following profile characteristics:

Depth of soil cm.	*Characteristics*
0— 40	Surface soil, brown to light brown, loose and friable silt loam with reddish brown streaks especially in the ricefields. Boundary to the subsoil is clear and smooth.
40— 80	Subsoil, light to dark brown to light reddish brown, silty clay loam to clay loam, loose to slightly compact. The presence of heavier materials is due to the leaching of the fine materials of the surface.
80—100	Substratum is either brownish yellow, reddish brown, yellowish brown, or brown silt loam to silty clay loam.

Indication from the surface soil and subsoil shows that this soil losses its moisture content easily, leaving the surface soil almost dry during the dry season. However, the available moisture supply in the substratum keeps the soil always at its optimum moisture conditions. Normally the yield of rice is 35 cavans to the hectare without fertilizer, and sugar cane gives 60 piculs to the hectare when the soil is not fertilized. This soil will respond readily to proper soil management.

BANTOG SERIES

The soil of the Bantog series is located along the Pampanga-Bulacan-Nueva Ecija border and is developed from materials washed down from the surrounding hills and uplands. It has a brown to dark brown surface soil and a dark brown mottled with brown or yellow and gray, heavy, and plastic subsoil. Bantog clay loam is the only soil type mapped.

Bantog clay loam (16).—A total of 3,855 hectares is mapped of this soil on the northeastern part of the Candaba Swamp. The surface is nearly flat and because of its location, being a part of the Candaba Swamp, it is poorly drained both externally and internally. During the rainy season, the area is under water and it is during this time when fine soil materials are deposited on the surface. Following are the profile characteristics of this soil type:

Depth of soil cm.	*Characteristics*
0— 30	Surface soil, dark brown clay loam, slightly sticky in consistency and fine texture. Absence of stones or gravels and has a diffused and smooth boundary with the subsoil.
30— 90	Subsoil, dark brown to light brown and yellowish brown heavy clay loam to clay, medium columnar to granular structure, compact, plastic and sticky.
90—150	Substratum, grayish clay with brown mottlings, moderately medium granular. There are no gravels or concretions. It is separated by gradual and smooth boundary from the subsoil.

Lowland rice is the principal crop grown in cultivated areas of this soil during the rainy season while watermelon is planted during the dry season. Corn and other locally grown crops can also be grown successfully in this soil during the dry season. The most important hazard to agriculture in this soil is its being under water during the rainy season, sometimes the water reaching up to two meters or more deep. This condition reduces the yield of lowland rice.

ANGELES SERIES

The soils of the Angeles series consist of pale brownish gray, or ash gray to nearly whitish gray in the surface layer. The subsoil is brownish-gray to light reddish-brown sand with gravels. These soils have been developed from the continual deposition of soil materials from the surrounding hills and uplands by flowing rivers. Among the important rivers are Bamban, Porac, Pasig, and Gumain Rivers. The relief ranges from nearly level to slightly undulating and the natural drainage condition is good. It covers the area from Bamban River to Fort Stotsenburg and down to Mabalacat, Magalang, Angeles, Porac, and Lubao, and a portion located in the northern part of San Fernando. Angeles fine sand, Angeles sand, and Angeles coarse sand were mapped.

Angeles fine sand (73).—This soil type has the biggest area among the soils of the Angeles series and, for this matter, among the soils of the province. The surface relief is nearly level to slightly undulating and is well drained both externally and internally. All types of farm machinery can be used. The soil is easy to till and responsive to management. It is not susceptible to serious erosion. However, because of the texture of the soil, crops suffer from lack of moisture during periods of drought. A total of 32,279 hectares was mapped. Under cultivated conditions it has the following profile characteristics (Plate 9, Fig. 1):

Depth of soil cm.	Characteristics
0— 30	Surface soil, pale brownish gray, loose structureless fine sand. Contains fair amount of organic matter.
30— 50	Subsoil, brown to light reddish brown medium sand with sandstones and gravels.
50— 95	Mixture of pale gray to nearly white sand and reddish brown gravels. Gravels are prominent in the lower portion of this layer.
95—110	Gray sand, coarse to medium, structureless with small amount of sand resembling silica.
110—150	Sandstone, coarse, grayish white.

This soil is planted principally to sugar cane and rice (Plate 9, Fig. 2). Under good farm practices and when properly managed, it can be made to produced relatively high yields of the crops. Besides sugar cane and rice, this soil is also suited to practically all locally grown crops. Being sandy by nature, it is essential to add a liberal amount of organic matter and/or practice green manuring besides the application of commercial fertilizer. Organic matter improves the water holding capacity of the soil, conserves plant nutrients and helps to make fertilizer elements more available to the plants.

Angeles sand (72).—This soil is located between the Arayat Mountain and the Angeles fine sand and has total area of 11,609 hectares. It is somewhat similar to Angeles fine sand, but differs from it largely in the texture of the surface soil. Their other external and internal characteristics are relatively the same.

Rice and sugar cane are the important crops grown on this soil. All other crops in the locality can also be readily grown. Management problems, fertilizer, and cropping requirements on Angeles fine sand are also applicable to this soil type.

Angeles coarse sand (71).—This soil type consists of beds of intermittent rivers and creeks which dry up after the rainy

Fig. 1.—Profile of Angeles fine sand. Pale brownish gray fine sand with sandy subsoil and substratum. Presence of gravels and sandstones in the lower strata is characteristic of the soil series.

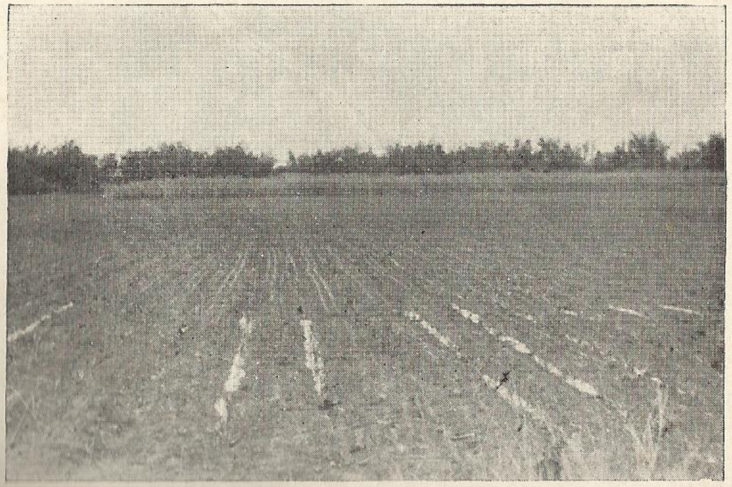


Fig. 2.—Angeles fine sand planted to sugar cane. This is generally level in topography and sandy in texture. Like the La Paz series, it is principally cropped to rice and sugar cane. Production of sugar cane is about 40 tons to a hectare.

PLATE 9

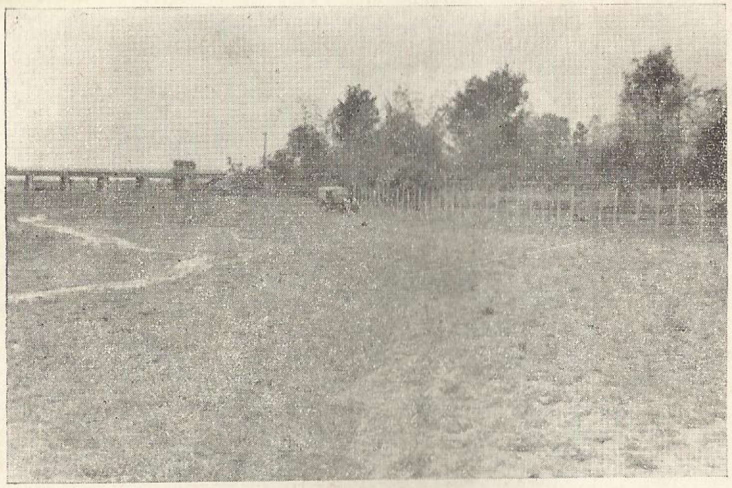


Fig. 1.—Landscape of Angeles coarse sand. It consists of beds of intermittent rivers and creeks which dry up after the rainy season.

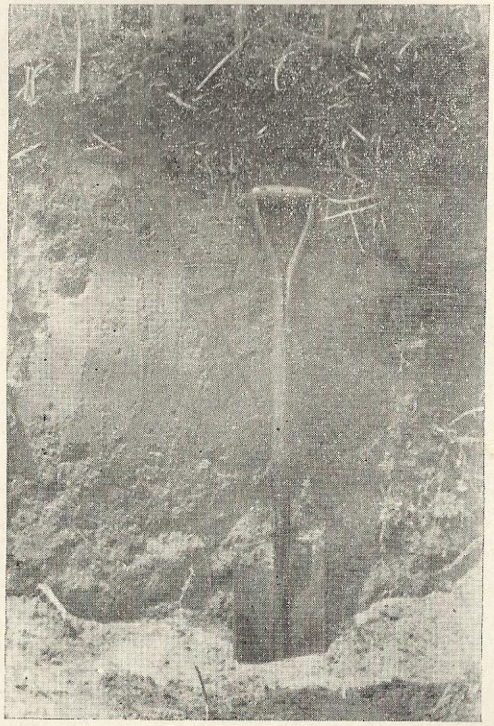


Fig. 2.—Profile of the La Paz fine sand. Pale gray fine sand, loose and structureless underlain by sandy materials and coarser substratum. The absence of gravels differentiates it from the Angeles series, which is similar in many other characteristics.

PLATE 10

season (Plate 10, Fig. 1). Where the rivers and creeks are shallow, most of the materials are deposited along the sides of the banks. This soil type is coarse to medium sand from the surface down to a depth of a meter or more. Gravels are present in the surface and subsoil. The river beds are sometimes utilized for sugar cane and upland rice. A total of 8,161 hectares was mapped.

LA PAZ SERIES

The soils of the La Paz series are quite extensive, covering the vicinities of Lubao, Floridablanca, between Porac and Sta. Rita, Angeles, San Fernando, and parts of Mexico, Sta. Ana, and Arayat. The surface soil is brownish gray to ash gray and a pale-gray to yellowish-gray porous, loose and friable sandy subsoil. The relief is nearly level to slightly undulating. This series is traversed by the Gumain, Porac, Pasig, and Abacan Rivers and their tributaries. Sufficient irrigation water is supplied by these rivers to the fields within the area and the neighboring areas. Drainage condition is good externally and internally. La Paz fine sand, La Paz sand, and La Paz silt loam were mapped.

La Paz fine sand (77).—Agriculturally, La Paz fine sand is one of the best and important soils of Pampanga Province. It occurs on nearly level to slightly undulating areas. The greatest slopes do not exceed 2 per cent. It has good drainage condition, both externally and internally and can be cultivated under clean culture without much danger from soil erosion. All types of farm machinery can be used in the sugar cane fields. It is suited to all locally grown crops, is easily tilled, responds well to good management, and is productive when properly fertilized. The total area mapped of this soil is 26,110 hectares. It has the following profile (Plate 10, Fig. 2) characteristics:

Depth of soil cm.	*Characteristics*
0—30	Surface soil, fine sand, which is pale gray under field condition but dark gray when wet and almost white or ash gray when dry. It is loose, friable and structureless.
30—100	Subsoil, pale grayish brown when dry and brown when wet, loose and friable fine sand.
100—150	Same as the subsoil; only it is coarser in texture.

Presently, this soil is principally planted to sugar cane. Lowland rice is the next important crop planted. There are also other crops grown but in small and scattered areas. The application of commercial fertilizer and lime and the liberal addition of organic matter would build up this soil to a high state of productivity. Green manuring is beneficial to this soil.

La Paz sand (76).—This soil is east of and closely associated with the La Paz fine sand. It occupies an area of 4,477 hectares. It has a pale gray dark gray, coarse to medium sand surface soil. The lower layers of the profile are similar to that of the La Paz fine sand, they being under the same soil series.

Rice and sugar cane are the principal crops grown. Citrus trees are also planted. Vegetables, such as eggplant, radish, pechay, and beans are also grown. Commercial fertilizers and lime should be applied in this soil, besides large quantities of organic matter to make the soil productive. Green manuring should be practiced because leaching of plant nutrients is rapid. The organic matter aids in the retention of moisture, and it also supplies plant nutrients, thus keeping this soil in a moderately productive state.

La Paz silt loam (78).—La Paz silt loam with an area of 5,355 hectares occurs between the Angeles fine sand and the La Paz fine sand near the Bataan-Pampanga boundary. The surface relief is nearly flat and it is adequately drained both externally and internally. It differs principally from the La Paz fine sand in that it has a silt loam texture of the surface soil. All other external and internal characteristics are similar.

Sugar cane is the most important crop grown in this soil. Rice is also grown in small scale. Citrus is found to thrive well in the area. The farm management problems, fertilizer and cropping requirements are the same as the La Paz fine sand.

SAN FERNANDO SERIES

The soils of the San Fernando series are low-lying areas between the Angeles and La Paz series on one side and the Pampanga River on the other side. A drainage canal leading to the Pampanga swamps passes through this soil series. The soils are developed from recent alluvial deposits. The surface soil is pale gray, brownish gray, dark gray to black and the subsoil is dark brown to nearly black heavy clay. Being low areas, the drainage condition is very poor and during the rainy season, they are under water, a hazard to agriculture in this soil

series. San Fernando clay loam and San Fernando clay were mapped.

San Fernando clay loam (67).—San Fernando clay loam has a total area of 6,362 hectares. It is located in low places and becomes waterlogged during the rainy season. Surface drainage is imperfect, and internal drainage is poor because of the heavy nature of the subsoil and substratum. Because of the high water during the rainy season, rice is oftentimes planted as soon as the rainy season ends. There are, however, scattered and small areas which are slightly elevated, and these are planted to sugar cane and corn. A number of mangoes, bamboos, and other trees are also planted. A typical profile of this soil is as follows:

Depth of soil cm.	*Characteristics*
0— 20	Surface soil, pale gray, brownish gray to black clay loam with reddish brown streaks. When dry it is hard and compact, but sticky and plastic when wet.
20— 40	Subsoil, black stiff, hard, and waxy clay. It is highly sticky when wet.
40—100	Lower subsoil, mottled black, dark grayish brown sticky clay.
100—150	Substratum, gray clay, sticky and plastic.

This is a good agricultural soil. It is principally planted to lowland rice. Due to the fact that it is oftentimes under water during the rainy season, planting is usually delayed. However, it produces good yield. When the soil is not fertilized and under normal condition, the yield of lowland rice is 55 cavans of palay to a hectare for the irrigated land and 35 cavans for the non-irrigated land. Corn yields 10 cavans per hectare.

San Fernando clay (68).—This soil occupies an area of 2,527 hectares located within the boundaries of Apalit, San Simon, and Minalin along the provincial road from San Fernando to Calumpit. It differs from the San Fernando clay loam in that the surface soil has clay texture. It is very dark gray to black, stiff, hard, and compact. This soil can not be plowed soon after heavy rains without injurious structural effects, hence it should be plowed when moisture conditions are ideal, as it is sticky when wet and tends to become hard if too dry. It has generally poor internal drainage.

Rice, corn, and sugar cane are the principal crops grown in this soil type (Plate 11, Fig. 1). Yields of these crops are almost the same as the San Fernando clay loam. With the incorporation of green manure, this soil will be easier to work.

CANDABA SERIES

The soils of the Candaba series are alluvial soils formed from the depositions of mixtures of different soil materials from the surrounding higher areas. The surface soils are pale brown, friable, and dark gray to dark or black, mottled reddish brown clay subsoil. The surface relief is nearly level, but some are located in low-lying areas like the San Fernando soils. Both the external and internal drainage are poor. Areas of this soil are under water to a depth of from 2 to 5 meters during the rainy season, usually beginning from June to November or December. This series occupies a big portion of the so-called Candaba swamps. Candaba silt loam and Candaba clay loam were mapped.

Candaba clay loam (70).—This soil type is within the vicinity of Candaba. It is developed from alluvial material. Both the internal and external drainage are poor. The area is under water throughout the rainy season to a depth of from 2 to 5 meters. Due to this condition the area is cultivated only during the dry season. A total area of 11,609 hectares is mapped of this soil in the province. The following are the profile characteristics:

Depth of soil cm.	*Characteristics*
0— 5	Surface soil, coarse fragmental pale brown silt loam.
5— 25	Lower surface soil, pale brown, and gray brown clay loam. Slightly friable when dry and sticky when wet.
25— 50	Subsoil, mottled reddish brown, dark gray, and dark or black clay, silty in texture; sticky when wet.
50—150	Substratum, mottled pale gray, reddish brown clay loam, soft and sticky.

This soil can not be cultivated during the rainy season because it is under water to a depth of from 2 to 3 meters. It is principally grown to watermelon and muskmelon during the dry season. About 3,000 to 5,000 hectares are planted to these crops every year usually beginning in December. In some areas, corn is planted. The elevated areas are planted to rice. A bigger portion of the area is not cultivated and the native vegetation are talahib and bamboos.

Candaba silt loam (69).—The surface soil of this type ranges in depth of from 20 to 30 centimeters. It is pale brown to reddish brown, moderately compact and hard silt loam. The subsoil is mottled dark brown to nearly black, soft and sticky clay loam. The depth varies from 60 to 80 centimeters from

the surface. The substratum is lighter in texture. There is abundant moisture in the subsoil and substratum.

This soil was mapped in Apalit, San Simon, San Luis, Candaba, and Arayat with a total area of 3,963 hectares. A little portion and only the elevated areas, which comprise a small portion, are cultivated to rice, corn, sugar cane, tomato, eggplants, squash, upo, and pepper. Rice is irrigated by the Angat River Irrigation System and the Gapan River Irrigation System. A greater portion of the area is covered with talahib and bamboos.

SOILS OF THE UPLANDS, ROLLING, AND HILLY AREAS

The soils of the uplands, rolling and hilly areas have a wide range of color, texture, consistence, and chemical composition as a result of the influence of the parent materials, climate, intensity of their use, and soil erosion. The relief is almost flat upland, rolling, strongly rolling, and hilly. The surface drainage is free to excessive and the internal drainage is poor to fair. These conditions of relief and drainage have rendered sheet erosion and gullying active in the area; consequently ravines and intermittent creeks are numerous. In many sections, terracing, contour plowing, green manuring, and crop rotation are essential and necessary farm practices to control too rapid runoff, so as to prevent erosion losses and conserve moisture. In some areas, strip cropping and close-growing crop may be advantageously used, whereas other areas should be retired to permanent cover.

The soils of this group have a total area of 11,288 hectares or 5.27 per cent of the total area of the province. Three soil series, namely, Buenavista, Prensa, and Arayat, comprising of four soil types were identified and mapped. The Buenavista and Prensa series belong to older terraces the soils of which have been developed through the weathering of water-laid volcanic tuff, but these were altered in the course of time through erosion and cultivation. The soils of the Arayat series have been developed in place from the weathered products of the country rocks, such as basalt, sandstones, tuff, and limestones.

BUENAVISTA SERIES

The soils of the Buenavista series had been developed from weathered water-laid volcanic tuff on rolling and hilly topography. The surface drainage is free to excessive while the internal drainage is poor. This soil has a brown to yellowish brown or light reddish brown surface soil and a light gray clay loam to clay subsoil. A distinguishing characteristic of this soil is the almost impervious clay subsoil with concretions. Buenavista silt loam was the only soil type mapped in the province under this soil series.

Buenavista silt loam (9).—This soil has the smallest area mapped in the province, being only 364 hectares. It is located on the southwestern part of Candaba, a continuation of the same soil type mapped in Bulacan Province. The relief is rolling and the land is well-drained externally, but the internal drainage is poor.

The surface soil has a depth of from 20 to 25 centimeters. It is brown to yellowish brown or light reddish brown, friable and moderately loose silt loam. There are few concretions in this layer. The subsoil to about 100 centimeters from the surface is light gray compact clay loam to clay. It is almost impervious making internal drainage imperfect. Concretions are present. The substratum to a depth of 150 centimeters or more is light yellowish gray to light gray, sticky and compact clay.

Agriculturally, this soil is not very important because of its limited area. It is principally planted to rice. The lower portion of the area is terraced and it is irrigated by the Angat River Irrigation System. It is planted to lowland rice. The higher portion is planted to upland rice. Corn is also grown in some sections of the area. During the dry season, watermelon is grown in great quantities.

PRENSA SERIES

The soil of the Prensa series, like the Buenavista series, had been developed from the weathering of water-laid volcanic tuff on rolling topography. It differs, however, from the latter in that it has a considerable amount of gravels and concretions especially in the subsoil. The surface soil is light brown to brown or light reddish brown and the subsoil is brown to dark grayish brown clay with plenty of gravels and iron concretions. The surface drainage is good to excessive and the internal drainage is poor. Prensa silt loam was mapped.

Prensa silt loam (66).—Prensa silt loam occupies a total area of 2,592 hectares in San Luis and Candaba bordering Bulacan Province. The relief is undulating to rolling, and because of poor internal drainage, runoff forms rapidly causing severe erosion. The lower part of the upland, however, is terraced and mostly irrigated. A portion of the area is flooded from the Candaba swamps during the rainy season. This soil has the following characteristics:

Depth of soil cm.	Characteristics
0— 30	Surface soil, light brown to light reddish brown friable, moderately loose and granular silt loan.
30— 90	Subsoil, brown to dark grayish brown to gray moderately compact clay. Gravels and iron concretions are numerous in this layer.
90—100	Substratum, brownish gray to gray clay loam to clay with concretions and gravels. In some places tuffaceous rocks are found below the substratum.

The cultivated area of this soil requires terracing to prevent erosion. While this soil can be planted to locally grown crops it is not suited to extensive agricultural methods. Lowland rice is the principal crop grown in the lower area which is terraced and generally irrigated. The area flooded during the rainy season when the water of the Candaba swamps gets high is planted to watermelon when it gets dry during the dry season.

ARAYAT SERIES

The soils of the Arayat series are confined to Mount Arayat and its vicinity. These soils were developed from weathered basalt, sandstones, tuff, and limestones. The soils have gray brown, reddish brown, chocolate brown and dark brown surface soil and dark brown to reddish brown clay loam to clay subsoil. The upper part of the mountain is covered with commercial and non-commercial forest and, therefore, erosion is normal. The base of the mountain, however, due to the destruction of the forest cover as a result of kaingin and cultivation, is now subject to varying degrees of erosion. This portion is being reforested by the Bureau of Forestry. Arayat clay loam and Arayat sandy clay loam were mapped.

Arayat clay loam (80).—Arayat clay loam occupies the higher portion of Mt. Arayat covering a total area of 7,068 hectares. It consists of reddish brown to chocolate brown friable and loose clay loam surface soil 25 to 35 centimeters deep.

The subsoil has a depth of from 60 to 70 centimeters from the surface. It is dark reddish brown friable and granular clay loam. Below the subsoil is a deep reddish brown to brown clay loam to clay underlain by light gray tuffaceous rock.

This soil is covered with commercial and non-commercial forests and should remain as such to protect it from erosion. It is neither suited to pasture nor agriculture but to forestry and wildlife.

Arayat sandy clay loam (79).—This soil occupies the base of Mt. Arayat and has sloping to rolling surface relief. External drainage is good to excessive but the internal drainage is poor. Many sections of the area are severely eroded.

The surface soil is brownish gray, brown to chocolate-brown gritty sandy clay loam 25 to 35 centimeters deep. The subsoil is dark reddish brown, compact and gritty sandy clay reaching a depth of 70 to 80 centimeters from the surface. Below this is the substratum, or parent material, which differs in many places according to the kinds of rocks.

Cultivated areas are grown to various vegetables. This soil should be plowed when the moisture conditions are just right, as it is sticky when wet and tends to become hard if too dry thus making plowing rather difficult. A greater area of this soil is not cultivated but it is being reforested by the Bureau of Forestry.

MISCELLANEOUS LAND TYPES

The miscellaneous land types mapped in the province are considered non-agricultural or have no agricultural value for the near future. They have either no true soil or because of inaccessibility, they have not been examined. Hydrosol and soil undifferentiated were mapped.

Hydrosol (1).—The hydrosol comprises the fishponds and the nipa and the mangrove swamps extending from Manila Bay to the vicinities of Masantol, Sto. Tomas, Guagua, Sexmoan, and Lubao (Plate 11, Fig. 2). The area is practically under water throughout the year and is considered the largest body of swamps and mangrove in Luzon. A total of 24,011 hectares was mapped.

The hydrosol has no agricultural importance. Economically, however, it is used for fishponds, a multi-million peso industry. There is also a thriving duck raising industry, a good source of cash for the people. The leaves of the nipa palms

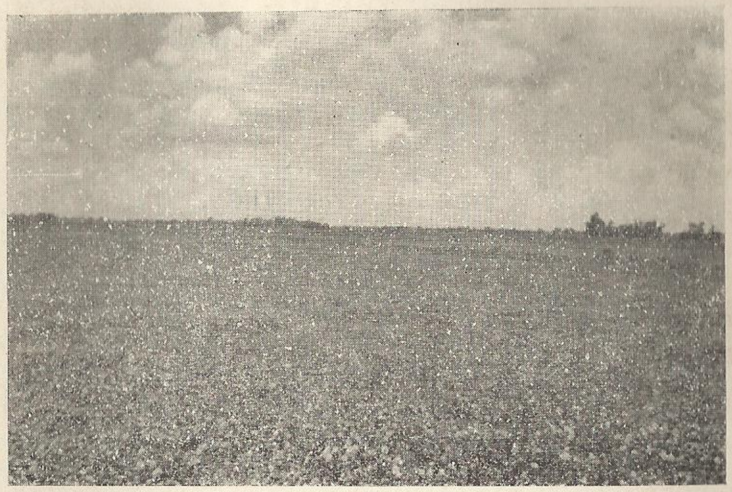


Fig. 1.—San Fernando clay. This soil type is mostly found along the San Fernando-Apalit national highway. It represents the low level areas which are frequently flooded during the rainy season. Planting time on these areas is timed so as not to coincide with the heavy rains.

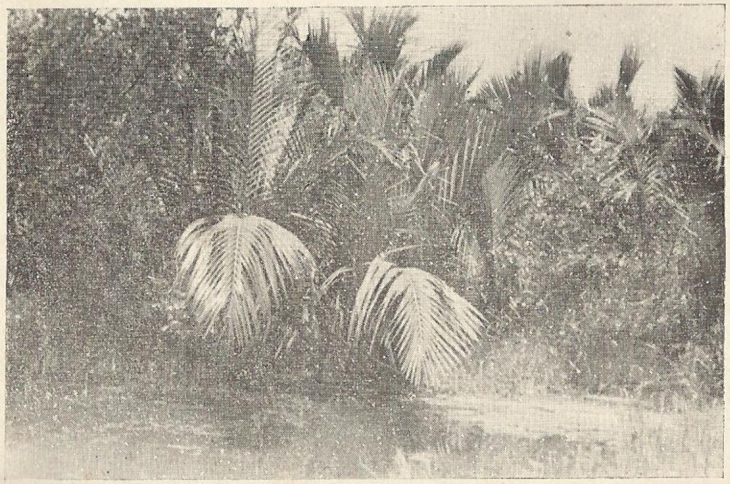


Fig. 2.—Hydrosol area with dense growth of nipa palm and bakauan. Nipa is the main source of raw material for the manufacture of nipa shingles, a roofing material for houses and bodegas. Bakauan is used mainly as firewood.

are made into nipa shingles used for roofing materials. They are sold locally or sent to other provinces. The mangrove trees, especially the *bakauan* species are cut for firewood and sold locally or sent to Manila. The hydrosol is also used for wildlife purposes.

Mountain soil, undifferentiated (75).—This soil covers the rolling, hilly, and mountainous regions on the western part of the province bordering Zambales Province. The vegetation of the rolling area is the "parang" type. The hills and mountain ranges are covered with non-commercial and commercial forests. Farther west along the Pampanga-Zambales boundary are prominent mountain peaks, namely, Mounts Pinatubo, Negron, Dorst, and Cumino, having deep ravines and canyons with rugged ridges. The aggregate area of this land type is 32,150 hectares, or 15.01 per cent of the area of the province.

MECHANICAL ANALYSIS OF PAMPANGA SOILS

The modified Bouyoucos method of mechanical analysis is adopted by the Bureau of Soil Conservation in the determination of the textural grades of soils by determining the percentage composition of sand, silt, and clay particles in the surface soil. The major textural grades of soils are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. Sandy soils are further defined according to the fineness of the sand particles as very fine, fine, medium or coarse sand. Only mineral particles less than 2 millimeters in diameter are considered as soil separates for the purpose of mechanical analysis. Clay particles have diameters less than 0.002 mm; silt 0.002 to 0.05; and sand 0.05 to 2 mm.

Soil textural classification classes based on the size distribution of mineral particles less than 2 millimeters in diameter are as follows:

Sands.—Soil material that contains 85 per cent or more of sand; percentage of silt, plus 1-1/2 times the percentage of clay, shall not exceed 15.

> *Coarse sand.*—25 per cent or more very coarse and coarse sand, andless than 50 per cent any other one grade of sand.
>
> *Sand.*—25 per cent or more very coarse, coarse, and medium sand, and less than 50 per cent or more fine sand.

Fine sand.—50 per cent or more fine sand (or) less than 25 per cent very coarse, coarse, and medium sand and less than 50 per cent very fine sand.

Very fine sand.—50 per cent or more very fine sand.

Loamy sands.—Soil material that contains at the upper limit 85 to 90 per cent sand, and the percentage of silt plus 1-1/2 times the precentage of clay is not less than 15; at the lower limit it contains not less than 70 to 85 per cent sand, and the percentage of silt plus twice the percentage of clay does not exceed 30.

Loamy coarse sand.—25 per cent or more very coarse and coarse sand, and less than 50 per cent any other one grade of sand.

Loamy sand.—25 per cent or more very coarse, coarse, and medium sand, and less than 50 per cent fine or very fine sand.

Loamy fine sand.—50 per cent or more fine sand (or) less than 25 per cent very coarse, coarse, and medium sand and less than 50 per cent very fine sand.

Loamy very fine sand.—50 per cent or more very fine sand.

Sandy loams.—Soil material that contains either 20 per cent clay or less, and the percentage of silt plus twice the percentage of clay exceeds 30, and 52 per cent or more sand; or less than 7 per cent clay, less than 50 per cent silt and between 43 per cent and 52 per cent sand.

Coarse sandy loam.—25 per cent or more very coarse and coarse sand, and less than 50 per cent any other one grade of sand.

Sandy loam.—30 per cent or more very coarse, coarse, and medium sand, but less than 25 per cent very coarse sand, and less than 30 per cent very fine or fine sand.

Fine sandy loam.—30 per cent or more fine sand and less than 30 per cent very fine sand (or) between 15 and 30 per cent very coarse, coarse, and medium sand.

Very fine sandy loam.—30 per cent or more very fine sand (or) more than 40 per cent fine and very fine sand, at least half of which is very fine sand and less than 15 per cent very coarse, and medium sand.

Loam.—Soil material that contains 7 to 27 per cent clay, 28 to 50 per cent silt, and less than 52 per cent sand.

Silt loam.—Soil material that contains 50 per cent or more silt and 12 to 27 per cent clay (or) 50 to 80 per cent silt and less than 12 per cent clay.

Silt.—Soil material that contains 80 per cent or more silt and less than 12 per cent clay.

Sandy clay loam.—Soil material that contains 20 to 35 per cent clay, less than 28 per cent silt, and 45 per cent or more sand.

Clay loam.—Soil material that contains 27 to 40 per cent clay and 20 to 45 per cent sand.

Silty clay loam.—Soil material that contains 27 to 04 per cent clay and less than 20 per cent sand.

Sandy clay.—Soil material that contains 35 per cent or more clay and 45 per cent or more sand.

Silty clay.—Soil material that contains 40 per cent or more clay, less than 45 per cent sand, and less than 40 per cent silt.

The textural grades of the soils have been determined with the use of a chart, (Fig. 22) after the percentages of sand, silt and clay, have been taken. The mechanical analysis of the surface soils of the different soil types mapped in Pampanga Province were determined in the laboratory to check up the field classification. The soil technologists determine the textural grades of the soil types in the field by the feel method, which is not always accurate. In some cases, clayey soils, because of their high humus content, exhibit a high state of friability, mellowness, and are easy to cultivate. This kind of soils carry the field classification given unless the mechanical analysis shows a wide discrepancy, in which case the result of the mechanical analysis is followed. Table 10 shows the results of the mechanical analysis of the surface soils of the different soil types in Pampanga Province.

PRODUCTIVITY RATINGS OF PAMPANGA SOILS

Different soils vary in their productiveness. The productiveness of soils is influenced by various factors, among which are climate, conditions of drainage, depth and texture of the surface soil, organic matter content of the soil, slope, erosion and parent material.

TABLE 10—*Mechanical analysis of important soil types of Pampanga Province.* [1]

Soil type No.	Soil type	Sand 2.0-0.05 mm.	Silt 0.05-0.002 mm.	Clay 0.002 mm.
5	Quingua silt loam	21.0	51.8	27.2
66	Prensa silt loam	24.8	44.8	30.4
16	Bantog clay loam	26.2	34.6	39.2
67	San Fernando clay loam	34.0	36.8	29.2
68	San Fernando clay	15.0	28.4	56.6
59	Candaba silt loam	38.2	36.6	25.2
70	Candaba clay loam	24.8	16.0	59.2
71	Angeles coarse sand	94.5	2.0	3.5
72	Angeles sand	94.5	2.2	3.3
73	Angeles fine sand	79.5	14.0	6.1
76	La Paz sand	93.4	0.4	6.2
77	La Paz fine sand	74.0	17.8	7.2
78	La Paz silt loam	32.4	52.6	15.0
79	Arayat sandy clay loam	51.8	27.0	21.2
80	Arayat clay loam	36.2	24.0	39.8

[1] Analyses by Miss Consuelo A. Gonzales, Jr. Soil Technologist, Division of Soil Conservation Surveys, Bureau of Soil Conservation, DANR.

The productivity rating of soils is a measure of comparison among different soil types and crop relationship, or the productiveness of each soil type with respect to the crop grown under similar climatic conditions and management. The productivity ratings are obtained either by inductive or deductive methods. The inductive method was devised by Storie of the University of California who considered four factors; "A" which refers to the soil profile and their general characteristics, "B" the texture of the surface, "C" the slope, and "X" all other conditions like drainage, alkali, nutrient level, acidity, erosion, and microrelief. These factors are given ratings expressed in percentage and are multiplied together to obtain the final index of productivity.

In the deductive method, ratings are assigned to the yields considered to be representative of the specified crop grown on a particular soil under current practices. That is, an average yield per hectare of a particular crop grown on the extensive and better soil types of the regions in which the crop is most widely grown under current practices and without the use of fertilizers or soil amendment is established as the standard. To get the productivity rating of a soil type is to compare the average yield of a certain crop grown in this soil type with the standard for the same crop. The comparison expressed in percentage gives an idea of the productiveness of the soil type. An index of 50 indicates that the soil is half as productive for the specific crop as the standard. A soil with a rating of 100 shows that it is as

productive for the specific crop as the standard. On the other hand, when the productivity index of the soil type exceeds 100, which happens in many cases, it means that this soil type is more productive for the specific crop than the soil with the standard.

The relative productivity indexes of each soil type of Pampanga Province are shown in Table 11. These indexes were made during and after the soil survey of the province. They are based on information from persons well acquainted with the agricultural history of the province, from landowners and farmers, from the records of the Municipal and Provincial Agriculturists of the province, and from pamphlets, census, and other publications concerning the agricultural conditions of the province.

The following averages of crop yield per hectare without the use of fertilizers or amendments that had been established as standard of 100 were used as basis for computation of the productivity rating indexes:

Lowland rice	60 cavans per hectare
Sugar cane	80 piculs per hectare
Upland rice	20 cavans per hectare
Corn	17 cavans per hectare

The different crops above are arranged in the order of their importance in the province.

It will be noted from Table 11 that the different soil types vary in their productivity for the different crops. For lowland rice, San Fernando clay loam, San Fernando clay, and Quingua silt loam have the highest productivity ratings, but for sugar cane, San Fernando clay and San Fernando clay loam registered the lowest ratings. Quingua silt loam is the highest for corn, while La Paz silt loam has the highest rating for sugar cane. Although the soils of Pampanga Province have lower ratings than the standard, generally they are fair in their relative productivity with the three important crops of the province. These ratings are under Pampanga conditions.

LAND USE AND SOIL MANAGEMENT

An important problem in agriculture is the proper use of land. Land's wise and proper utilization would mean maximum yields and conservation of its fertility. Land-use and management requirements differ as the relief, slope, erosion and other soil features vary. These different factors affect land use and managment because they influence the ability of

TABLE 11—*Productivity ratings of the major soil types of Pampanga Province.* [1]

Soil type[2]	Crop productivity rating index				
	Upland rice 100 = 20 cavans	Lowland rice 100 = 60 cavans	Lowland rice 100 = 80 cavans (Irrigated)	Sugar cane 100 = 80 piculs	Corn 100 = 17 cavans
San Fernando clay loam (67) ..	—	75	90	60	60
San Fernando clay (68)	—	75	90	60	60
Quingua silt loam (5)	80	75	85	75	85
La Paz silt loam (78)	80	75	80	85	70
La Paz fine sand (77)	65	75	80	75	60
La Paz sand (76)	65	75	80	75	60
Angeles fine sand (73)	65	75	80	75	60
Angeles sand (72)	65	75	80	75	60
Bantog clay loam (16)	—	85	—	—	75
Prensa silt loam (66)	—	85	—	—	75
Buenavista silt loam (9)	—	85	—	—	75
Bigaa silt loam (3)	—	85	—	—	70
Candaba silt loam (69)	—	—	—	—	80
Candaba clay loam (70)	—	—	—	—	80
Angeles coarse sand (71)	—	75	—	70	60
Arayat sandy clay loam (79) ..	50	—	—	—	50
Arayat clay loam (80)	—	—	—	—	—

[1] The major soil types of Pampanga Province are given indexes that give the approximate average production of each crop in per cent as the standard of reference. These are obtained without the use of amendments or fertilizers.

[2] Soils are listed in the approximate order in their general productivity under current practices.

[3] Absence of rating indicates that the crop is not commonly grown to the particular soil type.

the soils to produce crop under prevailng farming practices, the relative ease with which they can be worked and the degree of care necessary to maintain the productivity and workability of the soil when cultivated.

The soils of Pampanga Province are classified into land capability classes (Table 12) as guides for their land-use and soil management. It has been noted that, while the use of the land in the province has been determined to a great extent by the physical character of the land, misuse has been found too frequently. There are severely eroded or steep slopes under tillage. There are lands presently cultivated to crops which are not suited from the standpoint of permanent land use. On the other hand, there are areas under grassland which are physically adapted to the cultivation of crops.

In Table 12, the soils are grouped into seven classes, based on the best utilization of the land, so that their relation to agriculture may be discussed more appropriately. These classes are in the descending order of the suitability and workability

TABLE 12—*Area and land capability class of the different soils of Pampanga Province*

Soil type	Area in hectares	Land capability class
Angeles fine sand	32,279	Class A soils. Croplands on level to nearly level relief. Suitable for continuous cultivation of seasonal crops without employing special farm practices. Under irrigation, they give high yields.
La Paz fine sand	26,110	
La Paz silt loam	5,355	
Quingua silt loam	21,569	
San Fernando clay loam	6,362	
San Fernando clay	2,527	
Bigaa clay loam	8,953	
TOTAL	103,155	
Angeles coarse sand	8,161	Class B soils. Croplands on nearly level relief. Suitable for continuous seasonal crops using simple farm practices and conservation measures.
Angeles sand	11,609	
La Paz sand	4,477	
TOTAL	24,247	
Prensa silt loam	2,592	Class D soils. Crops on pasture land on greater slopes. Suitable for limited cultivation of seasonal crops employing intensive or complex application of management and conservation practices.
Buenavista silt loam	364	
TOTAL	2,956	
Bantog clay loam	3,855	Subclass DA. Level land that may be classified under Class A, but they are under water during the rainy season and they are imperfectly drained. Cultivated during the dry season.
Candaba silt loam	3,963	
Candaba clay loam	11,524	
TOTAL	19,342	
Arayat sandy clay loam	1,264	Class M soils. Pasture land or woodland on steep slopes. Suitable for economic production of pasture and woodland products.
Hydrosol	24,011	Class X soils. For wildlife only on level relief. Permanently under water throughout the year. May be used for fishing grounds and mangroves.
Arayat clay loam	7,068	Class Y soils. For wildlife and woodland. They are not suitable for cultivation.
Soils undifferentiated	32,150	
TOTAL	39,218	

of the soils for the present agriculture. These are Class A soils, Class B soils, Class D soils, Class DA soils, Class M soils, Class X soils, and Class Y soils. Of course it is hard to find Class A soil that is very, "productive, is easily worked, and can be conserved with minimum effort." The soils of the province lack the characteristics of the ideal. This grouping is under the present set-up of agrculture in Pampanga Province.

Class A soils.—This class of soils has a level or nearly level relief. It constitutes a very good to excellent cropland under the present set-up of management practice. The soils differ in degree of profile development, character of parent materials, chemical and biological characteristics, structure, permeability, and other respects, but they are similar in general physical suitability for agricultural use. They are suitable for continuous cultivation to seasonal crops without danger of soil erosion.

These soils comprise 103,155 hectares, or 48.16 per cent, of the total area of the province and they are all practically in cultivation. They are free from stones, friable, easily tilled, responsive to management and suitable to both general and special farming. They are adapted to all types of farm machinery especially when cultivated to sugar cane and can be planted to all the crops grown in the locality. Most of them have a good internal and external drainage and when they are properly managed using the ordinary method of farming, such as application of fertilizers, green manuring, crop rotation, use of irrigation water, and good tillage operation, they will produce moderate to high yields.

Class B soils.—Class B soils are physically good to very good cropland under present farming of the province. They have a relatively similar physical suitability for use in agriculture as Class A soils, but differ in the ability of the soils to produce and in conservability within a limited range. They are in general at least moderately productive but because of some deficiency in one or more desirable characteristics they need some special conservation measures to bring them to moderately good or very good croplands.

These soils are nearly level and they do not have erosion problem, but due to the fact that they are sandy they are often dificient in moisture unlike those of Class A soils. Their plant nutrient contents are also easily leached during heavy rains. To promote good tilth and normal circulation and retention of moisture and plant nutrients, the addition of organic matter and plowing under green manures is necessary. Besides these, the ordinary farming practices as mentioned for Class A soils should be followed. A total area of 24,247 hectares is occupied by these soils.

Class D soils.—The soils of Class D are rolling uplands, eroded, and have shallow surface soils. These soils are best suited as pasture lands. When used as croplands, they should be carefully managed because severe surface wash would occur

and ruin the surface soil. Their cultivation to seasonal crops must be limited and the use of intensive soil conservation measures, such as terracing, contour strip cropping, buffer-strip planting, contour furrowing, contour plowing, and proper crop rotation is a necessity.

The more sloping areas of these soils should be planted to permanent crops or cover crops to aid in the conservation of the soils. These soils consist of 2,956 hectares or 1.38 per cent of the total area of the province.

Class DA soils.—This class of soils occupies 19,342 hectares in the province. They are nearly level areas and imperfectly drained so during the rainy season they are under water. They are not subject to erosion. On the other hand, soil accumulation takes place every year. However, their cultivation is limited and it is only during the dry season that portions of these soils are grown principally to watermelon. This is because from June to November or December, they are under water, sometimes to a depth of 2 to 5 meters.

Class M soils.—Soils under Class M are best suited for growing permanent vegetation to serve for the production of either forage or woodland products with moderate restrictions of use. It could be used as pasture with restrictions and good management practices such as (1) contour furrowing to check run-off and conserve moisture; (2) planting forage plants; (3) fertilization and liming to produce quality forage; (4) seasonal or rotation of pasture to allow the grass to grow and seed; (5) development of stock pond; and (6) appropriate fencing.

Class X soils.—These are the hydrosol areas with dense growth of nipa and mangrove. Throughout the year, these areas are under water and cannot be drained. They are used for wildlife and most advantageously used as fishing grounds. The *bañgos* industry of Pampanga is located in these areas.

Class Y soils.—Soils of this class are characterized with steep, rocky, and very rugged relief. These areas are not suited either for cultivation or production of forage and woodland products. They should be left untouched and stay under natural vegetal cover to avoid further destruction of the topsoil due to erosion. The Arayat sandy clay loam and the mountain soils of western Pampanga fall under Class Y soils with a total area of 39,218 hectares, or 18.31 per cent, of the area of the province.

MORPHOLOGY AND GENESIS

Soil, as defined by Marbut, is the "outer layer of the earth's crust, usually unconsolidated, ranging in thickness from a mere film to a maximum of somewhat more than ten feet, which differs from the material beneath it, also usually unconsolidated, in color, structure, texture, physical constitution, chemical composition, biological characteristics, probably in chemical processes, in reaction, and in morphology." It is a natural geologic body, a mixture of fragments of partly or wholly weathered rocks and minerals, organic matter, water and air in varying proportions and have more or less a distinct layer of horizons developed under the influence of climate and living organisms. To the common man, it is just the thin layer of earth's surface which serves as the medium for the growth of plants.

Soils vary in their characteristics. Due to the dominant influence of one factor of soil formation over the other factors, certain definite characteristic of the soil is produced. The diversity of soils is a result of the different intensites of these factors of soil formation operating at any one time and place. The factors of soil formation are (1) parent material, including its physical and mineralogical composition, (2) climate, particularly rainfall and temperature, (3) relief or lay of the land, (4) native vegetation, and (5) the length of time the forces of development have acted on the materials.

The physiographic position of Pampanga Province has played no less an important role in determining the length of time the soil materials have been in place. The province is a part of the vast Central Plain of Luzon extending from Manila Bay northward up to the Lingayen Gulf. It consists of five physiographic sections, to wit: (a) the low plain comprising by far the larger part of the province which have been in most parts planted to seasonal crops; (b) the narrow strip of highland along the western border consisting of several high peaks, prominent of which are Mount Pinatubo, 1871 meters high, and Mount Negron, 1890 meters. This strip of highland is vegetated with cogon, second growth forest and primary forest; (c) the nipa and mangrove swamps in the southern part bordering Manila Bay on the delta of several tributaries of the Pampanga River and other small rivers; (d) the Candaba Swamps on the eastern part between the Pampanga River and the Pampanga-Bulacan boundary, which is under water almost

half of the year and which only a small portion is cultivated during the dry season; and (e) Mount Arayat, an extinct volcano, arising solitarily amidst the Central Plain, located in the northeastern part of the province, which is covered with non-commercial and commercial forests.

The soils of the plain are of Recent alluvial deposits influenced by the geologic formation of Tarlac, Bulacan, Rizal and Nueva Ecija Provinces where most of the soil materials come. The soils of the Candaba swamps, nipa and mangrove swamps are augmented by depositions every year. The soils of the highlands along the western border and Mount Arayat are developed in place from weathered water-laid tuff, basalt, limestone, and sandstones, and have been subjected to a more intense soil development. Hence these soils are mature and have a well developed soil profile in contrast with the soils of the plain and the swamps, which have either undeveloped or slightly to moderately developed profiles. Active soil erosion on the highlands and deposition of alluvial materials on the plain and swamps have kept a continuous modification and development of the soils of Pampanga Province.

Based on the topography, mode of formation and kind of profile the soils of Pampanga Province are under the following profile groups:

Profile Group II
- La Paz
- Angeles
- Quingua

Profile Group III
- Candaba
- Bigaa
- Bantog

Profile Group IV
- San Fernando

Profile Group VI
- Prensa
- Buenavista

Profile Group VII
- Arayat

The soils of Profile Group II are represented by the soils of La Paz, Angeles, and Quingua series which are closely related in their mode of formation and origin of parent material from which they have been developed. They have slightly developed profiles and are the soils of young alluvial fans and flood plains. As such the different factors of soil formation have no marked influence over the others on these soils. They are light soils and occupy a greater portion of the plain of the province. While these soils may differ slightly in color, texture, and other physical features, the development and age of their profiles are similar.

The soils of the Candaba, Bigaa, and Bantog series belong to Profile Group III. They have a moderately developed profile. The subsoils are denser and slightly more compact than those of profile group II. They occupy the low-lying areas of the plains subject to annual flooding. Most of these soils are darker in color and heavier in texture. Closely related to these soils are the soils of the San Fernando series under Profile Group IV. The profile is well developed underlain by unconsolidated material. They represent the older alluvial fans and are deep soils. These soils are also subject to annual flooding and have a darker color than the other soils of the province.

The upland soils of the Prensa and Buenavista series represent Profile Group VI which are soils on older terraces and upland areas having dense clay subsoil resting on moderately consolidated material. The parent rock from which these soils are developed consists of water-laid tuff. Both of these soils are the continuations of the same soils established in Bulacan Province. The distinct difference between these two soils is the presence and amount of gravel and concretionary materials in their profile. The Buenavista soil has few concretionary materials while the Prensa soil has plenty of gravels and concretions.

Profile Group VII includes the soils of the Arayat series which occupy the rolling to steep and mountainous relief. They are formed from the products of the underlying igneous rock. They are primary soils with reddish color which may be due to the hydrated oxides of iron. Less vegetated sections of these soils are excessively drained externally and the internal drainage is poor, rendering them severely eroded.

The acid reaction of the soils of the province may be partly the result of the prevailing climatic conditions. Because of the heavy precipitation during the rainy season and a relatively high and uniform temperature there is an active chemical reaction and the leaching of the soils has removed the soluble bases, such as calcium, magnesium, potassium, and sodium. Removal of these bases will cause the soil to become acid.

CHEMICAL CHARACTERISTICS OF THE SOILS OF PAMPANGA PROVINCE

By RICARDO T. MARFORI,[1] and IGNACIO E. VILLANUEVA[2]

Before the outbreak of World War II, the Bureau of Soil Conservation (formerly Division of Soil Surveys of the Department of Agriculture and Commerce) by virtue of the CA 418 had been carrying out soil surveys of the different provinces to properly classify the various soils found and identified according to the scientific methods for more efficent crop production.

The soil survey report of Pampanga was published as Report No. 5 of the Department of Agriculture and Commerce. Unfortunately, with the rapid progress of scientific agriculture abroad which up to now have naturally influenced this country, the results of the chemical analysis of the soils of Pampanga as presented and published require a revision so as to give to the farmers and interested citizens of Pampanga the most scientific and practical approach in helping the farmers solve their agricultural problems. The establishment of a branch soil laboratory at San Fernando in this province has facilitated the objective thereby bringing up to date data and with the interpretations serve better our farmers based of newer trends of scientific knowledge.

To-day, it is necessary to have a thorough knowledge of the province, and only such knowledge could be obtained from the proper classification of the soil based on the morphological and genetic studies conducted right in the fields and supplemented by the chemical interpretation of the results of analysis of the soil samples brought to the laboratory. Results obtained in the chemical analysis guide in adapting an efficient soil management and in formulating systematic cropping practices.

The laboratory furnishes the following information; soil reaction (or pH value) denoting acidity or alkalinity which serves as a guide to crop adaptation; deficiency or sufficiency of the nutrient elements needed for plant growth; toxic substances

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—if present, to what extent they are toxic; and lime and fertilizer requirements of the soil types for a maximum crop yield.

The nutrient elements mostly needed by plants in greater proportions are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and iron, while the other elements such as boron, copper, manganese and zinc are also essential to plant nutrition but are needed only in lesser amounts to the extent of 1/4 part per million in a soil solution. The last four elements are technically designated as trace elements because of the small amounts they are needed by plants. Their availability in big quantities give toxic effects to plants. Their absence however, causes necrotic symptoms on the plants due to their deficiencies in the soil. Excepting hydrogen, oxygen and carbon which are derived from the air, all the other elements come from the soil. A deficiency of any or several of these above mentioned elements affects very adversely crop plants; thereby, reducing crop yields.

These essential nutrients may run short in the soil otherwise depleted due to cropping, leaching and erosion. In almost rundown soils the deficiencies that could very likely occur are nitrogen, phosphorus and potassium. When these deficiencies happen in any soil type the effects to plants or crops become very critical, and unless these deficiencies are known, there may not be any way of determining what nutrients are lacking that may be supplied in amounts sufficient for the soil and the plant. Deficiencies of these three elements may however be corrected. In the case of nitrogen, addition of animal manures, green manures, commercial nitrogenous fertilizers such as ammonium sulfate, and sodium nitrate may be added to the soil. The phosphorus deficiency may be corrected by the application of phosphatic fertilizers and guano. For potassium, its deficiency may be remedied by the application of wood ashes and commercial potassic fertilizers such as potassium sulfate and muriate of potash.

Agricultural soils are mostly acid in reaction, sometimes very unusual and excessive acid reaction of the soils occur and may be due to calcium deficiency. Hence, the necessity of liming the soil with a view not only to correct the acidity but also to supply the calcium ions needed by the plants. Agricultural lime usually contains considerable amount of magnesium, hence, the application of lime includes magnesium as in the dolomitic limestone,

and magnesium sulfate. The progress of research and the rapid advancement in scientific work in the U. S. have led to the inclusion of calcium and magnesium in the compounding of feeds and fertilizers. Much and many more are to be known as years go by through extensive experimentation.

METHODS OF CHEMICAL ANALYSIS

The determination of readily available nutrient elements correlates crop responses to fertilizers applied in the soil and serves as an index of the degree of fertility. The rapid chemical tests for the available nutrients were used in the analysis of the soil type in Pampanga province. The total nitrogen was also determined as this element is readily convertible to available forms.

The Division of Soil Laboratories up to the present time is running calibration tests of the rapid chemical methods under Philippine conditions with the results of liming and fertilizer experiments conducted both in the field and in pots in the greenhouse. For lack of comprehensive data from local experiments, the results obtained abroad are still cited for comparison.

The soil samples for chemical analyses were prepared by having them air-dried, pulverized with the use of a wooden mallet, and then allowed to pass through a 2 mm. sieve.

The degree of acidity of the soil expressed as pH was determined by the modified method of Peech and English (30).

The total nitrogen content of the soil was determined according to the "Method of Analysis" of the Association of Official Agricultural Chemists of the United States (12). The ammonia and nitrates were determined by the methods of Spurway (34). The available phosphorus was determined by the methods of Truog (37), and the available potassium, calcium, magnesium, iron and manganese were determined according to the methods of Peech and English (30). The Leitz photoelectric colorimeter with light filters was used in the determination of the readily available nutrient elements.

INTERPRETATION OF CHEMICAL TESTS

Soil reaction or pH value.—Soil pH assumes an important place in soil research in plant physiological investigations and in the diagnosis of field agricultural problems. The soil reaction denotes the degree of acidity or alkalinity affecting

TABLE 13—*Chemical analysis of the surface soils of different soil types from Pampanga province arranged according to crop productivity ratings for lowland rice and corn*

Soil types	Productivity ratings for		pH value	Total nitrogen	Available constituents in parts per million (p. p. m.)							
	Lowland rice irrigated[1]	Corn[2]			Ammonia (NH_3)	Nitrates (NO_3)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Manganese (Mn)	Iron (Fe)
				%								
San Fernando clay loam	90	—	5.93	0.09	10	25	24	42	2700	240	44	21
San Fernando clay	90	—	6.05	0.08	10	25	10	38	3600	280	48	3
Quingua silt loam	85	—	5.96	0.09	10	2	7	82	4060	804	77	182
La Paz silt loam	80	—	5.83	0.07	25	25	97	385	4550	420	38	2
La Paz fine sand	80	—	5.45	0.07	25	10	26	56	359	128	8	4
La Paz sand	80	—	5.67	0.08	10	2	29	45	700	107	24	21
Angeles fine sand	80	—	5.38	0.07	10	10	23	60	275	75	10	
Angeles sand	80	—	5.83	0.08	25	10	62	55	283	118	6	18
Candaba silt loam	—	80	5.00	—	10	5	7	82	5500	330	39	42
Candaba clay loam	—	80	5.70	—	2	25	15	130	9300	570	62	34
Bantog clay loam	—	75	6.00	—	10	trace	15	100	6600	680	48	3
Prensa silt loam	—	75	5.80	—	10	25	7	86	5200	860	23	2
Angeles coarse sand	—	60	5.00	0.06	25	2	6	60	20	0	1	trace
Arayat sandy clay loam	—	50	5.50	—	10	25	20	448	2100	330	39	1
Arayat clay loam	—	—	5.25	—	10	trace	5	616	2200	330	19	1

[1] 100 per cent = 60 cavans. [2] 100 per cent = 17 cavans.

fundamentally the behavior and availability of the plant nutrient elements to plant growth. Soils that are highly acid or those with very low pH values render the soluble alumninum ions to accummulate in concentrated forms becoming toxic to plants. Soils of high pH values or of high alkalinity makes the iron, manganese, copper and zinc unavailable to plants, thus, causing abnormal growth.

The Pettinger's chart published by Truog (38) and reproduced here shows the general trend of the relation of soil reaction to the availability of plant nutrient elements. "In this chart, reaction is expressed in terms of the pH scale. The change in intensity of acidity from one pH value to another is shown graphically in the diagram by the change in width of the heavily cross-hatched area between the curved lines."

"The influence of reaction on availability of each nutrient element is expressed by the width of the band (the wider the band, the more favorable the influence) carrying the name of the respective element. Thus, for the maintenance of a satis-

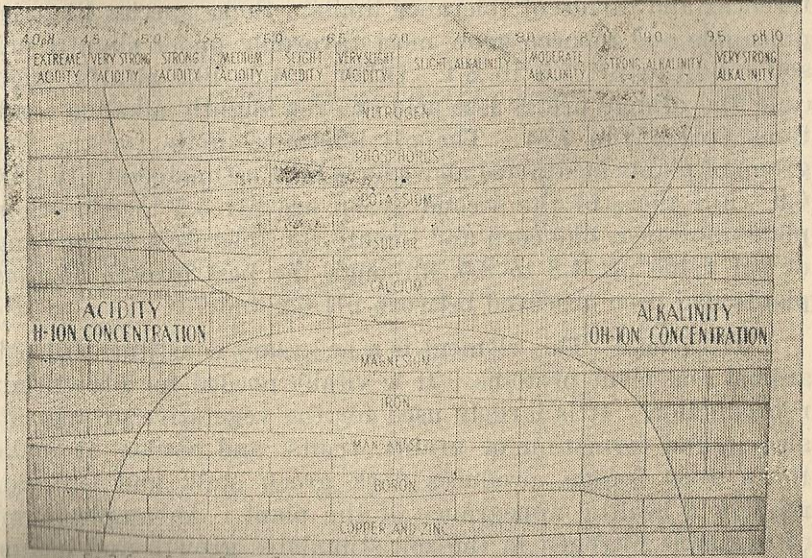

FIG 2 CHART SHOWING GENERAL TREND OF RELATION OF REACTION TO AVAILABILITY OF PLANT NUTRIENTS

Width of bands indicates *favorableness of reaction influence* to the presence of adequate amounts of the nutrients in readily available forms, and not to actual *amounts necessarily present*; these amounts are influenced by many other factors.

Fig. 4.—Width of bands indicates "favorableness of reaction influence" to the presence of adequate "amounts necessarily present"; these amounts are influenced by many other factors.

factory supply of available nitrogen, for example, a reaction or pH range of 6 to 8 is the most favorable. This does not mean that if the reaction of a soil falls in this range, a satisfactory supply of nitrogen is assured. All it means is that so far as reaction is concerned, the conditions are favorable for a satisfactory supply of this element in available form. Also the narrowed band for nitrogen at pH 5 does not necessarily mean that a deficiency of this element will prevail at that pH; it means that so far as reaction is concerned, the conditions are not favorable for an abundant supply in available form. Other factors than soil reaction may promote the presence of an abundant supply; moreover, certain crops having a low requirement may be fully satisfied with a low supply."

The soil reaction or pH value of the surface soils of the different soil types of the province ranges from pH 5.00 to 6.05. A few of them are strongly acid (pH 4.2—5.4) to medium acid acid (pH 5.5-6.1).

Table 1, shows that different plants have different pH preferences and different tolerance limits. Some species like rice, pineapple and tobacco grow most favorably under slightly acid soil condition-pH 5.5 to 6.1. Other crops like alfalfa, sugar cane and orange prefer less acid or even slightly alkaline conditions (pH 6.2 to 7.8). The pH tolerance limits for the first group of plants mentioned above have been estimated at pH 4.8 to 6.9 while those of the second group are pH 5.5 to 8.5. Some plants however, like corn and tomato can tolerate a wider range of pH value pH 4.8 to 8.5, although the best growth of these plants had been observed between pH 6.2 and 7.0.

Nitrogen. — This element is a necessary constituent of both animal and plant proteins. It is vitally needed for growth and reproduction. It is largely used for the vegetative growth and also in the formation of grains, fruits, and seeds. It makes for a good forage, produces dark green stalk and leaf, and renders a healthy appearance of the plant. An ample supply of available nitrogen in the soil stimulates growth and hastens maturity, but the presence of excessive amounts of it causes an overgrowth, and thereby delaying maturity and reducing the resistance of the plants to pest and diseases. Excessive supply of nitrogen affects the lodging of rice, wheat, oats and other cereals. It lowers the purity of cane juices and also decreases the tensile strength of the bast fibers of fibrous plants. But

for leafy vegetables and forage grasses grown for succulence and quality, a big supply of nitrogen is desirable. Plants grown on nitrogen deficient soils appear chlorotic and stunted.

The food source of plants is the soil. The soil nitrogen is found chiefly in the organic matter. When the organic matter decomposes through the action of specific microorganisms in the process of nitrification, the nitrogen of the organic matter is mineralized in three stages, namely—conversion to ammonia, then into nitrites and finally into nitrates.

Most plants assimilate their nitrogen from the soil in the form of nitrates, and to effectively produce this available nitrogen, the soils must be moist, warm and well aerated for the activity of the microorganisms. This is known as nitrification. Rice and other grasses of the same family absorb the ammoniacal form of nitrogen. This ammoniacal form can be

TABLE 14—*The pH requirements of some economic plants.*

X—most favorable reaction
Y—reaction at which plants grow fairly well or normally
O—unfavorable reaction

	SOIL REACTION					
	Strongly acid pH 4.2-5.4	Medium acid pH 5.5-6.1	Slightly acid pH 6.2-6.9	Neutral reaction pH 7.0	Slightly Alkaline pH 7.1-7.8	Medium Alkaline pH 7.9-8.5
Bean, lima (*Phosporous*		Y	X	X	Y	
Corn, Zea *mays* Linn[1]	Y	Y	X	Y	Y	Y
Onion, *Allium cepa* Linn[1]	O	Y	X	X		Y
Orange, sweet, *Citrus* sinensis Osbeck[2]	—	Y	X		X	Y
Peanut, *Arachis hypogaea* Linn[2]	Y	Y	X	X	Y	—
Pet-sai, *Brassica pekinensis* Rupr[3]	Y			X	X	X
Pineapple, *Ananas comosus*, Linn. Merr[3]	Y	X	Y	O	O	O
Rice, *Oryza sativa* Linn[4]	Y	X	Y	O	O	O
Soybean, Glycine max Linn. Merr[1]	Y	X	X	X	Y	Y
Sugar cane, *Saccharum* officinarum[1]	O	Y	X	X	X	Y
Sweet potato *Ipomoea batatas* (Linn) Poir[1]	Y	X	X	Y	O	O
Tobacco, *Nicotiana tabacum* Linn[1]	Y	X	Y	O	O	O
Tomato, *Lycopersicum esculentum*, Mill[2]	Y	Y	X	X	Y	Y

[1] From Weir Wilbert Weir, 1936. Soil Science, Its principles and practice. J. B. Lippincott Co., Chicago and Philadelphia.

[2] From Spurway, C. H. 1941. Soil reaction (pH) preferences of plants. Mich. Agr. Expt. Sp. Bull. 306. Optimum range given was pH 6.0-7.5.

[3] From Areiaga, Antonio N., and N. L. Galvez. 1948. The effect of soil reaction (pH) on the growth of petsai plants on their nitrogen, calcium, and phosphorus content. Phil. Agriculturist 32: 55-59. Normal growth reported was in pH 4.2 to 8.6; optimum range was pH 5.9 to 8.6 ( ).

[4] (A pH range of 5.7 to 6.8 was found to be most suitable for the growth of upland rice variety. Inintiw, by Reis, N. A. and N. L. Galvez, 1949. Phil. Agr. 33: 120-125).

fixed in the soil and not easily lost through leaching. The nitrate form of nitrogen however is very soluble and easily lost by leaching and therefore cannot be fixed.

When the soils are found to be deficient in nitrogen, the nitrogenous commercial fertilizers are resorted to. These fertilizers are applied depending on their source of nitrogen, their cost, the rate of application, and the crops to be grown. For immediate effect and for short season crops, nitrates are preferable to the ammoniacal form. But because of their effect to soil acidity the nitrates tend to reduce while the ammoniacal tend to increase. Growers of long-seasoned crops, like sugar cane, and rice prefer the ammoniacal form then the nitrate form of fertilizers for lower cost and best efficiency.

Following and according to the methods of Spurway (34) for determining ammonia and nitrates, 2-5 p.m. are considerably low, 10-25 ppm. as medium or normal, and 100 p.p.m. or over are quite high and excessive. Low ammonia but of medium nitrates are considered normal for most soils. The low values obtained may mean that the ammonia is used and absorbed by the plants as quickly as it is formed or fixed in the soil as a result of base exchange. If the ammonia is high it is because the soil has quite a big amount of decaying organic matter, or it has just been recently fertilized with ammoniacal compounds.

The available nitrogen content vary considerably during the period of growth of the plant. To properly correlate and have a proper diagnosis for inadequacy or sufficiency of the nitrogen in the soil, the test for available NO_3 and total nitrogen should be interpreted concurrently. Now if low values are obtained it simply means that nitrogen deficiency accompanied with stunted growth and cholorotic appearance of the plants are indications of nitrogen starvation. The high NH_3 content with low nitrate indicates some unfavorable soil conditions interfering with nitrification.

So far analyzed in the laboratory, the average total nitrogen content found in Philippine cultivated soils is about 0.14 per cent as against 0.08 per cent average for Pampanga province. All the soil types identified and analyzed as shown in table 2 are below the average for total nitrogen. The available NH_3 and nitrates except a few appear low in ammonia and nitrates and two of them, represented by the Bantog clay loam and the Arayat clay loam have traces for nitrates. It should be re-

called, however, that 10-25 p.p.m. is medium or normal; and nearly most of the soil types appear normal but the soils require the application of nitrogenous fertilizer.

Phosphorus.— Phosphorus is an essential constituent of plant and animal life. On an average soil, phosphorus is found relatively small in quantity. This element is removed from the farms in considerable amounts in cereal grains and in the bones of animals. It promotes and stimulates healthy root growth and hastens the ripening process. It is an important constituent of protein being needed in the production of nucleo-proteids and fats and albumin, as well as in the conversion of starch into sugars. A deficiency of this element, however, slows down growth due to retarded cell division. Plants grown on phosphorus deficient soils are of inferior feeding value because of their very low phosphorus contents. This fact is brought about in animal nutrition because phosphorus is needed in tooth and bone formation.

The plant takes from the soil phosphorus in the form of phosphates. An abundant supply of phosphorus stimulates extensive root development. Phosphorus starved plants have stunted roots and therefore less feeding zones. During the growing period of the plant, this element is found in the leaves and upper portions. It does not remain fixed in any one portion but it continuously moves about. Near seeding time, large amounts of phosphorus migrate to the seeds and become concentrated.

Because of its relatively small quantity as found in agricultural soils and being a major plant nutrient, its depletion or exhaustion from the soil should be carefully minimized. The stunted growth is the most characteristic symptom of plants grown in soils deficient in phosphorus. The growth symptom that serves to identify a phosphorus shortage is not however clearly defined. The plants usually appear dark green, but corn and some of the small grains sometimes show purplish tints on the leaves and stems when grown on phosphorus deficient soils. Legumes show bluish-green color of leaves and appear stunted. Tobacco manifests a dark green color and a delay in maturity. Citrus fruits are deep green and later fading to bronze, followed by development of necrotic areas and shedding In rice it may delay maturity for as long as two months.

The available phosphorus content necessary to maintain normal plant growth varies according to climate and soil. Under Wisconsin, U. S. A. conditions Truog (37) using his method of analysis, set a minimum limit of readily available phosphorus at 37.5 p.p.m. for a good heavy or clay soils and 25 p.p.m. for lighter and sandy soils. He further suggested that for certain sections in the southern U.S., 10 to 15 p.p.m. of readily available phosphorus might maintain a good crop of corn. In the Philippines, Marfori, (22) found that there was little response to phosphatic fertilization of Philippine rice soil having 37.3 p.p.m. of available phosphorus according to the Truog method. However, there are indications for some soils that 30 to 40 p.p.m. of available phosphorus might be a reasonable minimum requirement for a good crop of rice.

Table 13 shows the analysis of the different soil types for available phosphorus. It ranges from 5-97 p.p.m.; only 2 of the 15 soil types have above 40 p.p.m. while the rest are below 30 p.p.m. The two soil types represented by La Paz silt loam which has 97 p.p.m. and the Angeles sand which has 62 p.p.m. of available phosphorus respectively do not require any phosphatic fertilizer. But all others require from heavy to light application of commercial phosphatic fertilizers. This phosphorus deficiency which occurs on the 13 soil types accounts for the low average crop productions for both rice and sugar cane, the two major crops of the province.

Potassium. — The plants contain and require more potassium than the other essential nutrient element drawn out from the soil. When ashed, the plants usually give about 40 per cent of potassium as potash (K_2O). This element is not localized at definite portions of the plant, but in some crops tend to accumulate in the leaves and stems rather than in the grains. Potassium is vital for photosynthesis in the production of carbohydrates and proteins. It is essential for the development of chlorophyll, production of starch and sugar, and then in the synthesis of fats and albuminoids. It also improves the vigor of the plants and increases resistance to pests and diseases. Potassium increases plumpness in grains and makes the stalks or stems of plants more rigid, thus minimizing lodging (Millar and Turk (25).

The deficiency of potassium in the soil causes marked effects and are striking characteristics on plant growth.

Generally, the leaves become yellowish or dark colored at the tips and margins and finally become brown spreading upward and inward toward the center. This deficiency may cause the formation of shrunken or misshaped leaves, flowers, pods, fruits, tubers and roots. In corn, potassium deficiency is shown by a yellowish-green streaking. Stalks are short and the roots usually poor. The legumes show different chlorotic and necrotic patterns. There may be chlorosis and yellowing with small necrotic areas at first which later enlarge and coalesce to form rim-burned areas on older leaves. In tobacco it has been observed that mottling generally takes place during the latter growth of the plant. The upper leaves may show the first symptoms of potassium deficiency. The mottling is followed by necrotic spotting at the leaf tips and margins. The shortage of this element gives a favorable development of bacterial leaf spot in tobacco, rust in cotton, and ruts of small grains. Deciduous fruits show intervein chlorosis, necrosis and marginal scorch.

Potassium is found in both organic and mineral matter of the soil in the hardly available or replaceable form. Most soils contain relatively large amounts of total potassium, but the amount available to plants is generally small. These unavailable mineral potassium gradually becomes available to plants through weathering, base exchange and through solution in the soil water.

The major portion of the soil potassium exists in the difficultly available form, principally in primary minerals such as feldspars and micas which are constituents of igneous rocks, while the minor portion or available form of the total potassium exists of about one per cent in clay minerals as Kaolinite, Montmorillonite, Beidelite, Halloysite, etc. The water soluble potassium is much smaller than the available and is the one easily lost through drainage and leaching.

Where the base exchange capacity of the soil is large and the total exchangeable base content is low, part or all of the potassium added as fertilizers become fixed in the clay minerals and they are considered fixed or stored for future use by the plants.

Marfori *et al* (24) of the Bureau of Soil Conservation in their study of the fertilizer requirements for lowland rice on some Philippine rice soils found that where the soil is highly deficient in available potassium, small applications of potassium fertilizers generally will not give immediate significant increases in crop yields because of the fixation of the added potassium in the base exchange complex of the soil. However, large initial applications of potassic fertilizers on such a soil will satisfy or saturate its potassium-fixing capacity and will leave enough available potassium for immediate use by plants, thereby increasing yields. With larger applications on the Buenavista silt loam and Maligaya clay loam containing 9 p.p.m. and 50 p.p.m. of available potassium, it was found that larger application gave a significant increase in the crop yield with Guinangang rice variety as the plant indicator. Of the Marikina clay loam, and San Manuel silt loam cotaining 132 p.p.m. and 161 p.p.m. of available potassium, respectively, repeated large applications of potassic fertilizers did not give any significant increase in yields using Guinangang also.

Locsin (19) in his experiments on potash fertilization on sugar cane in various haciendas at Victorias, Occidental Negros reported that soils containing 85 p.p.m. or less of available potassium as determined by Peech and English method gave positive crop response to potash applications while soils containing 151 p.p.m. or more gave negative response.

It might also be expected that rice and sugar cane will have greatly varying minimum available potassium requirements when one considers that the amount of potash removed from the soil by a good crop of sugar cane has been estimated to be about 480 kg. of K_2O per hectare, while that removed by rice has been estimated to be about 98 kg. of K_2O per hectare (Phil. Agriculture Field Crops) (8). More fertilizer experiments must be made in places where the nutrient contents vary gradually from soil to soil to establish more definite limits of the nutrient requirements.

According to Bray (14) for most Illinois or Corn Belt soils, the corn or clovers will not respond to potassium fertilization when the available potassium requirement is 150 p.p.m. or more (350 lbs./acre). The minimum requirement of available potassium for soy beans was estimated at 100 p.p.m. However, Linsley (18) reported that Bray recommends 100 p.p.m. per acre as the minimum available potassium requirement for the principal crops in Illinois. Also, reported by Murphy (26), Oklahoma soils containing less than 60 p.p.m. of replaceable

potassium generally respond to potash application when other factors are favorable for plant growth. He found that the soils in Oklahoma containing 100 to 124 p.p.m. of available potassium have doubtful crop responses and no crop response with soils of 155-199 p.p.m. and with those over 200 p.p.m.

From the results obtained in the islands and from abroad, it may be safe to assume tentatively that 100-150 p.p.m. is the average minimum available potassium requirement of most Philippine crops such as rice and sugar cane. In table 2, the available potassium contents of the fifteen different soil types in Pampanga province range from 38 to 616 p.p.m. Five of these soil types have available potassium of 100 p.p.m. and up, and the rest are all below 100 p.p.m. The three soil types having sufficient available potassium are the La Paz silt loam, 385 p.p.m.; Angat sandy clay loam, 448 p.p.m.; and Arayat clay loam, 616 p.p.m.

Calcium. — This element is one of the essential plant nutrients which affects the soil physically, chemically and biologically. For plant growth, this element is required in the translocation of carbohydrates and certain mineral elements. It appears to stimulate root growth and adds strength to cell walls. It helps in regulating acid-base exchange within the plants. It also remains in the leaves and stalks as the plant matures. The calcium content of the plants is an index of their feed value, because of its effectiveness in the development of bones and teeth of animals. According to Sherman (31), calcium is the outstanding element of the mineral matter which gives shape and permanence to the body's framework and endows our bones with strength, and our teeth with hardness that they need. Thatcher (36) also in his experiments with algae, have shown that in the absence of calcium salts, mitotic cell division takes place showing that the nucleus functions properly but the formation of the new transverse cell-wall is retarded, supporting the fact therefore that calcium is needed for cell wall formation.

The physical structure of a cell is affected by the amount it contains of the element calcium. Soil of high calcium content usually have better tilth, are granular and porous, and are easy to work with. Calcium causes flocculation of soil cololids and liming the soil neutralizes the acidity of acid soils and corrects the toxic effects caused by such acidity of plants. Lime when added to the soil tends to increase the availability of phosphorus in the soil. It helps in neutralizing organic acids or regulates the acid-base balance within the plants. Now, how this element affects the availability of soil mineral element have been discussed under soil reaction. The calcium content of soil at below pH 6.5 affects the availability of phosphorus. Thus in calcium deficient soils, phosphorus is usually comparatively unavailable to plant although the total phophorus content is relatively high. Below pH 6.0 the tendency to form calcium phosphate soluble in carbonic acid that is readily available to plants decreases, and increasing amounts of phosphate combine with hydrated oxides of iron and aluminum forming compounds with very low phosphate availability. Liming, therefore, does not only increase the pH value of the soil but also increases the availability of phosphorus through the formation of calcium phosphate which has greater availability than the phosphates of iron and aluminum.

Beneficial microorganisms found in the soil thrive best on neutral to slightly alkaline soils. At these conditions, the acid soils are limed to adjust to the most suitable and favorable conditions for the plants and the microorganisms to thrive best symbiotically, or nonsymbiotically. Lime promotes decomposition of organic matter which under favorable conditions, nitrification and sulfofication take place in addition to furnishing the microorganisms the nutrients required by them in their metabolism. In nitrification, the oxidation of ammonia to nitrous acid by nitrosomonas and other related species and of nitrite into nitric acid by nitrobacteria are markedly retarded by soil acidity. Therefore, lime should be applied to distinctly acid soils to stimulate nitrification, according to Truog (38).

Among the effects of liming the soil on plant composition as reported in the literature (33) are the following; (a) the calcium content of the cabbage leaves have been increased from 4.42 per cent to as much as 7.53 per cent, (b) besides increasing the yield of tomatoes to more than double, their vitamin C or ascorbic acid content had been almost doubled also from 96 p.p.m. to 170 p.p.m.; and (c) corn grain showed an increase in the protein content of 40 per cent due to application of lime alone.

Calcium deficient soils result in the death of the terminal buds.

Among the many soil types analyzed so far for available calcium by the Peech and English method in this laboratory, those that rated high in crop productivity gave on the average of about 2,000 to 6,000 p.p.m.

From the published results of the effect of lime and ammophos experiments conducted by Madamba and Hernandez (21) of the Bureau of Soil Conservation in San Ildefonso, Bulacan for upland rice and the unpublished data of about 2 cavans yield in the unlimed control (no ammophos also), it was estimated that the increase in yield of upland rice due to the six tons of lime applied per hectare was about 20 cavans. Even without statistical treatment an increase in yield of about 20 cavans over the control which was about 2 cavans only was certainly significant. The pH of the soil where the experiment was conducted was 4.80 and the available calcium content was 617.5 p.p.m.

The unpublished results on liming experiments on two other soil types conducted in our laboratory showed that with the same variety of upland rice, Dumali, not one of the several rates of liming (even up to an application of 240 tons per Ha.) gave statistically significant increase in yield. This may be explained by the fact that both soils used in the experiments had rather high available calcium contents to start with. The soils used were Buenavista clay having a pH value of 6.17 and an available calcium content of 3,800 p.p.m. and the Carmona clay having a pH value of 5.39 and an available calcium content of 3,600 p.p.m.

The results of available calcium content obtained from the analysis of the surface soils sampled from the fifteen different soil types of the province of Pampanga are shown in table 2 which ranges from 20 p.p.m. as the minimum represented by the Angeles coarse sand to 9300 p.p.m. as the maximum represented by the Candaba clay loam. The following soil types as shown in table 2 such as La Paz fine sand, La Paz coarse sand, Angeles fine sand, Angeles sand, and Angeles coarse sand reveal the need of agricultural lime so as to meet the minimum available calcium requirements of crops especially rice and sugar cane. All others contain enough or sufficient available calcium and therefore do not need anymore lime.

Magnesium.—The other essential element for plant growth is magnesium, which is a constituent of chlorophyll and of most seeds. It appears to be needed in the translocation of starch and the formation of fats and oils and aids in the transportation of phosphorus from the older leaves to the younger portions of the plant. The characteristic discoloration of the leaves purplish-red leaves with green veins in cotton, chlorotic leaves in legumes and striped leaves in corn with the veins remaining green and the other portion becoming yellow are all symptoms of magnesium deficiency.

The symptoms of magnesium deficiency occur on mature leaves of citrus at any season of the year. The irregular yellow blotches start along the midrib of the leaves near the fruits and eventually coalesce to form irregular yellow bands on each side of the midrib. This area rapidly enlarges until only the tip and the base of the leaf are green, the base showing a more or less V-shaped area pointed on the midrib. In more advanced states the entire leaf may become yellow. Other findings at the Citrus Expt. Station in Florida, U.S.A. have shown that magnesium deficiency causes a reduction in the total crop, size of fruit and in the sugar, acid, and vitamin C contents of the citrus juice (Camp *et al*), (15).

The addition of magnesium-bearing fertilizers principally of dolomitic limestone and magnesium sulfate on the magnesium deficient soils in Florida (U.S.A.) has become common practice. The increase in the yield of the crop is due to magnesium and that standard fertilizers in Florida has included or incorporated a certain percentage of magnesium. (Anonymous (9). Also a state survey of the fertilizer practice in Florida in 1944 revealed that in 41 cases or estimates, proper fertilization increased the average yield of citrus more than fourteen times that of the control with an estimated yield of citrus fruits without fertilizer to be 24.4 boxes per acre, while that with the fertilizer 358.5 boxes. (National Fertilizer Assn. (27).

The soils of Pampanga show that only three of the fifteen soil types analyzed gave the minimum available magnesium content of over 600 p.p.m. The available magnesium contents of the different soil types in Pampanga ranges from 10 p.p.m. as represented by the Angeles coarse sand to 860 p.p.m. as represented by the Prensa silt loam. Our findings shows that the soil types that rated high in crop productivity and which had been analyzed so far by the Peech and English method in our laboratory gave about 600 to 1700 p.p.m. of available magnesium on the average. However, for certain species of citrus (pumelo or *citrus maxima* Brun. Merr), symptoms of magnesium deficiency had been observed on soils that contained even as much as 950 p.p.m. of available magnesium. As mentioned earlier excepting the three soil types mentioned above, all others are deficient in this element. Such deficiency, however, may be corrected by applying magnesium bearing fertilizers or magnesite or magnesium carbonate.

Iron. — This element is also needed by the plant but only in very small or limited quantities.

Different soil types from various places in Luzon which according to their crop productivity ratings, were rated high or at least medium were analyzed for available iron content in this laboratory. Following the Peech and English method the results obtained ranged from about 2 p.p.m. to 30 p.p.m. of available iron. Table 2 shows the available iron content of the soil types which ranges from trace of the Angeles coarse sand to 182 p.p.m. of the Quingua silt loam.

Manganese. — Most agricultural soils contain very small amounts of total manganese—less than 0.1 per cent (1,000 p.p.m.), and the requirements of plants are also very small. The literature reports that the cabbage leaves contain 23 p.p.m. of manganese; radish roots, 29 p.p.m.; rice grains 23 p.p.m.; and tomato fruits, 46 p.p.m. Some soil types from various places in the Philippines that were rated high or at least medium in crop productivity were analyzed in this laboratory for available manganese content following the Peech and English method. The manganese content of these soils are found to vary from about 15 p.p.m. to 250 p.p.m. The soils of Pampanga when analyzed for available manganese were found to vary from 1 p.p.m. in that of Angeles coarse sand to 77 p.p.m. in that of Quingua silt loam. Four soil types show available manganese below 15 p.p.m.; and this reveals that these soil types are deficient with this element.

The leaf symptoms of manganese deficiency had been observed on ladu and szinkom mandarin orange (*Citrus nobilis Linn.*) growing on certain soil types in Batangas province which was found to contain traces only of available manganese.

The unpublished data of the experiment on the effect of the manganese treated citrus trees on the yield and vitamin C content of the juices over the untreated reveal that there is an increase in yield as well as the vitamin C content of the juice of those manganese treated trees over the control but so far are not statistically significant.

FERTILIZER AND LIME REQUIREMENTS

The chemical characteristics and the results of analysis of the various soil types are presented in table 13, and have been discussed lengthily under separate headings. Under this topic an attempt is given here to serve us a guide as to the requirements for rice, corn and sugar cane.

TABLE 15—*Fertilizer and lime requirements of Pampanga.*

Soil types	Agricultural lime[1]	Ammonium sulfate (20% N)	Superphosphate (20% P_2O_5)	Muriate of potash (60% K_2O)
	Tons/Ha.	*Kg./Ha.*	*Kg./Ha.*	*Kg./Ha.*
		For Rice		
San Fernando clay loam ..	—	300	100	200
San Fernando clay	—	300	250	200
Quingua silt loam	—	300	300	150
La Paz silt loam	—	300	—	—
La Paz fine sand	4.00	300	100	200
La Paz sand	3.25	300	50	200
Angeles fine sand	4.25	300	100	200
Angeles sand	4.25	300	—	200
Candaba silt loam	—	300	300	150
Candaba clay loam	—	300	200	50
Bantog clay loam	—	300	200	100
Prensa silt loam	—	300	300	150
Angeles coarse sand	5.00	300	300	200
Arayat sand clay loam ...	—	300	150	—
Arayat clay loam	—	300	300	—
		For Corn		
San Fernando clay loam ..	—	300	100	250
San Fernando clay	—	300	250	250
Quingua silt loam	—	300	300	200
La Paz silt loam	—	300	—	—
La Paz fine sand	8.00	300	100	250
La Paz sand	8.50	300	50	250
Angeles fine sand	8.50	300	100	250
Angeles sand	8.50	300	—	250
Candaba silt loam	—	300	300	200
Candaba clay loam	—	300	200	100
Bantog clay loam	—	300	200	150
Prensa silt loam	—	300	300	200
Angeles coarse sand	10.00	300	300	250
Arayat sand clay loam ...	—	300	150	—
Arayat clay loam	—	300	300	—
		For Sugar Cane		
San Fernando clay	1.50	500	115	400
San Fernando clay	—	500	460	400
Quingua silt loam	—	500	575	300
La Paz silt loam	—	500	—	—
La Paz fine sand	8.00	500	115	400
La Paz sand	6.50	500	50	400
Angeles fine sand	8.50	500	115	400
Angeles sand	8.50	500	—	400
Candaba silt loam	—	500	575	300
Candaba clay loam	—	500	345	100
Bantog clay loam	—	500	345	200
Prensa silt loam	—	500	575	300
Angeles coarse sand	10.00	500	575	400
Arayat sand clay loam ...	1.50	500	230	—
Arayat clay loam	2.50	500	575	—

[1] For description of samples, see table 1.
[2] Limestone ($CaCO_3$) pulverized to 20 mesh and about 50% to pass 100 mesh.

For information and guidance, the unpublished results on the preliminary fertilizer and liming experiments of upland rice in Bohol, conducted by the Division of Conservation Operations are cited here. The yield of the control was 10.51 cavans of palay per hectare. With an application of 300 kg. ammophos (16% N and 20% P_2O_5) per Ha. to another lot the yield became 28.36 cavans with an increase of 17.85 cavans over the control. However, with another application of not only 300 kg. ammophos but also with 2 tons of lime per Ha. the yield was 41.91 cavans. Another treatment was made in which 300 kg. ammophos and 4 tons lime per Ha. were applied, the yield was 42.41 cavans. From the data presented, there was an increase yield of 17.85 cavans of palay from the ammophos treated over the control. The application of ammophos and 2 tons of lime gave an increase yield of 13.55 cavans of palay per Ha. over the ammophos treatment alone. Increasing the application of lime to 4 tons with the same amount of ammophos it gave only an increase yield of 14.05 cavans over the ammophos treatment alone, or 5 cavans increase from 2 to 4 tons lime applied. This shows therefore that the 2 tons application of agricultural lime per hectare is more profitable and economical than 4 tons. The crop responses to the nitrogenous and phosphatic fertilizers and to lime may be expected due to the low contents of nitrogen and available phosphorus and calcium of Ubay sandy loam in Bohol province. The total nitrogen is only 0.09 per cent and 15 p.p.m. of NH_3 and 10 p.p.m. NO_3. The available P is only 6 p.p.m., available K is 53 p.p.m. and available Ca is 1800 p.p.m. The available K is low, so that potash should have been added and tried but potassic fertilizers were not available in the market at the time the experiment was conducted. The total increase in yield due to liming and fertilization would have been greater had the potassic fertilizers been included in the treatments.

The table for fertilizer and lime requirements for a crop of rice shows five of the soil types in Pampanga need liming from 3 tons to 5 tons per hectare. The nitrogenous fertilizer required is 300 kg. ammonium sulfate analysing 20% N. The phosphatic fertilizer required ranges from 100 kg. to 300 kg. per hectare of single superphosphate analysing 20% P_2O_5 with only 2 soil types showing sufficiency of this element and therefore do not need any phosphatic fertilizer application. As for potassium, there are only 3 soil types that give sufficient supply and therefore do not need phosphatic fertilizer, but the others require from 50 kg. to 200 kg. per hectare of muriate of potash analyzing 60 per cent K_2O. All of these fertilizers are available from the market now and are not very costly. If applied properly and correctly, these fertilizers will boost for a very conservative increase in yield, but one thing sure is that for every peso investment in commercial fertilizers there will be a corresponding increase in profits from the increase yield in cavans of palay per hectare. They are applied to obtain an optimum yield of the crop.

Corn is generally a cultivated cereal crop in Pampanga. It is a heavy feeder and a quick food depleting crop. It is a calcareous loving crop and therefore with the acid soils found in Pampanga and the crop do not respond well to the soils becuse the soils need some liming ranging from 6.5 to 10 tons of agricultural lime per hectare. This crop also need 300 kg. application of $(NH_4)_2SO_4$ per hectare. Crop also require phosphorus ranging from 50 kg. to 300 kg. application of single superphosphate per Ha. There are however, 2 soil types that do not require phosphatic fertilizer application as the La Paz silt loam and the Angeles sand. The potassium requirement ranges from 100 kg. to 250 kg. of muriate of potash per hectare analyzing 60% K_2O. Only 3 of all the soil types have sufficient potash for the corn but the others need potash.

Sugar cane is one of the major crops in Pampanga whereby the sugar barons or hacenderos make plenty of money as a cash crop. The best sugar cane producing soils in Pampanga are the San Fernando clay loam and San Fernando clay according to the crop productivity ratings for this crop. These two soils which have ratings of 90 per cent although considered the best sugar cane soils in Pampanga are far below those of the sugar cane soils in Negros Occidental. The yields of sugar from these areas per hectare could not be compared to the high yields of sugar per hectare from the sugar cane soils in Negros. The Negros soils are better soils and because of heavy applications of lime and fertilizers and perhaps because the Negros planters are faster and quicker to adapt the modern methods of culture, selection of varieties, soil improvement and many other factors going with the growing of sugar cane and the processing. There are 5 soil types in Pampanga that require applications of agricultural lime ranging from 6.5 tons to 10

per hectare. All the soils especially where the sugar cane is mostly grown need 300 kg. application per hectare of ammonium sulfate. The phosphatic fertilizer requirement varies from 50 kg. to 300 kg. of superphosphate application per Ha. La Paz silt loam and the Angeles sand do not require any phosphatic fertilizer. The potassium requirement also ranges from 100 kg. to 250 kg. of muriate of potash per hectare. The same La Paz silt loam, Arayat sandy clay and Arayat clay loam do not require any application of muriate of potash. The last two have the maximum available K contents of 448 p.p.m. and 616 p.p.m. respectively.

Summary

One of the most progressive provinces in Central Luzon is Pampanga. Agriculture is the most important industry in this province. Sugar cane and rice have been the most important crops since time immemorial. This paper has attempted to revise the soil survey report for this province published in 1939, and to bring up-to-date or present agricultural concepts for better farming practices and increase crop yields—such piece of work has been expanded to serve and guide the farmers in general. This province is the leading sugar cane producer in Luzon, but its production when compared to that of Negros Occidental is rather low. It has been found that of all the soil types identified and analyzed there are nine devoted to sugar cane with La Paz silt loam as the best as shown in the crop productivity rating. Other crops that thrive and grow well in Pampanga are rice, corn, banana, beans, watermelon, tobacco, cacao, coffee, peanut and fruit trees like chico, mandarin, lanzones and mangoes.

The fertility of some soils in Pampanga, especially in those places bordering the Pampanga River because of its frequent overflowing of its banks helps in one way to keep maintain, and accounts for the fertility level of these soil types. However, the fertility level on the average is presented in table 2 showing the chemical analysis of the surface soils of fifteen different soil types. In general, the soils if planted to sugar cane and rice being the major crops, some require agricultural lime, and the commercial fertilizers such as ammonium sulfate to supply the nitrogen needed by the crops, superphosphate to supply the phosphorus and muriate potash to supply the potassium also needed by the crops. There are many fertilizer mixtures available in the market. Another method to improve the fertility level, build the soil and increase crop yield is green manuring or application of organic matter. Removal of the nutrient elements by crops, is one of the strongest factors responsible for the low crop yields of the Pampanga soils. Unless the soils are treated or something must be done to improve the soil, yields will be at a low level, accompanied by a low standard of living of the farmers. Every farmer should aim at self-sufficiency from the farm produce. Because of the fast growing population in the province, and with constant agricultural area, every thing must be done to increase the crop production to take care of such rapid increase of population. Restlessness and poverty are usually the outcome of rundown soils. The office of the Bureau of Soil Conservation will exert every effort to help the farmers of Pampanga conserve their soils to obtain better yields and returns than they used to have from their farms.

GLOSSARY OF COMMON ECONOMIC PLANTS FOUND IN PAMPANGA PROVINCE

Common Name	*Scientific Name*	*Family Name*
Agiñgai	*Rottboellia exaltata Linn.*	Gramineae
Agoho	*Casuarina equisetifolia Linn.*	Casuarinaceae
Ampalaya	*Momordica charantia Linn.*	Cucurbitaceae
Arrowroot	*Maranta arundinacea Linn.*	Marantaceae
Atis	*Anona squamosa Linn.*	Anonaceae
Avocado	*Persea americana Mill.*	Lauraceae
Bakauan	*Rhizophora mucronata Lam.*	Rhizophoraceae
Bamboo	*Bambusa spinosa Roxb.*	Gramineae
Banana	*Musa sapientum Linn.*	Musaceae
Bangkal	*Nauclea orientalis Linn.*	Rubiaceae
Batao	*Dolichos lablab Linn.*	Leguminosae
Bermuda grass	*Cynodon dactylon (Linn.) Pers*	Gramineae
Binayoyo	*Antidesma ghaesembilla Gaerth*	Euphorbiaceae
Breadfruit	*Artocarpus communis Forst.*	Moraceae
Buri	*Corypha elata Roxb.*	Palmae
Cabbage	*Brassica oleracea Linn. var. capitata Linn.*	Cruciferae
Cacao	*Theobroma cacao Linn.*	Sterculiaceae
Cadios	*Cajanus cajan (Linn.) Millsp*	Leguminosae
Caimito	*Chrysophyllum cainito Linn.*	Sapotaceae
Cashew	*Anacardium occidentale Linn.*	Anacardiaceae
Cauliflower	*Brassica oleracea var. botrytis Linn.*	Cruciferae
Cassava	*Manihot esculenta Crantz*	Euphorbiaceae
Chico	*Achras zapota Linn.*	Sapotaceae
Coffee	*Coffea spp.*	Rubiaceae
Cogon	*Imperata cylindrica (Linn.) Beauv.*	Gramineae
Corn	*Zea mays Linn.*	Gramineae
Cowpea	*Vigna sinensis (Linn.) Savi.*	Leguminosae
Cucumber	*Cucumis sativus Linn.*	Cucurbitaceae
Derris	*Derris elliptica (Roxb.) Benth*	Leguminosae
Duhat	*Eugenia cumini (Linn.) Druce*	Myrtaceae
Eggplant	*Solanum melongena Linn.*	Solanaceae
Gabi	*Colocasia esculenta (Linn.) Schott*	Araceae
Garlic	*Allium sativum Linn.*	Liliaceae
Ginger	*Zingiber officinale Rosc.*	Zingiberaceae
Ipil	*Intsia bijuga (Colebr.) O. Kuntze*	Leguminosae
Ipil-ipil	*Leucaena glauca (Linn.) Benth*	Leguminosae
Kamachili	*Pithecolobium dulce (Roxb.) Benth*	Leguminosae
Kapok	*Ceiba pentandra (Linn.) Gaerth*	Bombacaceae
Kondol	*Benincasa hispida (Thumb.) Cogn*	Cucurbitaceae

Lettuce	*Lactuca sativa Linn.*	Compositae
Maguey	*Agave cantala Roxb.*	Amaryllidaceae
Mandarin	*Citrus nobilis Lour.*	Rutaceae
Mango	*Mangifera indica Linn.*	Anacardiaceae
Maranggo	*Azadirachta integrifoliola Merr.*	Meliaceae
Molave	*Vitex parviflora Juss.*	Verbenaceae
Mungo	*Phaseolus aureus Roxb.*	Leguminosae
Nangka	*Artocarpus heterophyllus Lam.*	Moraceae
Nipa	*Nypa fructicans Wurmb.*	Palmae
Onion	*Allium cepa Linn.*	Liliaceae
Orange	*Citrus aurantium Linn.*	Rutaceae
Pandan	*Pandanus tectorius Sol.*	Pandanaceae
Papaya	*Carica papaya Linn.*	Caricaceae
Patani	*Phaseolus lunatus Linn.*	Leguminosae
Patola	*Luffa cylindrica (Linn.) M. Roem.* .	Cucurbitaceae
Peanut	*Arachis hypogaea Linn.*	Leguminosae
Pechay	*Brassica chinensis Linn.*	Cruciferae
Pineapple	*Ananas comosus (Linn.) Merr.*	Bromeliaceae
Pummelo	*Citrus maxima (Burm.) Merr.*	Rutaceae
Radish	*Raphanus sativus Linn.*	Cruciferae
Santol	*Sandoricum koetjape (Burm. f.) Merr.*	Meliaceae
Rice	*Oryza sativa Linn.*	Gramineae
Sitao	*Vigna sesquipedalis Fruw.*	Leguminosae
Soybean	*Glycine max (Linn.) Merr.*	Leguminosae
Squash	*Cucurbita maxima Duchesne*	Cucurbitaceae
Sugar cane	*Saccharum officinarum Linn.*	Gramineae
Sweet potato ...	*Ipomoea batatas (Linn.) Poir.*	Convolvulaceae
Talahib	*Saccharum spontaneum Linn.*	Gramineae
Tobacco	*Nicotiana tabacum Linn.*	Solanaceae
Tomato	*Lycopersicum esculentum Mill.*	Solanaceae
Tugui	*Dioscorea esculenta (Lour.) Burkill* .	Dioscoreaceae
Ubi	*Diocorea alata Linn.*	Dioscoreaceae
Upo	*Lagenaria leucantha (Duch.) Rusby*	Cucurbitaceae
Watermelon	*Citrulus vulgaris schrad.*	Cucurbitaceae

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