REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
MANILA

Soil Report 11

SOIL SURVEY OF BATAAN PROVINCE PHILIPPINES

BY

M. M. ALICANTE, D. Z. ROSELL, J. A. MARIANO
F. L. CALIMBAS, AND J. A. TINGZON

WITH A DISCUSSION ON THE CHEMICAL CHARACTERISTICS OF THE SOILS OF BATAAN PROVINCE

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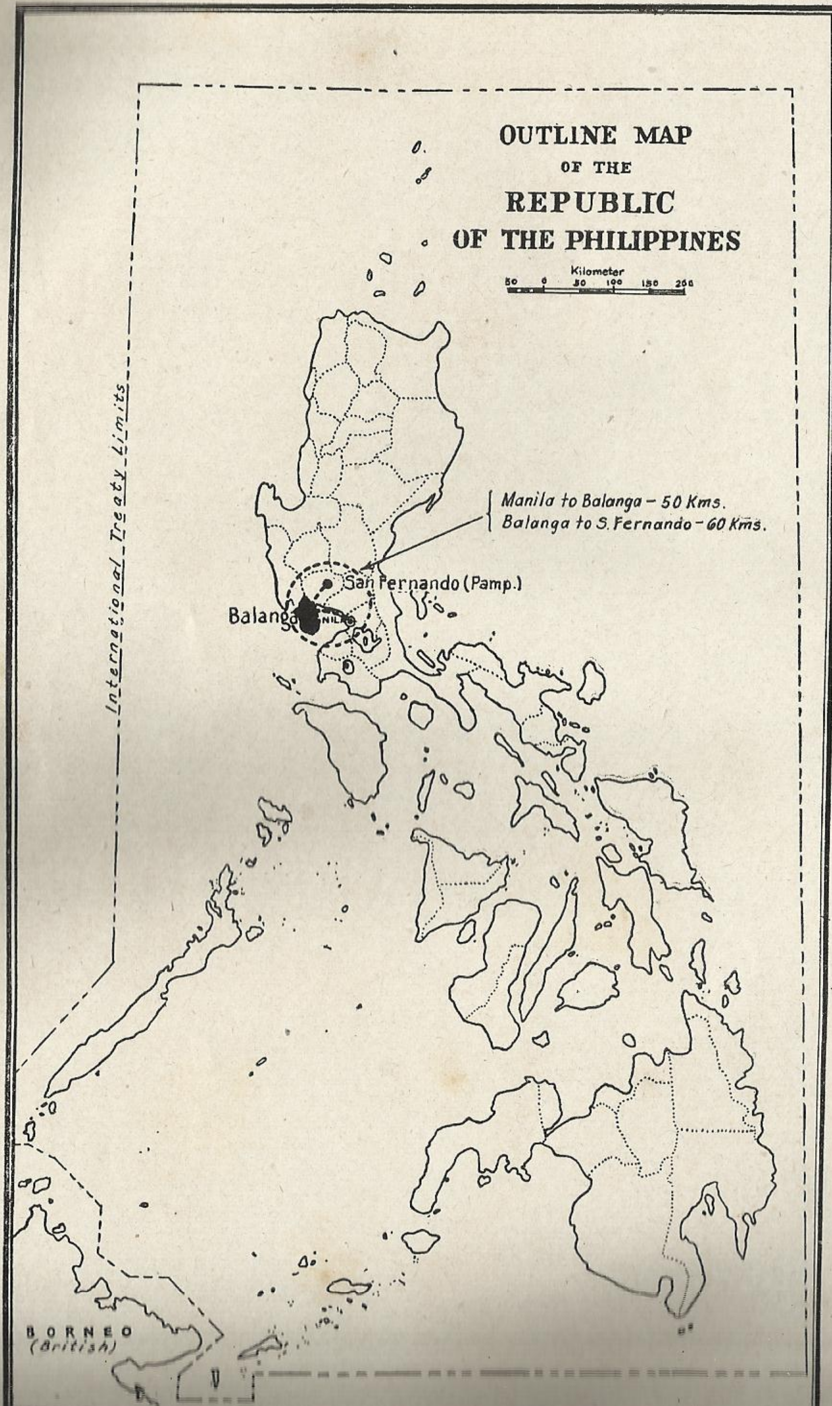
CONTENTS



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ILLUSTRATIONS

SOIL SURVEY OF BATAAN PROVINCE PHILIPPINES

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INTRODUCTION

The projected industrialization of the Philippines, if carried out, will mean an increased demand for agricultural products as sources of raw materials. Farmers will be induced to raise crops more extensively and intensively than before, which may ultimately result in the impoverishment of our soils if these are cultivated injudiciously. There is still an abundance of available virgin agricultural lands, it is true, but sooner or later all these areas will also be brought under cultivation. With due regard for the welfare of succeeding generations we must utilize our soils wisely in order that their natural fertility may be maintained, if not actually increased. A soil survey furnishes information and serves as a guide for the attainment of such an objective.

The soil map, including the accompanying report, has several uses. It shows the location and extent of the different kinds of soil in the province or locality surveyed. The soil survey not only provides an inventory of the soil resources of a given area but it also serves as a basis for the formulation of sound programs of land-use planning and soil-management practices. In short, the soil map and the accompanying report "must be considered as a handbook of the agricultural geography of the area."

DESCRIPTION OF THE AREA

Bataan Province comprises the whole of the peninsula hedged in by the China Sea and Manila Bay in the western part of Luzon (frontispiece). It is bounded on the north by Zambales and Pampanga Provinces; on the east by the Manila Bay; and on the west and south by the China Sea. Balanga, the capital of the province, is 31.2 miles from Manila across Manila Bay,

1800

and 37.5 miles from San Fernando, Pampanga. The province has an area of 136,000 hectares classified in Table 1, as follows:

TABLE 1.—*Classification of the soil cover of Bataan Province*[a]

Kind of land.	Area in Ha.	Per cent.
Commercial forest	52,650	38.71
Noncommercial forest	41,670	30.63
Open land	300	0.22
Cultivated land	34,330	25.25
Swamp, fresh, and salt-water marsh	7,050	5.19
Total	136,000	100.00

[a] Tamesis, Florencio. Forest Resources of the Philippines. Proceedings of the Sixth Pacific Congress of the Pacific Association 1939 4 (1940).

Except for the narrow coastal plain which hugs the northern half of the eastern coast of the province, the whole area is covered by hills and mountains belonging to the Western Cordillera, generally known as the Zambales range (fig. 1). There are two groups of extinct volcanic stocks, the northern group composed principally of Mount Natib (1,288 meters), Mount Sta. Rosa (931 meters), and Mount Silanganan (1,104 meters), and the southern group composed of Mount Mariveles (1,355 meters), and Mount Bataan (1,420 meters).* Between these two mountain groups is a pass, the highest point of which does not exceed 200 meters in elevation, which divides the province into the northern and southern sections. The Pilar-Bagac road traverses this pass connecting the eastern and western coasts of the province. There are no intermontane valleys of agricultural importance. The rocks of the mountains are predominantly andesites, although other extrusive rocks are also found. The narrow coastal plain is all alluvium.

The mountains slope down gradually from the center of the province outward to the sea. Numerous small rivers, generally short with very few meanders, radiate from the mountain groups to the sea, draining the whole area very efficiently. The more important rivers in the province are the Colo, Hermosa, Tapulao, Orani, Samal, Calaguiman, Salian, Balanga, Talisay, Pilar and Limay Rivers in the eastern sector, and the Moron, Bagac, Binanga, Saysain, and Aglaloma Rivers in the western sector. Not one of these rivers is navigable throughout the year even to small crafts.

* Elevations taken from the Coast and Geodetic Survey map of the Philippines (1941).

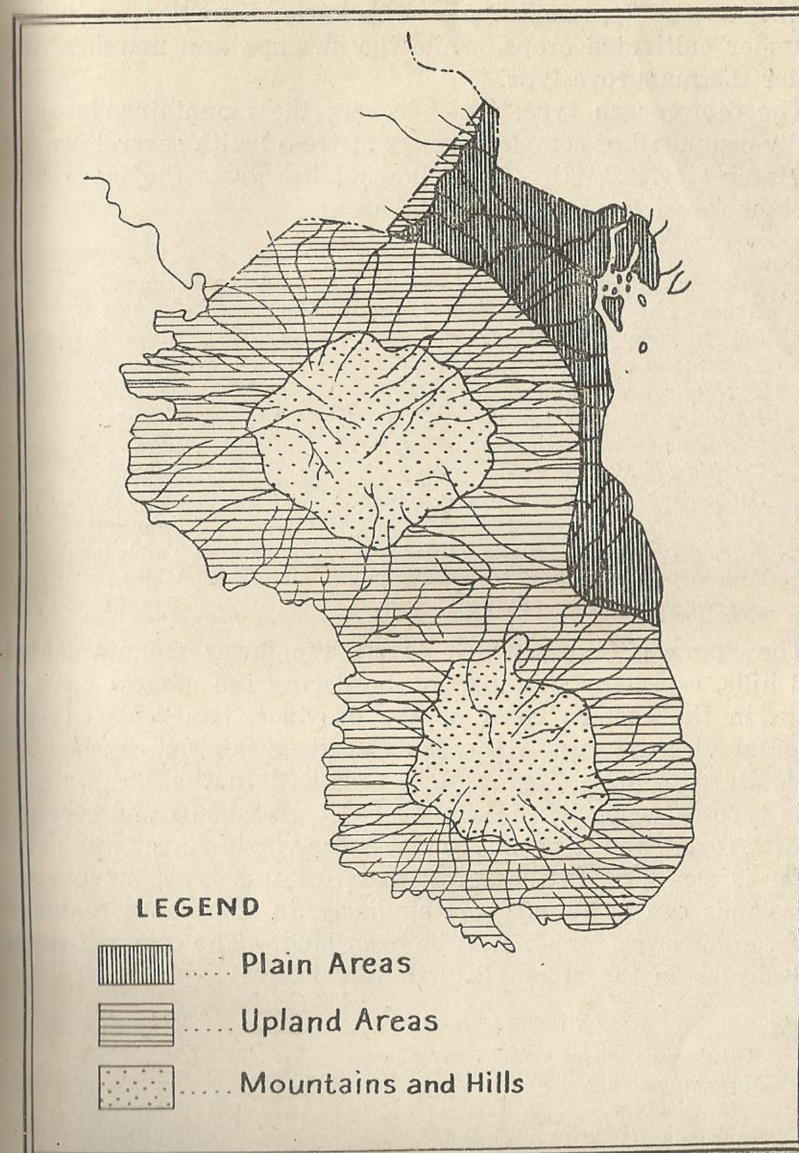


FIG. 1. Sketch map of Bataan Province showing general topography and natural drainage system.

The greater part, mostly the central portion, of the province is under primary forest of the dipterocarp type. The hills and lower mountainsides up to an elevation of 300 meters are generally under second-growth forest and open grassland commonly known as the "parang" type. The lowland portion, or plain, is under cultivated crops, while the swamps and marshes are under the mangrove type.

The dipterocarp type, which covers the mountains, is generally composed of complex groups of trees "with several crown levels or stories." (7) The following list gives the more important forest trees native to the area:

Scientific name	Common name
Pygeum vulgare (Koehne)	Amugan
Koordersiodendron pinnatum (Blanco) Merr.	Amugis
Shorea guiso (Blanco) Merr.	Giso
Terminalia edulis Blanco	Kalumpit
Buchania arborescens Blume	Kaming
Parkia javanica (Lam.) Merr.	Kupang
Zizyphus talanai (Blanco) Merr.	Ligaa
Cubilia blancoi Blume	Lubilubi
Anisoptera thurifera (Blanco) Merr.	Palosapis
Cinnamomum mercadoi Vidal	Samiling
Knema glomerata (Blanco) Merr.	Tambalau
Artocarpus cumingiana Trec.	Ubien
Shorea polysperma (Blanco) Merr.	Tangili

The "parang" type, which covers the lower mountainsides and hills, especially that portion bordering the narrow coastal plain in the eastern coast of the province, has replaced the original virgin forest as a result of the "caiñgin" system of agriculture, which is extensively practiced in the Philippines. This type of vegetation is a mixture of grasslands and second-growth forest and it usually replaces the virgin forest when the latter is cleared. In the forest areas of this type, patches of grasslands can be found; and similarly, in grasslands, patches of second-growth forests dot the open land. The common trees and shrubs in the second-growth forests are:

Scientific name	Common name
Antidesma ghaesembilla Gaertn.	Binayuyu
Macaranga tanarius var. *tomentosa* (Blume) Muell.-Arg.	Binunga
Leucaena glauca (Linn.) Benth.	Ipil-ipil
Gliricidia sepium (Jacq.) Steud.	Madre cacao
Pithecolobium dulce (Roxb.) Benth.	Kamanchile
Tectona philippinensis Benth.	Teak
Blumea balsamifera (Linn.)	Subusub
Schizostachyum lumampao (Blanco) Merr.	Boho
Bambusa spinosa Roxb.	Bamboo (most common sp.)
Psidium guajava Linn.	Guava

Nipa and bakauan are the most common vegetation of the swamps, which belong to the hydrosol series.

The trees of the forest at the Bataan-Zambales boundary have been so badly shelled during the war of liberation that some of them died. Note the leafless dead trees.

Fig. 2

The coarse grasses which cover the open grasslands are: cogon [*Imperata cylindrica* (Linn.) Beauv.], talahib (*Saccharum spontaneum* Linn.), tambo [*Phragmites vulgaris* (Lam.) Trin.], and several species of *Themeda*. These are all gregarious grasses.

The mangrove swamps are inhabited by two kinds of plants: (1) Those with stems, and (2) those without stems. Some of the common species of the first group are the bakauans (*Rhizophora* spp.) and aroma [*Acacia farnesiana* (Linn.) Willd.]. Those of the second group are represented by the nipa (*Nypa fructicans* Wurmb.) and ferns called tinglog (*Acanthus ilicifolius* Linn.).

Organization and population.—The earliest settlements in Bataan Province were native villages which later grew into towns. Samal, Abucay and Mariveles (formerly Kamaya) are the oldest of these settlements and had already been in existence long before the Spanish Dominican Friars came to the region in the early part of the seventeenth century. (8) Bataan became a province in 1754. Before that time the northern portion of the peninsula had been a part of Pampanga and the southern part constituted the "corregimiento" of Mariveles. The province as now constituted is composed of the following towns: Balanga, Abucay, Samal, Orani, Hermosa, Dinalupihan, Pilar, and Orion, all taken from Pampanga, and the towns of Mariveles, Limay, Bagac, and Morong which formerly belonged to the corregimiento of Mariveles.

There has been a steady increase in the population of the region in spite of the early depredations of the Dutch along the coast. The following figures show the population of the province for the corresponding years given:

1799	16,654	1903	46,787
1818	23,393	1918	58,380
1850	39,000	1939	85,555

Most of the early settlers came from Pampanga and its neighboring provinces. Later, immigrants from Zambales also came to Bataan. From 1941 to 1944 there was a decrease in the population of the province because of the war, the region having been the battleground between the USAFFE and the Japanese Forces in the first stage of the war in the Far East.

In 1939 the density of the population in the province was 62.9 per square kilometer. The greater number of the inhabitants in this region live in the coastal plain along the eastern coast. According to the census of 1939, Balanga had a population of 11,684; Abucay, 10,216; Dinalupihan, 8,821; and Orion, 10,909.

Transportation.—Transportation facilities in the province are adequate for the needs of the inhabitants. There are 107 kilometers of first-class roads, 137.7 kilometers of second-class roads, and 29.3 kilometers of third-class roads. The main highway, which also connects Bataan with Pampanga, runs through the whole length of the province southward along the eastern coast from the town of Hermosa to Mariveles passing through all the towns in between. Two roads, the Dinalupihan-Olongapo and the Pilar-Bagac, cut through the province from east to west making the western towns accessible from the east.

The Pampanga Bus Company, Bataan Express Company, Maningas Transportation Company, Batac Transit Company, and many other minor operators operate passenger and freight trucks throughout the province. The Metropolitan Transportation Service of the City of Manila maintains water transportation facilities from Manila to Orani, Balanga and Limay across the Manila Bay.

Water supply.—The most common sources of water for domestic and drinking purposes are artesian wells sunk at depths ranging from 15 to 30 meters. In some places, especially in remote settlements, water from springs, creeks and rivers is used by the people. In a few instances surface water from open wells is the only available supply.

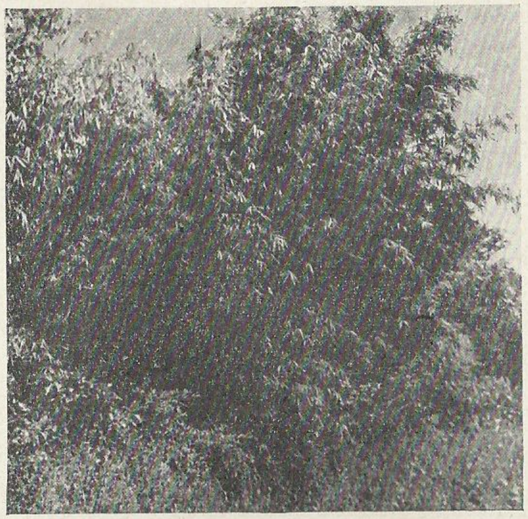
Generally, artesian water is safe for drinking without any treatment, but water from open wells, creeks and rivers need purification to make it safe for domestic use.

Other cultural features.—There are 65 elementary schools in the province. A public high school is located in Balanga, and in addition there are three private high schools located one in each of the towns of Dinalupihan, Orani, and Orion.

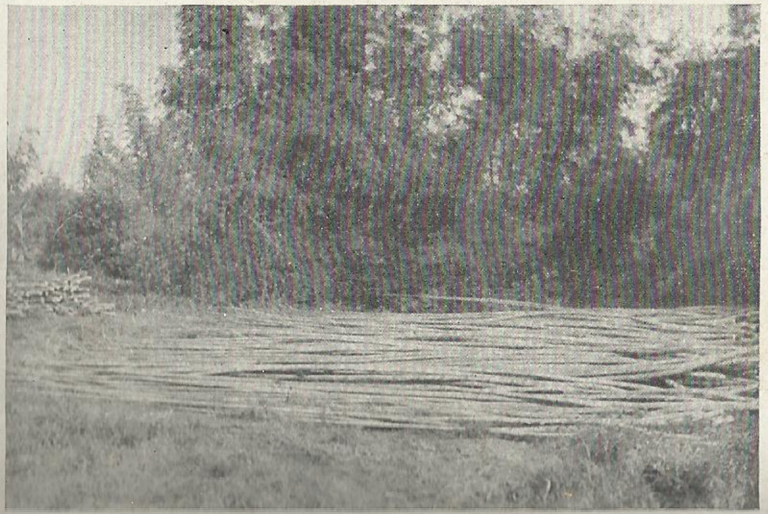
The Bureau of Health maintains a public hospital in Balanga and a public dispensary and charity clinic in each municipality. Government dentists, school nurses, and doctors are also available to take care of the health of school children and teachers.

There is a Roman Catholic Church in every town and a Protestant Church in some towns. Several of these churches, however, were destroyed during the war operations in 1942.

The Military Police Command at Balanga operates and maintains a telephone system connecting the different towns with



Boho is a common species in the secondary forests of the province. Sawali is manufactured from this plant.



Bamboo, an important source of building material, is a common constituent of the secondary forests.

Fig. 3

the capital and with Pampanga. Mail is dispatched and received everyday except Sundays in all the towns with the exception of Bagac and Moron. In these two towns, mail is dispatched and received only three times a week.

The Bataan National Park, containing 31,400 hectares, has recently been established at Mount Samat, eight kilometers west of the towns of Pilar and Orion. It is dedicated to the Filipino soldiers who died in the historic siege of Bataan.

Industries.—Agriculture is the major industry of the province. Fishing is next in importance and lumbering, third.

Fishing is mostly done along the coast, which abound in fish and other sea foods like crabs and shrimps. It is best developed as a calling in the towns of Orani, Balanga, Orion, and Pilar. A large portion of the daily catch is shipped to Manila. In Orion, part of the daily haul is made into "tuyo."

The culture of milkfish (*Chanos chanos* Forskal), locally known as "bañgos," is one of the most important industries in this province. Extensive areas of fishponds are found in Hermosa, Orani, Samal, Abucay, and Balanga. The soil and water conditions along the deltas and mouths of the rivers where these towns are located are favorable to the growth of algae and other lower forms of plant life which serve as food for the fish. The young fish or fry are caught along the western coast of the province, in the town of Moron and along the Zambales coast, and cultured in fishponds for from several months to a year, after which time, they are ready for the market. The greater portion of the milkfish harvest is sold in Manila.

The area presently devoted to this industry could be easily increased by converting into fishponds areas now under nipa.

Bataan has a rich stand of timber in its commercial forests. Lumbering and logging is at present the most lucrative industry in the province due to the great demand for building materials throughout the country. There are at present six saw mills, with an aggregate daily capacity of 16,500 board feet, representing an investment of ₱277,000. The two largest saw mills, the St. Joseph's Saw Mill and the Cadwallader Sawmill, have daily capacities of 7,000 and 5,000 board feet, respectively.

The home industries in the province include "sawali" and mat weaving, broom making and the manufacture of wooden slipper (bakia). Sawali is made principally in the towns of Hermosa and Dinalupihan. Buri mats are woven in Abucay and Moron. In Abucay brooms are manufactured from a species of grass locally known as "tambo" [*Phragmites vulgaris* (Lam.) Trin.]. Canoes are also made in this town. Wooden slippers are made in Samal, Balanga, and Pilar.

Two ice plants are found in the province—one in Orani and one in Orion. Rice mills are found in Dinalupihan, Hermosa, Balanga, and Pilar.

CLIMATE

Climate is one of the five factors in soil development. With the factors relief, time and biological activity remaining constant, different rocks or parent materials under identical or very similar climates give rise to similar soils. The length of the cropping season, the types of crops to be grown, the need for irrigation, and other requirements of crops, depend to a great extent on the climate of the locality. Oftentimes, even the health and industries of the people are affected by the prevailing climate.

The Philippines fall under the type of climate known as tropical rainforest, monsoon variety.(10) This climate is characterized by high temperature and heavy rainfall.

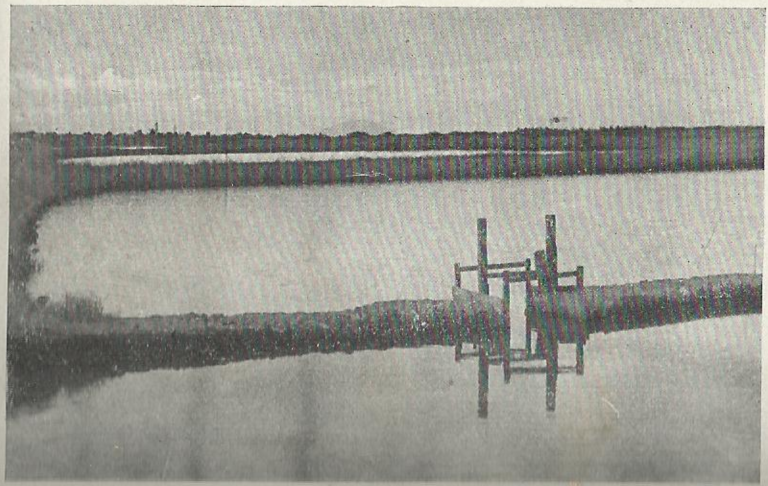
The climate of a province is classified according to the type of rainfall distribution during the year. Temperature variations within a province are small and do not play a significant role in the classification of the climate of the different provinces.

Bataan falls under the first type of rainfall, a wet season from May to October, and a dry season from November to April.(8) Table 2 gives the monthly average rainfall for the four weather stations in the province. Table 2*a* gives the monthly average number of rainy days for the same stations. The heaviest rains fall in July, August, and September. Along the western coast the westerly and southwesterly winds bring in "cyclonic rainfall." Typhoons at times hit the province especially during the latter part of the rainy season, often causing serious damage to crops and loss of lives.

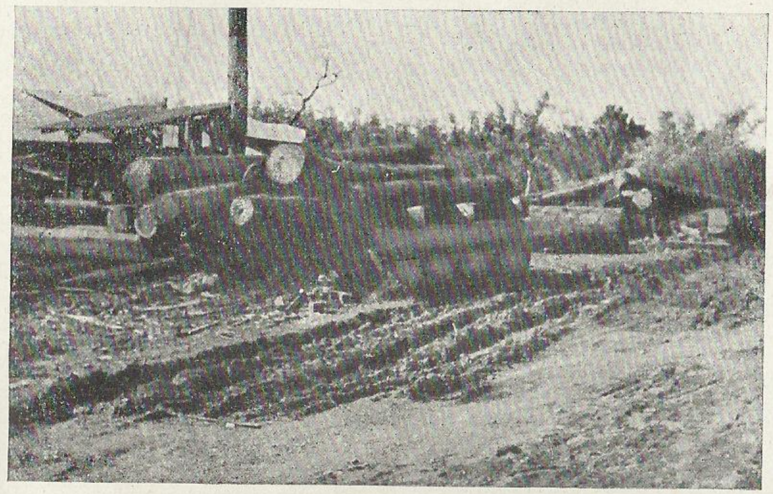
Westerly and southwesterly winds prevail from June to October, and southeasterly and northeasterly winds predominate from November to May.

The relative humidity and seasonal variations in temperature are similar to those of Manila. It is most humid in September and least humid in April. The coolest months are December and January, and the hottest season lasts from April to May.

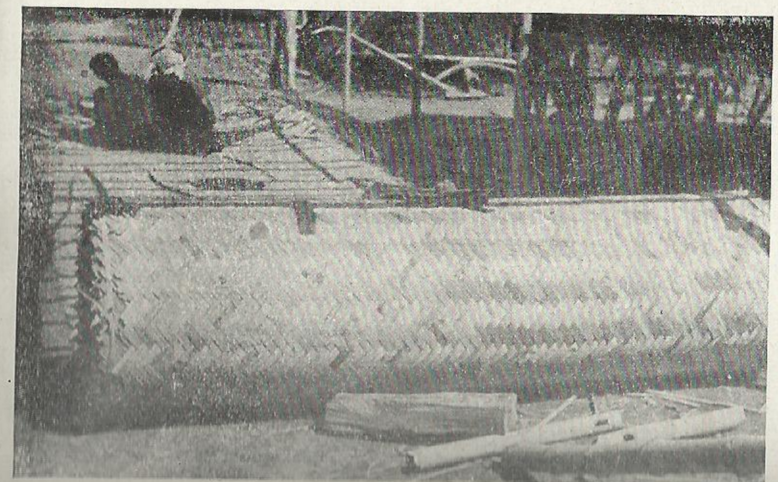
Fish corrals, or "baclad," being dried preparatory to setting in the sea as fish traps. Fishing is second only to agriculture in importance as an industry of the province.



A large part of the fish supply comes from fishponds where milkfish is cultured. Most of the fishponds are located in the towns of Hermosa, Orani, Samal, Abucay, and Balanga.



Logging is a lucrative industry in the province. The logs are piled along the road where they are later loaded into trucks and taken to the sawmills or to Manila.



Sawali weaving is a home industry in the towns of Dinalupihan and Hermosa

Fig. 5.

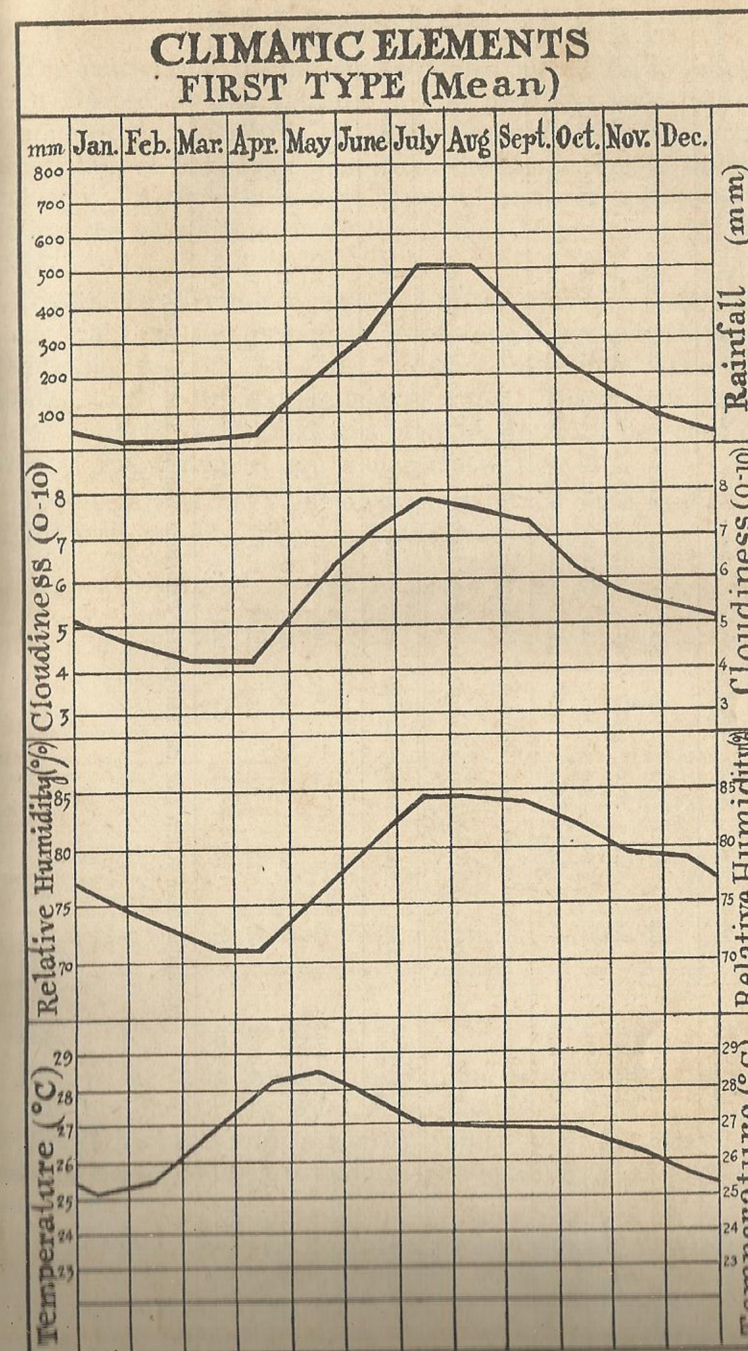


Fig. 7. Graph of the First type of Climate of the Philippines.

TABLE 2.—*Average rainfall in millimeters in different towns of Bataan Province* [a]

Station.	Years of observation.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Lamao Experiment Station, Lamao, Limay	1918–1933 1902–1908	8.3	9.9	7.4	17.2	263.3	375.3	699.4	910.6	403.3	229.5	122.3	39.0	3,058
Balanga	1920–1932	9.5	13.5	10.3	32.2	227.5	367.1	613.6	651.1	386.0	195.1	102.2	32.8	2,640.9
Hacienda San Jose, Dinalupihan	1929–1933	1.9	2.4	0.6	10.2	182.2	340.9	641.5	683.6	275.6	158.2	53.0	19.5	2,369.6
Hacienda San Benito, Dinalupihan	1929–1933	3.1	4.2	5.4	20.9	239.4	429.4	884.5	902.2	347.9	205.3	55.3	27.8	3,125.1

[a] Compiled from Rainfall of the Philippines, Philippine Weather Bureau (1935).

TABLE 2a.—*Average number of rainy days in different towns of Bataan Province* [a]

Station.	Years of observation.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Lamao Experiment Station, Lamao, Limay	1918–1933 1902–1908	1.9	0.7	1.4	1.5	10.1	18.1	20.1	22.2	18.3	13.8	8.0	4.2	120.3
Balanga	1920–1932	3.0	2.3	1.9	2.9	10.6	18.4	20.9	32.6	19.7	13.6	9.0	5.5	130.4
Hacienda San Jose, Dinalupihan	1929–1933	0.7	1.2	0.2	2.5	11.2	17.0	22.8	19.8	16.2	13.2	6.8	2.6	114.2
Hacienda San Benito, Dinalupihan	1929–1933	1.5	1.5	0.5	3.2	13.0	18.2	24.2	21.4	18.4	14.8	8.2	4.6	129.5

[a] Compiled from Rainfall of the Philippines, Philippine Weather Bureau (1935).

AGRICULTURE

The cultivation of the soil to raise agricultural crops had been started by the settlers in the province long before the coming of the Spaniards to the Philippines. It is the principal occupation of the people in spite of the attractions of the fishing industry. Agricultural development, however, has been slow before the establishment of the Lamao Experiment Station in 1904.

Diversified farming is practiced in the province, with rice and sugar cane as the principal crops, and corn, sweet potatoes, yambeans, peanuts, bananas, mangoes, pineapple, cashew, vegetables, and fruits as secondary crops. Thirty-four thousand three hundred thirty hectares of land, or 25.25 per cent of the area of the province, are under cultivation. (27)

The hectarage and value of produce of the eight leading crops of the province are given in Table 3.

TABLE 3.—*The area and value of produce of the eight leading crops grown in Bataan Province* [a]

Crops.	Area planted in hectares.	Production.	Value in pesos.	Average production per hectare.
Rice	10,962.75	[b]364,013	₱1,071,908	[b]33.2
Sugar cane	3,360.08	[c]45,600 [d]25,236	359,542	[c]13.6 [d]75.1
Bananas	1,148.73	[e]768,636	154,495	670
Corn	462.42	[b]4,221	12,151	[b]9.0
Mangoes	374.03	[f]3,271,280	85,377	[f]875
Sweet potato	306.70	[g]670,228	13,000	[g]2,190
Pineapple	106,45	[f]501,766	13,706	[f]4,784
Yambean	82.80	[g]846,043	25,962	[g]10,193

[a] Data obtained from Bull. No. 5–A Census of the Philippines: 1939:
[b] Cavans.
[c] Piculs. Other products such as stalks for chewing, and "basi" are not included.
[d] Panocha.
[e] Bunches.
[f] Fruits.
[g] Kilos.

Rice is the most important crop and is grown in every town in the province. The total area planted to rice in 1938 was 10,962.75 hectares with a harvest valued at ₱1,071,908.00. The leading rice-producing towns are Balanga, Pilar, Abucay, Orion, and Bagac.

The lowland varieties grown in Bataan are Raminad Strain 3 (Quezon rice), Elon-elon, Apostol, Macan Bino, Macan Sta. Rosa, and Macan Tago. The average yield of these varieties ranges from 30 to 80 cavans of palay per hectare, depending upon the fertility of the soil, the method of soil management, and the availability of water for irrigation.

The rice varieties used for "palagad" are Kinawayan II, Pinursigueng Puti, and Binato. The average yield of these varieties is from 20 to 30 cavans of palay to the hectare.

The upland rice varieties found in the province are Kinandang Puti, Dumali, Kinastila, Ginolong, and Inilangilang. The average yield of these varieties ranges from 15 to 20 cavans per hectare.

The use of fertilizers in rice culture is very limited. Ammonium sulfate is sometimes applied on seedbeds two weeks after sowing, but rarely on fields.

Communal irrigation systems are found in almost all the towns of the province, irrigating approximately 6,000 hectares. The Pilar Irrigation System which is owned and operated by the government irrigates about 300 hectares of riceland.

Sugar cane is the second most important crop of the province. The area planted to sugar cane in 1938 was 3,360.08 hectares, with a total production valued at ₱359,542.00. Most of the crop was planted on the La Paz fine sand, La Paz silt loam, Pilar fine sandy loam and to a small extent on the Antipolo clay. The common varieties of cane grown in this region are: P.O.J. 2878, Mauritius 1900, Badilla, Luzon white, Superior, and Alunan. The average yield per hectare ranges from 40 to 60 tons of cane. There is only one sugar central in the province, the Bataan Sugar Central, located in Cupang, Balanga, with a milling capacity of 250 tons of cane per twenty-four hours. The towns leading in the production of sugar cane are Dinalupihan, Hermosa, Balanga, Pilar, Abucay, and Samal.

Ammonium sulfate is the most common fertilizer used in sugar cane culture. It is generally applied at the rate of from 200 to 300 kilos per hectare.

During the war the sugar central and most of the small sugar mills in the province were destroyed, causing the sugar cane planters to abandon this crop for the time being. Sugar cane lands have been idle for the last five years.

Corn, a secondary crop, is grown extensively in both lowland and upland areas, after the rice is harvested, at times intercropped with peanuts, upland rice and yambeans. Generally there are two crops a year, the first crop being planted in May or June and the second in October or November. A large portion of the first crop is harvested green. The more common varieties grown are the Calauan Yellow Flint and Calauan White Flint. The towns leading in the production of corn are Pilar, Orani, Balanga, and Hermosa.

The native plow and the carabao, or water buffalo, are still the main implement and source of "power" on the farm in Bataan Province. The nearly flat to level topography of the La Paz series is adapted to the use of farm machinery, such as tractors, disc harrows, etc.

Sincamas, or yambean, is a secondary crop commonly grown in the province. This particular field is planted in yambean for seed production.

Fig. 6

Sweet potato, or camote, is the most important root crop in the province. Like corn, there are usually two crops a year, the first planted in May to June and the second in October to December. Inube, Nilabanos, and Hawaii are the more common varieties grown. This crop is grown throughout the province, but the towns of Orani, Samal, Pilar, Hermosa, and Abucay account for most of the harvest.

Yambeans, or sincamas, is another root crop grown. It is usually planted in October or November and harvested during the dry season. The two varieties grown are the blue-flowered and the white-flowered, the former being preferred by the people.

The other root crops grown in this region are cassava, ubi, tugui, arrowroot, and gabi.

The fruits produced in Bataan are banana, mango, and pineapple. The harvests of these crops generally exceed local demand and the surplus is marketed in Manila and the neighboring provinces.

The common vegetables grown in other parts of the country are also grown here, mostly in home gardens. The demand of the people in the province for vegetables is adequately met by local production.

AGRICULTURAL PRACTICES

The prevailing agricultural practices in the province are similar to those in other parts of the country. The native plow and harrow are the main implements of tillage with the carabao as the source of power. The use of farm machinery and fertilizer is very limited, mostly confined to sugar cane fields before the war. There is, however, a growing consciousness on the part of the farmers that present agricultural methods can be improved, that better seeds and the elimination of competing weeds by a thorough preparation of the land before planting will increase the yields.

Clean culture is practiced in the growing of most crops, resulting in accelerated erosion especially in the rolling regions. A program of soil conservation is necessary to arrest soil wastage and if possible to build up the badly depleted areas.

Simulated crop rotation is practiced to some extent. Different crops are planted but no particular consideration is given to the kinds of crops planted in succession.

Communal irrigation systems irrigate only a small fraction of the cultivated area of the province. Dams and diversion canals are mostly of the improvised and makeshift types. The agricultural possibilities of the region can be better exploited, and more efficiently, by the construction of adequate irrigation systems throughout the level areas, at least.

LIVESTOCK AND LIVESTOCK PRODUCTS

The livestock industry of the province is not well developed. The Philippine Census of 1939 classifies its livestock population as shown in Table 4.

TABLE 4.—*Number and value of livestock and poultry on farms and those not on farms in Bataan Province*

Livestock or poultry	Livestock and poultry on farms.						Livestock and poultry not on farms.		Total value.[a] *Pesos.*
	All ages and breeds		Native.		Grade.				
	Number.	Farms reporting.	Number.	Farms reporting.	Number.	Farms reporting.	Number.	Persons reporting.	
Carabaos	[b]18,288	5,121	....	....	....	....	3,942	1,379	735,363
Cattle	498	39	470	37	25	2	140	24	11,461
Horses	572	294	567	294	5	3	632	409	33,839
Hogs	7,615	2,928	7,489	2,905	106	40	8,483	3,855	173,464
Chickens	55,807	4,066	50,079	4,016	2,119	136	38,977	5,034	44,701
Goats	360	57	326	56	34	7	153	51	1,431
Sheep	33	2	33	2	....	....	....	....	149
Ducks	418	77	....	....	....	....	1,357	123	1,175
Turkeys	137	18	....	....	....	....	152	41	880
Pigeons	619	11	....	....	....	....	403	30	304
Geese	16	8	....	....	....	....	100	28	183

[a] Total value includes value of livestock and poultry on farms as well as value of livestock and poultry not on farms.

[b] Of this number 12,614 are work animals as reported by 4,905 farms.

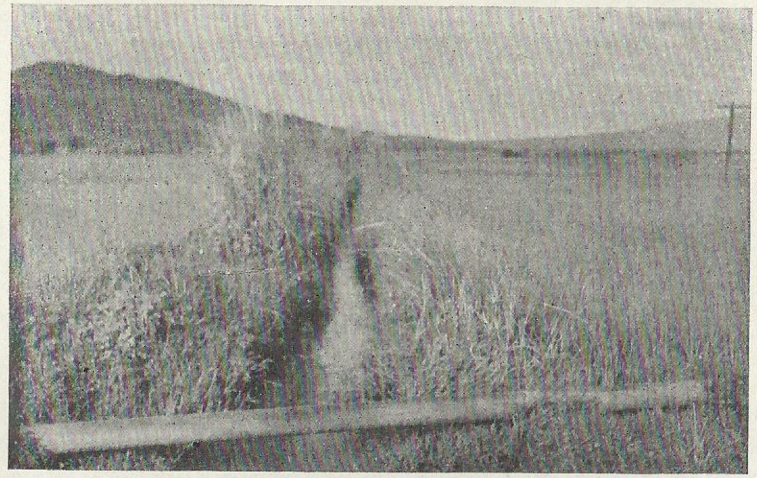
The most important animals raised are carabaos, cattle and horses. The carabao is principally used on the farm as a beast of burden, the cattle for beef, and the horse to pull native vehicles called "caretela." Hogs and chickens are raised mostly for home consumption and rarely as a source of income. Goats, sheep, and poultry other than chickens are of minor importance, being raised on very few farms.

FARM TENURE

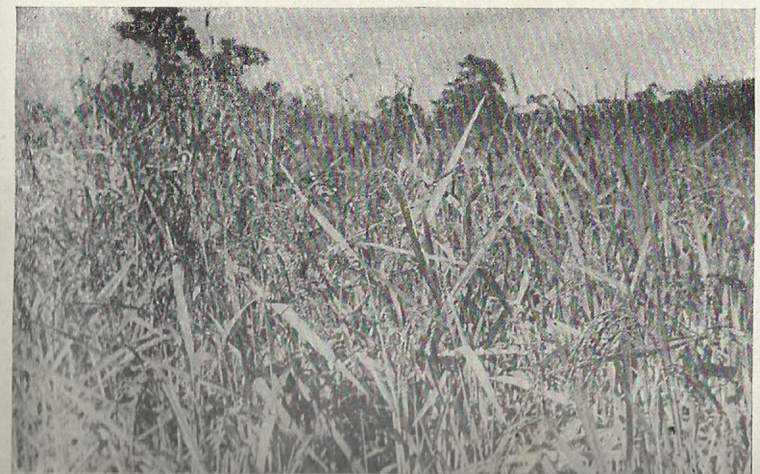
The Philippine Census of 1939 classifies farmers or farm operators into four classes, namely, owners, part-owners, tenants, and managers.

Owners are farm operators who own all the land they work. A farm operator who works the land owned by a member of his family is classified as owner.

Part-owners are farm operators who own part and rent or lease from others part of the land which they work.



A typical irrigation ditch at Calungusan, Orion. Several private communal irrigation systems provide water to many of the rice farms in the province.



A good crop of upland rice in a "kaiñgin" on the more gentle slopes of Antipolo clay at Limay, Bataan Province.

Fig. 8

Tenants are farm operators who rent or lease from others all the land which they work. Tenants are subdivided into (*a*) share-tenants—farm operators who rent the land they work and pay the rent by sharing the crop or crops grown with the owner; (*b*) cash-tenants—farm operators who rent the land they work and pay a definite rent either in the form of money or produce; (*c*) share-cash-tenants—farm operators who rent all the land they till and share the harvest with the owner in addition to paying rental in cash.

Managers are farm operators who supervise the working of the farm of a landowner, receiving wages or salaries, or part of the crops for their services.

In 1939 there were 6,305 farmers in the province. Twenty-eight and seven-tenths per cent of this number owned their farms; 18.8 per cent were part-owners of the land they work; 35.8 per cent were share-tenants; 10.2 per cent share-cash-tenants; 6.4 per cent cash-tenants; and 0.07 per cent managers.

Of the total farm area in the province, 37.7 per cent is farmed by owners; 18.0 per cent worked by part-owners; 31.0 per cent worked by share-tenants, 6.0 per cent by share-cash-tenants; 2.7 per cent by cash-tenants; and 4.7 per cent by managers.

The average size of a farm in Bataan is 4.22 hectares.

FARM INVESTMENTS

Table 5, taken from the Philippine Census of 1939, gives the farm equipments available in the province at that time. These equipments represent nearly all of the farm investments in the province.

TABLE 5.—*Showing farm investments in Bataan Province as per census of 1939*

Kind of equipment	Number of equipment	Value in pesos
Plows	7,171	133,402.00 (Plows, Harrows, Carts, Sleds)
Harrows	6,670	
Carts	1,689	
Sleds	1,863	
Work animals (carabaos)	12,614	416,262.00
Farm machinery	(a)	

[a] No records available.

As a consequence of the war a great fraction of these listed equipments was destroyed and at the time of the survey replacements were not easily available.

TYPES OF FARMS

According to the Census of 1939, of the 6,305 farms in the province, 4,835, or 76 per cent, are rice farms; 40 or 0.6 per cent, corn farms; 349, or 5.8 per cent, sugar cane farms; 432, or 6.6 per cent, fruit farms; 55, or 0.8 per cent, vegetable farms; and 602, or 9.5 per cent, are classified as other farms. There were two poultry farms in the province at that time.

A farm was classified as belonging to a certain type, say rice farm, if 50 per cent or more of the cultivated area in the farm was planted to rice; a corn farm if 50 per cent or more of the cultivated area in the farm was planted to corn; and a poultry farm if it had more than 300 chickens or 200 ducks and less than two hectares of cultivated land.

SOIL SURVEY METHODS AND DEFINITIONS

Soil survey is an institution devoted to the study of the soil in its natural habitat. It consists of (*a*) the determination of the morphological characteristics of soils; (*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 either in the field or 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 or localities where the soil was first identified. For example, the Culis series was first found and classified in the vicinity of Culis, a barrio in the town of Hermosa, Bataan Province.

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, Culis loam is a soil type within the Culis 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 Sara, Sta. Rita, Alimodian and others that are mixed together, the two dominant series must bear the name of the complex, as Sara-Sta. Rita complex or Sara-Alimodian complex, as the case may be. If there is only one dominant constituent, that series or type bears the name of the complex as Sara complex or Alimodian complex.

Surface and subsoil 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 types or phases. 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 artificial 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.

BATAAN SOILS

The soils of the province of Bataan have few variations due to the simplicity of the soil formation as represented by the series of mountains and the short and narrow coastal plain. The Antipolo soils, which occupy a great portion of the region, exhibit to a slight extent the characteristics of a mature soil. The soils of the plain are young soils, with incomplete profile development.

Table 6 gives the hectarage of the different soil types found in the province, their location and the principal crops grown on them.

The soils of Bataan were classified for the purpose of this survey as follows:

1. Soils of the swamps and marshes
   a. Hydrosol
2. Soils of the plain
   a. La Paz fine sand
   b. La Paz silt loam
   c. Culis loam
   d. San Manuel fine sandy loam
   e. Pilar silt loam
   f. Pilar fine sandy loam
   g. Beach sand

TABLE 6.—*Area, percentage, location, and principal crops grown on each soil type in Bataan Province* [a]

Type number.	Soil type.	Area (Ha.).	Percentage.	Location.	Principal crops grown.
1	Hydrosol	3,544	2.61	Along the seacoasts of the towns of Hermosa, Orani, Samal, Pilar and Balanga: a part of Moron near Nagcaban point.	Nipa, pandan, (fishponds).
26	Antipolo clay	72,630	53.41	All the rolling upland and almost hilly regions surrounding Mt. Sta. Rosa and Mt. Natib in the north and Mt. Mariveles in the south	Upland rice, fruit trees such as mangoes, guavas, casoy, corn, etc.
28	Antipolo soils, undifferentiated	37,372	27.48	Area of land composing and bordering Mt. Sta. Rosa, Mt. Natib, Mt. Samat and Mt. Mariveles.	Commercial and noncommercial forests.
77	La Paz fine sand	3,200	2.35	Barrios of Tabacan and Balsic, of Dinalupihan; Batbat and Saba, Hermosa; Parang na Munti, Orani; and the upper portions of Sta. Cruz and Tuyu Rivera; Tuyu, Balanga.	Sugar cane, corn, rice, peanuts, sweet potatoes, and cassava.
78	La Paz silt loam	5,970	4.39	A great portion of the town of Dinalupihan; along the provincial highway including the towns of Orani & Samal.	Rice, sugar cane, corn, peanuts, sweet potatoes, cassava and vegetables.
95	San Manuel fine sandy loam	234	0.17	Small area from Balanga poblacion to barrio Puerto Rivas; barrios of Balut and Sta. Rosa, Pilar.	Corn, sugar cane, rice, vegetables, yambeans, sweet potatoes, cassava and peanut.
118	Beach sand	55	0.04	All along the southern coast of Moron up to Bayandati.	Bare.
136	Pilar fine sandy loam	2,178	1.60	Barrio of Tinajero, Balanga; Bane, Molauan, Casamluan and Aningay, Pilar; and Balugan and Bangad, Orion.	Sugar cane, corn, rice, vegetables, sweet potatoes, cassava and peanuts.
137	Pilar silt loam	6,794	4.99	Along the national road from Calaguiman, Samal southward up to Orion; Lamao and Lucanin, Limay part of Mariveles; small portion of Bagac and Moron.	Rice, corn, fruit trees and vegetables.
138	Culis loam	4,023	2.96	Western part of Hermosa, Orani and Samal.	Sugar cane, corn, rice. Most of the area is grassland or under second-growth forest.
	Total	136,000	100.00		

[a] 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 20, 1939.

3. Soils of the upland, hills and mountains
    a. Antipolo clay
    b. Antipolo soils, undifferentiated

SOILS OF THE SWAMPS AND MARSHES

Hydrosol (1)*.—Under this classification belong the swamps, marshes, and fishponds, which are under water most of the time. The water portion of the hydrosol is known as the aqueous horizon while the surface soil is called the subaqueous horizon.(21) Generally, the subaqueous horizon is slimy, dark gray to black plastic clay with sandy clay in some places. The texture and organic matter content are widely variable. In newly opened fishponds this horizon is invariably alluvium. Because of the difficulty in delineating the various textural grades these soils are all grouped under one general hydrosol series. The most common vegetation are nipa, pandan, mangrove, and aroma [*Acasia farnesiana* (Linn.) Willd.]. This soil occupies a total area of 3,544 hectares along the seacoasts of the towns of Hermosa, Orani, Samal, Abucay, Pilar, and Balanga.

SOILS OF THE PLAIN

The soils of the narrow and short plains, or lowland portions in the eastern coast have different physical properties, but they also possess common characteristics. All the soils have but slight profile development. They are of light to medium texture in both the surface and subsoil layers, varying from fine sand to silt loams. The color ranges from light gray, brownish gray to grayish brown. The reaction does not vary much, ranging from slightly acid (6.36) to very mildly alkaline (7.04). With the exception of the Culis loam, a soil of low natural fertility, most of the soils are of medium to high fertility.

Similarity in origin and mode of formation are the most important factors responsible for the common characteristics of the soils in the plains or valleys. All the soils are derived from recently transported soil materials or secondary materials which have not been in place long enough for the full force or intensity of the soil-forming factors and processes to produce marked effects on their profile. The more or less level topography coupled with low elevation are also responsible for the slight profile development of the soils. The soils in this group

* A number in parenthesis after a soil type indicates soil type number.

belong to the La Paz, Culis, San Manuel and Pilar series. A small area of "Beach sand," a miscellaneous land type, is also included in this group. With the exception of the Culis series and "beach sand," all the soils in this group are productive and adapted to a wide variety of crops. Each soil series, however, is especially suited to certain crops.

La Paz Series

This series was first established and mapped in Pampanga Province.(2) These soils, as mapped in Bataan, are extensions of the same soils in Pampanga. They are characterized by ash-gray to brownish gray, loose and structureless surface soil and light gray to brownish gray sandy subsoil. The substratum consists of gray, brownish gray or grayish brown fine to medium sand. These different layers grade into each other gradually, and the whole soil mass is loose and porous. This series occupies the northern half of the plain extending from the southern part of the town of Samal northward up to the Bataan–Pampanga boundary, including the towns of Orani, Hermosa and Dinalupihan. The topography is nearly level or flat, and the elevation ranges from a few feet to 100 feet above sea level. Drainage, both external and internal, of the area is good.

There are two soil types mapped under this series, La Paz fine sand and La Paz silt loam.

La Paz fine sand (77).—A typical profile of the type shows the following characteristics:

La Paz fine sand

Depth of soil cm.	Characteristics
0 to 25	Surface soil, light gray to gray, loose, structureless fine sand. Appears dark gray when moist. Loose; roots penetrate easily; low organic matter content. Boundary between surface and subsoil is gradual and wavy.
25 to 90	Pale-gray to brownish-gray very fine to fine sand more compact than surface soil. Poor, very fine granular to structureless; low organic matter content. Roots penetrate easily. Clear smooth boundary between subsoil and substratum.
90 to 150	Substratum, gray medium to coarse sand, loose and structureless. Very low organic matter content.

This type occurs in the northeastern part of the province on both sides of the national highway (Pampanga–Balanga) from Pampanga until Colo River at Layac in the northern part of the town of Hermosa. It covers about 3,000 hectares or 2.3

per cent of the area of the province. The topography is nearly level to level and is only a few feet above sea level. Some portions of it are flooded during months of extremely heavy rainfall.

The parent material of this soil is sandy alluvium from the higher areas deposited by the rivers. Because of the looseness and coarse texture of the whole soil mass, external and internal drainage are both good despite the more or less level topography of the area.

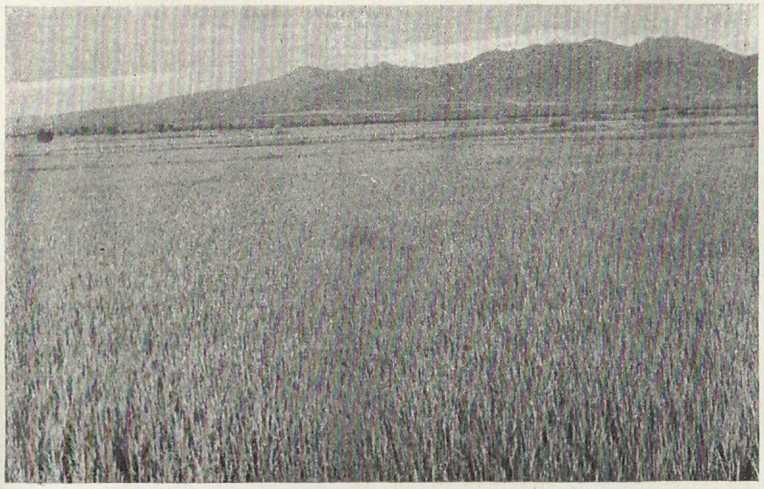
Before the war, this type was utilized for the growing of sugar cane. Ammonium sulphate was the most common fertilizer used on this soil at the rate of 200 to 300 kilos per hectare. During this survey, however, only a few patches of peanut and corn are raised, the greater portion being idle. This is attributed to the lack of planting materials and scarcity of work animals as a result of the war.

Due to its light texture this soil is easily worked, but its water-holding capacity is low. By increasing the organic matter content through the return of all stubble and crop residues and green manuring preferably with legumes if possible, the field capacity could be increased. Physically, this soil is well adapted to the growing of root crops, vegetables, peanuts, and sugar cane provided that there is continuous available water supply during the growth period of such crops.

This soil is low in both ammoniacal and nitrate nitrogen, relatively high in phosphorus, and moderate in potassium.* It may be expected to respond to nitrogen and potash fertilizers.

La Paz silt loam (78).—Like the La Paz fine sand, this soil type is an extension of the same type in Pampanga Province. It is more extensive than the former, and it comprises the greater portion of the narrow plain from the town of Dinalupihan southward until Calaguiman barrio in the town of Samal. The 23- to 28-centimeter surface soil is light gray, gray to brownish gray silt loam with a crumb structure. The subsoil, which reaches a depth of 60 to 70 centimeters, is brownish gray to grayish brown very fine sand slightly more compact than the surface soil. The substratum is brownish gray to gray fine to medium sand, porous and structureless. This type, as mapped in Bataan Province, is a little heavier than the same type in Pampanga Province.

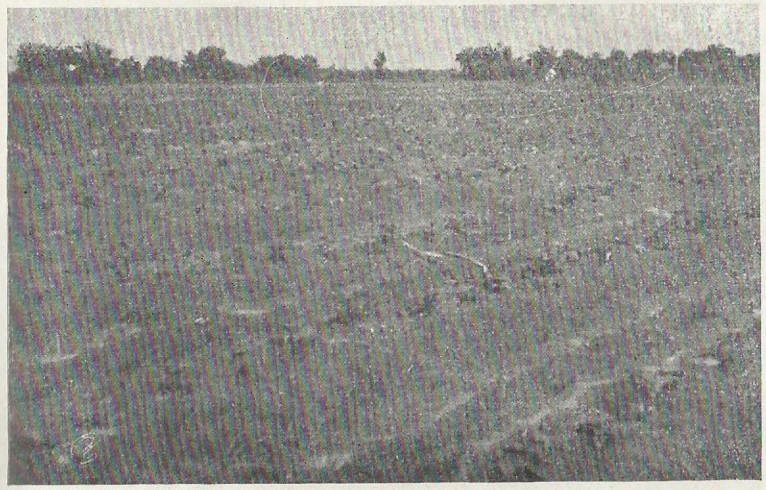
* See Table 10, page 45.



The La Paz silt loam is one of the most productive soils for lowland rice in the province.

A field of sitao on La Paz fine sand. Other vegetables do well on this soil.

Fig. 9



A newly planted field of sweet potatoes on La Paz fine sand, at Orani. Sweet potatoes is one of the most common crops planted on this soil.

Peanuts are raised extensively on La Paz fine sand.

Fig. 10

This type is the second most important rice land in the province, with Pilar silt loam taking the lead. It covers an area of 5,970 hectares, or 4.4 per cent of the province. Some portions of this soil located in the town of Dinalupihan were devoted to the growing of sugar cane before the war, but during this survey most of those areas were being planted to lowland rice. Secondary crops such as corn, peanuts, and sweet potatoes are also raised on this soil. In the towns of Orani and Hermosa "palagad," or dry season rice, is planted where irrigation water is available.

Included in this type are two small separate areas of slightly heavier and deeper soils than the typical La Paz silt loam. They are located along the national highway about one hundred meters just south of the town proper of Hermosa and the other in the barrio of Tapulao in the northern part of the town of Orani. In a detailed soil survey these soils would be classified separately from the La Paz silt loam.

The requirements for management of this soil are not very different from those of the La Paz fine sand. The slightly heavier texture indicates a higher water-holding capacity than that of the latter. It possesses good tilth and is also physically suitable for rice and other crops.

The reaction of the soil is 7.04, which could be considered neutral for practical purposes. Rice prefers medium acid soils * for optimum growth so it may be inferred that maximum yields cannot be expected from this soil with respect to rice unless the pH is lowered in some way. Experiments, however, are lacking to substantiate this view, and the importance of soil reaction in the growth of rice on this soil type has not been determined as yet. The supply of nitrogen is relatively higher than in any other soil of the province, but this is only temporary and depends largely upon the season and whether the soil is cultivated or not. The phosphorous and potassium contents are relatively moderate. It may yet respond to phosphatic and potash fertilizers. As the slope is gentle and the water-absorbing capacity is good, it is only slightly susceptible to accelerated erosion and no special practices are necessary for its management.

Culis Series

The soils of the Culis series consist of brownish gray, gray to dark gray fine to coarse granular loam to sandy loam,

* Please see Table 9 on page 45.

slightly compact fine to medium blocky clay loam to clay subsoil with buckshotlike iron concretions. The substratum consists of whitish gray mixture of coarse sandy clay and weathered sandstones.

The land is undulating to gently rolling with slopes ranging from 3 to 8 per cent. Due to the heavy subsoil, which restricts water penetration, this series is susceptible to erosion.

The native vegetation is of the "parang" type. Second growth trees and shrubs are usually found along the creeks and depressions. Boho also abounds and a few clumps of bamboos are occasionally present.

In a few localized places few cobblestones and boulders are found on the surface. This series is best suited for pasture or reforestation because of its high erodibility and low fertility. A few patches of upland rice and few mango trees are grown on it, and some tamarind trees are growing wild. This is not an important agricultural soil of the province.

Only one soil type, the Culis loam, has been mapped under this series.

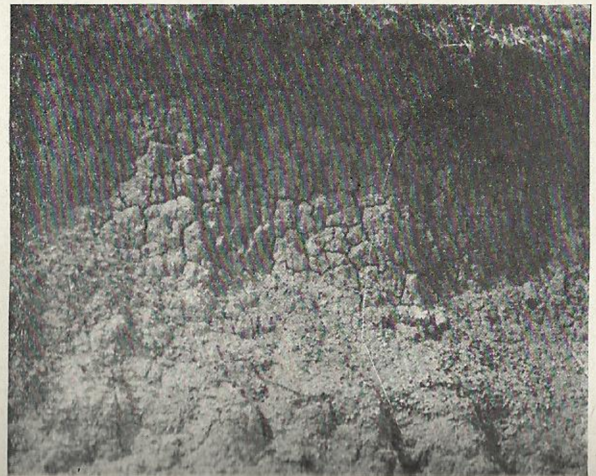
Culis loam (138).—A typical profile of this soil type has the following characteristics:

Culis loam

Depth of soil cm.	Characteristics
0 to 19	Surface soil, brownish gray, gray to dark-gray fine to medium granular, slightly compact loam. Fair amount of organic matter. Roots especially those of grass mostly found in this layer. Clear smooth boundary between this horizon and the lower layer.
19 to 27	Dark-gray slightly compact clay loam to clay with plenty of buckshotlike iron concretions. Good fine blocky structure. Roots have slight difficulty penetrating this layer.
27 to 85	Gray to dark-gray hard and stiff moderately compact medium to coarse cloddy clay. Low organic matter content; gradual wavy boundary between this layer and upper layer. Roots penetrate only with difficulty.
85 to 150	Whitish-gray compact mixture of sandy clay and weathered sandstone. Waterworn gravels and pebbles sometimes present in this layer in some places. Clear wavy boundary from upper layer.

This soil occupies approximately 4,000 hectares, or about 2.2 per cent of the area of the province. It is not an important agricultural soil. It is located in the northeastern part of the province west of the towns of Hermosa and Orani.

A typical landscape of Culis loam. It has an undulating to gently rolling topography.



Profile of Culis loam. Note the heavy clay subsoil and the whitish gray weathered sandstone substratum.

Fig. 11

The Culis loam is developed under an undulating to gently rolling topography and at an elevation ranging from about 15 to 60 meters. Due to the heavy subsoil which prevents normal penetration of water in the lower layers, the soil is susceptible to erosion. In places where the natural vegetation has been disturbed and the soil subjected to intense erosion the buckshotlike concretions are exposed on the surface or are conspicuously accumulated along furrows or depressions.

The parent material of this soil originated from whitish gray sandstone. External drainage is good but internal drainage is poor due to the heavy nature of the subsoil.

This soil is poorly suited to most crops because of its sticky and impervious clay subsoil. The feeding zone of the roots is shallow due to the thin surface soil, which averages only 15 centimeters in depth, and the heavy subsoil restricts the penetration of the roots. As would be expected, there is also poor aeration and slow water movement in the subsoil. The low phosphorous (3 p.p.m.) and potash (26 p.p.m.) content and low content of other essential plant nutrients (0.06 per cent total nitrogen and 40 p.p.m. of calcium) may be contributory factors to the low fertility of this soil.

Because of its natural low fertility and susceptibility to erosion, no agricultural crops are planted on this type except a few patches of upland rice and few mango trees. This soil should be reforested rather than be planted to agricultural crops.

San Manuel Series

This series was first described and mapped in Tarlac Province, but it occurs extensively in Pangasinan Province.(3) This is one of the best agricultural soils of Bataan Province, but it is limited in area.

The soil consists of light brown to light brownish-gray surface soil and a brown to grayish-brown subsoil ranging in depth from 70 to 110 centimeters. The substratum is yellowish brown to reddish brown fine to medium sand. Generally, the soil is of recent alluvial origin with the Talisay and the Balanga Rivers as the main agencies of deposition. The series occurs in low-lying and flat areas, and is, therefore, subject to floods during the rainy season.

In uncultivated areas the most common native vegetation consists of *talahib* and *agingai* and a few clumps of bamboos.

Because of its natural fertility nearly all of the area under this series is cultivated. Corn is the principal crop grown, but peanuts, yambeans, vegetables, sweet potatoes, sugar cane, bananas and other fruit trees are grown also.

Only one soil type, the San Manuel fine sandy loam, has been mapped under this series.

San Manuel fine sandy loam (95).—A typical profile of this type has the following characteristics:

San Manuel fine sandy loam

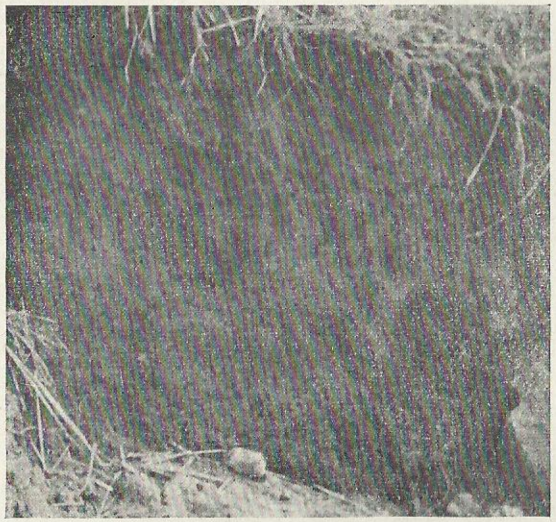
Depth of soil cm.	Characteristics
0 to 35	Surface soil, grayish-brown to light brown, friable fine granular to almost structureless fine sandy loam. Fair amount of organic matter. Roots penetrate easily. Gradual smooth boundary between the surface and the subsoil.
35 to 70	Upper subsoil, grayish-brown friable very fine to fine sandy loam slightly more compact than the surface soil. Easily penetrated by roots. Appears dark brown when moist.
70 to 100	Lower subsoil, grayish-brown to yellowish-brown very fine to fine sandy loam slightly denser than the upper subsoil. Diffuse smooth boundary between this horizon and the substratum.
100 to 150	Substratum, grayish-brown to reddish-brown fine sandy loam to fine sand. Slightly compact.

This type occurs along the Talisay and Balanga Rivers in the towns of Balanga and Pilar. It covers an area of about 234 hectares or approximately 0.17 per cent of the area of the province. The yearly inundation of the rivers surrounding this soil accounts for its great fertility. Despite the low elevation and relatively level topography, external and internal drainage are both good.

The San Manuel fine sandy loam has developed from recent alluvial materials transported from the higher elevations and deposited by the Talisay and Balanga Rivers on the lower part of their courses.

Almost all of this soil is under cultivation and kept planted to various crops all the year round except during the two or three driest months of the year. Corn is the principal crop grown on this type, but peanuts, yambeans, sweet potatoes, vegetables, bananas and fruit trees are raised besides.

Because of the light texture throughout the profile and the friability and looseness of the upper layers, the roots of plants as well as water penetrate into the soil easily.



Profile of San Manuel fine sandy loam. It is a deep alluvial soil of medium texture.

Corn growing on San Manuel fine sandy loam at Cupang, Balanga. Almost all areas of this type are cultivated due to their relatively high productivity.

Fig. 12

It is easy to maintain the favorable physical condition of this soil so long as it is not worked when wet. Due to its frequent, if not continuous, cropping the organic matter content should be maintained by plowing under all crop residues or by the use of green manure, preferably legumes if possible. The water retentiveness is increased and the biological activity is promoted incidentally by the increase of the organic matter content. Decrease in yields is not so evident at present, but fertilizers may be required in the future in order to maintain or increase the present level of production. Among the soils of the province this soil type has the highest phosphorus content (55 p.p.m.). The total nitrogen, however, is low (0.06 per cent) and its content of potassium is moderate, hence nitrogen and potash fertilizers may be expected to give increased yields. Accelerated soil erosion is not so much of a problem because of the nearly level topography and high water-absorbing capacity of the soil.

Pilar Series

This series comprises one of the most productive soils of the province especially with respect to lowland rice. The soils of this series consist of brownish-gray, grayish-brown, or light brown friable fine to coarse granular fine sandy loam to silt loam surface soil underlain by a yellowish-brown to brown friable sandy loam subsoil ranging in depth from 70 to 80 centimeters. The substratum is a gray to brownish-gray slightly compact sandy loam to coarse sandy loam.

These soils occupy the southern half of the plain extending from the town of Abucay southward to the town of Orion. The topography is nearly flat, and the elevation ranges from only a few meters above sea level to 30 meters. Although the external drainage is inclined to be poor due to the nearly flat relief, the good internal drainage offsets it.

This series has developed from recent alluvial deposits, just like the other soils of the plain such as the La Paz and San Manuel series. The native vegetation consists primarily of *talahib*, *agingai*, cogon, and second-growth forests.

The greater part of this series is devoted to the growing of lowland rice and corn. Before the war sugar cane was also an important crop grown, but most of the areas formerly devoted to the crop are now idle due to lack of planting materials.

Peanuts, mungo, cowpeas, and vegetables are also raised on this series.

There are two soil types, namely, the Pilar silt loam and Pilar fine sandy loam.

Pilar silt loam (137).—The typical profile of the Pilar series is shown by Pilar silt loam, the profile of which has the following characteristics:

Pilar silt loam

Depth of soil cm.	Characteristics
0 to 25	Grayish-brown to light brown, medium to coarse granular, friable very fine sandy loam to silt loam. Plenty of lowland rice and grass roots. Fair amount of organic matter. Dark brown when moist. Gradual smooth boundary between the surface and the subsoil.
25 to 51	Upper subsoil, darker in color than surface soil and slightly more compact than above. Fine to medium blocky structure. Roots penetrate easily.
51 to 80	Lower subsoil, yellowish-brown to light brown or brown friable sandy loam. Fine granular structure. Clear smooth boundary between the subsoil and the substratum.
80 to 150	Substratum, grayish-brown, brownish-gray, or gray slightly compact sandy loam to coarse sandy loam.

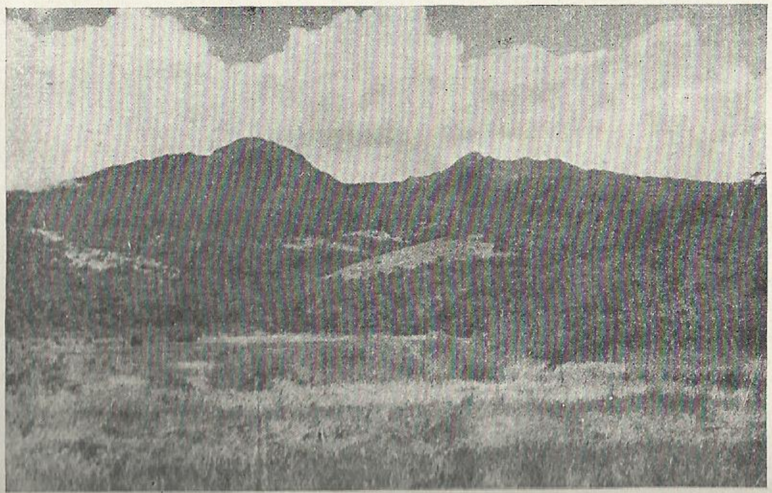
There are small areas in small pockets along the coast that have been classified under this type although they appear to be a little heavier and darker in color than the typical Pilar silt loam. This is especially true with those soils in Mariveles, Lucanin, and Lamao, in the southern part of the province. Usually these pockets occur at the mouths of rivers. In a detailed soil survey, these soils would undoubtedly be classified separately from the Pilar series.

Due to the light texture and friable nature of the whole soil mass, both the internal and external drainage are good although the area has a level to nearly level topography.

These soils are derived from recent alluvium of sandy material. This accounts for the slight profile development and light texture of the soil.

The favorable relief together with the ease with which it can be cultivated and its medium fertility make Pilar silt loam the most valuable rice land of the province. The relative porosity of the subsoil, a characteristic unfavorable from the standpoint of optimum growth for lowland rice, is offset by the abundance of water available for irrigation. Lowland rice is the principal crop grown on this soil type. Secondary crops such as cowpeas, beans, and vegetables are also grown.

Irrigated lowland rice on Pilar silt loam, at Pilar, Bataan. An average yield of 60 cavans of palay per hectare is obtained from such fields.



The plain in the foreground is made up of Pilar silt loam. The lower mountainsides in the background is of Antipolo clay, and the peaks and higher elevations are of Antipolo soils, undifferentiated.

Fig. 13

A large portion of this soil is irrigated from private communal irrigation systems managed and operated by the farmers themselves. However, a government-owned irrigation system also exists in Pilar supplying water to about 300 hectares.

The requirements for management of this soil are similar to those for the La Paz silt loam but with slight difference. Ordinarily good yields of rice as well as other crops are obtained under the prevailing farming practices, but the application of moderate amount of complete fertilizer to supplement the natural fertility may give maximum yields. The organic matter should also be replenished yearly if the favorable physical condition of the soil is to be maintained. As in other soils, this could be done best by returning crop residues and farm manures to the soil and, if necessary, by the use of leguminous green manure. This soil is not so susceptible to accelerated erosion because of its gentle slope and high water-absorbing capacity.

Pilar fine sandy loam (136).—This type occupies the adjoining area of slightly higher elevation west of the Pilar silt loam in the towns of Pilar, Balanga, and Orion. It comprises most of the soils devoted to the growing of sugar cane before the war. This type differs from Pilar silt loam mainly with respect to the texture of the surface soil and the absence of reddish streaks. Generally the surface soil is around 20 centimeters deep and is slightly lighter in color than the surface soil of Pilar silt loam. The yellowish tint of the subsoil is not so pronounced as in the silt loam type, and this layer is of a slightly lighter texture.

Drainage, both external and internal, is adequate.

As most of this type has been left uncultivated for three years during the Japanese occupation, cogon has gained a foothold and madre cacao [*Gliricidia sepium* (Jacq.) Steud.] are scattered here and there with a tendency to spread at a rapid rate.

Only a very small portion of this soil was under cultivation during the time of this survey. However, there is a possibility of the whole area being returned to sugar cane, if and when planting materials become available. Corn, peanuts, and lowland rice are being grown on the small area cultivated.

Being of a lighter texture than the Pilar silt loam the water-holding capacity is lower than that of the latter. It is easy to work and special practices are not necessary to maintain its good tilth. Increasing the organic matter content, however, would undoubtedly make it more retentive of water. The phosphorus and potassium contents are relatively high, but its nitrogen content is low. Nitrogen fertilizers may give increases in yields. Ammonium sulphate was applied to sugar cane before the war with favorable economic returns.

The porous surface soil and subsoil permit easy penetration of water rendering the soil resistant to water erosion.

This type has an area of about 2,178 hectares or 1.6 per cent of the area of the province.

Beach sand.—Although the soil map is primarily concerned only with soil, other areas of land that are without a definite soil must be indicated on the map. One such area is mapped in Bataan Province and is designated as "beach sand". This miscellaneous land type occurs as a narrow strip about 150 meters wide along the coast from the barrio of Bayandati until the town proper, or poblacion, of Moron in the northwestern coast of the province. It consists of dark gray to black coarse sand of no agricultural value whatsoever. It has a total area of about 55 hectares, or 0.04 per cent of the area of the province.

SOILS OF THE UPLAND, HILLS, AND MOUNTAINS

The soils of this group occupy about 110,000 hectares, or 80.9 per cent of the area of the province, and comprise soils of the Antipolo series. The topography varies from undulating, gently rolling to hilly and mountainous. Only a small fraction of the soils in this group is cultivated mainly because of the unfavorable topography.

Antipolo Series

The series was first identified and mapped in Rizal Province. (1) As it is mapped in Bataan, the series occupies the greatest portion (approximately 80.9 per cent) of the province.

The Antipolo series comprises the red or reddish-brown soils developed from volcanic igneous rocks. They are generally friable even in the lower layers of the profile. Two soil types are mapped in Bataan Province: the Antipolo clay, which occupies the lower elevations of the mountainsides and foothills up to

around 1,000 feet elevation, and the Antipolo soils, undifferentiated, which comprise the rough mountainous lands which are inaccessible, hence unclassified.

Most of the area under this series is under virgin forest. The rest is under second-growth forest and "parang" type of forest vegetation.

Antipolo clay (26).—This soil is typical of the undulating or gently rolling foothills and lower mountainsides that are for the most part under second-growth forest and "parang" type of forest vegetation. Of the upland soils, it is the most important soil for agricultural purposes in the province. A typical profile of this type as mapped in Bataan Province has the following characteristics:

Antipolo clay.

Depth of soil cm.	Characteristics
0 to 25	Light reddish-brown, fine to medium-granular, friable clay to loam clay. Few spherical tuffaceous concretions present. Slightly compact. Gradual wavy boundary between the surface and the subsoil. High organic matter content. Roots penetrate easily.
25 to 65	Subsoil, reddish brown, darker than surface soil. Friable fine to coarse-granular clay slightly more compact than surface soil. Few concretions present. Boulders sometimes imbedded in this layer.
65 to 90	Lower subsoil, more pronounced reddish brown color. Friable coarse-granular clay. Increasing amount of weathered rock fragments. Diffuse wavy boundary between the subsoil and substratum.
90 to 150	Substratum, layer of weathering rocks mixed with boulders.

Antipolo clay is the most extensive soil of the province with an area of about 72,630 hectares, or 53.4 per cent of the total area of the province. On the higher elevations, especially on steep slopes, the soil is shallower than in the gentler slopes and lower elevations. In a few places of this type volcanic rock boulders are sometimes present in the lower subsoil and substratum. In denuded areas which are more or less subjected to accelerated erosion, a few of those boulders are exposed on the surface.

Surface drainage is excessive, and internal drainage is adequate. Because of its characteristic friability despite its clayey nature, roots penetrate the soil readily and the same holds true for water and air. The high percentage of slope in some places, however, renders the soil susceptible to erosion where the native vegetation has been disturbed because the water is not given ample time to percolate through or be absorbed into the soil.

The parent material of this soil is the weathered material from the volcanic rocks, which are mostly andesites.(23) This type, as it occurs in the western part of the province near and up to the Bataan–Zambales boundary, has a little higher percentage of coarse skeleton than in the rest of the province.

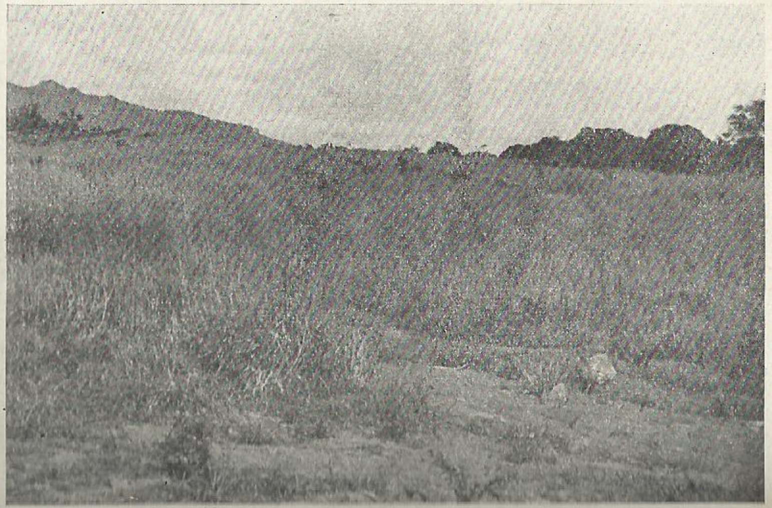
Only a small area of this type is cultivated. Upland rice, corn, sugar cane, cassava, pineapples, bananas, papayas, mangoes, and other fruit trees are the crops grown on this soil. Because of the scarcity of work animals and the decrease in the peasant population as an aftermath of the war, very limited area of this type was being cultivated at the time of this survey.

Although this soil has a heavy texture, its good tilth is easy to maintain so long as it is worked at the proper moisture content. The nature of the clay is such that the friable granular structure is fairly stable, permitting easy penetration of water. The soil reaction is very slightly acid (pH 6.64) and the total nitrogen is relatively high in comparison with the other soils of the province. It has the highest potassium content but is low in phosphorus (7.0 p.p.m.). Phosphatic fertilizers may increase production on this soil. Sugar cane was one of the most common crops planted before the war, and ammonium sulphate was the fertilizer used. This soil is well suited to fruit trees, however, especially mangoes and pineapples.

Antipolo soils, undifferentiated (28).—This type occupies the rough and mountainous area of higher elevations than the Antipolo clay. It covers an area of about 37,372 hectares, or 27.5 per cent of the area of the province. It is covered with virgin forest with a good stand of commercial timber. It is of no agricultural value because of the exceedingly steep slopes and rough topography. Due to the inaccessibility of the areas under this type the soils have all been classified into the Antipolo soils, undifferentiated.

A soil of this type is similar to that of Antipolo clay, but the surface soil is generally thinner and lighter-textured. Included in this type are areas of stony, rocky and rough character which have little or no true soil.

Profile of Antipolo clay. The friable and good granular structure of the surface soil and subsoil permits easy penetration of plant roots.



The Antipolo clay area has an undulating to gently rolling topography. Some places of this type are under the "parang" type of forest.

Fig. 14

MORPHOLOGY AND GENESIS OF SOILS

Soil is the synthetic product of the factors of soil development acting on the parent materials deposited or accumulated by geologic agencies. The characteristics of any given soils are determined by the five general factors of soil formation, namely, (1) parent material, (2) climate, (3) living organisms, both plants and animals, (4) relief, or lay of the land, and (5) length of time the forces of development have acted on the material.(30) The state or nature of the profile of a soil is dependent upon which of the above factors exerts the greatest influence. If the so-called active factors, the climate and living organisms, especially vegetation, have the ascendancy over the others, the soil may have reached the mature state; if the passive factors, the parent material, relief, and time, have the edge over the active forces, the soil may still be young or semimature; and if neither of the factors has any marked effects on the soil, the soil is still very young and as such, it does not manifest true profile development.

The Philippines is in the tropical and subtropical red and yellow soil region of the world.(10) The mature soils in this region are of two general groups: (1) The laterites and the tropical red soils, and (2) the subtropical red and yellow soils. Associated with these mature soils are soils of immature and incompletely developed profiles and soils without true profile, or those of recent accumulation. Flood plains and delta deposits, marshland soils, and soils derived from recent deposits of volcanic ash are examples of the last-named type. Due to the very limited area which has been surveyed in the Philippines, no definite statement could be made as to what group or types of soils are most common.

Although the Philippines has a relatively small area, the various landscapes and different positions and exposures of the several islands with respect to the prevailing winds and ocean currents give rise to four general types of rainfall distribution which exert a great influence on soil formation.

Bataan Province has a long dry season of about six months with an average annual rainfall of 2,798.4 millimeters (about 110 inches). The intense weathering engendered by the constant high temperature, high humidity and high rainfall, together with the luxuriant forest and grass vegetation, are mainly the factors contributing to the characteristics of the Antipolo series, which constitute the soils of the upland, hills;

4800——3

and mountains. In other words, the active factors of soil formation have gained an ascendancy over the passive factors of relief, parent material and age. From this standpoint, the Antipolo series may be considered to belong to the so-called zonal soils.

In a preliminary outline of profile studies and classification of Philippine soils adopted by the Division of Soil Survey and Conservation, of the Department of Agriculture and Natural Resources, nine profile groups were established on the basis of topography, mode of formation, and kind of profile. (20) Under this grouping, the Antipolo soils fall under profile group No. VII, which consists of soils on upland areas developed on hard igneous bedrock. These soils are formed from the underlying igneous rocks and occupy a rolling to steep topography.

The reddish-brown color and the friability of both the surface and subsoil layers of the soils of the Antipolo series suggest that this series belongs to the lateritic group known as tropical red soils. The reddish tinge is due to the unhydrated oxides of iron. A deep red color usually indicates good drainage, whereas a yellow or yellowish coloration is imparted by hydrated iron oxides. The friable nature and porosity is due to the peculiar structure of the substance making up such soils. In their process of development from the parent material, the oxides cohere together forming granules or pellets of various sizes. Some of the larger aggregates are sometimes cemented giving rise to concretions. Because of the high permeability of these soils they are not much subject to erosion so long as the native vegetation is not disturbed, since the drainage water seeps readily downward instead of forming run-off water.

The soils of the Culis series may fall under profile group No. IV, which consists of soils on older plains or terraces having strongly developed profiles (dense clay subsoils) underlain by unconsolidated material. These are secondary claypan soils. The parent material of this series is the weathered sandstone material, which has a heavy texture. The topography under which this series developed is undulating to gently rolling, and the slope ranges from 3 to 8 per cent.

The distinguishing characteristics of this series are its thin surface soil which is less than 20 centimeters and its layer of gray to dark gray clay loam with plenty of buckshotlike iron concretions. This series is one of the very few soils in

the Philippines derived from parent materials originating from soft sandstone. The low fertility level, and heavy impermeable subsoil reflect the influence of its parent material. Most soils derived from sandstones are usually poor soils. The heavy subsoil also aggravates the low productivity by restricting the movement of water, air, and roots. The internal drainage is poor and as a consequence, the soil has a high erodibility. Also, the surface soil disperses readily due to its loamy texture and the relatively low organic matter content.

The Pilar series, which is first established in this survey, belongs to profile group No. II, or soils on young alluvial fans, flood plains, or other secondary deposits having slightly developed profiles, underlain by unconsolidated material. These have profiles with slightly compact subsoil horizons. The San Manuel series, which is also mapped in this province, also belongs to this group. It was first identified in Tarlac Province, but the most extensive area of the series is found in Pangasinan Province.

The Pilar series differs from the San Manuel series mainly in color and in the depth and thickness of the different horizons. The surface soil and subsoil of the Pilar series are generally darker than the San Manuel series. The surface soil of the Pilar series is thinner, the usual depth being 25 centimeters from the surface, while that of the San Manuel series averages 35 centimeters in thickness. The San Manuel series has much deeper soils than the Pilar series. The surface and subsoil combined reaches a depth of 120 centimeters as compared to 80 centimeters for the Pilar series. And besides, the Pilar series has slightly denser soils than the San Manuel series.

While both of these soils are developed from alluvial deposits, the profile characteristics of the Pilar series tend to show that it is slightly older than the San Manuel series. These two soils are both of relatively high productivity.

PRODUCTIVITY RATINGS

The productivity rating of soils is one of the latest contributions to the soil survey reports to supplement the soil description. These calculations made during and after the field operation aim at the rating of each soil type or phase by designating an index number which represents its productivity compared with a standard of 100. The primary object of the rating of soils is to portray more specifically the soil type and crop relationship or the comparative productiveness of the individual soil types with respect to the different crops grown in the province.

The ratings are obtained either by inductive or deductive method. The inductive method weighs the profile characteristics in relation to their effects upon crop production. Conditions and properties such as drainage, content of organic matter, texture of the surface soil, character of the profile, slope, erosion, nutrient level and other factors are considered. In the deductive method, ratings are assigned to the yields considered to be representative of the specified crop on the particular soil.

An interesting method of rating the soil was devised by Storie of the University of California at Berkeley. It is by the inductive method where four general factors which are most likely to influence the land's potential utilization and productive capacity are considered. The first factor called "A" consists of the soil profile and its general characteristics. The second factor, "B", is the texture of the surface soil; the third factor, "C", is the slope, and the fourth factor, "X", are the conditions other than those in the first three factors such as drainage, alkali, nutrient level, acidity, erosion, and microrelief. These four factors are given ratings expressed in percentage, and the final rating for the soil is obtained by multiplying them together.

So far a well-defined quantitative method of rating the productivity of soils based on their characteristics and properties is not yet available. There is still a wide gap between the pedologist on one hand and the economic botanist on the other. Perhaps a consolidation of the different methods and systems would be a good foundation for a better understanding of the factors contributing to crop productivity.

The yields adopted as standards are obtained by arbitrary selection on the basis of information relative to the average yield per hectare for the different crops without the use of fertilizers or amendments on the more extensive and better soils of the regions of the Philippines where the crop is most widely grown. Such information is gathered through interviews with farmers, from census reports, bulletins, and

reports of the Provincial Agricultural Supervisors. It should be understood that this method can only be applied in a well-settled country where long-term yield averages can be ascertained and customary agricultural practices are well established. The productivity ratings of the soils of the province are shown in Table 8, as follows:

TABLE 8.—*Productivity ratings of the soils of Bataan Province*

Type of soil [a]	Crop productivity index [b] for—								
	Lowland rice.	Upland rice.	Sugar-cane.	Corn.	Sweet potatoes	Bananas.	Mangoes.	Pineapple.	Yambean.
San Manuel fine sandy loam	85	....	....	90	90	100	....	....	90
Pilar silt loam	95	....	....	80	....	95	....	....	....
La Paz silt loam	80	....	80	75	....	80	....	....	....
Pilar fine sandy loam	65	....	80	75	80	80	80	60	85
Antipolo clay	....	130	80	75	....	85	90	90	....
La Paz fine sand	60	....	70	70	85	75	75	....	85
Culis loam	....	45	....	....	....	25	40	....	....
Antipolo soils, undifferentiated	....	....	....	....	....	....	....	....	....
Beach sand	....	....	....	....	....	....	....	....	....
Hydrosol	....	....	....	....	....	....	....	....	....

[a] The soils are listed in the approximate order of their productivity—the most productive first.

[b] The soils of Bataan Province are given indexes showing the approximate average yield of each crop in per cent of the standard of reference. The standard represents the approximate yield obtained without the use of fertilizer or other amendments on the extensive and better soil types of the regions of the Philippines in which the crop is most widely grown. Most of the indexes are essentially estimates and determined inductively. Absence of an index indicates that the crop is not commonly grown on the particular type.

NOTE.—Under the prevailing system of management the average yield per hectare of the following crops have been adopted as standard of 100:

Lowland rice	60 cavans of palay.	Sweet potatoes	8 tons of tubers.
Upland rice	20 cavans of palay.	Bananas	900 bunches of fruit.
Sugar cane	80 piculs of sugar.	Mangoes	500 fruits per tree.
Corn	17 cavans of shelled corn.	Pineaple	7,500 fruits.
		Yambean	10.5 tons of tubers.

The following yields per hectare have been used as standards in the preparation of the crop productivity indexes for the soils of Bataan Province:

Lowland rice, cavans of palay	60
Sugar cane, piculs of sugar	80
Corn (grain) cavan of shelled corn	17
Sweet potatoes, tons of tubers	8
Bananas, bunches of fruit	900
Mangoes, fruit per tree	500
Pineapples, fruits	7,500
Yambean, tons of tubers	10.5

WATER CONTROL ON THE LAND

Water control on the land is concerned primarily with the regulation of run-off and with the maintenance of favorable soil moisture conditions.(18) Agricultural practices necessary for the attainment of the above objectives may be grouped into: (*a*) control of run-off and erosion, (*b*) protection from floods or overflow, (*c*) drainage, and (*d*) irrigation. Irrigation is the most important of these water control measures in Bataan Province. Protection from overflow and the control of run-off and erosion are important in some places. Artificial drainage is of little or no importance at present.

In almost all agricultural areas, rainfall provides some part of the water required by crops, so that, in one sense, all irrigation is supplemental. It is most needed during droughty years, and its importance is evident when one remembers that it determines the success or the failure of the early maturing lowland rice crop in provinces having a long dry season, of which Bataan is a good example.

Increased production of rice and secondary crops like corn and beans such as mongo, cowpeas, and sitao could be brought about by irrigation, of which there are three types: (1) supplementing the natural precipitation during dry periods; (2) providing all the water needed for the "palagad", or dry season crop of rice; and (3) supplying all the water needed by secondary crops.

Since under irrigation water supply ceases to be a problem, the early maturing rice varieties may be replaced by late maturing varieties, which are generally higher yielders than the former. Experience during the Japanese occupation and subsequent trials have shown that the growing of "palagad," or dry season rice, is feasible in Dinalupihan, Hermosa, Orani, Samal, Abucay, Balanga, and Pilar so long as there is an adequate supply of water. Likewise, irrigation would surely make possible the growing of more secondary crops during the dry season since water has always been the limiting factor for extensive plantings of such crops as corn, peanuts, mungo, cowpeas, sitao, sweet potatoes and the like. It should be borne in mind, however, that the classification of lands to be irrigated is important for three reasons, namely, (1) The requirements and possibilities of farm land are both peculiar to and higher under irrigation; (2) because the water supply available for irrigation is usually insufficient for all the irrigable

area, the water should be used on the better lands first; and (3) the cost of providing irrigation water cannot be borne by poor lands.

Other factors to consider in the classification of lands for irrigation aside from all those that apply to nonirrigated lands are: (1) topography, which must be such that it permits economical and even distribution of water over the area; and (2) natural drainage, which must be adequate or that adequate artificial drainage can be provided at a reasonable cost. Other points to consider are that the soil must not contain excessive quantities of alkali salts and that the irrigation water must not also carry so much of similar salts. Generally, these last two factors are not important in Bataan because the soils are usually leached, thus precluding the presence of excessive amounts of salts and that there are no limestone or similar formations where the possible sources of irrigation water may dissolve excessive alkali salts.

The nearly flat relief of the plain is favorable to an economical and even distribution of the water, and the light texture of the soils is conducive to good internal drainage. Add to these the presence of several live streams which could be diverted, and one can see readily why irrigation in Bataan Province is sure to increase, if not double, the production of the different crops, especially rice.

While it is true that several private communal systems are in operation in the province, it is obvious that more extensive irrigation projects in the future must be financed and built from public funds, the cost to be shared by all who benefit from them. Another point that should not be overlooked is the careful classification of the irrigable lands on the basis of their probable productivity and the more equitable assessment of costs against them on the basis of their varying possibilities. Such classification must not only consider soil, water, and plant relationship but economic factors as well.

The problems connected with irrigation are not so simple as they appear, but it is not within the scope of this report to discuss its various ramifications. Suffice it to say that if the increased production of food crops is to be achieved, one of the most practical means of reaching the goal is to provide sufficient irrigation water to irrigable lands, such as those in the coastal plain of Bataan Province. This does not mean that the other several ways of increasing production such as the more extensive use of farm machinery,/the increased use of fertilizers, commercial or otherwise, and the control of pests and diseases, could be dispensed with, but they should all be practiced together to obtain the highest production possible from a given kind of soil.

The control of run-off and erosion is perhaps of secondary importance in the control of water on land in Bataan Province. Although no studies have been made as yet regarding the extent and degree of erosion of the soils of the province, their physical characteristics and topography tend to show that only two soil types, the Culis loam and Antipolo clay, are susceptible to accelerated erosion. Culis loam has a high erodibility primarily because of its clayey impermeable subsoil, which restricts the free movement of water into the lower layers, thus resulting in the fast accumulation of water on the surface forming run-off.

The Antipolo clay is likewise susceptible to erosion due to its undulating to gently rolling topography. While the entire soil mass is relatively porous, the topography in most places is steep enough not to give the water sufficient time to sink into the friable and porous soil. Considering the small extent of the cultivated area in these two soil types, it is safe to assumed that accelerated erosion has not gone far enough. In spite of this, however, it is always best to start preventing or reducing erosion to the minimum rather than to let it develop to a degree where its prevention later may entail so much expense of time and labor.

Since the Culis loam is a naturally unproductive soil, it is best suited for pasture and reforestation. In order to protect this soil from further erosion, it should be seeded to Bermuda grass or some thick-growing legume, preferably one which makes a good forage plant.(30) Or if it is not seeded to grass, it should be planted to ipil-ipil or madre cacao, which will be good sources of firewood in later years.

The Antipolo clay is a good agricultural soil and some portions of this type have been used to grow sugar cane before the war. To reduce erosion to a minimum in the cultivated areas requires the adoption of certain practices, prominent among which are contour tillage, strip-cropping, and terracing. All these measures are designed to slow down the velocity of the water flow, thus affording the water more time to infiltrate into the soil. Under a system of contour farming, all plowing and furrows are on the level. The furrows and rows of

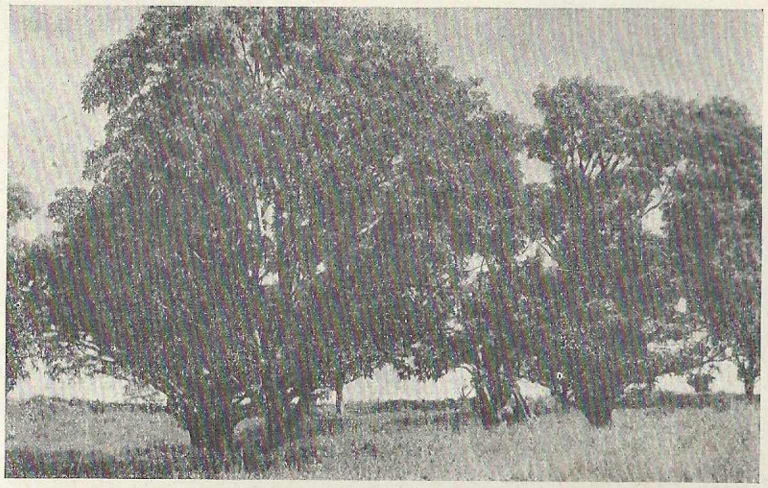
plants under contour tillage function as small dams or terraces that retard the flow of water.(29)

The practice of strip cropping functions under the same principle as contour farming—it retards the flow of water through the use of close-growing vegetation. Under this system of cropping, row crops like corn or peanuts are planted in bands between bands of close-growing crops such as sweet potatoes or upland rice. Run-off from land in row crops, even under contour cultivation, is more rapid than run-off from land in close-growing crops. When the water leaves the band of row crops and passes through a strip of close-growing crop, the movement or flow is slowed down, part of the soil load is deposited and more moisture enters the soil. By rotating crops in the strips, and including green manure crops and legumes in the rotation, the organic matter content and fertility of the soil may be maintained or improved. This helps in increasing infiltration of water into the soil.

Run-off from steeper slopes is unusually more rapid and more erosive than run-off from slopes less steep. Waterflow and erosion on the slopes now cultivated which are too steep for crops planted in rows could not be controlled sufficiently by the usual water and soil-control measures for cultivated land, such as contour farming, strip-cropping in rotation, and terracing. Such slopes should be planted to close-growing perennial crops or trees. The soil on gullied lands can be held in place only if it is planted to trees, shrubs, and vines. In such places it is often necessary to construct in the gullies inexpensive soil-saving dams made of native materials to aid the plants in getting started.

Protection from floods, or overflow, is not so serious a problem in Bataan Province. Such floods could be minimized or controlled mainly by the reforestation of steep slopes which have been cleared and by stopping altogether the practice of "caiñgin" agriculture in all the watersheds of the several streams of the province.

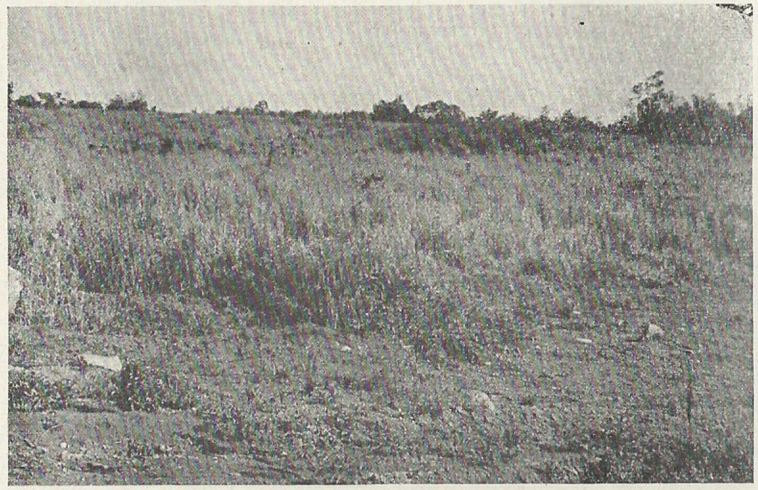
Drainage is not a problem at present, but it may sometime become a need when irrigation farming is developed in the province. The excess water resulting from irrigation has to be conducted off the field and at the same time leach out the salts that may accumulate. This function of drainage in irrigated areas is very important because if neglected, the accumulation of alkali salts may result in a poor physical condition of the soil.



The Antipolo clay is adapted to the growing of mangoes and other fruit trees. Permanent crops such as fruit trees could be planted without danger of erosion even on moderate slopes.

Some of the areas cleared for "kaiñgin" have high percentage of slope that renders them susceptible to erosion. The above is a "kaiñgin" on Antipolo clay planted to upland rice and camote.

Fig. 15



Accelerated erosion starting on Antipolo clay through the destruction of the native vegetation of sod-forming grasses.

A road-cut at Culis, Hermosa. The soil is Culis loam, an erosive soil. Such exposed cuts should be protected by planting them to quick-growing grasses or shrubs.

Fig. 16

CHEMICAL CHARACTERISTICS OF THE SOILS OF BATAAN PROVINCE

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The survey of Philippine soils, as conducted by the Division of Soil Survey and Conservation, involves not only genetic, morphological, and cartographic studies in the field, but also physical, chemical, and biological investigations in the laboratory. The laboratory investigations, especially the chemical, are aids in the formation of farm practices and cropping systems and in the study of the origin and formation of the soil type, as well as in the determination of its fertilizer requirements. Chemical tests also reveal the causes of unfavorable soil conditions, such as the presence of toxic elements or the presence of plant nutrient elements in excessive or toxic concentrations.

Plants need in relatively large quantities such essential elements as carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, sulphur, and iron. Very minute quantities of boron, copper, manganese, and zinc have been found essential for the normal metabolism of plants. The latter group of elements are classified as trace or rarer essential elements for plant nutrition, because they are needed in such small amounts as one-fourth part per million in the soil solution. Of the fourteen essential elements just mentioned only three, namely, carbon, hydrogen, and oxygen, are derived from the air and water, and the rest are taken by plants from the soil. Deficiency in any of these essential plant nutrient elements in the soil invariably causes adverse effects on the quality and quantity of crop yields.

Modern farm practices tend to deplete the supply of nitrogen, phosphorus, and potassium which in most agricultural soils are present in critical or inadequate amounts. To replenish the supply of nitrogen, phosphorus, and potassium or to replace what the crops take in from the soil, the application of green or farm manures and of commercial fertilizers become necessary. For the insufficiency of such minor elements as calcium and magnesium, and for the correction of excessive soil acidity, ground dolomitic limestone is added to the soil.

METHODS OF CHEMICAL ANALYSIS

Except for total nitrogen where total analysis was followed, preference was given to the determination of replaceable or readily available soil constituents for two considerations: (1) at present, facilities for total analysis are obtainable only for nitrogen and phosphorus, while those for the rest of the elements are not yet available in our laboratory, and (2) the results obtained with the rapid or availability tests correlate with plant growth or the response of plants to fertilizer application better than those obtained with total analysis.

Availability or rapid chemical tests are being calibrated under Philippine conditions with actual results of fertilizer and liming experiments conducted in pots and in the field. While studies along this line are still underway in the Division of Soil Survey and Conservation, selected availability tests which had been successfully used abroad have been followed in the study of the soils of Bataan Province.

Soil reaction or the hydrogen-ion concentration of the soil was determined by the potentiometric method, using the glass electrode. Total nitrogen content of the soil was determined according to the "Methods of Analysis" of the Association of Official Agricultural Chemists of the United States. (5) Nitrates, ammonia, and replaceable calcium were determined by the methods of Spurway. (24) For the readily available phosphorus determination, the method of Truog, (28) as modified by Marfori, (14) was followed. Available potassium was determined according to the method of Peech and English (19) and the interpretation of the results made according to the findings of Bray (6) and Murphy. (17)

INTERPRETATION OF CHEMICAL TESTS

*Soil reaction or pH value.**—Soil reaction which affects the behaviour and availability of plant nutrients in the soil is a very important limiting factor for plant growth. In very strongly acid soils, or soils of very low pH values, toxic concentrations of aluminum and manganese usually develop and retard plant growth. In very alkaline soils, or those with very high pH values, iron, manganese, and phosphorus become unavailable to plants, and thus cause their malnutrition or abnormal growth.

* Soil reaction means the degree of acidity or alkalinity of the soil expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, lower values indicate acidity, and higher values indicate alkalinity.

Different plants have been found to have different specific optimum reaction requirements or pH preferences in their media—whether soil or culture solution. Table 9 shows the pH requirements of some economic plants. It can be noted from these data that some plants, like pineapple, rice, and tobacco, prefer to grow on medium acid soils (pH 5.5 to 6.1), while other species like alfalfa, sugar cane, and orange, prefer more alkaline condition (pH 6.2 to 7.8). Some plants like corn and tomato have rather wide pH tolerance limits (pH 4.8 to 8.5), although their optimum requirements are of narrower ranges (pH 6.2 to 7.0).

TABLE 9.—*The pH requirements of some economic plants.* [a]

[X, most favorable reaction; o, unfavorable reaction; y, reaction at which plants may grow fairly well or normally.]

Plants	Soil reaction					
	Strongly acid, pH 4.8–5.4	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
Alfalfa (*Medicago sativa* Linn.)	o	y	y	X	X	y
Corn, or maize (*Zea mays* Linn.)	y	y	X	X	y	y
Bean, lima (*Phaseolus lunatus* Linn.)	—	y	X	y	y	—
Lettuce (*Lactuca sativa* Linn.)	o	y	X	y	o	o
Onion (*Allium cepa* Linn.)	o	y	X	y	y	y
Peanut (*Arachis hypogaea* Linn.)	y	y	X	X	y	—
Pineapple [*Ananas comosus* (Linn.) Merr.]	y	X	y	o	o	o
Rice (*Oryza sativa* Linn.)	y	X	y	o	o	o
Soy bean [*Glycine max* (Linn.) Merr.]	y	X	X	X	y	y
Sugar cane (*Saccharum officinarum* Linn.)	o	y	X	X	X	y
Sweet potato [*Ipomea batatas* (Linn.) Poir.]	y	X	X	y	o	o
Tobacco (*Nicotiana tabacum* Linn.)	y	X	y	o	o	o
Tomato (*Lycopersicum esculentum* Mill.)	y	y	X	X	y	y
Orange, sweet (*Citrus sinensis* Osbeck) [b]	—	y	X	X	X	y

[a] Data taken mostly from Weir, Wilbert Walter. Soil Science, its principles and practice (1936) 1–1615. J. B. Lippincott Co., Chicago and Philippines.

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

TABLE 10.—*Average chemical analysis of the surface soil of the major soil types in Bataan Province.*

Type No.	Soil type.	pH value	Total nitrogen (N)	Available constituents in parts per million (p. p. m.).				
				Ammonia (NH_3).	Nitrates (NO_3)	Phosphorus (P)	Potassium (K)	Calcium (Ca)
			Per cent					
187	Pilar silt loam	6.86	0.07	10	2	27.5	105.0	100
95	San Manuel fine sandy loam	6.64	0.06	2	2	55.0	132.0	40
78	La Paz silt loam	7.04	0.17	2	2	80.0	105.0	100
186	Pilar fine sandy loam	6.58	0.08	10	2	47.5	250.0	100
26	Antipolo clay	6.64	0.15	2	2	7.0	276.0	100
77	La Paz fine sand	6.87	0.06	2	2	48.5	122.5	100
188	Culis loam	6.52	0.06	2	2	3.0	26.0	40

Table 10 shows the average chemical analysis of the surface soil of the principal soil types in Bataan Province. The soil types are arranged in decreasing productivity ratings as given in Table 8 to facilitate comparison of data.

The pH values of the soils studied ranged from pH 6.36 to 7.04. In so far as the pH values of the soils of Bataan Province are considered, rice, pineapple, and tobacco cannot be expected to give maximum yields, because the average pH values of these soils do not fall within the optimum preference limits (pH 5.5 to 6.1) of the above-mentioned crops. Table 8 shows the productivity ratings of the soils of the province. It will be seen from these data that Pilar silt loam which had been rated as the most productive soil type of the province, as far as rice is concerned, has a productivity rating of 85 only for this particular crop, unlike productive soil types in other provinces (Laguna, for example), where the ratings were even over 100 for rice. Sugar cane, corn, beans, peanuts, lettuce, onions, tomatoes, and orange, however, can be widely grown in Bataan Province considering soil reaction alone as a factor.

Nitrogen.—Being a constituent of the protoplasm of every living cell, nitrogen is used largely by the plant in its vegetative growth. However, nitrogen functions also in the development of fruit, grains and seeds. If present in ample amounts in the soil, nitrogen stimulates growth and hastens the maturity of the crop, but the presence of excessive amounts tends to produce excessive vegetative growth and delays maturity. Sufficiency of nitrogen in the soil produces dark green leaves in plants, while deficiency of the element cause chlorosis or yellowing of the leaves, and in advanced cases, slow stunted growth results.

Aside from delayed maturity, other adverse effects of excessive supply of nitrogen in the soil are: (1) Lodging in rice and other small grains, (2) decreased resistance of plants to deseases, (3) lowering of the purity of cane juice in the case of sugar cane, and (4) decreased tensile strength of bast fibers in fiber plants. However, for leafy vegetables and forage crops where succulence is a gauge for quality, abundance of nitrogen in the soil is highly desirable.

In soils, nitrogen occurs chiefly in the organic matter, which consists of the decaying plant and animal residues and the complex substances which make up the bodies of the living soil microorganisms. Through the action of specific soil microorganisms in a process called nitrification, the nitrogen of nitrogenous organic matter is mineralized, passing three stages,

namely, (1) its conversion into ammonia, (2) then into nitrites, and (3) finally into nitrates. Moist, warm soils which are sufficiently aerated, the proper microorganisms, and a good supply of nitrogenous organic matter are necessary to maintain production of nitrates through nitrification.

Most plants assimilate their nitrogen as nitrates, while rice and other members of the grass family can absorb nitrogen in the ammoniacal form. Ammoniacal nitrogen can be fixed in the soil and therefore not easily lost through leaching unlike nitrates which cannot be fixed and which are very soluble. In cases where a deficiency of nitrogen in the soil is to be remedied with the use of commercial fertilizers, the choice of the kind of nitrogen-carriers will depend on the cost of the fertilizers, the ease in handling and application, and the cropping system. For the growing of vegetables or short-season crops where immediate effect is desired, nitrates are preferable to ammoniacal nitrogen. In combination with calcium or sodium nitrates tend to reduce soil acidity, while ammoniacals generally increase soil acidity. However, for long-season crops, like sugar cane and some varieties of rice, ammoniacal nitrogen is preferable to nitrate as far as efficiency and lower cost are concerned.

Of the seven soils types identified in Bataan Province, five were quite low in total nitrogen, below 0.10 per cent, which may be considered an approximate average for Philippine soil types so far studied. Only La Paz silt loam and Antipolo clay which had 0.17 and 0.15 per cent of total nitrogen, respectively, may be considered fair in nitrogen contents.

Using Spurway's interpretations, low ammonia tests (2–5 p. p. m.) are normal for many soils where nitrification proceeds to completion; that is, the ammonia is converted into nitrates right away. Low tests may also mean that the ammonia is fixed in the base-exchange complex, or it is taken up by plants as fast as formed. Relatively high tests for ammonia (10–25 p.p.m.) may mean that the soil has a high content of decaying organic matter or it was recently treated with ammoniacal fertilizers. Of the Bataan soils analyzed, only Pilar silt loam and Pilar sandy loam had fairly high ammonia contents (10 p. p.m.), although their total nitrogen contents were not high.

Spurway classifies 2–5 p.p.m. as medium or normal supply, and 100 p.p.m. or more as very high or excessive with deleterious effects on plants to be expected. These tests for the different forms of nitrogen taken individually are not absolute, because the amounts indicated by these tests may vary considerably during the growing period of the plant. In order to be of some diagnostic value regarding sufficiency or deficiency of nitrogen in the soil, the results of the three nitrogen tests have to be interpreted together as follows: Low nitrate test with chlorotic and stunted plants means nitrate deficiency. Low nitrate tests may indicate that the nitrate is absorbed by the plants as fast as produced, or that it is lost from the soil through leaching.

The data in Table 10 show that the majority of the soils in Bataan Province are deficient in nitrogen and all were found low in nitrates at the time of the survey. The medium (not high) productivity ratings (Table 8), of the three soil types, namely, San Manuel fine sandy loam, Pilar fine sandy loam, and La Paz fine sand, which may be considered to have sufficient available phosphorus (over 40 p.p.m.) and sufficient available potassium (over 100 p.p.m.), may be attributed partly to their low nitrogen contents.

Phosphorus.—Like nitrogen, phosphorus is a component of every living plant and animal cell. In the absence of phosphorus, cell division is retarded and results in stunted growth. Phosphorus is essential for seed formation and has a marked influence on hastening the maturity of crops, especially grain crops. In general, phosphorus hastens the ripening processes in plants. Phosphorus is needed in the production of nucleoproteids, of fats and albumin, and in the conversion of starch into sugar. Phosphorus-starved plants, or those grown on phosphorus-deficient soils are of inferior feeding value, because of their reduced phosphorus content. The importance of this in the nutrition of animals is obvious even considering only that phosphorus is essential in the formation of bones and teeth. A very important effect of phosphorus on plants is the stimulation of the development of the root system, particularly in the root crops. Phosphorus-starved plants have stunted root system which means decreased feeding zone.

Among the major plant nutrient elements, phosphorus is probably the most often deficient in agricultural soils. The most characteristic symptom in plants of phosphorus deficiency in soil is stunted growth. The stunted plants usually have dark green color, while some plants, like corn, develop reddish or purplish coloration on the leaves and stems when grown on phosphorus-deficient soils. For some varieties of rice, phosphorus deficiency may delay maturity by as much as two months.

Truog, using his method of analysis, (28) tentatively set a minimum limit of readily available phosphorus at 37.5 p.p.m. for heavier or clayey soil and 25 p.p.m. for lighter or sandy soils under Wisconsin conditions. He also suggested that for certain sections of the southern part of the United States where the climate permits a longer growing period than in the northern part, 10 to 15 p.p.m. of readily available phosphorus might maintain a good crop of corn. Marfori (14) found that there was still a little response to phosphatic fertilization in Philippine rice soils containing as much as 37.3 p.p.m. of available phosphorus as determined by the Truog method. Since more extensive investigations along this line had been disrupted by the last war, and the present studies have not yet yielded enough results, only estimates may be made. For some Philippine soil types, 30 to 40 p.p.m. of available phosphorus might be a reasonable minimum requirement for a good crop of rice.

The data in Table 8 show that as far as the average productivity ratings for all the crops grown are concerned, San Manuel fine sandy loam (average rating is 89) is the most productive soil type in Bataan Province. This soil type has the highest available phosphorus content (55.0 p.p.m.). This has the highest productivity rating on bananas (100), on corn (90), and on sweet potato (90). Pilar fine sandy loam which has the second highest available phosphorus content (47.5 p.p.m.) has a productivity rating of 85 on yambean (sincamas) and ratings of 80 on four other crops. La Paz fine sand which has the third highest available phosphorus content (43.5 p.p.m.) has productivity rating of 85 on yambean, and on sweet potato. La Paz silt loam with 30 p.p.m. of available phosphorus has productivity ratings of 80 on sugar cane and on bananas. Pilar silt loam with the second highest average productivity rating (87) has an available phosphorus content of 27.5 p.p.m. These data show that these soil types which gave around 30 p.p.m. or more of available phosphorus are definitely not very low in their productivity, although they may still be expected to respond to fertilizer treatments other than phosphatic. The rather low productivity rating of Antipolo clay for the grains (45 for rice and 70 for corn) may be due mainly to the rather low available phosphorous content (7 p.p.m.) of that soil type. The very low productivity ratings of Culis loam for all crops (15 for rice, 25 for bananas, and 40 for mangoes) are probably due principally to the extremely low contents of available phosphorus (3 p.p.m.) and available potassium (26 p.p.m.).

Potassium.—Plants need and contain more potassium than any other essential nutrient elements derived from the soil. Plant ash generally contains about 40 per cent of potassium as K_2O or potash. This element, unlike phosphorus, is not localized in any part of the plant, although in some crops it tends to accumulate in the leaves and stems instead of in the grain. One of the most important functions attributed to potassium is its effect on the synthesis of carbohydrates and proteins by plants. Potassium is needed in the production of starch, sugar, and other carbohydrates and in the translocation of these materials within the plant. It is also needed in the development of chlorophyll and in the synthesis of oils and albuminoids. Potassium improves the general vigor of the plant and increases its resistance to diseases. Potassium increases also plumpness in grains, and makes the stalks or stems of plants more rigid, thus minimizing lodging (Millar and Turk).(16)

Potassium deficiency in the soil causes marked disturbances in plants. The leaves become yellowish or dull colored at the tips and margins and finally brown, spreading upward and inward toward the centers. The deficiency may cause also the formation of small shruken, or misshaped flowers, pods, fruits, tubers, and roots.

Potassium occurs in both the organic and mineral matter of the soil but is found chiefly in the mineral portion in unavailable form. It becomes available to plants through the action of weathering, by base exchange, and through solution in the soil water. All soils, except peats and mucks, contain relatively large amounts of total potassium but the amount available to plants is generally small especially in sandy soils.

The major portion of the soil potassium usually exists in the difficultly available or nonreplaceable form, mostly in primary minerals such as the feldspars and micas which are prominent constituents of igneous rocks. A minor portion of the total potassium, usually not more than one per cent, is present in available or replaceable form, that is, in the clay minerals (principally kaolinite, montmorillonite, beidellite, halloysite, etc.). The portion of total potassium that is water-soluble is still much smaller than that in replaceable form and it is quite desirable, indeed a blessing to agriculture, for it is the water-soluble potassium that is easily lost by the soil through leaching or in drainage.

In soils of high base-exchange capacity and rather low total replaceable base content, part or all of the potassium added as

fertilizers is fixed in the base-exchange complex. Once fixed that way, the potassium may be considered stored and to be released little by little for plants' use.

The results of the chemical test for available potassium of the principal soil types in Bataan Province as shown in Table 10 were obtained using the method of Peech and English.(19) Because no data for the minimum potassium requirements of plants are given with this method, and fertilizer and liming experiments for calibrating chemical tests suitable for Philippine conditions are still in progress, the data of Bray(6) and of Murphy(17) for available potassium which were obtained with similar procedures are referred to for estimating roughly the potash fertilizer requirements of the Bataan soils.

Bray states that for most Illinois or Corn Belt soils with 150 p.p.m. (300 pounds per acre) or more of available potassium, corn or clover will not respond to potassium fertilization. The minimum requirement of replaceable potassium of soy beans was estimated at 100 p.p.m. while that for wheat or oats was about 65 p.p.m. However, for the principal Illinois crops to be grown in a 4-year rotation, he recommends 100 p.p.m. of available potassium as the minimum requirement (Linsley) .(12)

According to Murphy,(17) Oklahoma soils containing less than 60 p.p.m. of replaceable potassium generally respond to potash fertilization when other factors are favorable for plant growth. He found that on Oklahoma soils with 100 to 124 p.p.m. of replaceable potassium, the crop response was very doubtful; on soils with 125 to 199 p.p.m. there was no crop response ordinarily; and no soils with over 200 p.p.m. of replaceable potassium ever gave crop response to potash fertilization.

Basing on the data of Bray and of Murphy, it may be tentatively assumed that about 100 p.p.m. of replaceable potassium is the average minimum requirement of the principal crops of the province, particularly of rice and corn. Of the seven major soil types identified in Bataan Province, only Culis loam is very deficient in available potassium (26 p.p.m.), while the rest seem to be sufficient in available potassium, which ranges from 105 to 276 p.p.m.

Calcium.—In addition to being one of the essential plant nutrient elements, calcium performs many important functions in the soil, affecting the latter physically, chemically, and biologically. As an essential element for plant growth, calcium is required in the translocation of carbohydrates and certain mineral elements in the plant. It is needed in the development of healthy cell walls. It helps in neutralizing organic acids or regulating acid-base balance within the plant. The calcium content of plants is an index of their feed value, calcium being needed in the development of the bones and teeth of animals.

The calcium content of the soil affects its physical structure. Soil colloids saturated with calcium are flocculated, while those deficient in calcium are generally deflocculated. This is why soils high in lime content are usually in better tilth, more granular and porous, and less easily puddled than soils low in lime content. Soils with good tilth are easier to cultivate and have better aeration and drainage than soils with poor tilth.

Added as a liming material, calcium neutralizes the acidity of acid soils and corrects the toxic conditions usually caused by soil acidity. In this way calcium affects the solubility of soil mineral elements as already explained under the topic "soil reaction." Very important in this respect is the effect of calcium on the availability of phosphate (content may be relatively high). Liming, in this case, tends to increase the availability of phosphorus in the soil.

Relatively large amounts of available calcium are needed by beneficial microorganisms in the soil and by legumes and sugar cane especially. For the microbiological processes in the soil, calcium promotes the decomposition of matter and provides favorable conditions, especially reaction for nitrification, and sulfofication, in addition to supplying the nutrient requirement of microorganisms in their metabolism. Liming, however, should be regulated as there are certain crops, like rice and watermelon, that are easily injured even by slight overliming.

According to Spurway, whose method for determining available soil calcium had been followed in testing the Bataan soils, low test for calcium, below 40 p.p.m., indicates a low available supply and, if the soil is acid, also emphasizes the need for liming to grow "high lime" crops. He considers 100-150 p.p.m. of available calcium good for most plants, while higher amounts may be excessive especially for plants with low pH preferences.

Table 10 shows that of the seven major soil types identified and studied in Bataan Province, only two, San Manuel fine sandy loam and Culis loam, gave 40 p.p.m. of available calcium, which according to interpretation of Spurway are low, and the rest of the soil types had sufficient available calcium, 100 p.p.m. It will be noted in Table 8, however, that San Manuel fine sandy loam had the highest productivity rating in corn (90), sweet potato (90), and bananas (100). As had been explained

already under the topic "Phosphorus", the very low productivity ratings of Culis loam for all the crops grown on that soil type were probably due principally to its extremely low contents of available phosphorus and potassium, and probably not due to its available calcium content. Pending completion of enough liming experiments, the results of which will be used in calibrating tests for available calcium under Philippine conditions, it may be inferred from the date presented above that 40 p.p.m. of available calcium as obtained by the Spurway method may be considered not low, if not totally sufficient for most crops under Bataan Province conditions.

SUMMARY

Bataan Province is in the southwestern part of Central Luzon. It covers an area of 1,360 square kilometers, or 136,000 hectares, most of which is occupied by reddish brown to almost red sedentary soils developed from volcanic rocks. The province is generally mountainous and hilly with a narrow coastal plain on the eastern coast. The plain together with the undulating to gently rolling portions of the mountainsides comprise the agricultural area of the province. According to the Philippine Census of 1939, the population of the province is 85,555.

The climate is humid and tropical, with a long dry season of about six months from November to the middle of May. The mean annual rainfall of Balanga is 2,640.9 millimeters.

Agriculture is the principal industry. The soils are well adapted to a variety of crops, but rice and sugar cane are the most important products. Rice, the most important crop, occupies, about 32 per cent of all the cultivated area. Bananas, corn, mangoes, sweet potatoes, pineapples, and yambeans are some of the minor crops. The livestock industry is not well developed and suffered further setback during the Japanese occupation.

The change from primitive to more advanced agriculture is rather slow, but there is a trend towards improvement. Soil-improvement practices are not in general use. Erosion is not severe, and the soils are relatively of average to high productivity. The primary needs of the province are work animals, seeds and planting materials, especially sugar cane, and more irrigation systems.

About 19.5 per cent of the area of the province is farm land, and 61.1 per cent of the farm area is cultivated. According to the census of 1939, 35.8 per cent of all the farms were operated by share-tenants and 28.7 per cent by owners.

Due to the simplicity of the landscape of the province, the soils have few variations. The soils of the coastal plain are represented by the La Paz, Culis, San Manuel, and Pilar series. With the exception of the Culis series, all are important agricultural soils. These soils have light to medium-textured surface and subsoils, and the color ranges from gray, brownish gray to grayish brown. The soils of the uplands, hills, and mountains occupy 80.9 per cent of the area of the province. All the soils in this group belong to the Antipolo series. This series has reddish brown to almost red friable clay surface soil and subsoil. Due to the steep slopes in most places, only a small portion of this series is cultivated. Most of it is under virgin and second-growth forest. The swamps and marshes are of no agricultural importance. They are utilized as fishponds for the culture of milkfish.

Generally the soils of Bataan Province are low in their content of available nitrogen and phosphorus but are fairly well supplied with potassium. To increase the productivity of the soils, the nitrogen and phosphorus contents may have to be increased by the application of commercial fertilizers and the adoption of good soil-management practices.

As far as the pH value of the soils of Bataan Province are concerned, rice, pineapple, tobacco, and other similar acid-tolerant plants cannot be expected to give maximum yields, because the average pH values of these soils (ranging from pH 6.36 to 7.04) do not fall within the optimum soil reaction requirement of the above-mentioned crops (pH 5.5 to 6.1). Sugar cane, corn, orange, the various legumes and other acid-sensitive plants, however, may be widely grown in the province considering soil reactions alone as a factor.

Of the seven soil types identified in the province, five were low in total nitrogen contents, and only two, namely, La Paz silt loam and Antipolo clay, may be considered fair in total nitrogen contents. All the soil types were found low in nitrates at the time of the survey. The medium (not high) productivity ratings of three soil types which had fairly sufficient available phosphorus and potassium may be attributed, at least partly, to their low nitrogen contents.

Three soil types gave fairly high contents of available phosphorus, but they may still be expected to respond to fertilizer treatments other than phosphatic as indicated by their present

medium productivity ratings. It is significant, however, that the soil type that gave the highest available phosphorus content (San Manuel fine sandy loam) was the most productive soil type in Bataan Province as far as the average productivity ratings for all the crops grown are concerned. It may be noted that the soil type which gave the lowest average productivity rating for all crops (Culis loam) gave the lowest content of available phosphorus.

Except Culis loam which is quite deficient in available potassium, all the major soil types identified in the province seem to be sufficient in available potassium.

As verified by the pH values obtained, no soil type identified in Bataan Province seems to be quite deficient in available calcium.

GLOSSARY OF COMMON ECONOMIC PLANTS FOUND IN BATAAN PROVINCE

Common name	Scientific name	Family name
Achuete	*Bixa orellana* Linn.	Bixaceæ.
Ampalaya	*Momordica charantia* Linn.	Cucurbitaceæ.
Aroma	*Acacia farnesiana* (Linn.) Willd.	Leguminosæ.
Atis or sugar apple	*Anona squamosa* Linn.	Anonaceæ.
Arrowroot	*Maranta arundinacea* Linn.	Marantaceæ.
Avocado	*Persia americana* Mill.	Lauraceæ.
Bamboo	*Bambusa spinosa* Roxb.	Gramineæ.
Boho	*Schizostachyum lumampao* (Blanco) Merr.	Do.
Banana	*Musa sapientum* Linn.	Musaceæ.
Batao	*Dolichos lablab* Linn.	Leguminosæ.
Bitangol	*Calophyllum blancoi* Pl. & Tr.	Guttiferæ.
Breadfruit	*Artocarpus communis* Forst.	Moraceæ.
Buri	*Corypha elata* Roxb.	Palmæ.
Cassava	*Manihot utilissima* Pohl.	Euphorbiaceæ.
Cacao	*Theobroma cacao* Linn.	Sterculiaceæ
Caimito or star apple	*Chrysophyllum caimito* Linn.	Sapotaceæ
Cashew	*Anacardium occidentale* Linn.	Anacardiaceæ.
Chico	*Achras sapota* Linn.	Sapotaceæ.
Coconut	*Cocos nucifera* Linn.	Palmæ.
Coffee	*Coffea arabica* Linn.	Rubiaceæ.
Cogon	*Imperata cylindrica* (Linn.) Beauv.	Gramineæ.
Corn	*Zea mays* Linn.	Gramineæ.
Cowpeas	*Vigna sinensis* (Linn.) Savi.	Leguminosæ.
Dayap	*Citrus aurantifolia* (Christm.) Swingle	Rutaceae.
Duhat	*Eugenia cumini* (Linn.) Druce	Myrtaceæ
Eggplant	*Solanum melongena* Linn.	Solanaceæ.
Gabi	*Colocasia esculentum* (Linn.) Schott.	Araceæ.

Common name	Scientific name	Family name
Guava	*Psidium guajava* Linn.	Myrtaceæ.
Ipil-ipil	*Leucaena glauca* (Linn.) Benth.	Leguminosæ.
Kamias	*Averrhoa bilimbi* Linn.	Oxalidaceæ.
Kamachile	*Pithecolobium dulce* (Roxb.) Benth.	Leguminosæ.
Katmon	*Dillenia philippinensis* Rolfe	Dilliniaceæ.
Kapok	*Ceiba pentandra* (Linn.) Gaerth.	Bombacaceæ.
Madre cacao	*Gliricidia sepium* (Jacq.) Steud.	Leguminosæ,
Macopa	*Eugenia mallaccensis* Linn.	Myrtaceæ.
Mandarin	*Citrus nobilis* Lour.	Rutaceæ.
Mango	*Mangifera indica* Linn.	Anacardiaceæ.
Mungo	*Phaseolus aureus* Roxb.	Leguminosæ.
Mustard	*Brassica integrifolia* (West) Schultz	Cruciferæ.
Nangka	*Artocarpus heterophyllus* Lam.	Moraceæ.
Nipa	*Nypa fructicans* Wurmb.	Palmæ.
Onion	*Allium cepa* Linn.	Liliaceæ.
Orange	*Citrus aurantium* Linn.	Rutaceæ.
Pechay	*Brassica pekinensis* Rupr.	Cruciferæ.
Pandan	*Pandanus tectorius* Sol.	Pandanaceæ.
Paayap	*Vigna sinensis*	Leguminosæ.
Papaya	*Carica papaya* Linn.	Caricaceæ.
Patola	*Luffa cylindrica* (Linn.) M. Roem.	Cucurbitaceæ.
Patani	*Phaseolus lunatus* Linn.	Leguminosæ.
Peanut	*Arachis hypogaea* Linn.	Do.
Pepper	*Capsicum annum* Linn.	Solanaceæ.
Pineapple	*Ananas comosus* (Linn.) Merr.	Bromeliaceæ
Pummelo or lukban	*Citrus maxima* (Burm.) Merr.	Rutaceæ.
Radish	*Raphanus sativus* Linn.	Cruciferæ.
Rice or palay	*Oryza sativa* Linn.	Gramineæ.
Santol	*Sandoricum koetjape* (Burm.) F. Merr.	Meliaceæ.
Sincamas or yambean	*Pachyrrhizus erosus* (Linn.)	Leguminosæ.
Sineguelas	*Spondias purpurea* Linn.	Anacardiaceæ.
Sitao	*Vigna sesquipedalis* Linn.	Leguminosæ.
Squash	*Cucurbita maxima* Duchesne	Cucurbitaceæ.
Soursop	*Anona muricata* Linn.	Anonaceæ.
Sugar cane	*Saccharum officinarum* Linn.	Gramineæ.
Sweet potato or camote	*Ipomea batatas* Linn. (Poir)	Convolvulaceæ.
Talahib	*Saccharum spontaneum* Linn.	Graminæ.
Tamarind	*Tamarindus indica* Linn.	Leguminosæ.
Tobacco	*Nicotiana tabacum* Linn.	Solanaceæ.
Tomatoes	*Lycopersicum esculentum* Mill.	Do.
Tugui	*Dioscorea esculenta* (Lour.) Burk.	Dioscoreaceæ.
Ubi	*Dioscorea alata* Linn.	Do.
Upo	*Lagenaria leucantha* (Duch.) Rusby	Cucurbitaceæ.
Watermelon	*Citrullus vulgaris* Schrad.	Do.

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ORGANIZATION OF THE DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

(As of July 1, 1949)

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Secretary of Agriculture and Natural Resources

Hon. JOSE S. CAMUS
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