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SOIL SURVEY OF BULACAN PROVINCE PHILIPPINE ISLANDS

BY

M. M. ALICANTE, D. Z. ROSELL, R. ISIDRO
AND S. HERNANDEZ

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PREFACE

Soil erosion has always been a great problem all over the world. In certain districts in the Philippines it is especially serious because of excessive rainfall. Information gained from soil surveys is useful in formulating preventive measures to check the effect of erosion and thus conserve the potential fertility of the soil.

A committee on Philippine soil surveys was appointed by the Secretary of Agriculture and Commerce in October, 1934. This committee, consisting of representatives from the Bureaus of Science, Plant Industry, Forestry, Lands, and Weather, approved the surveys of Philippine soils and decided to establish this project in the Bureau of Science. This work is now in progress and is carried on by the Bureau of Science in cooperation with the Bureau of Plant Industry and also with the assistance of the other bureaus concerned.

Since agriculture is the principal industry in the Philippines, it is a paramount importance to investigate the soil in order to increase the yield and improve the quality of crops and thus facilitate agricultural development. This objective can be attained, to a considerable extent, by carrying out a system of soil surveys.

The acquisition of field data, correlated with the results of chemical and mechanical analyses, furnishes valuable information for devising a proper system of agricultural practice for each locality. This work finds special application in the Philippines because of the varied degrees of fertility of the lands and the well-known differences of adaptability to the various crops. There are farms in the Philippines that have been under cultivation for

many years with the same crop, and in many cases no effort has been made to return to the soil any of the plant foods removed. The result is a constantly diminishing yield to the point of complete exhaustion of the soil.

Experience has demonstrated that a given area is best suited to certain crops, such as tobacco, rice, and hemp. A scientific soil survey of these principal lands will make possible the establishment of a standard type of soil for a particular crop. Some preliminary work along this line has been undertaken for the coconut and sugar districts. The valuable results that have been acquired should be determine, with a fair degree of accuracy, the adaptability of a region to those particular crops. The accumulation of reliable data concerning the most favorable conditions under which the principal crops grow would suggest means for improving poor land that is now undesirable.

These soil surveys, which give basic scientific data showing present conditions in a given area, should be supplemented by actual field experiments on the growing of crops. The results, thus obtained, indicate which crops are desirable for a particular soil. Such information serves as a guide for those who wish to acquire land for agricultural development.

A. S. ARGUELLES
Director, Bureau of Science
Vice-Chairman, Soil-Survey Committee

ILLUSTRATION

SOIL SURVEY OF BULACAN PROVINCE
PHILIPPINE ISLANDS

By M. M. ALICANTE and D. Z. ROSELL
Of the Bureau of Science, Manila

and

R. ISIDRO and S. HERNANDEZ
Of the Bureau of Plant Industry, Manila

INTRODUCTION

Settlement and history. --- Bulacan was one of the earliest Philippine Provinces founded by the Spanish government. This occured about 1578. It has been stated, however, that even before the arrival of the Spaniards there was already in existence, in what is now called Bulacan, a thriving settlement. The first missionary towns founded in the early years of the Spanish government were Calumpit (1572), Meycauayan (1576), Bulacan (1578), and Malolos (1582).

In the interval between the British occupation (1762-1764) and the middle of the nineteenth century the boundaries of the province were extended and the weaving of cotton and sinamay fabrics became important industries.

During the Philippine Revolution, Bulacan was one of the scenes of conflict. Mariano Ponce and M. H. del Pilar, whose names were prominent in this period, were sons of this province. Biac-na-bato, in the mountains of Bulacan, was the place where, in December, 1897, the famous Pact of Biac-na-bato was concluded. Malolos was for a time the capital of the Archipelago. It was in this place that in 1897 Philippine independence was proclaimed.

Congress was organized and the constitution of the Philippine Republic was drafted in the historic church of Barasoain, Malolos. The civil government was establish in Bulacan February 27, 1901.

The population of Bulacan was estimated in 1935 to be 275,900. The province has 23 towns; 4 first class, 3 second, 8 third, and 8 fourth. Malolos is the capital. It is 45 kilometers from Manila.

Transportation and communication. --- Bulacan Province is well supplied with good roads, railroads, waterways, and telephone and telegraph lines. In 1934 there were 182.9 kilometers of first-class roads, 142.1 of second class, and 48.3 of third class. These roads connect the various towns to the main Manila North Road. In addition the land transportation water transportation is also used to certain extent, especially along the coast.

Public Health. --- Sanitary conditions, medical and dental inspection of school children and teachers, industries hygiene health centers, communicable diseases and other public health activities are taken care by the Philippine Bureau of Health. A detailed account of this work is given the annual report of this Bureau.

Education. --- There are a number of public schools, 212 elementary and 2 secondary. These schools are conducted by the Philippine Bureau of Education. The annual report of this bureau gives a complete account of the work that is done in the schools. There are also some private schools conducted by the Catholic Church.

Industries. --- Agriculture is the chief industry. Fishing is carried on the fishponds, rivers, esteros, and Manila Bay. Fishponds are located in Malolos, Hagonoy, Bulacan, Paombong, Polo,

Obando, Meycauayan, and Bocaue. Bangus culture has been developed extensively around Manila Bay and is now a source of considerable income. The area covered by bangus fishponds alone was estimated at about 14,540 hectares in 1934. Obando has important oyster fisheries. Tanning and weaving are also important industries. There are other minor activities, such as the manufacture of cigars, cigarettes, hats, furniture, and beverages. Mining operations were begun recently and are now in progress.

AGRICULTURE

Bulacan Province has an approximate area of 260,800 hectares of which 150,879 (57.8 per cent) are under cultivation. There are still 43,955 hectares (16.8 per cent) available for agriculture, thus making a total of 74.6 per cent for agricultural purposes. Of the remaining area, the upland sections are under forest and the swamp sections are devoted fishponds.

The seven leading agricultural crops arranged in the order of their value are rice, mangoes, sugar cane, bananas, corn, tomatoes, and sweet potatoes. The minor crops arranged in a similar manner are camotes, peanuts, coconuts, papayas, sugar apples, pineapples, cotton, and pomelos.

Rice grown in 1933 was estimated to be worth 4,791,170 pesos, which is greater than the value of the rest of the crops combined. The area planted was 69,750 hectares, or 46.2 per cent of the total agricultural area. This cereal is planted in almost all types of soil, from the fine sandy loam of Obando and Polo to the clay soil of Bulacan. The method of cultivation, especially the application of

water for irrigation, varies in different localities. In those located in the vicinity of swamps and rivers the land is irrigated naturally by the water available. In the upper levels of the lowland regions, where river irrigation is impracticable, the rice paddies are dependent on rain water.

The principal varieties of rice that are cultivated are elon-elon and the different kinds of macan. Farmers usually harvest the crop by hand. Threshing machines, however, are used on the large plantations. The unhulled rice (palay) is stored in warehouses (bodegas). There are eighty of these, and they are usually located near rice mills.

It has been claimed that this province produces the best mangoes in the Islands. The area given to this crop in 1933 was 919 hectares and the estimated number of trees was 49,400. The commonest varieties grown are the carabao and the pico. The principal localities producing them are Pulilan, Quingua, Malolos, Bustos, Baliuag, Guiguinto, Bigaa, Calumpit, and Santa Maria. Generally the trees are scattered here and there, singly or in groups, without systematic planting.

Sugar cane is usually grown on Quingua silt loam soils in the slightly elevated portions of the lowlands. The area cultivated in 1933 was 1,700 hectares with a total producing value of about 400,000 pesos. This province has only one sugar central, which mills most of the cane.

In 1933 the areas planted to corn and bananas were 2,340 and 925 hectares, respectively. Peanuts and vegetables, such as eggplants

and radishes, are grown in the vicinity of Bustos on the Quingua fine sandy loam.

Poultry is raised to some extent in various localities. The cattle district is in the region between Sibul and San Rafael. At Tungkong Manga the Hacienda Carmencita, which has an area of about 500 hectares, raises both poultry and cattle.

The large estates in Bulacan are generally owned by the different orders of the Catholic Church. For instance, the Hacienda Buenavista is the property of the San Juan de Dios Hospital in Manila. This hacienda, which is located in the districts of San Rafael and San Ildefonso, has an area of about 27,000 hectares and is the largest in the province. It has 4,393 tenants who rent the land. Each tenant has about 40 or more farmers who work the land on shares. Palay is the principal crop. Some farmers get half of the crop produced, while others get only a third.

The other large estates in Bulacan are the Panginay in Bigaa, the Pandi in Bocaue and Bigaa, and the Recoletos in Guiguinto. The system of working the land is the same in these estates as at the Hacienda Buenavista.

CLIMATE

In any agricultural country the climatic conditions extending over a long period are important, for they affect soil development. Young soils usually have the characteristics of the parent material. However, under the influence of climate they develop in time regional characteristics. In the Philippines surface soils are gradually leached by rainfall and as a result the chemical and physical properties

are gradually changed.

There are two distinct seasons in Bulacan. The dry season occurs during the winter and spring months, while the wet season is in the summer and autumn. Usually the heaviest rainfall comes during the summer months, while the autumn rains are generally moderate and seldom result in floods. There is always some slight rainfall during the dry months.

The monthly rainfall recorded at the three stations in Bulacan is given in Table 1. The station in the lowland section is located at Malolos, while those in the upland are at Ipo Junction and Tungkong Mangga. The rainfall at those three stations differs slightly as shown by the mean annual reports. The typhoons and resulting floods that occur in the vicinity of Manila and the Luzon Central Plain affect also Bulacan Province since it is near Manila. The greatest floods occurred in July, 1904, and September, 1914. Typhoons may be expected at times between June and November. Droughts are rare though they do occur occasionally. Those of 1903, 1912, and 1915 affected the agricultural activity of the people, not only in Bulacan, but in most of the Archipelago.

The temperature of the province is generally rather uniform throughout the year (Table 1). The hottest months are April and May, just before the beginning of the rainy season.

PHYSIOGRAPHY AND GEOLOGY

Bulacan Province lies between two great physiographic divisions of Central Luzon and is situated within 14° 40' and 15° 17' north latitude and 120° 40' east longitude. It covers an area of approxi-

mately 260,800 hectares. It is bounded by Nueva Ecija Province on the north, Tayabas on the east, Rizal on the south, and Pampanga on the west, Manila Bay is southwest of the province. It is 10.41 kilometers from Manila to the nearest Rizal-Bulacan boundary.

The eastern part of Bulacan lies on the western flank of the Eastern Cordillera, which is composed of several high parallel ranges extending north and south. Because of the topographic condition of this district, agriculture is not well developed, but valuable forests of first - and second-group timbers are found.

Geologically this section consists mostly of extrusive and coarse rocks and contains iron, limestone, and gold deposits. It has many mineral springs of which Sibul, Pandi, and Marilao are the most important.

The western section of Bulacan contains level alluvial deposits, the low-lying tuffaceous portions of which are included in the Luzon Central Plain. This portion of the province is low country intersected by numerous tributaries of the Rio Grande de Pampanga and Bamlico and Bocaue Rivers.

The foothills, adjacent to this low country, are made up of tuffaceous and alluvial materials in the lower levels and conglomerates on the higher altitudes. These hills gradually increase in height from San Jose del Monte to Angat and the eastern part of San Rafael. The rise in elevation is about 40 meters.

Farther east of these foothills is a lava plateau underlain by andesite, basalt, and some limestone. Merging with this lava plateau is an area of high parallel ranges made up of coarse-grained intru-

sive rocks (diorite, gabbro, periodotite, etc.)

The loftiest peak in Bulacan is Mount Oriol, which is 1,193 meters in height.

IRRIGATION AND DRAINAGE

The central part of Bulacan is well drained by the Pampanga and Angat River system. Other small rivers, such as the Marilao, the Bocaue, and the Bigaa, drain the southern portion of the province. The region south of San Rafael is drained by Maasin, Garlang, San Miguel, and Ilog Rivers to Candaba Swamp. This swamp empties into Manila Bay through the Rio Grande Pampanga.

There are two large irrigation systems in the rice districts of the province. The Angat system overs an area of about 17,000 hectares. It includes the towns of Bustos, Quingua, Guiguinto, Bigaa, Bocaue, Bulacan, Malolos, Paombong, Hagonoy, and Calumpit on the south side, and San Rafael, Baliuag, and Pulilan on the north side. The Peñaranda system is located in the town of San Miguel. This irrigates about 2,550 hectares.

In Table 2 are given the names of the principal towns in the districts irrigated by the Angat system. The area (hectares) of land irrigated is also included in the table.

The average yield of rice before irrigation was about 28 cavans per hectare. After irrigation it was about 57 cavans. This increased yield was produced on different types of soil. In some districts where intensive cultivation was practiced the yield amounted to 80 cavans.

BULACAN SOILS

The most important factors affecting the utilization of land and the distribution of crops are the climate and the water supply, previously mentioned, and the topography and types of soils.

Topography. ---- Topography plays a rather important role in the distribution of crops. For instance, the rough and rolling areas are given to crops other than rice. The lowland areas are usually planted to rice.

Soil series and types. --- A number of distinct soil series are developed through differences in climatic influence, degree of weathering, character of parent material, drainage, irrigation, and the lime content of soils.

A soil series is a group of soils having the same range in color, the same character of subsoil (particularly color and structure), the same type of relief and drainage, and a similar or common origin. The series is divided into soil types.

The type is the unit of classification and mapping. The types within a series differ from each other only in the texture of the surface soil. Subordinate differences in the character of a soil type are designated as phases.

The soil type determines to a considerable extent the kind of crops that may be grown profitably and serves as a basic basis for diversification. Again a particular crop grown on various types of soil is likely to produce different yields. This is shown by the data recorded in Table 3.

The soils of Bulacan fall naturally into three major groups with various subdivisions. These may be classified as follows:

Bulacan soils

1. Island and basin soils
   - Bulacan series
   - Obando series
     - Obando fine sandy loam

2. Alluvial fans and plain soils
   - Quingua series
     - Quingua silt loam
     - Quingua fine sandy loam
   - Bigaa series
     - Bigaa clay loam
   - Bantog series
     - Bantog clay loam

3. Upland and mountain soils
   - Prensa series
     - Prensa silty clay loam
     - Prensa clay loam
   - Novaliches series
     - Novaliches loam
     - Novaliches clay loam
   - Buenavista series
     - Buenavista sandy clay loam
     - Buenavista silt loam
     - Buenavista clay loam
   - Sibul series
     - Sibul clay
   - Novaliches and Sibul soils undifferentiated.

In the following pages the soils of this province are described in detail, their location and distribution are shown in the accompanying soil map. Their relative areas and proportionate extent are given in Table 4.

ISLAND AND BASIN SOILS

The soils of the island and basin group occupy the region bordering Manila Bay. They comprise the Bulacan and Obando series. This soils, with the exception of the Obando fine brown sandy loam, are dark in color.

The submerged soils (hydrosols) extend along the swamps and mouths of the rivers. These soils are a mixture of decayed plants, clay, silt, and sand in various proportions.

Bulacan series. --- The Bulacan series is composed of hydrosols of several types and is located along the braided streams and rivers that empty into Manila Bay. As these hydrosols are under water it is difficult to delineate the boundaries of the different types, so in the complete map the Bulacan series is represented by one color. The area covered is about 6 per cent of the total area of the province. Fishponds have been constructed in the hydrosols, which also contain swamps of nipa palms and aquatic plants.

Obando series. --- The Obando series has a brown surface soil and a brown fine sandy subsoil. The most distinguishing feature of this series is the presence of marine shells in the lower subsoil horizon. The soil is planted to rice and vegetable crops. It occupies the vicinities of Obando and Polo.

Obando fine sandy loam. --- The Obando fine sandy loam is the result of the accumulation of sandy materials from the sea and nearby areas of Obando and Polo. It is characterized by a brown fine sandy loam surface soil with a depth ranging from 10 to 30 centimeters. The layer below the surface soil at a depth of about 80 centimeters is

a subsoil of fine brown sand. Beneath the subsoil is a gray and mixed with marine shells. Rice is the principal crop grown in this type of soil, though some sugar cane and vegetables of various kinds are also cultivated.

ALLUVIAL FANS AND PLAIN SOILS

The alluvial fans and plain soils, with but slight indication of true profile development, consist of assorted coarse stream sediments and recent fine alluvial deposits. They include the Quingua, Bigaa, Bantog, and a portion of the Prensa series. The properties of these soils vary with the character of the rocks in the adjoining upland. The areas bordering Candaba Swamp, the marshland, and the fishponds along Manila Bay are always flooded during the rainy season. The upper areas are seldom, if ever, inundated. The slight elevation gives a somewhat better protection from floods during the rainy season.

The Bigaa and the Bantog soils are poorly drained, and the profiles of this soils differ considerably depending upon the depth to which drainage and oxidation have extended. During the wet season the soils planted to rice are covered with water for two to three months. Other districts remain under water or are saturated with water until the advent of the dry season. Mottlings of gray, brown, dark brown, and black are present in the subsoils and in the substratum.

Quingua series. --- The Quingua soils are light brown to light reddish brown with light-textured subsoils. Like the Bantog and the Bigaa series these soils have the reddish brown streaks

characteristics of ricefield soils. The surface is usually loose and very seldom compact except in higher areas. The subsoil is characterized by light-brown heavier material.

The slightly elevated and drained part of this series is devoted to sugar cane and vegetables, while the low districts are irrigated and planted to rice. Fruit trees such as santol and mango grow well along the roads. The mangoes are especially good in this region.

Quingua silt loam. --- The Quingua silt loam consists of coarse-textured soil accumulated on the slightly elevated areas. This soil has developed under better drainage than the Bigaa and Bustos soils. The color is light brown to yellowish brown. There is scarcely a perceptible change in color and structure from the surface soil to the subsoils. The loose and structureless surface soils, however, vary in color according to the amount of organic matter present.

This silt loam has brown friable surface material to a depth of 25 to 40 centimeters. Reddish-brown streaks similar to those of the soils are present. The upper subsoil is dark brown, though sometimes light reddish brown in some parts. This material is heavier than the surface soil as it varies from silty clay loam to clay loam in texture. The occurence of heavier texture is due to the amount of fine material from the surface soil. In some portions of the area the subsoil is loose and friable, but on the average it is somewhat compact. The substratum below a depth of 80 to 100 centimeters is either brownish yellow, reddish brown,

yellowish brown silt loam to silty clay loam.

Indications from the texture of the surface and subsoil are that the soil loses moisture and drains easily. This type covers an area of about 20,850 hectares, or 8 per cent of the total area of Bulacan. It extends from Bustos and Baliuag to Quingua and Pulilan, Calumpit and a part of Hagonoy and Malolos. The unirrigated areas around Calumpit, Pulilan, and a portion west of Quingua are planted to sugar cane and corn. The irrigated portions are planted to lowland rice. The upper districts on both sides of Angat River, covering the areas of Baliuag, east of Quingua and Bustos, are also utilized for rice. The production of rice in this area varies from 35 to 70 cavans per hectare.

Quingua fine sandy loam. --- The Quingua fine sandy loam is a typical river deposit of sandy materials. The depth of the soil varies according to the level of the river flood terraces. Usually it ranges from 50 to 150 centimeters. The color is typically light brown and sometimes pale brown along the water. This soil, especially in the upper and the lower parts of Angat River between Quingua and San Rafael, is used for corn and vegetables. Tobacco are grown extensively in this type of soil.

Bigaa series. --- The soils of the Bigaa series distinguished by brown to dark-brown surface soil with notable reddish-brown or dark yellowish brown streaks. In some places the surface soil is compact, while in others it is either loose or slightly compact. The subsoil is light gray to dark brownish gray, mottled with yellowish and reddish brown clay. Concretions are present both

in the surface and in the subsoil. This series is located in the vicinity of Bocaue, Bigaa, Bulacan, Guiguinto, Malolos and a portion of Baliuag and Calumpit. There is a small area between San Ildefonso and San Miguel along Carlang River. This series is mostly irrigated and used for lowland rice.

Bigaa clay loam. --- Bigaa clay loam is a brown to dark-brown clay loam surface soil with brick-red streaks. It is very fine granular, sticky, and sometimes plastic and heavy. The depth ranges from 20 to 30 centimeters from the surface. The subsoil, which ranges from a depth of 40 to 100 centimeters from the surface, is light-gray, dark-gray to light and yellowish-brown heavy clay loam to clay. Iron concretions are present in both the surface soil and the subsoil. The presence of concretions is partly due to the Prensa series adjoining this type. This series contains a high percentage of iron concretions. The substratum to a depth of 60 to 120 centimeters downward is a light-gray with a few concretions.

The area covered by this type is approximately 17,550 hectares situated within the towns of Marilao, Bocaue, Bigaa, Guiguinto, Bulacan, Malolos, and a portion of Calumpit. A small area is located between San Ildefonso and San Miguel. Rice, with or without irrigation, is planted yearly in this type of soil. The production is slightly above that of the average soils in this region (Table 3). Some fruit trees also grow well.

The following description is typical of the Bigaa clay loam.

Bigaa clay loam

Depth of soil cm.	Characteristics
0 - 25	Heavy brown clay loam, sticky when wet. Dried surface soil is finely granular. Contains reddish-brown to red streaks.
25 - 60	Light-gray to brown heavy clay loam to clay. Mottled dark brown and yellowish brown; few concretions present. Slightly compact to compact sticky. Exposed to dryness the soil separates into fine granular structure.
60 - 110	Texture heavier than above, being light-gray clay to heavy. Concretions are present.

The clay content of the surface soil of the Bigaa clay loam is 48 per cent, and this increases in the subsoil. The substratum, however, has a lower percentage of clay. The sand content is almost constant from the surface down to the substratum.

The surface soil is somewhat acidic with pH 6.23. The plant food content appeared to be normal as compared with other Bulacan soils.

The Bigaa clay loam has a high percentage of iron concretions.

Bantog series. --- Like the Bigaa series the Bantog soils have a brown to dark-brown surface soil with reddish-brown or dark-yellowish brown streaks. The only difference between these two is that the Bantog soils do not have concretions in the surface and subsoil. The subsoils are dark-brown, mottled brown, yellow and gray heavy clay loam to clay.

This series is located in the southwestern and northern parts of San Miguel. The eastern and northern districts receive water from the Peñaranda Irrigation Systems.

Bantog clay loam. --- This soils is located in the northwestern part of Bulacan, bordering Pampanga and Nueva Ecija, and is considered first-class land. The most important features of this type are its dark color, slightly sticky consistency, and fine texture of the surface soil which ranges from 25 to 30 centimeters in depth. It is dark-brown heavy clay loam, with brownish-red streaks, becoming mellow when wet. Some parts of the area are light-brown to yellowish brown clay loam to clay. This soil has been under rice for several years. It covers an area of about 8,550 hectares.

UPLAND AND MOUNTAIN SOILS

The upland and mountain districts include the Prensa, Buenavista, and Novaliches, soils and the Sibul series. These districts also embrace the undifferentiated Novaliches and Sibul series. These soils have developed in places from the weathering and disintegration of the underlying bedrock. They range in color from rich brown, brown, light brown to light reddish brown, reddish brown, brick red, and almost red. The subsoils of those different series vary in the accumulation of clay and degree of weathering of the parent rock. The water-holding capacity of these soils is about normal, though it is limited by the depth of bedrock. About a third of the agricultural area of the province belongs to this group.

In the mountain regions the leaves and other plant residues serve as surface mulch. When the area is cleared and cultivated the humus is easily used up, leached or washed away in time by heavy rains. The oxides of iron and aluminum, rather than humus, determine of the color of the surface soils with the result that most of the well drained soils are light-brown and the subsoils are brighter in color than the surface soils.

Prensa series. --- This series has a slightly rolling topography. It is distinguished by a light-brown, brown, to light-reddish brown, friable and granular surface soil and subsoil. The subsoil has a considerable amount of gravel and concretions. It is more sticky and contains more plastic clayey materials than that in the higher regions.

The lower part of the upland area is generally employed for rice, though the yield is usually quite low. Application of manure and other organic materials is practiced by some farmers. In rough areas fruit trees and bamboos are grown.

In the poorly drained districts this clay is mottled with gray, dark brown, and reddish brown. Like the Novaliches series, the Prensa series is derived from a tuffaceous material. In many places where from a tuffaceous material. In many places where the tuff is exposed, it is mined for building material. The soil is, however, different from that of the Novaliches series because of the presence of a high percentage of gravel and concretions in the subsoil.

Prensa silty clay loam. --- The surface soil of the Prensa silty clay loam is yellowish brown to light reddish brown. It is a loose and gritty, silty clay loam. The depth ranges from 15 to 25 centimeters. The subsoil to a depth of 20 to 80 centimeters is a mottled gray and black loam with numerous concretions and gravelly material. The lower subsoil is brownish-gray clay, sticky, and hard, sometimes with whitish specks. The substratum at a depth ranging from 80 to 110 centimeters is brownish-gray, gravelly clay loam with concretions of various sizes. This type extends from Polo to Angat. It is extensively planted to rice, with or without irrigation. Because of the poor production of rice in the unirrigated area the farmers apply manure and other fertilizers to increase the yield. This area is about 10,230 hectares.

Prensa clay loam. --- The surface soil of the Prensa clay loam is brown to dark yellowish brown or light reddish-brown clay loam, loose and granular with numerous spherical iron concretions. The depth ranges from 20 to 25 centimeters. The subsoil is gray, sometimes light yellowish gray to dull grayish brown. It is loose and gravelly clay grading to sandy clay with many concretions. It ranges in depth from 40 to 50 centimeters. The substratum from a depth of 50 centimeters downward is gravelly clay, light grayish brown to dark brown. The most important characteristics of this area is the presence in some places of volcanic tuffaceous material. Rice is grown in some parts, but the extent of the crop is dependent upon the available water supply.

Novaliches series. --- The soils of the Novaliches series are light reddish brown, reddish brown, to bright reddish brown. The surface soil and the subsoil are friable and granular, concretions are present, especially in the subsoil. They are underlain by volcanic tuffaceous material of varying degrees of disintegration and weathering.

This series occurs both in upland and lowland rolling and hilly topography.

In the upland area the lower subsoil has a horizon of light-gray sticky and plastic clay. The uncultivated soil is covered with cogon and a few trees. Alibangbang (Bauhinia malabarica Roxburg) trees are commonly found in this soil. Upland rice is the main crop. Diversified farming is practiced on the large estates. Fruit trees especially cashew, are also grown.

Novaliches loam. --- Adjoining the Prensa clay loam on the eastern side of the upland region of Bulacan is the Novaliches loam. The surface soil is reddish-brown, friable and fine to coarse granular loam with a depth ranging from 20 to 40 centimeters. Concretions are commonly found in this soil, which is comparatively poor in organic matter. Being very friable, the soil is easily eroded. The subsoil down to a depth of 60 centimeters is brownish red, friable and granular clay loam with some concretions and gravel. The substratum from a depth of 111 centimeters downward consists of tuffaceous material partly disintegrated.

Novaliches clay loam. --- The upper 12 to 29 centimeters of surface soil is brownish-red to bright reddish-brown clay loam,

granular and friable when seemingly dry and slightly sticky when wet. Reddish brown concretions are present in considerable amounts. The subsoil to a depth ranging from 54 to 81 centimeters is brick red clay loam to clay with gravel and reddish-brown concretions. The substratum to a depth of 100 to 150 centimeters downward is highly weathered tuffaceous material.

This area is covered mostly with cogon, though in some places cashew trees are planted. Diversified farming is practiced.

Novaliches clay loam

Depth of soil cm.	Characteristics
0 - 20	Medium reddish-brown fine granular, friable clay loam. Surface soil is fine fragmental.
20 - 45	Brown to light reddish-brown clay loam to clay, granular and friable, slightly compact.
45 - 70	Light reddish brown clay loam. Horizon of gravel accumulation ranging in sizes from 0.5 to 2 centimeters in diameter.
70 - 100	Reddish-brown coarse granular and friable clay loam with concretions. Slightly compact tuffaceous material.
100 - 150	Granular clay loam to clay. Tuffaceous rock with reddish-brown concretions of various sizes.

Buenavista series. --- The soils of the Buenavista series are brown, light brown to light reddish brown, to reddish brown. The surface soil is friable and loose. In some localities, however, it is slightly compact. The peculiarity of this series is the presence in the subsoil of almost impervious light-gray to light

yellowish-gray clay and concretions.

The series is found in the rolling and hilly regions of San Rafael, San Ildefonso, and San Miguel. The soils are utilized principally for rice. A large portion of the soils of the Hacienda Buenavista, owned by San Juan de Dios Hospital, is classified under this series.

Areas not planted to rice are planted to corn and other crops. The hilly areas are used for grazing. Alibangbang (Bauhinia malabarica Roxburg) is the commonest tree in this region with various species of shrubs, bamboos, and other trees.

Buenavista sandy clay loam. --- This type of soil is a brown sandy clay surface soil with some concretions and gravel. It is gritty and loose. The depth ranges from 20 to 40 centimeters. The subsoil is light-gray clay, stiff and sticky, becoming gritty downward. A high percentage of sand is usually found in the lower subsoil. It ranges in depth from 60 to 100 centimeters. The substratum from 100 centimeters down is yellowish-gray clay, sometimes mottled light gray and brown sandy clay. Concretions are present in some parts of this area. A portion of this type is worked for unirrigated rice.

Buenavista silt loam. --- The surface soil of the Buenavista silt loam has yellowish brown to light reddish-brown silt loam with a few concretions. It is gritty and loose on the surface but becomes compact at a lower depth. The depth ranges from 20 to 25 centimeters. The subsoil down to indefinite depth is light gray to whitish-gray, stiff and sticky clay. This type of soil, like

the rest of the Buenavista series, is used for unirrigated rice. Some portions serve as grazing land.

Buenavista clay loam. --- The surface soil of the Buenavista clay loam is medium-brown heavy clay loam, sometimes slightly friable, granular, and fine in texture. The dark coloration of the surface soil was developed because of poor drainage. The depth of the surface soil ranges from 25 to 30 centimeters. The subsoil is mottled black and brown heavy clay loam to clay. Concretions are present in places near the Prensa silty clay loam type. The lower subsoil down to an indefinite depth is light yellowish-gray to light gray sticky clay. A portion of this soil is irrigated by the Angat System. Rice is said to have a high yield in this type of soil as compared with the other type in this series.

Sibul series. --- The Sibul soil is brown to light grayish-brown surface soil with a calcareous subsoil. The substratum is a highly weathered calcareous rock material. This series occupies an upland area of rough rolling and hilly topography.

Being a region of limestone formation, the area has luzuriant vegetation of various species of shrubs and trees. The rather level portion is planted to rice and corn. The highly rolling country is used for grazing. Young forest land is found in the upland section where several mining claims have been located.

Sibul clay. --- The Sibul clay soil occupies a considerable portion of the province. The surface soil ranging from 25 to 30 centimeters in depth is dark-brown to light grayish-brown heavy

clay loam to clay with whitish to dark-brown spherical concretions. The soil is finely granular when dry and somewhat porous but sticky when wet. The upper part of the subsoil is dull brown to dull grayish brown and almost compact in places that have an appreciably heavier texture of calcareous material. The lower part of the subsoil which extends to a depth ranging from 45 to 70 centimeters, is coarse granular to cloddy or friable clay with varying quantities of calcareous material. The substratum is whitish-gray or light-brown, highly weathered suffaceous material which is highly calcareous. The upper part of this substratum, however, is a zone of light gray with whitish specks of limestone concretions.

A description of typical Sibul clay is as follows:

Sibul clay

Depth of soil cm.	Characteristics
0 - 5	A layer of fine-fragmental soil mixed with decayed leaves, and roots of plants.
5 - 20	Dark-brown to dark-gray fine granular sticky clay. When seemingly wet the soil is plastic.
20 - 40	Dark-brown to dark-gray coarse granular to cloddy, sticky clay. Plastic when seemingly wet.
40 - 80	Sticky light-gray clay. Breaks into fine clods and sharp columnar structure.
80 - 110	Light-gray to gray clay with limestone concretions and white specks. The presence of white specks makes the color lighter than the upper zones.

The clay content in the surface soil of the Sibul clay is high but decreases with depth. The sand content is almost constant from the surface down to the lower subsoil and then it increases in the substratum.

The reaction is lightly acidic with pH 6.55. Plant-food elements are somewhat low as compared with average normal soils.

Novaliches and Sibul soils undifferentiated. --- The areas comprising the Novaliches and Sibul soils undifferentiated are rough and mountainous and covered mostly with forests, though in a few places the land is utilized for upland rice and grazing.

This undifferentiated areas are a part of the western flank of the Eastern Cordillera.

ANALYSIS OF BULACAN SOILS

Soil surveys made in the Philippines include also, for completeness, chemical and mechanical analyses of the soil.

Mechanical analysis.--- Mechanical analyses were made in accordance with the method of Olmstead, Alexander, and Middleton.* In Table 5 are given the mechanical analyses of the surface soils of the different types found in Bulacan Province. In general these data serve as a check on the field descriptions of the soil types.

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*Olmstead, L. B., L. T. Alexander, and H. E. Middleton. U. S. Dept. Agr. Tech. Bull. 170 (1930).

Chemical analysis. --- Chemical analysis give data concerning the principal nutritive constituents contained in the soil. The methods of the Association of Official Agricultural Chemists* were used in making these analyses. The major soil types were sampled and these were analyzed for the essential plant-food elements such as nitrogen, phosphorous and potassium. The analysis also includes calcium, magnesium, organic carbon, and the pH value, which was ascertained by the electrometric method, using the antimony electrode. The organic carbon was determined by Parr's method.

The number of samples obtained from each soil type depends upon the extent and the agricultural importance of the type. In our survey the chemical analysis was confined to surface samples. These were taken at a depth of about 16 centimeters. Subsoil samples were also taken in conjunction with this work.

The average chemical analysis for each type is given in Table 6. The results represent total determinations.

As shown by the data the soils of Bulacan are slightly acidic in reaction with a pH range of 5.55 to 6.55. In general they are somewhat low in essential plant-food elements, especially phosphorous, potassium, and nitrogen, and require re-enforcement with fertilizers containing these elements.

Soils in the upland and rolling regions are decidedly acidic and should be treated with lime to neutralize this acidity. These are poor and therefore require the application of complete fertilizers for normal crop production. To increase the organic content, which is quite low, the practice of green manuring is advisable.

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*Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists (1930).

SUMMARY

Bulacan Province in the Philippine Island was inhabited long before the Spanish settlement of 1578.

The climate is tropical and generally of the wet and dry seasons.

Agricultural development did not take place until about the middle of the nineteenth century.

The population according to the census of 1935 was 275,900.

Transportation and communication conveniences, electricity and telephone service, are available in most of the province.

The principal towns have satisfactory schools conducted by the Philippine Bureau of Education.

Public-health activities are taken care of by the Philippine Bureau of Health.

Water and good quality is plentiful. The province is well drained by Pampanga and Angat Rivers. There are two large irrigation systems. The Angat system covers an area of about 17,000 hectares and the Peñaranda, an area of about 2,550 hectares. Irrigation has greatly facilitated agricultural development.

Rice is the leading crop, occuyping 69,750 hectares (46.2 per cent) of the total area (150,879 hectares) cultivated. Mango is next in importance followed by sugar cane. Other minor crops are bananas, corn, tomatoes, sweet potatoes, etc.

Bulacan Province is situated in the central part of Luzon. Its total area is about 260,800 hectares. The whole province is within the two great physiographic divisions of Central Luzon,

the Luzon Central Plain and the Eastern Cordillera.

The soils are divided into three main groups; namely, 1, Island and basin soils; 2, alluvial fans and plain soils; 3, upland and mountain soils.

The island and basin soils comprise 17,740 hectares (6.8 per cent); the alluvial fans and plain soils, 60,930 hectares (23.4 per cent); and the upland and mountain soils, 182,130 hectares (69.8 per cent). The area cultivated in addition to that which is still available for cultivation amounts to 194,834 hectares (74.6 per cent). The remaining land is covered with commercial and non-commercial forests.

Nine period of soils established in the province. Fourteen soil types were identified and mapped. The remaining soils were classified as undifferentiated. The largest area of soil identified and mapped is the Sibul clay, followed by Novaliches clay loam, Quingua silt loam, Bigaa clay loam, and Prensa clay loam. Profile studies were made of each soil series.

Of the types of soil cultivated for rice, the Bigaa clay loam gave the highest yield per hectares. Bantog clay loam was next, followed by the Prensa and Quingua and silt loam.

Mechanical and chemical analyses were made for each major soil type.

The average chemical analyses showed that even the highest yielding types. Bigaa and Bantog clay loam, indicate a certain degree of phosphorous, nitrogen, and potash deficiency. On the whole the soils of Bulacan require fertilizer application to

obtain optimum production. The kind and quantity of fertilizer to be used is best determined by actual field experiments in growing individual crops.

Soil survey give basic scientific data showing the present conditions in a given area. The results of these survey should be supplemented by actual field experiments on the growing of crops. The information thus obtained indicates the kind of soils that are suitable for the cultivation of certain crops; knowledge obtained from soil surveys in one province may be applied in other provinces where similar conditions exist.

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Table 1. --- Records of Average Monthly Rainfall at Malolos, at Ipo Junction, Angat, and the Tungkong Manga, San Jose del Monte, Bulacan Province, and Average Monthly Temperatures at Malolos.

	Malolos			Ipo Junction, Angat	Tungkong Manga, San Juan del Monte
	Rainfall	Temperature		Rainfall	Rainfall
	1923 to 1931	1925 to 1934		1923 to 1931	1923 to 1931
		Max.	Min.		
	mm.	°C.	°C.	mm.	mm.
January	24.5	31.0	19.4	57.0	29.9
February	11.8	31.9	19.8	23.5	21.5
March	16.8	33.3	20.1	29.1	18.4
April	21.5	34.4	22.6	73.8	54.6
May	198.0	34.4	23.5	335.9	333.9
June	295.7	32.3	23.6	591.3	319.2
July	498.3	31.3	23.1	770.0	593.3
August	607.0	31.0	23.1	611.1	479.2
September	237.4	31.5	23.1	571.3	445.4
October	155.1	31.6	22.7	343.3	284.9
November	231.1	31.0	21.6	284.9	285.4
December	36.2	30.6	20.0	135.3	96.7
Mean Annual	2,333.4	-	-	3,826.5	2,962.4

The data given in this table from the numerous reports of the Philippine Weather Bureau.

Table 2. --- Towns in the area irrigated by the Angat Irrigation System.

Town	Hectares irrigated
[illegible]	2,700.38
[illegible]	361.16
[illegible]	1,347.76
[illegible]	446.26
[illegible]	328.16
[illegible]	654.56
[illegible]	1,665.97
[illegible]	2,883.41
[illegible]	2,814.12
[illegible]	2,402.73
[illegible]	406.59
[illegible]	186.76
[illegible]	129.23
[illegible] (Bocaue and Bigaa)	658.34
[illegible] Estate (Guiguinto)	114.50
	16,999.93

Table 3. --- Yield of rice per hectares in different types of soil in irrigated areas.

Type of Soil	1931	1932	1933
	Cavans	Cavans	Cavans
Bigaa clay loam	51.5	55.4	63.3
Prensa silty clay loam	48.2	54.0	52.5
Quingua silt loam	46.5	48.2	51.4
Buenavista clay loam	39.6	37.0	
Bantog clay loam	44.8	45.4	61.0

Table 4. --- Area and proportional amount of each soil type mapped in Bulacan Province.[a]

Type No.	Type of Soil	Area	Proportion of Total Area
		Hectares	Per cent
1	Bulacan hydrosol	15,530.0	6.0
2	Obando fine sandy loam	2,210.0	0.8
3	Bigaa clay loam	17,550.0	6.7
4	Quingua fine sandy loam	3,750.0	1.4
5	Quingua silt loam	20,850.0	8.0
6	Prensa clay loam	17,250.0	6.6
7	Prensa silty clay loam	10,230.0	3.9
8	Buenavista clay loam	3,930.0	1.5
9	Buenavista silt loam	13,260.0	5.0
10	Buenavista sandy clay loam	13,260.0	5.1
11	Novaliches loam	8,040.0	3.1
12	Novaliches clay loam	21,240.0	8.2
13	Novaliches soil (undifferentiated)	39,210.0	15.0
14	Sibul clay	25,440.0	9.8
15	Sibul clay (undifferentiated)	40,680.0	15.6
16	Bantog clay loam	8,550.0	3.3
	Total area in hectares	260,300.0	100.0

[a]The figures for areas of the several types have been obtained by the use of a planimeter. Areas determined in this way are totals and show no deduction for space occupied by roads, houses, towns, streams, or for other non-agricultural purposes.