REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
MANILA

Soil Report 12

SOIL SURVEY OF LA UNION PROVINCE, PHILIPPINES

BY

M. M. ALICANTE, D. Z. ROSELL, A. E. MOJICA
R. SAMANIEGO, AND F. B. LOPEZ

WITH A DISCUSSION ON THE CHEMICAL CHARACTERISTICS
OF THE SOILS OF LA UNION PROVINCE

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DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

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ILLUSTRATIONS

[All photographs by Mr. Ramon Samaniego.]

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Of the Division of Soil Survey and Conservation
Department of Agriculture and Natural Resources

INTRODUCTION

The soils of the Philippines constitute the greatest source of raw material for any ambitious program of industrialization in this country. Any industry, to be established and developed here, will depend upon the soil either directly or indirectly for such material. The production cost of manufactured goods depends upon the rise and fall of the prices of agricultural commodities, which in turn depend upon the rise and fall of crop yields. For the wise utilization of our lands, study of Philippine soils is of prime necessity.

The soil survey of the Philippines being conducted by the Division of Soil Survey and Conservation of the Department of Agriculture and Natural Resources, is the first step towards the study of our soils. Its primary object is to secure valuable data to serve as basis for the conservation or wise utilization of the soil of the country. In addition, it also furnishes information and data for varied purposes, namely, land settlement and colonization projects, realtors, assessors, land taxation; in the construction of highways, railways, telephone and power lines; establishment of urban sites, recreational grounds, game preserves and sanctuaries; and for teachers and students in agricultural science, geography, sociology, and anthropology.

This report presents the result of the soil survey of La Union Province, as conducted by the Division of Soil Survey and Conservation of the Department of Agriculture and Natural Resources, from June 19 to November 16, 1946.

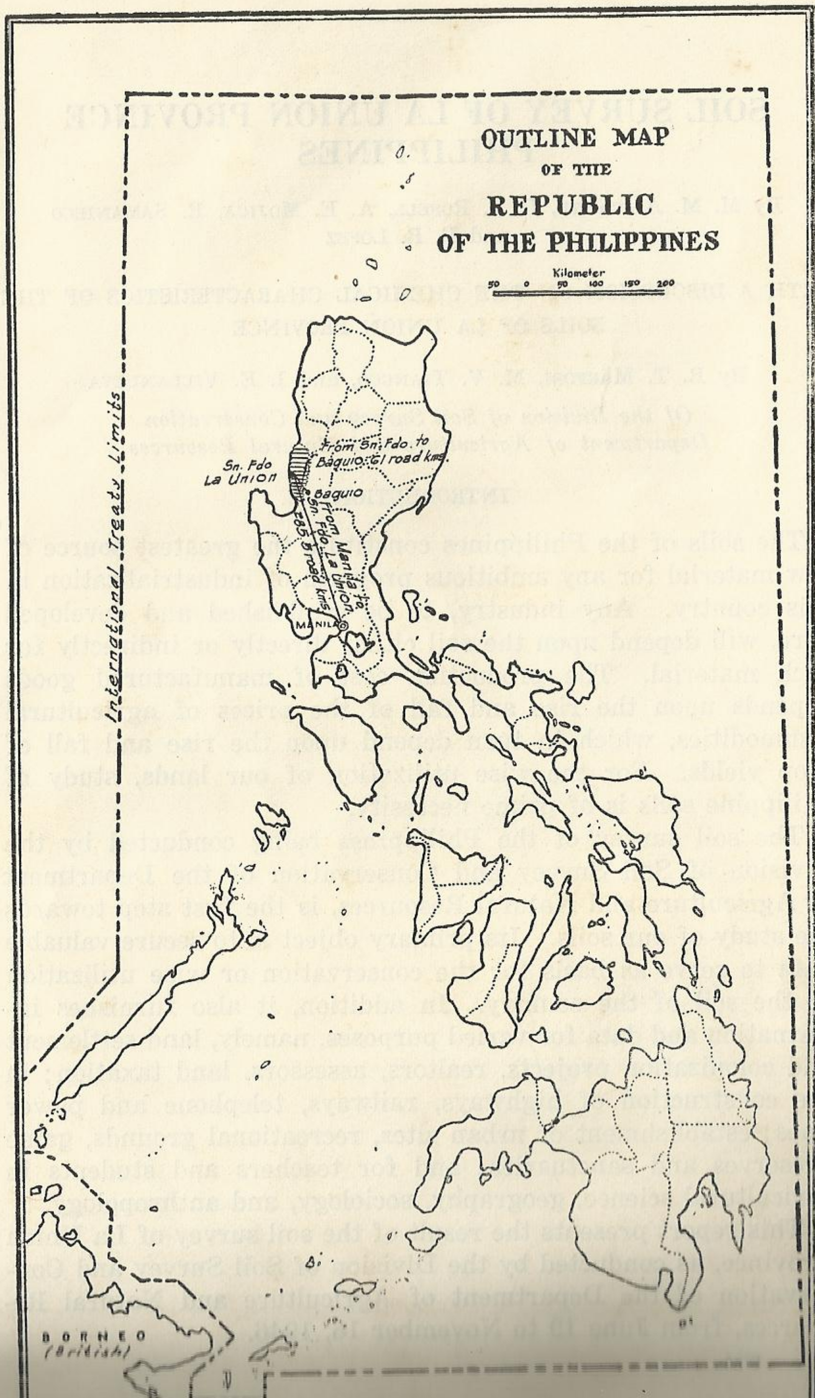

FIG. 1. Outline Map of the Republic of the Philippines Showing La Union Province.

DESCRIPTION OF THE AREA

Location and extent.—La Union is the southernmost province of the Ilocos Coast strip (fig. 1). It is bounded on the north and northeast by Ilocos Sur Province; on the east by the Mountain Province; on the south by Pangasinan Province; and on the west by the China Sea. It is roughly rectangular in form with an area of approximately 137,290 hectares. The actual soil cover of the province as classified by the Bureau of Forestry as of June 30, 1946 is shown in Table 1. San Fernando, the capital of the province, is 285 kilometers from Manila and 61 kilometers from Baguio.

TABLE 1.—*Approximate area of the actual soil cover of La Union Province and the necessary balance computed and prepared by the Bureau of Forestry as of June 30, 1946.*[a]

Kind of cover	Area			
	Hectares		Per cent	
Commercial forest.				
Necessary balance.				
Alienable	316		0.23	
Timberland	10,635		7.75	
Actual soil cover		10,951		7.98
Noncommercial forest.				
Necessary balance.				
Alienable	137		0.10	
Timberland	830		0.60	
Actual soil cover		967		0.70
Cultivated.				
Actual soil cover		58,501		42.62
Open land.				
Necessary balance.				
Alienable	56,234		40.96	
Timberland	10,637		7.74	
Actual soil cover		66,871		48.70
Total.				
Necessary balance.				
Alienable and cultivated	115,168		83.91	
Timberland	22,102		16.09	
Total soil cover		137,290		100.00

[a] Yearbook of Philippine Statistics, 1946. Bureau of Printing, Manila, 1947.

Physiography and geology.—The western part of La Union consists largely of an elevated coastal tract made in part of raised coral and in part of alluvium overlying older sediments. This coastal plain is narrowest at Damortis and widest at Balaoan where it extends almost 15 kilometers inland from the shore.

East of this plain is a series of hills lower than the ranges that make up the cordilleras, with a linear north and south arrangement; that is, parallel with the coast, between which lie

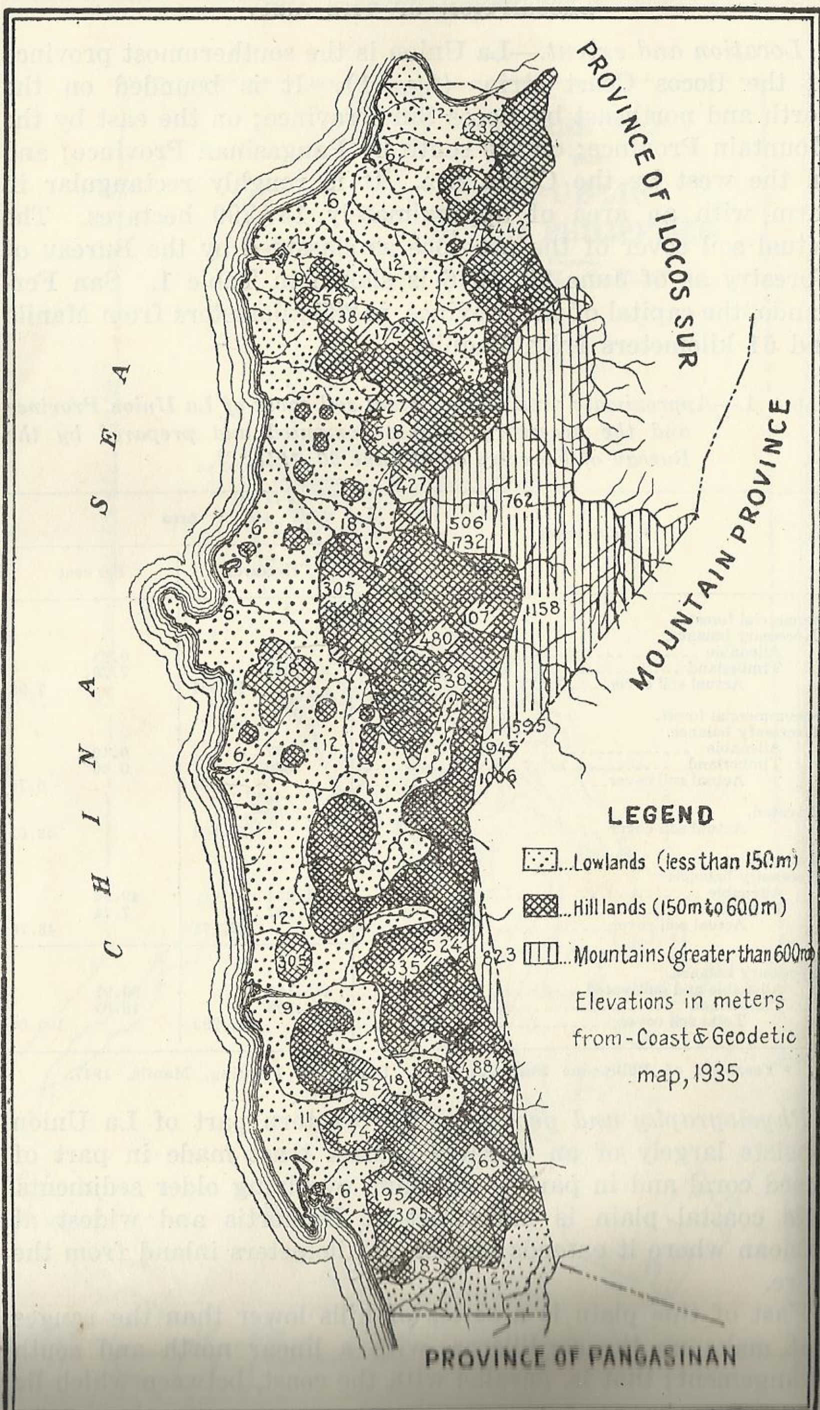

FIG. 2. Physiographic map of La Union Province.

comparatively flat reaches occupied by streams of various sizes. These bands or belts of hills are made up of folded tertiary sediments of limestones, sandstones, and shales. They are roughly asymmetrical and usually present steeper faces towards the inland and more gentle slopes seaward. Ridges of this kind are called "cuestas" and the topography is called "cuesta" topography.

The pattern of the streams is adjusted to the rock structures of the region. The southern part of the province is drained by the Apangat, Cupang, Agoo, and Aringay Rivers; the central section by the Caba, Bauang, and Baroro Rivers; and the northern part by the Maragayap, Darigayos, and the Amburayan Rivers. Figure 2 shows the physiography and relief of the province.

Vegetation.—The hills and mountains of La Union are sparsely forested, and wood for construction purposes is scarce because of the excessive cutting of timber. Second-growth forests from the Parang type to the Molave and Dipterocarp type are found in some of the hills and mountains, but the dominant cover of the hills is cogon (fig. 3). The hills of the towns of San Fernando, San Juan, Luna, and Bauang are thickly covered with ipil-ipil and madre cacao. The slopes around the towns of Rosario and Naguilian are planted to bananas and different varieties of bamboos. The valleys and plains are devoted to rice, corn, sugar cane, camotes, tobacco, cassava, etc. Along the shore, coconut is the principal crop planted.

History.—When the Spaniards came to the Philippines in the sixteenth century they found here a flourishing Malayan culture. In May, 1572, Legaspi commissioned Salcedo to conquer the Ilocos regions. Among the places he visited was "Atulay" which does not exist now, but must have been in what is now La Union, and the town of Porao, now Balaoan, where he was opposed vigorously by the natives. Salcedo succeeded in reducing the inhabitants to vassalage and since then Spanish power had been felt in that region.

In 1574 Limahong, a Chinese pirate, landed at the mouth of the Agno River in Pangasinan with the object of colonizing northern Luzon. However, Salcedo was able to drive him out of the place.

Brick watch towers at San Juan, Bacnotan, Darigayos Point, and Luna bear silent testimony to the days when Chinese piratical raids constantly threatened the Ilocos Coast.

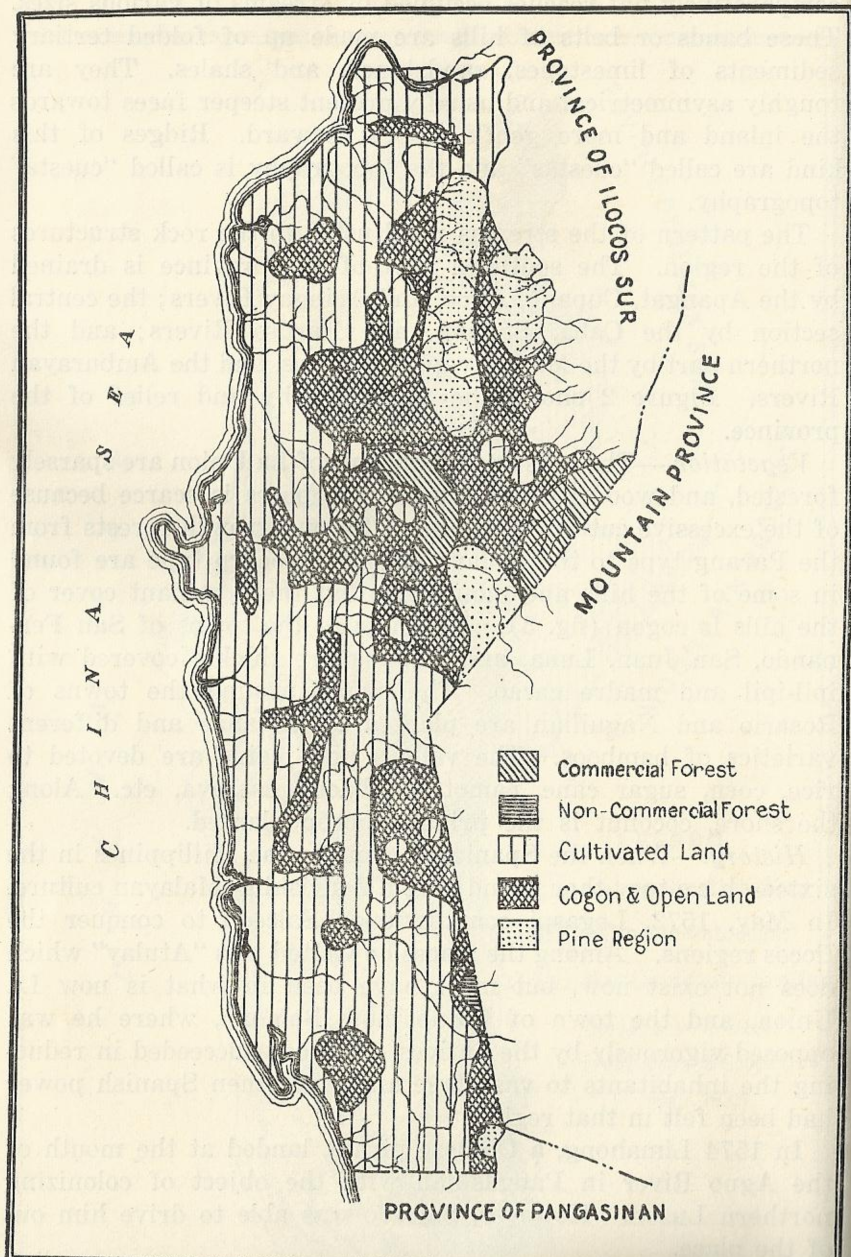

FIG. 3. Actual Soil Cover of La Union Province.

The Filipinos were discontented under the Spanish rule. There were numerous revolts, notable among which was that of Pedro Malong. In 1660 he proclaimed himself king of Pangasinan and in order to extend his sway over the northern provinces he ordered Gumapos to invade the Ilocos and Cagayan Provinces. Gumapos defeated the Spanish forces at Agoo, and Malong's army triumphantly made its way through La Union up to Vigan. Shortly afterwards, however, Malong was captured and the revolt was quelled.

In 1854 La Union as a province was created out of the northern towns of Pangasinan and the southern towns of Ilocos Sur. The union of these two groups of municipalities gave the name of the province.

As constituted at that time, La Union included Bangar, Namacpacan, now Luna, Porao, now Balaoan, which then included the present towns of Bacnotan, San Juan, San Fernando, Bauang, Naguilian, Aringay, Agoo, and Sto. Tomas. Balaoan, Bauang, and Agoo are among the oldest towns in the Archipelago.

On August 15, 1901, civil government under the American regime was established and later the Subprovince of Amburayan, Mountain Province, was added to it.

Under the American regime great progress was made, especially in matters of health, education and self-government. This remarkable progress was interrupted in December, 1941, when the Japanese invaded and occupied the Philippines. During the Japanese occupation, which lasted until the early part of 1945, there was untold misery and suffering among the people.

La Union, like every other province in the Philippines, is now recovering slowly from the ravages of World War II.

Population.—The population of La Union in 1876 was about 8,500. At the end of the Spanish rule, according to the Guia Oficial (1898), the province had a population of about 116,000. According to the census of March 2, 1903, its population was 137,847; * of December 31, 1918, 178,386; and on January 1, 1939, 207,701. The increase of population from 1903 to 1939 was 50 per cent. The estimated population as of 1940 was 208,900.

Transportation and communication.—All towns of La Union except Bagulin are linked by a net-work of first- and second-class

* These figures include those of the districts which were transferred from the Mountain Province to La Union.

roads. The Manila-Laoag National road which enters La Union on the south at Rosario passes through the coastal towns (Plate 1, fig. 1). San Fernando is connected by a first-class road to Baguio either via Naguilian and Burgos (Plate 1, fig. 2) or by way of Rosario. Bagulin can be reached by trail from Naguilian, San Fernando, San Juan, and San Gabriel.

TABLE 2.—*Number of kilometers of each class of road in La Union as of 1946.*[a]

Class	National	Provincial
	Kilometers	*Kilometers*
First	135.00	30.50
Second	0.65	128.10
Third	----------	15.60
Total	135.65	174.20

[a] Data furnished by the District Engineer's Office, San Fernando, La Union.

There are several private transportation companies operating in the province, namely, the Northern Luzon Transportation Company, Benguet Auto Line Company, Santiago Sambrano Transportation Company, Baguio Bus Company, Halili Transit, and Galbusco Company.

The northern terminal of the Manila Railroad Northern Line is at San Fernando. The line passes through Damortis, Sto. Tomas, Agoo, Aringay, Caba, and Bauang. Before the war, a bus connection between Damortis and Baguio was maintained by the Benguet Auto Line. Due to the destruction of the Damortis Railroad Station and because the Baguio-Rosario road is still closed to traffic, the City of Baguio is now reached from Bauang, La Union.

Commercial planes arrive at the San Fernando airport twice a week. The prewar landing fields at Naguilian, Rosario, and Luna have been abandoned. The port at Poro is being maintained and used by the United States Army.

Before the war La Union operated a Telephone System connecting all municipalities within the province. The Philippine Long Distance Telephone Company had branch offices at San Fernando, Aringay, and Naguilian. These telephone systems were destroyed during the Japanese occupation. The only telephone system now in operation in the province is that maintained by the United States Army in all its camps.

Of the prewar telegraph stations in the province, only those of Bauang, Aringay, and San Fernando have so far been reopened.

FIG. 1. The narrow coastal plain at Bauang (looking West). The white ribbon across the picture is Highway No. 5.

FIG. 2. Burgos overlooking Naguilian and Bauang (looking West). The picture presents a typical landscape of the Burgos series. The light areas are cogon-covered; the darker, second-growth forest.

PLATE 1

Cultural features.—The Bureau of Public Schools has a Provincial High School and a Provincial Trade School at San Fernando. It also maintains the North Provincial High School at Bacnotan and the South Provincial High School at Agoo. The elementary schools of the province, numbering 161, are distributed in all towns and in the majority of the barrios. Private schools both secondary and vocational run by the Catholic Church and private organizations are found in San Fernando, Bauang, Agoo, Balaoan, and Naguilian.

The Bureau of Health safeguards individual and community health. Puericulture centers with physicians are organized in Rosario, Balaoan, Bauang, and Agoo, while in Naguilian, Bacnotan, Aringay, and Bangar, the Puericulture Centers employ only nurses. The towns of San Juan and San Fernando have Puericulture Centers organized but are not as yet functioning. The Provincial Hospital, the Bethany, and the Lorma Hospitals are all in San Fernando.

Industries.—Agriculture is the most important industry of the province. Next in importance is fishing. Practically all the fishing is confined inshore, that is, less than 3 miles off the coast where boho traps, beach seines (pukot), cast nets (dala), and scissor's nets (sakag) are used. The illegal use of dynamite for fishing which became rampant shortly after the surrender of Japan has not been completely stopped because the Fish and Game Administration does not have enough facilities and personnel for patrolling the La Union waters.

Fishponds for the culture of milkfish (bañgos) are found in Bacnotan, San Juàn, San Fernando, Bauang, Aringay, and Sto. Tomas.

Of the manufacturing industries, cigar making is receiving an increasing attention. There are now two cigar factories in Tubao and one each in Aringay and Bauang.

Weaving of native textiles used to be a profitable industry in northern La Union, especially in Bangar and Sudipen where cotton was once grown extensively. Since imported cotton goods are now cheaper, it no longer pays to engage in this industry. The small amount of native textiles still being woven is mostly for family use only.

Pottery making is an important means of livelihood in Sto. Tomas. Hats, mats, slippers, brooms, brushes, sawali, and ropes are manufactured on a household-industry scale.

CLIMATE

Climate is one of the five factors of soil formation. The important direct effects of climate are the weathering of rocks and the alteration of the parent materials. The formation of laterites, lateritic soils, and red soils in the tropics is the result of the direct effect of climate upon the parent rocks. Hydrolysis, carbonation, and other forms of chemical weathering are extremely rapid in the warm and humid regions.

Climate is also an important factor in crop production. It determines the length of the growing season. In designing a system of farming for a given region, the elements of climate, namely, rainfall, temperature, relative humidity, wind velocity, etc., are considered carefully so that a well-planned system of farm management can be drawn. Field operations such as plowing, harrowing, seeding, cultivating, and harvesting must harmonize with the existing favorable climatic elements.

The climate of La Union belongs to the first type in accordance with the classification based on rainfall. The principal climatic characteristics of the first type are:

1. There is a distinct wet and dry season, the dry period generally lasting from November to April.

2. The percentage of rainfall during the months from June to October, popularly known as the "rainy season" is at least 75 per cent of the total precipitation of the year, while the rainfall from November to February does not exceed 12 per cent of the total.

3. The amount of clouds coincides with the average precipitation. The clearest months are from January to April; the cloudest, from July to September.

4. The annual percentage humidity is not very high owing to the influence and duration of the dry season. It is not more than 80 per cent.

The temperature is either high (above 27°C.) or intermediate (26–27°C.), seldom or never mild (below 26°C.).

These climatic characteristics are shown in figure 4.

The mean monthly distribution of rainfall in La Union is as follows: January, 5.2 mm.; February, 6.4 mm.; March, 13.3 mm.; April, 27.1 mm.; May, 197.1. mm.; June, 406.3 mm.; July, 558.0 mm.; August, 712.1 mm.; September, 340.3 mm.; October, 169.0 mm.; November, 61.3 mm.; and December, 16.6 mm.; or a total of 2,443.1 mm.

The strikingly low rainfall during the dry season from December to April is due to the very effective shielding of La Union

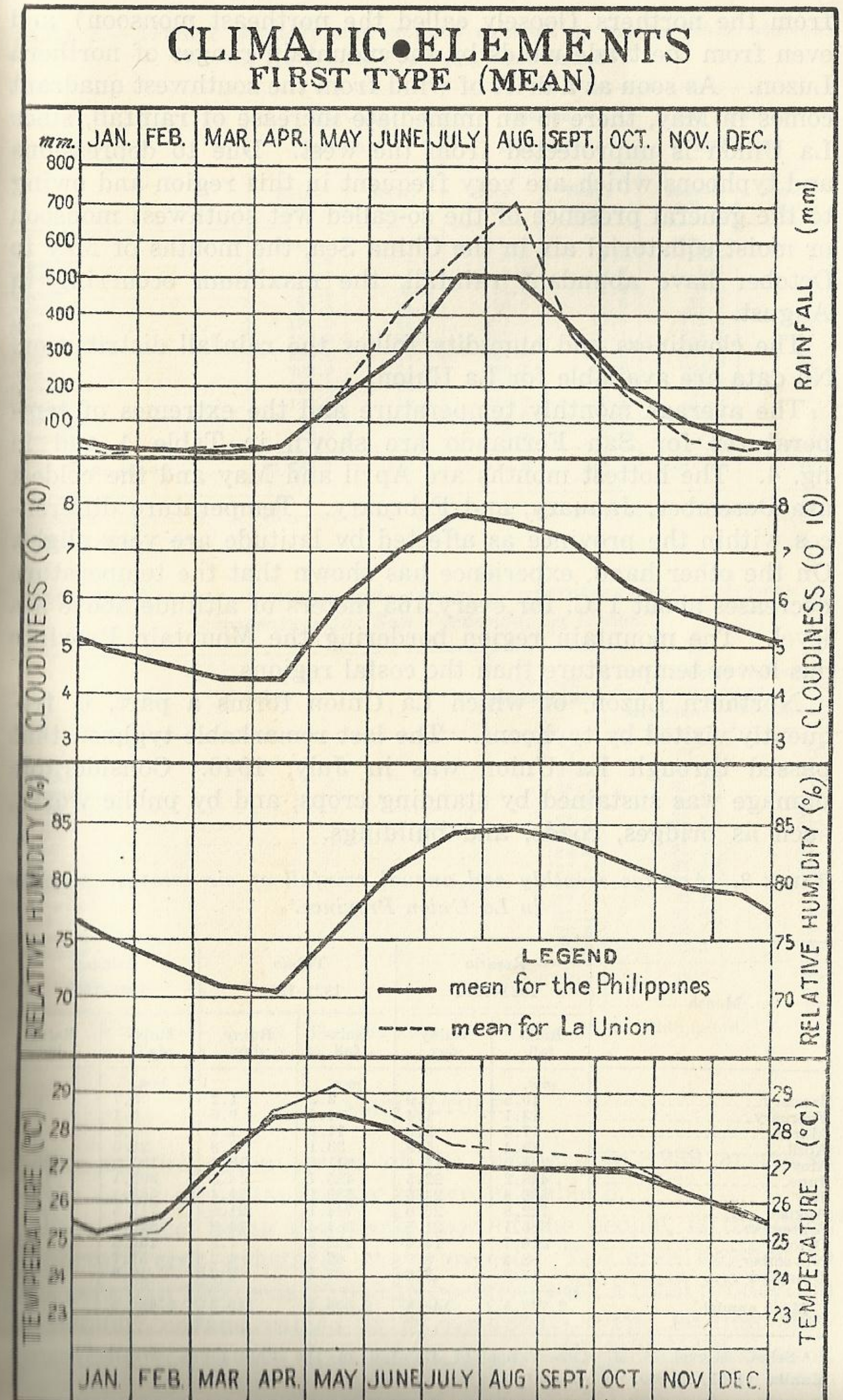

FIG. 4. Graph of the first type of climate of the Philippines and of La Union Province.

from the northers (loosely called the northeast monsoon) and even from the trade winds by the mountain ranges of northern Luzon. As soon as a drift of wind from the southwest quadrant comes in May, there is an immediate increase of rainfall, since La Union is unprotected from the west. Due to depressions and typhoons which are very frequent in this region and owing to the general presence of the so-called wet southwest monsoon or moist equatorial air in the China Sea, the months of May to October have abundant rainfall, the maximum occurring in August.

The cloudiness and humidity follow the rainfall distribution. Nȯ data are available for La Union.

The average monthly temperature and the extremes of temperatures for San Fernando are shown in Table 4 and in fig. 4. The hottest months are April and May and the coldest are December, January, and February. Temperature differences within the province as affected by latitude are very slight. On the other hand, experience has shown that the temperature decreases about 1°C. for every 165 meters of altitude above sea level. The mountain region bordering the Mountain Province has lower temperature than the costal regions.

Northern Luzon, of which La Union forms a part, is frequently visited by typhoons. The last remarkable typhoon that passed through La Union was in July, 1946. Considerable damage was sustained by standing crops, and by public works, such as bridges, roads, and buildings.

TABLE 3.—*Average monthly and annual rainfall of six weather stations in La Union Province.*[a]

Month	Rosario 1921–1932		Tubao 1921–1932		Aringay 1921–1932	
	Rain-fall	Rainy day	Rain-fall	Rainy day	Rain-fall	Rainy day
	mm.		*mm.*		*mm.*	
January	10.5	2.0	3.2	1.2	3.7	0.7
February	13.1	1.4	4.5	0.6	6.1	0.6
March	17.6	2.8	11.0	1.6	6.9	1.2
April	39.4	5.9	33.1	3.8	21.0	2.3
May	228.0	15.8	211.4	12.4	197.0	10.7
June	438.2	22.5	425.7	18.3	392.1	18.6
July	586.8	24.5	539.1	21.4	583.4	20.4
August	722.8	25.0	744.1	21.8	717.5	22.1
September	386.1	21.5	354.4	14.8	325.4	15.7
October	228.7	14.6	196.6	7.8	156.2	7.0
November	88.4	8.9	62.8	4.2	51.7	4.5
December	17.8	3.6	23.5	2.3	19.9	1.8
Mean annual	2,777.4	148.5	2,609.4	110.4	2,480.9	105.6

[a] Selga, Miguel, S. J. Observation of Rainfall in the Philippines. Weather Bureau, Manila (1935) 1–289.

TABLE 3.—*Average monthly and annual rainfull of six weather stations in La Union Province.*—continued

Months	Naguilian 1921–1932		Balaoan 1921–1932		San Fernando 1902–1933	
	Rain-fall	Rainy day	Rain-fall	Rainy day	Rain-fall	Rainy day
	mm.		*mm.*		*mm.*	
January	3.6	1.8	2.6	1.5	8.6	1.3
February	4.0	1.0	5.6	0.7	5.3	1.0
March	14.2	2.3	21.6	1.4	8.5	1.3
April	33.4	4.0	20.6	2.6	15.2	2.3
May	193.9	13.7	181.3	12.3	171.1	10.5
June	487.9	22.2	407.4	20.1	338.1	18.1
July	625.6	24.0	624.9	20.9	568.5	21.6
August	792.9	24.9	630.1	22.5	684.2	22.9
September	359.8	20.9	329.9	17.3	386.2	18.3
October	163.4	11.5	130.2	9.2	137.9	8.7
November	66.4	7.2	54.6	5.8	44.0	4.4
December	20.0	3.1	8.8	2.0	9.5	2.3
Mean annual	2,765.1	136.6	2,417.6	116.3	2,377.1	112.7

[a] Selga, Miguel, S. J. Observation of Rainfall in the Philippine Weather Bureau, Manila (1935) 1–289.

TABLE 4.—*Average monthly and annual temperature and extremes of temperature for San Fernando, La Union.*[a]

Months	Average temperature[b]	Extremes of tem perature[a]	
		Maximum	Minimum
	°C	*°C*	*°C*
January	23.0	31.8	17.1
February	25.1	32.5	17.1
March	26.8	34.2	19.1
April	28.6	35.8	21.4
May	29.1	36.2	22.4
June	28.4	35.2	21.6
July	27.6	33.8	21.8
August	27.5	33.7	21.8
September	27.3	33.3	21.8
October	27.2	33.0	21.3
November	26.3	32.5	19.8
December	25.8	32.1	18.9
Mean annual	27.1	33.7	19.5

[a] Rev. Jose Coronas. The Climate and WeWather of the Philippines.,
[b] Length of record is 16 years.

AGRICULTURE

The ten important crops of the province in 1939 arranged in the order of hectarage are shown in Table 5.

Rice.—Rice, being the staple food of the people, is the most important crop grown in the province. The area devoted to this cereal in 1939 was 27,665.18 hectares with a total production of 526,007 cavans valued at ₱1,578,723.00. The leading rice-producing towns are Balaoan, Aringay, Naguilian, Bacnotan,

TABLE 5.—*Area, production, and value of produce of ten leading crops of La Union.*[a]

Kind of crop	Area	Production	Value
	Hectares		*Pesos*
Palay	27,665.19	[c] 526,007	1,578,723
Tobacco	3,367.23	[d] 1,784,343	162,181
Corn	2,089.16	[c] 24,167	62,535
Coconuts	1,605.66	[e] 1,958,805 [f] 12,164	27,805
Sugar cane	1,160.69	[b] 1,379,899 [g] 1,137,174 [h] 2,237,910	207,010
Camote	658.45	[d] 1,784,343	45,503
Cassava	340.44	[d] 1,229,798	27,823
Peanuts	171.35	[d] 111,120	9,910
Mungo	132.18	[d] 61,606	8,325
Pineapples	117.96	[i] 202,662	5,296
Total	37,308.31	----------	2,135,111

[a] Census of the Philippines (1939).
[b] Stalks for chewing.
[c] Cavans.
[d] Kilos.
[e] Nuts.
[f] Liters of tuba.
[g] Panocha.
[h] Liters of basi.
[i] Fruits.

and San Fernando. The average yield per hectare of rice in these towns is from 30 cavans for Sinanpurin in Aringay and 70 cavans for Raminad in Balaoan. These varieties are planted on several soil types, namely, Maligaya clay loam, San Manuel silt loam, Umingan clay loam, Bigaa clay loam, Barcelona clay, Sinapangan clay, and San Manuel sand.

There are three groups of rice varieties planted in La Union according to the method and season of planting. The lowland rice varieties planted are the Sinapurin, Piñas, Mimis, Malloc, Mantica, Macanining, Raminad, Ramai, and Pricepe. These varieties are planted in irrigated lowland areas or lands that are dependent on rain for water. Under normal conditions these varieties give an average yield of from 49 to 60 cavans per hectare.

The upland varieties are the Boric, Guinaoa, Cayading Biit, and Piñas. Piñas is an early-maturing variety. The average production per hectare of upland rice is from 15 to 25 cavans. This low yield is due to the depleted soil as a result of continuous cultivation without fertilizer application. Unless proper soil management is practiced, the yield of rice will always be low.

The *palagad* or lowland second crop varieties are Boric, Sipot, and Piñas. They are planted in irrigated areas during the dry months of the year. The towns growing palagad rice are Sudipen, Bangar, Bacnotan, and Luna, where irrigation water

FIG. 1. Terraces on a mountainside. Terracing has been practiced long before the Spaniards came. Lowland rice is planted on the terraces.

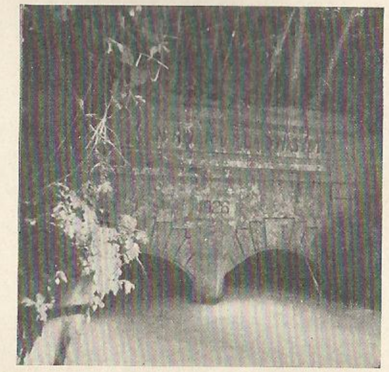

FIG. 2. The Amburayan Irrigation System. It irrigates a total of 3,700 hectares in Sudipen, Bangar, Balaoan, and Luna.

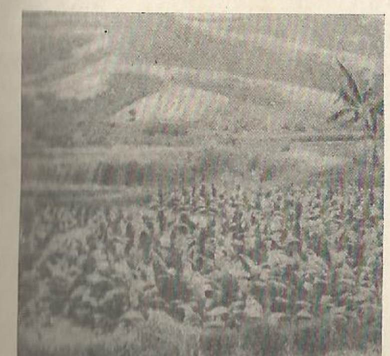

FIG. 3. A tobacco field.

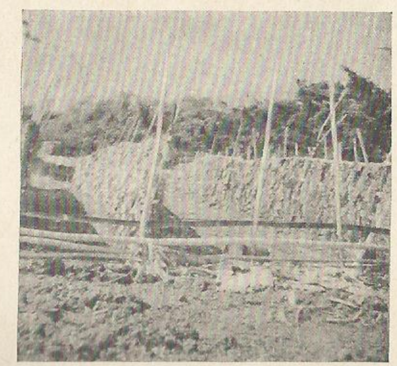

FIG. 4. The delicate tobacco seedlings are protected from the heat of the sun by a small shade of dried banana leaves.

is available during the dry season. The Amburayan Irrigation System (Plate 2, fig. 2) irrigates most of the rice fields of these towns. The towns of Rosario, Naguilian, and San Gabriel occasionally plant palagad rice. The average production per hectare is from 35 to 40 cavans. The planting season for palagad rice is from January to February, and the harvesting period is from April to May.

Tobacco.—This is the second important crop grown in La Union, with respect to area cultivated (Plate 2, figs. 3 and 4). The area planted to this crop in 1939 was 3,367.23 hectares while the total value of the produce was ₱162,131.00. Agoo, Bauang, Naguilian, Tubao, San Fernando, and San Juan are the leading towns producing tobacco in La Union. The province is among the leading tobacco-producing provinces of the Philippines. The average yield per hectare of tobacco leaves in the province is 8 quintals (one quintal is 50 kilos). Most of the tobacco leaves produced in La Union are for filler and wrapper. Batek is also produced on a small scale. The Virginia type for cigarettes is also planted. Tobacco is usually rotated with rice. The most important varieties planted are Simmaba, Vizcaya, Romero, Espada, Pinmena, Carawit, and Pinmekak. The important soil types planted to tobacco are Umingan clay loam, San Manuel silt loam, Barcelona clay and Sinapangan clay.

Corn.—Corn ranks second to rice as a major staple crop of the province. It is planted in all towns. When corn is grown as feed for cattle, carabaos, and horses, they are planted closely and harvested while green by cutting them close to the ground.

Corn is planted three times a year in certain parts of La Union. The Amburayan River Irrigation System in La Union makes possible the growing of three crops of corn annually, although in general only two crops are raised. The first crop is planted in April and May and harvested in June and July, while the second planting is done in November and December and harvested in January and February. The total area devoted to this crop in 1939 was 2,089.16 hectares, the value of produce being ₱62,535.00, as shown in Table 6. It is generally planted in well-drained soils like the San Manuel silt loam, Umingan clay loam, and in soils of rolling areas like the Bauang clay, Annam clay loam, San Fabian clay loam, and Bolinao clay. The varieties planted are the yellow and the white flint, and the average production per hectare is 11 cavans for the first planting or the wet season culture, and 6 cavans for the second planting or the dry season crop.

TABLE 6.—*Area, yield, and value of corn planted in La Union in 1939.*[a]

Crop.	Area.	Production.	Value.
	Hectares.	*Cavans.*	*Pesos.*
First	1,413.94	15,764	42,117
Second	330.39	3,958	10,395
Third	74.78	845	2,352
Green	270.05	[b]1,778,739	7,671
Total	2,089.16	20,567 [b]1,778,739	62,535 93

[a] Census of the Philippines (1939).
[b] Ears

Coconut.—The area planted to this crop in 1939 was 1,605.66 hectares and the total value of the produce was ₱27,805.00. In the same year, there were 1,958,805 nuts harvested besides 12,164 liters of tuba tapped. Coconut grows well in the San Manuel series, Umingan series, Bigaa series, and Sinapangan series. The leading towns growing coconuts in La Union are Aringay, Balaoan, Bauang, Rosario, and Bacnotan. Most of the trees are found along the coast.

Sugar cane.—This is one of the most important crops of the province. Grown mostly for home consumption and for the local market, it gives some cash to the farmers. The canes or stalks are harvested and sold for chewing or are milled in local wooden mills and manufactured into panocha, molasses, and basi. In the 1939 census the total area planted to sugar cane in La Union was 1,160.69 hectares, the produce of which was valued at ₱207,010. In that same year, there were 1,379,899 stalks harvested for chewing, besides 1,137,174 panochas made and 2,237,910 liters of basi manufactured. The leading towns in the province producing sugar cane are Bacnotan, Luna, Naguilian, Agoo, and Balaoan.

Other crops; Root crops.—Next to rice and corn as food crops of La Union are the root crops. These crops constitute the main food of the mountain people. Even in the coastal plains these crops are important as secondary food. They are not, however, planted on a large scale but only in small areas where the soil is light and easily worked, especially the San Manuel silt loam and the Umingan clay loam. The total area planted to these crops in 1939 was 1,244.94 hectares and the produce was valued at ₱112,523.

Camote is the most important root crop. In 1939 it occupied an area of 653.45 hectares and the value of the produce was placed at ₱45,503. Cassava ranks second in importance

and tugue, third. The other root crops planted are ubi, gabi, onion, potato, sincamas, and ginger.

Leguminous crops.—The leguminous crops planted in the province are peanuts, mungo, soy beans, sitao, cowpeas, patani, and batao. Peanuts, mungo, and soy beans are usually planted in rotation with rice, while the rest are planted in small areas in the backyards. According to the 1939 census, the total area planted to these crops was 171.35 hectares with a production of 11,120 kilos valued at ₱9,910. The leading towns planting peanuts are Balaoan, Tubao, Bauang, Aringay, Rosario, and Bacnotan. This is mostly planted in well-drained soils, such as the San Manuel silt loam, Umingan clay loam, and Sinapangan clay.

Like peanuts, mungo is mostly planted in well-drained soils, like the San Manuel silt loam, Umingan clay loam, and Sinapangan clay. The leading towns growing mungo are Bacnotan, Sudipen, San Fernando, Naguilian, San Juan, and Balaoan. The leading towns growing dry beans (sitao, cowpeas, patani, and batao) are Balaoan, Naguilian, San Fernando, Sudipen, Bacnotan, and Santol.

Fiber crops.—There are very few fiber crops planted in La Union. These are cotton, maguey, and kapok. Cotton is planted in every town of the province on a very limited scale. While weaving is one of the household industries of the people, cotton is not grown extensively. This is because the people could buy the raw material for weaving much cheaper than to produce them. In the 1939 census, the area planted to cotton was 66.94 hectares with a total production of 16,639 kilos, valued at ₱1,574. Sudipen, Bangar, Luna, Naguilian, Balaoan, Aringay, and San Fernando are the leading towns growing cotton. Maguey is not as important as cotton, the area planted to it in 1939 being only 8.47 hectares, with a total value of produce of ₱240. Balaoan, Luna, Naguilian, and Bauang are the leading towns planting this crop.

Vegetable crops.—Like the culture of major crops, vegetable growing is an old industry of the province. Vegetables were at first grown for family consumption but later found their way to the markets of the province. However, in no case are they planted on a commercial scale, most of them being in home gardens, in the backyards, or in small open areas. Eggplant is the most important vegetable crop planted in bigger areas. Tomato is second in importance. In the 1939 census, the area planted to eggplant was 139.90 hectares with a produce valued at ₱10,560, while for tomato the area planted was 95.43 hectares and the total value of the produce was ₱18,236. Other vegetable crops grown are ampalaya, patola, upo, kondol, pechay, cabbage, raddish, and mustard. The total area planted to these crops was 281.42 hectares, with a produce valued at ₱33,509. The leading vegetable-growing towns are Naguilian, Agoo, Balaoan, San Fernando, and Luna.

Fruit trees.—Fruit trees constitute one of the important crops of the province. The fruits produced in the province are more than sufficient to supply the demand. In time of good season the surplus fruits are sold in other provinces and in the City of Baguio. Naguilian, a town in the eastern part of the province, is an ideal place for the growing of fruit trees. Its climate is milder and colder than that of the towns along the coast. For these reasons, it is the only town where orchards of chico and pummelo are to be found. The ten leading fruit trees of the province, with the number of bearing trees, their production, and the value of produce are shown in Table 7. Banana is the most important of the fruit trees grown. This is planted not only in the backyards but also on the slopes of hills and mountains.

TABLE 7.—*Number of bearing trees, production, and value of produce of the ten leading fruit trees of the province of La Union.*[a]

Name of tree	Number of bearing trees	Production	Value
			Pesos
Banana	343,388	[b] 449,218	111,825.00
Mango	33,764	[c] 5,625,928	82,135.00
Papaya	77,044	[c] 1,802,382	29,619.00
Guava	28,731	[d] 305,486	12,217.00
Cacao	18,767	[d] 13,584	8,116.00
Soursop	17,406	[c] 229,849	4,124.00
Pummelo	12,067	[c] 628,337	12,707.00
Siniguelas	11,054	[c] 9,516,990	10,626.00
Jackfruit	8,252	[c] 80,289	17,269.00
Coffee	7,287	[c] 5,275	1,933.00

[a] Census of the Philippines (1939).
[b] Bunches. [c] Fruits. [d] Kilos.

The town of Caba is one of the leading producers of bananas. A certain variety of banana is grown in this town for the production of "alupasi" or dried banana sheets used in wrapping tobacco bales. This province annually makes about ₱20,000 from the "alupasi" industry of Caba.(30)

The leading fruit growing towns are Naguilian, Bauang, Balaoan, Bacnotan, Rosario, and Caba for bananas; Rosario, Naguilian, Bauang, Balaoan, and San Fernando for papaya; Naguilian, San Fernando, Bauang, Rosario, and Aringay for mango; and Naguilian, Balaoan, Bauang, Bacnotan, and Aringay for pummelo.

Livestock and livestock products.—The carabao or the cow is the beast of burden of farmers in the Philippines. However, the enterprising farmer has more than one of these animals grazing on his fallowed land. They are maintained either for milk or for meat to get extra cash. He has also some of either goats, chickens, hogs, ducks, horses, sheeps, turkeys, geese, or pigeons.

The wide area of rolling uplands are utilized as grazing lands for cattle. Table 8 shows the number and value of the livestock, while Table 9 shows the poultry population of the province in 1939.

TABLE 8.—*Kind, number, and value of livestock in La Union Province in 1939.*[a]

Kinds of livestock	Total livestock		Value
	On farm	Not on farm	
			Pesos
Carabaos	40,294	4,784	1,372,258.00
Cattle	16,047	2,433	391,397.00
Horses	3,371	942	66,170.00
Goats	17,477	4,122	63,005.00
Sheep	419	179	1,842.00
Hogs	38,787	14,144	308,169.00
Total	116,395	26,604	2,202,841.00

[a] Census of the Philippines (1939).

TABLE 9.—*Kind, number, and value of poultry in La Union Province.*[a]

Kinds of poultry	Total poultry		Value
	On farm	Not on farm	
			Pesos
Chickens	356,655	103,190	166,653.00
Ducks	3,570	1,467	3,605.00
Turkeys	584	332	2,517.00
Geese	331	290	880.00
Pigeons	819	686	361.00
Guinea fowls	311	117	564.00
Total	362,270	106,082	174,580.00

[a] Census of the Philippines (1939).

Before the war hogs, chickens, and eggs were sold in the Mountain Province, City of Baguio, Manila, and in some other provinces. At present, however, they are sold in the City of Baguio only.

Poultry is raised in every home. While some poultry raisers keep relatively large numbers of chickens, such projects cannot be considered of commercial importance. Besides the native chickens, there are also imported breeds, such as the Nagoya, White Leghorn, Cantonese, Rhode Island Red, etc. In 1939, the total number of chicken eggs produced in La Union was 606,431 distributed by breeds as follows:

Native chickens	348,560
Grade chickens	5,135
Other breeds of chickens	2,960

Like the other industries of La Union, the livestock and livestock products were adversely affected by the war, especially during the Japanese Occupation. It is, however, being rejuvenated by the farmers themselves with the help of the government. The government breeding station in La Union located at Paraoir, Luna, is greatly helping the rehabilitation of this industry. Moreover, there is a plan to establish another breeding station at Rosario, La Union.

Kinds of land-use.—La Union is a rolling, hilly, and mountainous province with a narrow coastal plain. Because it is thickly populated, the coastal plains, valleys, and even the hills and mountains are cultivated. The seashores are planted to coconuts which are included in the cultivated areas. Of the farm area of 55,201.09 hectares of La Union, 33,225.17 hectares or 60.19 per cent, is cultivated and the rest is divided among idle land, pasture land, forest land, and other land. Table 10 shows the farm land of La Union Province classified according to kinds of land-use.

The total area of cultivated land shown in Table 10 could be

TABLE 10.—*Farm land of La Union Province classified according to kinds of land-use in 1939.* [a]

Kind of land	Area in hectares	Per cent
Farm area of La Union	55,291.09	100.00
Cultivated land	33,225.17	60.19
Idle land	5,022.28	9.09
Pasture land	9,390.92	17.01
Forest land	5,085.29	9.22
Other land	2,477.43	4.49

[a] Census of the Philippines (1939).

increased, as some sections now classified as forests, idle, and pasture lands can be cleared and cultivated (Forest land here means small areas covered with forests and not included in the forest cover of the province). Even in the hills and mountains, large areas which were at first open and idle lands had been cleared for cultivation. After the harvest of the crops, certain cultivated lands are used for pasture but these cannot be included in the areas of pasture land, because they are not permanently utilized for pasture purposes.

Farm tenure and size of farms.—The land of the province is well distributed among the people. The average land holding is 2.14 hectares per farmer. The number and percentage by sizes of the farms of the province compared to that of Pangasinan and Ilocos Sur Provinces, are shown in Table 11.

The census of the Philippines of 1939 classifies the farmers or farm operators into four classes; namely, owners, part-owners, tenants, and managers. The number of farms operated by these classes in La Union compared to that of Pangasinan and Ilocos Sur is shown in Table 12.

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.

TABLE 11.—*Number and percentage by size of farms of La Union compared with Pangasinan and Ilocos Sur Provinces.* [a]

Province	Total number of farms	Number and percentage by size of farms— I: 0.20 to 0.99 hectare		II: 1.00 to 4.99 hectares	
		Number	Per cent	Number	Per cent
Pangasinan	86,615	33,454	27.08	59,034	68.16
La Union	25,739	10,568	41.06	14,524	56.43
Ilocos Sur	27,163	11,914	43.86	14,845	54.65

Province	Number and percentage by size of farms— III: 5.00 to 9.99 hectares		IV: 10.00 to 19.99 hectares		V: 20 up hectares	
	Number	Per cent	Number	Per cent	Number	Per cent
Pangasinan	3,513	4.07	486	0.56	111	0.13
La Union	541	2.11	100	0.38	6	0.02
Ilocos Sur	356	1.31	41	0.15	7	0.03

[a] Census of the Philippines (1939).

TABLE 12.—*Number and areas of farms operated by owners, part-owners, share-tenants, share-cash-tenants, cash-tenants, and farm managers of La Union Province compared with Pangasinan and Ilocos Sur Provinces.*[a]

Province	Number of farms operated by—				
	All farmers	Owners		Part-owners	
	Number	Number	Per cent	Number	Per cent
Pangasinan	86,615	33,450	38.62	24,444	28.22
La Union	25,739	13,543	52.62	7,621	29.60
Ilocos Sur	27,163	10,576	38.93	10,015	36.87

Province	Number of farms operated by—							
	Share-tenants		Share cash-tenants		Cash-tenants		Managers	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Pangasinan	26,530	30.60	715	0.83	1,465	1.69	11	0.01
La Union	4,458	17.32	31	0.12	85	0.33	1	0.01
Ilocos Sur	6,451	23.75	99	0.36	21	0.08	1	0.01

Province	Area of farms operated by—				
	All farmers	Owners		Part-owners	
	Hectares	Hectares	Per cent	Hectares	Per cent
Pangasinan	202,130.39	77,290.53	38.24	61,534.71	30.44
La Union	55,201.09	32,389.88	58.68	14,493.34	26.26
Ilocos Sur	44,698.39	16,163.52	36.16	18,105.58	40.50

Province	Area of farms operated by—							
	Share-tenants		Share cash-tenants		Cash-tenants		Managers	
	Hectares	Per cent	Hectares	Per cent	Hectares	Per cent	Hectares	Per cent
Pangasinan	56,125.15	27.77	1,858.42	0.92	2,999.99	1.48	2,321.59	1.15
La Union	7,487.32	13.57	101.24	0.18	234.92	0.42	494.49	0.89
Ilocos Sur	9,749.91	21.81	127.04	0.29	24.62	0.05	527.72	1.19

[a] Census of the Philippines (1939).

Part-owners are farm operators who own part and rent or lease from others part of the land which they work. The tenants are subdivided into (*a*) share-tenants, (*b*) cash-tenants, and (*c*) share-cash-tenants.

Share-tenants are farm operators who rent the land they work and pay the rent by sharing with the owner the crop or crops grown.

The cash-tenants are farm operators who rent the land they work and pay a definite rent either in the form of money or crops. The share-cash-tenants are 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 land-owner, receiving wages or salaries, or part of the crops for their services.

The landlord and tenants in La Union are on good terms. This is shown by the fact that there has not been any agrarian discontent in the province. Before the outbreak of World War II, Rural Credit Associations were found in nearly all the towns of the province where the farmers could borrow money for agricultural purposes. The Philippine National Bank and the Industrial Bank with offices located at San Fernando were also accessible to the farmers for loans for their agricultural enterprises. The Rural Credit Association charged 7 per cent interest, while the two other banks charged 6 per cent interest.

Farm investment.—With the average landholding of 2.14 hectares the farmers see no need for big farm investments. So far there has been no record regarding the amount of investment on the farms of La Union, as the farmers have no inventory of their expenses and income. The farm equipment and the work animals are here considered as investments.

According to the 1939 census, the following are some of the investments of the province on farm equipment:

Kind of equipment	Number of equipment	Value (Pesos)
1. Plows	30,570	1,735,032
2. Harrows	26,570	
3. Carts	3,348	
4. Sleds	18,630	
5. Work animals (carabaos)	40,294	

Types of farms.—La Union although rolling, hilly, and mountainous with a narrow coastal plain, is an agricultural province. Because it is thickly populated land cultivation has reached up to the hilly and mountainous regions. There seems to be no room for agricultural expansion in the province in relation to the growing population, hence the needs of each family are produced on the small family farm. Consequently, there is no specialized farming in the province where only one kind of crop is produced. The farmers plant two or more crops a year.

The 1939 census of the Philippines shows the following twelve types of farms in La Union, the areas of which are shown in Table 13:

1. Palay farms are farms on which the area planted to lowland and/or upland palay was equal to 50 per cent or more of the area of the cultivated land.

2. Corn farms are farms on which the area planted to corn was equal to 50 per cent or more of the area of the cultivated land.

3. Sugar cane farms are farms on which the area planted to sugar cane was equal to 50 per cent or more of the area of cultivated land.

4. Coconut farms are farms on which 50 per cent or more of the cultivated land was planted to coconuts.

5. Fruit farms are farms on which the cultivated area planted to fruit trees was equal to 50 per cent or more of the area cultivated.

6. Tobacco farms are farms on which the area planted to tobacco was equal to 50 per cent or more of the cultivated area.

7. Palay-tobacco farms are farms on which the area planted to palay was equal to at least 25 per cent and the area planted to tobacco was equal to at least 25 per cent of the cultivated land.

8. Vegetable farms are farms on which the area planted to camotes, mungo, soybeans, tomatoes, sitao, cowpeas, patani, beans, cadios, onions, radishes, eggplants, cabbages, gabi, watermelons, and/or potatoes was equal to 50 per cent or more of the area of the cultivated land.

9. Livestock farms are farms which have (*a*) an area of 10 hectares or more, (*b*) more than 10 heads of cattle, horses, goats, and sheep, and (*c*) less than 20 per cent of the total farm area used for the production of crops, fruits, and nuts.

10. Poultry farms are farms on which there were more than 300 chickens or 200 ducks and less than 2 hectares of cultivated land.

11. Other farms are farms which could not be classified under any of the foregoing groups.

TABLE 13.—*Number of farms by types in La Union Province.*[a]

Type of farm.	Number of farms.	Percentage.
Palay	22,809	88.62
Corn	123	.47
Sugar cane	99	.38
Coconut	512	1.99
Fruit	152	.59
Tobacco	139	.54
Palay-tobacco	627	2.44
Vegetables	70	.28
Others	1,208	4.69
Total	25,739	100.00

[a] Census of the Philippines (1939).

SOIL SURVEY METHODS AND DEFINITIONS

Soil Survey is an institution devoted to the study of the soil in its natural habitat. It consists primarily of (*a*) the determination of the morphological characteristics of soils, (*b*) the grouping and classifying 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 man.

The soils including their landscapes and underlying formations, are examined systematically in as many sites as possible. Borings with the soil auger are made, test pits are dug, and exposures such as those found in roads and railroad cuts are studied. An excavation, road-cut, or railroad-cut, exposes a series of layers or horizons called collectively the soil profile. These horizons of the soil, as well as the parent material beneath, are studied in detail, and the color, structure, porosity, consistency, texture, and content of organic matter, roots, gravels, and stones are noted. The reaction of the soil and its contents of available plant nutrients are determined in the laboratory. The drainage, both external and internal; the relief of the land; climate; and natural and artificial features are taken into consideration, and the interrelationships of the soil and the vegetation and other environmental factors are studied.

On the basis of both the external and internal characteristics, the soils are grouped into classfication units, of which the three principal ones are (1) soil series, (2) soil types, and (3) phases. When two or more of these principal mapping units are in such intimate or mixed pattern that they cannot be clearly shown on a small-scale soil map, they are mapped or grouped into (4) a complex. Areas of land that have no true soil, such as river beds, coastal beaches, and bare rocky mountainsides, are grouped into (5) miscellaneous land types. Soils of areas that are inaccessible, like mountains and great forest regions, which are of no agricultural value for the present, are classified as 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 internal and external characteristics. In the establishment of a series, a geographic name is selected, taken usually from the locality where the soil was first identified. For example, the Bauang series was first studied and classified in the vicinity of Bauang, La Union Province.

A soil series includes one or more soil types defined according to the texture of the surface soil. The class name, such as sand, loamy sand, sandy loam, silt, silt loam, silty clay loam, clay loam, or clay, is added to the series name to give the complete name of the soil type. For example, Bauang clay is a soil type of the Bauang series. The soil type is the principal unit of mapping. Because of its specific characteristics, it is usually the unit to which agronomic data are definitely related.

The phase of a soil type is a variation within the type, which may be of special practical significance, differing from the soil type only in some minor features, generally external. Difference in relief, stoniness, and extent or degrees of erosion are shown as phases. A minor difference in relief may cause a change in the necessary agricultural operation or a change in the kind of machinery to be used. The phase of a type with a slight degree of accelerated erosion may present different fertilizer requirements and other cultural management practices from the normal soil type. The phase of a type due mainly to degree of erosion, degree of slope, and the amount of gravel and stones on the surface soils, is delineated on the map.

A soil complex is a soil association composed of such intimate mixture of series, types, or phases that cannot be indicated separately in a small-scale map. This is mapped as a unit and is called a soil complex. If in the area there are several series, such as Bauang, Annam, San Fabian, and others that are mixed together, the complex is named after the dominant member or members, such as Bauang-Annam complex, or San Fabian complex.

Surface and subsoil samples for chemical and physical analyses are collected representing each soil type or phase, the number of samples 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.

The soil survey party composed of two or three soils men, maps the area and delineates on the map the various soil types, phases, complex, 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, telephones and telegraph lines; barrios, towns, and cities; irrigation canals, rivers and lakes; prominent mountains, etc.

SOILS OF LA UNION

The soils of La Union are divided into three physiographic groups, namely, (*a*) soils of the plains and undulating areas, (*b*) soils of the rolling areas, steep hill, and mountains, and (*c*) miscellaneous land types. Areas that have no true soil such as river beds, coastal beach sand, or bare rocky mountain sides and those that are not differentiated are called miscellaneous land types. The soil types under each physiographic group are as follows:

1. *Soils of the plains and undulating areas:*
   (*a*) Bigaa clay loam (3).*
   (*b*) San Manuel silt loam (82).
   (*c*) San Manuel sand (97).
   (*d*) Umingan clay loam (168).
   (*e*) Maligaya clay loam (117).
   (*f*) Barcelona clay (148).
   (*g*) Sinapangan clay (150).
2. *Soils of the rolling areas, steep hills, and mountains:*
   (*a*) Annam clay loam (98).
   (*b*) San Fabian clay loam (102).
   (*c*) Bolinao clay (153).
   (*d*) Mountain soils, undifferentiated (45).
   (*e*) Bauang clay (121).
   (*f*) Burgos clay (151).
3. *Miscellaneous land types:*
   (*a*) Hydrosol (1).
   (*b*) Beach sand (118).
   (*c*) Gravel deposit (149).
   (*d*) River wash (152).

The mechanical analysis of the surface soils of the various types are shown in Table 14. This analysis of the surface soils was made to check up the field classification which was done by the "feel method." In most cases the field classification agrees with the results of the mechanical analysis. In few cases, however, the field classification is doubtful. For example, some red soils exhibit the loam texture in the field. This group of soil has colloidal properties different from those of the other group of soils, such as the dark-gray and dark-brown soils. The clay content of these red soils is high, but in the field these soils are friable, mellow, and easy to

* Number in parenthesis after each soil type is the type number.

cultivate. Under these conditions the field classification is maintained, unless the clay content is so high in which case the textural class is made to conform with that obtained by mechanical analysis. The hydrometer method of mechanical analysis by Bouyoucos (9) was used.

TABLE 14.—*Average mechanical analysis of La Union soils.* [a]

Type number	Soil type	Sand 2.0-0.05 mm.	Silt 0.05-0.005 mm.	Clay 0.005-0.00 mm.
		Per cent	*Per cent*	*Per cent*
3	Bigaa clay loam	42.86	35.24	21.90
82	San Manuel silt loam	34.72	41.75	23.53
97	San Manuel sand	79.76	11.06	9.18
98	Annam clay loam	33.59	28.05	38.36
102	San Fabian clay loam	28.75	26.86	45.39
117	Maligaya clay loam	20.30	25.00	54.70
121	Bauang clay	21.05	29.33	49.62
148	Barcelona clay	22.55	22.18	55.27
150	Sinapangan clay	17.74	47.17	35.09
151	Burgos clay	25.81	25.24	48.95
153	Bolinao clay	31.45	17.51	51.04
168	Umingan clay loam	32.56	37.85	29.59

[a] Analysis by Mr. Isaac J. Aristorenas, Soil Surveys Section, Division of Soil Survey and Conservation.

In the following pages the soils of La Union are described in detail and their agricultural importance is discussed. Their distribution in the province is shown in the accompanying soil map. The areas, percentages, location, and principal crops in each soil type are shown in Table 15.

TABLE 15.—*Area, location, and principal crops grown on each soil type in La Union Province.* [a]

Type number.	Soil type.	Area in hectares.	Per cent.	Location.	Principal crops grown.
3	Bigaa clay loam	1,215.97	0.88	Northern and eastern plains of Balaoan.	Rice, corn, coconuts, sugar cane, beans.
82	San Manuel silt loam	13,853.55	10.09	Valley at barrio Sta. Teresa, Tubao; barrio Sta. Cecilia, Aringay; Naguilian, and the plains at San Juan, Bacnotan, Balaoan, Luna, Bangar, and Sudipen.	Lowland rice, corn, sugar cane, coconuts, tobacco, vegetables.
97	San Manuel sand	1,635.38	1.19	Coastal plains at Sto. Tomas, Agoo, Aringay, and Bauang.	Lowland rice, coconuts, sugar cane
168	Umingan clay loam	6,156.83	4.48	Southeastern plains of Rosario, the valley at Pugo and Tubao, the plains at San Gabriel, and barrio Castro, Sudipen.	Lowland rice, sugar cane, corn, tobacco vegetables.
117	Maligaya clay loam	3,995.63	2,92	Slightly undulating plains at Sto. Tomas, Agoo, Aringay, Caba and the valley at the barrios of Cuenca, San Luis, and Garampong, Rosario.	Lowland rice, corn, sugar cane, camote, peanuts, tobacco.

TABLE 15.—*Area, location, and principal crops grown on each soil type in La Union Province.*—Continued

Type number.	Soil type.	Area in hectares.	Per cent.	Location.	Principal crops grown.
148	Barcelona clay	2,994.79	2.19	Coastal plains from Bauang to San Fernando a small area in Tubao valley, at barrios San Gregorio and Sobredillo, municipality of Caba.	Lowland rice, corn, sugar cane, coconuts, tobacco, and vegetables.
150	Sinapangan clay	897.41	0.65	The valley at barrios Sinapangan, Calliat, Tallipago, San Francisco and Rissing, Balaoan, and a small area at Sudipen.	Lowland rice corn, sugar, cane, coconut, cassava, vegetables.
153	Bolinao clay	1,761.47	1.30	Barrio Porro, San Fernando, limestone hills along the coast, between San Fernando and San Juan and between Maragayap River and barrio Nalvo, Luna.	Upland rice, corn, sugar-cane, tobacco madre cacao, ipil-ipil.
98	Annam clay loam	7,520.25	5.47	Hilly to mountainous areas of Rosario, Sto. Tomas, Agoo, Tubao, and San Fernando.	Upland rice, corn, cassava, bananas, fruit trees, cogon, second growth forests.
102	San Fabian clay loam	131.98	0.09	The rolling to hilly areas along the coast from the boundary of Pangasinan and La Union up to Damortis.	Upland rice, corn, maguey, papaya, pineapple, ipil-ipil, and madre-cacao
121	Bauang clay	54,955.60	40.05	Most of the hills and mountains throughout the province.	Upland rice, camote, cassava, fruit trees, cogonal pastures, forests.
151	Burgos clay	10,137.72	7.38	Mountains east of Naguilian and the mountains around Burgos up to the western border of Mountain Province.	Upland rice corn, camote cassava, cogonal pastures, forests, pine trees.
45	Mountain soils (undifferentiated)	28,722.57	20.92	Mountains along the eastern border of the province.	Dipterocarp forests, pine trees.
1	Hydrosol	332.74	0.24	Small areas along the coast of San Fernando and Sto. Tomas, near the mouth of Darigayos River, and at barrio Paratong, Sur Bangar.	Nipa, mangrove, fishponds.
118	Beach sand	2,057.66	1.49	Along the coast.	No agricultural importance.
149	Gravel deposit	297.79	0.21	Barrios of Victoria, Magallanes, Nalvo N. and Barrientos, Luna.	Material for surfacing roads.
152	River wash	622.66	0.45	On the big rivers of Aringay, Bauang, and Amburayan.	No agricultural value.
	Total	137,290.00	100.00		

[a] The area of each soil type was obtained with the use of a planimeter.

SOILS OF THE PLAINS AND UNDULATING AREAS

The soils of this group include those located along the coastal plain, the valleys in the interior, and the undulating areas of the lower uplands. The series are Bigaa, San Manuel, Umingan, Maligaya, Barcelona, and Sinapangan. They have many characteristics in common, having developed or are developing from materials of recent alluvial depositions. The surface soils are fairly deep with moderate fertility. They are slightly acidic ranging from pH 6.35 * in the Maligaya clay loam to pH 6.96 in the Bigaa clay loam.

Generally, this group of soils is the most important in the province. The staple and money crops of the province such as rice, corn, tobacco, and vegetables are grown on these soils. Coconuts, bananas, and other permanent crops are also grown. Of the total area of the province which is 137,290 hectares, 29,920.74 hectares belong to this group of soils. The largest type is San Manuel silt loam. This type is considered to be the best soil in Pangasinan Province planted to rice. In La Union, this type is devoted mainly to rice, corn, and tobacco.

Bigaa clay loam (3).—The 20 to 30 centimeters surface soil with an average pH of 6.95 is brown to dark brown clay loam with dark brownish red streaks. It is fine granular, sticky when wet, and hard and cloddy when dry. The subsoil consists of light gray to dark brownish gray, compact, clay loam to clay, which continues to a depth of 40 to 100 centimeters where it grades into light gray clay. Iron concretions are usually present throughout the profile, the amount decreasing with depth.

This soil had developed from recently deposited alluvium. The area covered by this soil is about 1,215.97 hectares located on the northern and eastern plains of Balaoan (Plate 3, fig. 1). The relief is nearly flat. The flow of run-off is slow and the internal drainage is poor.

Practically the whole area is devoted to rice production. The area irrigated by the Amburayan River Irrigation System has a higher yield than the areas not irrigated. Small areas of this soil type are planted to corn, sugar cane, beans, vegetables, and coconuts.

* pH determinations made by Mr. S. B. Etorma, Soil Chemist, Division of Soil Survey and Conservation.

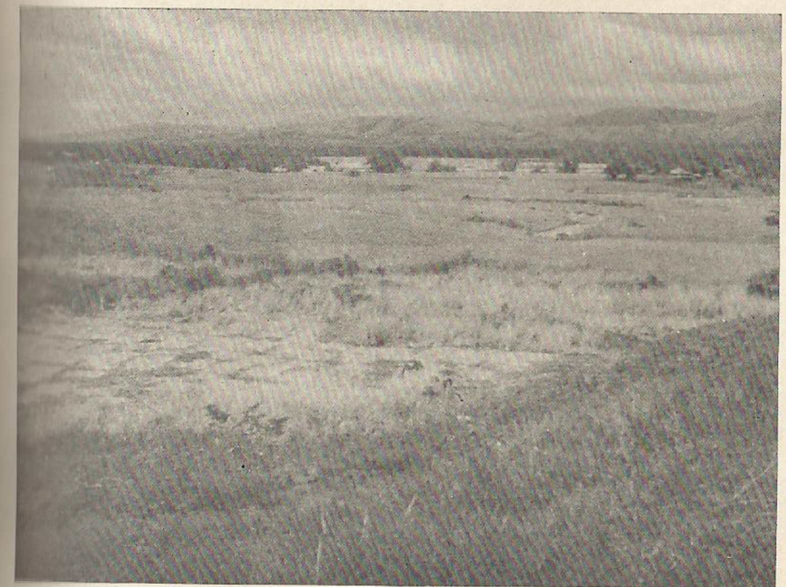

FIG. 1. A slightly undulating plain at Balaoan (looking North). In the foreground the soil is Bigaa clay loam; the soil of the plain in the background is San Miguel silt loam.

FIG. 2. The plain at Cantoria, Balaoan, extends to almost 15 km. from the shore. This plain is mostly San Manuel silt loam.

A typical Bigaa clay loam profile examined in Pantar, Balaoan, is described as follows:

Bigaa clay loam.

Depth of soil. cm.	Characteristics.
0–25	Brown to dark brown, slightly compact, fine granular clay loam with reddish brown streaks. Consistency varies from sticky, plastic, friable to hard with decreasing moisture content. Cracks into big clods when dry. Roots abundant down to 25 centimeters deep. Some very dark reddish brown roughly spherical iron concretions present, varying in diameter from 1 to 4 millimeters. Concretions soft enough to be crushed by the hands. Boundary between surface soil and subsoil is gradual.
25-45	Light brown to brownish gray, moderately compact, fine granular clay loam, slightly heavier than above horizon. Concretions present. Some roots penetrate down to 30 centimeters. Boundary between subsoil and substratum is diffuse.
45–120	Texture heavier than above. Light gray almost massive clay. Fewer concretions than above layers.

San Manuel silt loam (*82*).—The surface soil is light brown to brownish gray, fine to coarse granular silt loam ranging from 35 to 40 centimeters in depth. The average pH is 6.43. When dry, it is hard and breaks into clods. Reddish brown streaks in the upper surface soil are present especially in rice fields. When wet it is easy to cultivate. The subsoil is light brown to brownish gray granular silt loam to loam. It is less compact than the surface soil. At a depth of 85 to 100 centimeters the subsoil grades into light yellowish brown, loose, very fine to fine sand, which is in a very fine granular to structureless condition.

This soil type occupies one of the largest areas in the province. It is found in the valleys at Barrio Sta. Teresa, Tubao; Barrio Cecilia, Aringay; Barrio Liquicia, Caba; Naguilian; and the plains at San Juan, Bacnotan, Balaoan (Plate 3, fig. 2, and Plate 4, fig. 1), Luna, Bangar, and Sudipen, and at the mouth of the Aringay River. The aggregate area is 13,853.55 hectares which is 10.09 per cent of the total area of La Union.

The land is nearly level to undulating. Surface drainage is fair. Internal drainage is good.

Lowland rice is the principal crop. In the areas irrigated by the Amburayan River Irrigation System, two rice crops a year are raised. Sugar cane is grown in small patches. Corn, tobacco, camote, and vegetables are also grown after the rice harvest.

The following is the description of a San Manuel silt loam profile, studied in barrio Guising, Naguilian:

San Manuel silt loam.

Depth of soil. cm.	Characteristics.
0–30	Light brown to brown, slightly compact, granular silt loam. Consistency varies from slightly plastic to hard with decreasing moisture content. Plant roots very abundant. Moderate amount of organic matter. Boundary between surface soil and subsoil is gradual.
30–100	Light brown to brown, moderately compact, granular loam with dark red mottlings. Some roots are found as deep as 50 centimeters. Boundary between subsoil and substratum is gradual.
100-150	Yellowish brown, slightly compact silt loam grading into loose structureless fine sand in the lower substratum.

San Manuel sand (97).—The 30 to 40 centimeters surface soil is fine granular, loose, brownish gray sand. The subsoil and substratum are similar to those of the San Manuel silt loam.

This soil covers an area of 1,635.38 hectares. It occurs on the level coastal plain at Sto. Tomas, Agoo, Aringay, and Bauang.

This soil is mostly devoted to coconut and rice. Lowland rice is grown, sometimes interplanted with coconuts (Plate 5, fig. 1). Sugar cane is also grown on limited areas.

A typical profile found in Sto. Tomas is described as follows:

San Manuel sand.

Depth of soil. cm.	Characteristics.
0–35	Brownish gray, loose, friable, granular sand. Roots penetrate easily. Low organic matter content. Boundary between surface soil and subsoil is gradual.
35–70	Dark brownish gray, fine granular sandy loam. Few roots found in upper subsoil. Boundary between subsoil and substratum is gradual.
70–150	Reddish brown, loose, structureless, fine sand. Water table is at 100 centimeters depth.

Umingan clay loam (168).—The 20 to 30 centimeters surface soil consists of brown to dark brown, loose, fine granular clay loam (Plate 5, fig. 2). This is underlain by a material of coarse texture which continues to a depth of 40 to 150 centi-

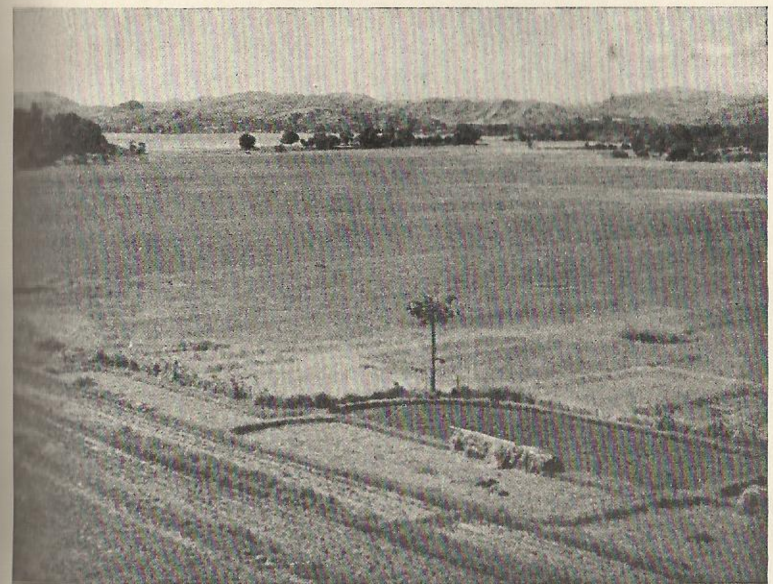

FIG. 1. San Manuel silt loam on the extensive valley at Guising, Naguilian (looking South), is very well suited to rice.

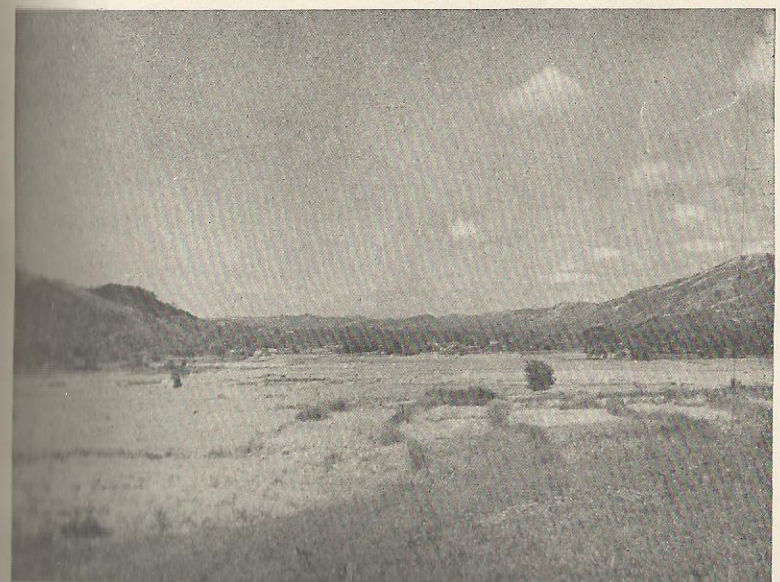

FIG. 2. Tubao valley (looking North). This picture was taken during the harvesting season for rice in January. The white specks on the rice fields are portable shades for protecting the harvesters from the heat of the sun. The soil is Umingan clay loam.

PLATE 4

meters where it rests on a layer of water-worn gravel and pebble accumulation. Sometimes two layers of gravel separated by a thicker layer of coarse to fine sand may be found in the same profile. The total area of Umingan clay loam is 6,156.83 hectares. This soil occurs in the southeastern part of Rosario, the valley at Pugo and Tubao (Plate 4, fig. 2) ; the southern bank of Bauang river near the mouth; and the plains at San Gabriel and Barrio Castro, Sudipen.

The topography of the land is flat to undulating. The internal drainage is good but run-off is slow.

This soil is planted mostly to rice. Sugar cane is grown in small areas. Corn and tobacco are usually planted after the rice harvest. Vegetables, particularly onions, are profitably raised at Pugo.

An Umingan clay loam profile from a river cut located at Tubao shows the following characteristics:

Umingan clay loam.

Depth of soil. cm.	Characteristics.
0–30	Brown, loose, granular clay loam. Small amount of organic matter. Plant roots abundant. Boundary between surface, and subsoil is gradual.
30–60	Brown, loose, coarse granular silt loam. Roots penetrate easily. Boundary between upper and lower subsoil is clear and wavy.
60–120	Light reddish brown, loose, structureless, fine sand. Boundary between this layer and the next is smooth and abrupt.
120–150	A mixture of smooth, watersworn, roughly spherical to disk-like gravel, occasional pebbles up to 10 centimeters in diameter and coarse sand.

Maligaya clay loam (*117*).—To a depth of 20 to 30 centimeters Maligaya clay loam is brown to dark brown, granular slightly compact, clay loam with dark brownish red streaks. It is sticky when wet and becomes hard when dry. Beneath this horizon is light brown to grayish brown compact clay loam to clay. At a depth of 70 to 80 centimeters this layer grades into another layer of coarse-textured material.

Covering an area of 3,995.63 hectares this type is located on the slightly undulating plains at Sto. Tomas, Agoo, Aringay, Caba, and the valley at the Barrios of Cuenca, San Luis and Garampang, Rosario. The land is nearly level to undulating. Run-off is slow and the internal drainage is poor.

Rice is the most important crop grown on this type. Corn, sugar cane, camotes, peanuts, and tobacco are also grown.

A typical Maligaya clay loam profile examined at Sto. Tomas has the following characteristics:

Maligaya clay loam.

Depth of soil. cm.	Characteristics.
0–30	Dark brown, slightly compact, fine granular clay loam to clay with brownish red streaks. Consistency varies from sticky to hard with decreasing moisture content. When the soil is dry the surface soil presents a network of cracks. Fair amount of organic matter. Roots abundant down to 25 centimeters. Boundary between surface soil and subsoil is gradual.
30–80	Light brown to grayish brown, compact, almost massive clay loam to clay, with brownish red mottlings. Few roots penetrate this layer. Boundary between subsoil and substratum is diffuse.
80–130	Yellowish brown slightly compact to compact gritty clay loam.

BARCELONA SERIES

The soils of the Barcelona series consist of brown, dark brown to dark grayish brown, granular, sticky to plastic surface soils underlain by yellowish brown to grayish brown granular clay loam subsoil. There are few concretions in the surface soils but the subsoils have abundant amount, increasing in size and number with increasing depth. The substratum is dark gray to almost black clay material. On drying this turns to gray or slate gray that becomes hard and brittle. Except for the concretions in the subsoil, the surface and the substratum are free from coarse skeleton. Boundary is clear and smooth between horizons.

Like the Bigaa, San Manuel, and Maligaya series, the Barcelona series has developed from recent alluvial deposits. But unlike it the subsoils of Barcelona have plenty of concretions and the substratum has dark gray to almost black clay material. The soil material came from the hills and mountains containing shales and sandstones.

The vegetal cover of this series consists of economic crops, such as rice, corn, sugar cane, vegetables, and fruit trees. The general topography is undulating to gently rolling. In small areas, however, where rice and corn are planted, the land is almost level. Surface drainage is good, while internal drainage is poor to fair.

So far there is only one type classified in La Union Province.

Barcelona clay (*148*).—The 15 to 30 centimeters surface layer of Barcelona clay is brown, dark brown to dark grayish brown, slightly compact, granular clay, which is friable when wet and

FIG. 1. Near the mouth of the Bauang River rice is interplanted between rows of coconuts on San Manuel sand.

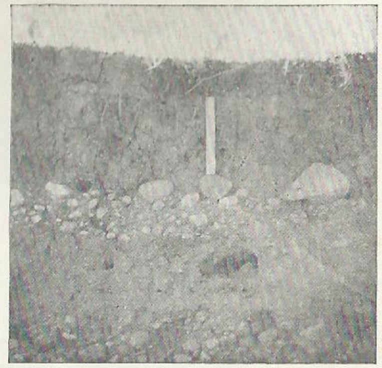

FIG. 2. Umingan silt loam profile from a river cut at Tubao. Sometimes two layers of gravel are separated by a layer of coarse or fine sand.

FIG. 3. A Barcelona clay profile from a gully cut at Barcelona, Tubao. The picture was taken during the dry season, hence the cloddy structure of the surface soil and subsoil.

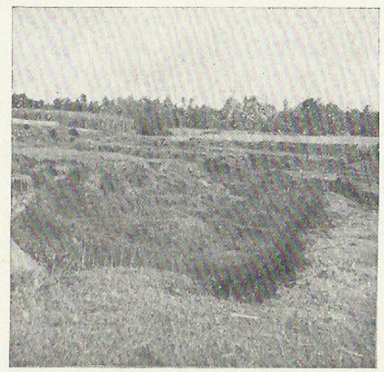

FIG. 4. An extensive gully at Sinapangan, Balaoan. The "volunteer" grass cover has partially stopped further gullying.

hard when dry. It cracks into big clods during the dry season. The subsoil is grayish brown, light brown to dark yellowish brown, granular clay loam (Plate 5, fig. 3). At a depth of 65 to 80 centimeters this grades into a material of lighter color which continues down to 100 centimeters where the soil becomes dark gray to almost black shalelike clay. Concretions are abundant in the lower subsoil.

The material from which most of the soil is formed has been washed from nearby slopes underlain by sandstones and shales.

This soil occupies 2,994.79 hectares and is found on the eastern part of San Fernando (Plate 6, fig. 1) along the coast of San Fernando to Bauang, and on a small area in Tubao Valley (Plate 6, fig. 2).

The surface of the land is nearly flat to undulating. Surface drainage is fair, but internal drainage is poor.

A Barcelona clay profile examined at Barcelona, Tubao, has the following characteristics:

Barcelona clay.

Depth of soil. cm.	Characteristics.
0-30	Brown to dark brown, slightly compact, granular, heavy clay loam to clay. Consistency varies from sticky, plastic, friable to hard with decreasing moisture content. When dry it cracks into big clods. Moderate amount of organic matter. Roots abundant. Few dark reddish brown, roughly spherical iron concretions varying in size from 1 to 5 millimeters. Boundary between the surface soil and subsoil is clear and smooth.
30-65	Light brown to dark yellowish brown, granular clay loam. Few roots penetrate down to 60 centimeters. Few concretions present. Boundary between upper subsoil and lower subsoil is diffuse.
65-100	Lighter in color than above. Concretions varying from 5 to 15 millimeters in diameter increase in amount and size with increasing depth until at 80 to 100 centimeters they occupy about 30 per cent of the volume of the soil mass. Boundary between lower subsoil and substratum is smooth and abrupt.
100-150	Dark gray to almost black shalelike material, massive, soft, cheesy clay. Can be broken with the hands into angular lumps with glistening fracture planes. On drying becomes dark gray, hard, and brittle. No concretions in this horizon.

SINAPANGAN SERIES

The soils of the Sinapangan series have developed from recent alluvial deposits derived mainly from shales and sandstones. The general topographic feature of the area is gently undulating to flat. Drainage, both internal and external, is fair to good. The vegetative cover consists of economic crops, such as rice, corn, sugar cane, coconuts, bananas, vegetables, and fruit trees.

The soils of this series are characterized by light brown, brown to yellowish brown, loose, friable and granular surface soils underlain by grayish brown to almost black compact clay subsoil. The substratum is yellowish brown to light brownish red, loose, friable, and granular clay. The boundary between surface and subsoil is abrupt and smooth.

Like the Bigaa series, clay predominates in the different horizons of the Sinapangan series. The main difference between the Sinapangan series and the Bigaa series is the presence of concretions in the latter. The former contains a large amount of silt which accounts for its better physical condition than the Bigaa series.

So far there is only one soil type classified in the Province of La Union.

Sinapangan clay (150).—The surface soil, which ranges from 10 to 50 centimeters in depth, is light brown, brown to yellowish brown, loose to slightly compact, fine to coarse granular clay. This layer changes abruptly to a dark grayish brown to almost black compact clay subsoil which is sticky to plastic when wet and brittle and hard when dry (Plate 7, fig. 1). At a depth of 60 to 80 centimeters this gradually passes into yellowish brown to light brownish red, loose to moderately compact clay.

The surface soil, because of its loose nature, is easily eroded and in certain cases completely washed away, exposing the dark subsoil. In still other areas big gullies have been formed (Plate 5, fig. 4).

This soil has developed from comparatively recent alluvial deposits washed away from the neighboring hills.

This soil covers an area of 897.41 hectares distributed on a valley at barrios Sinapangan, Calliat, Talipago, San Francisco, and Rissing, Balaoan, and a small area at Sudipen.

The land is nearly flat to undulating. The surface run-off is slow. The surface soil is porous and rain water soaks readily but further drainage is obstructed by a dense subsoil.

This soil is planted mainly to lowland rice, sugar cane, corn, coconut, camote, cassava, and bananas to a limited extent.

A Sinapangan clay profile examined on a gully cut at Barrio Sinapangan, Balaoan, presents the following characteristics:

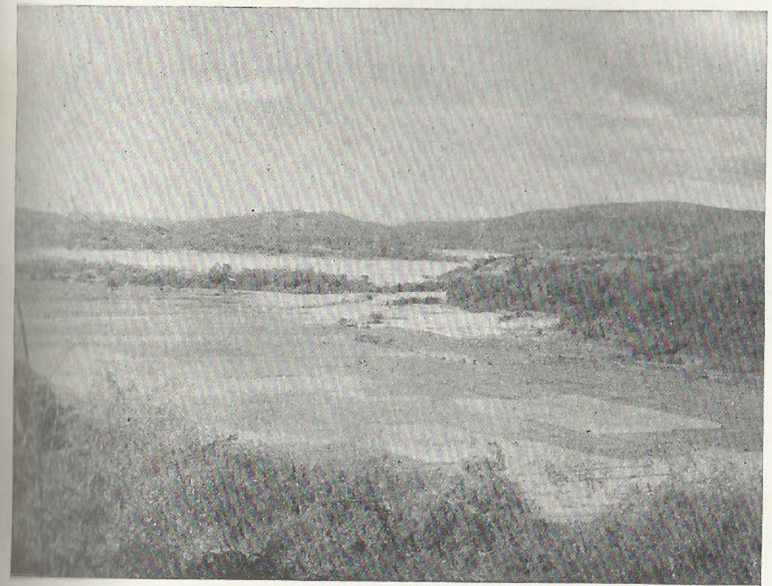

FIG. 1. Coastal plain at San Fernando (looking Northeast). Rice is the most important crop grown on Barcelona clay. The soils of the hills in the background belong to the Annam series.

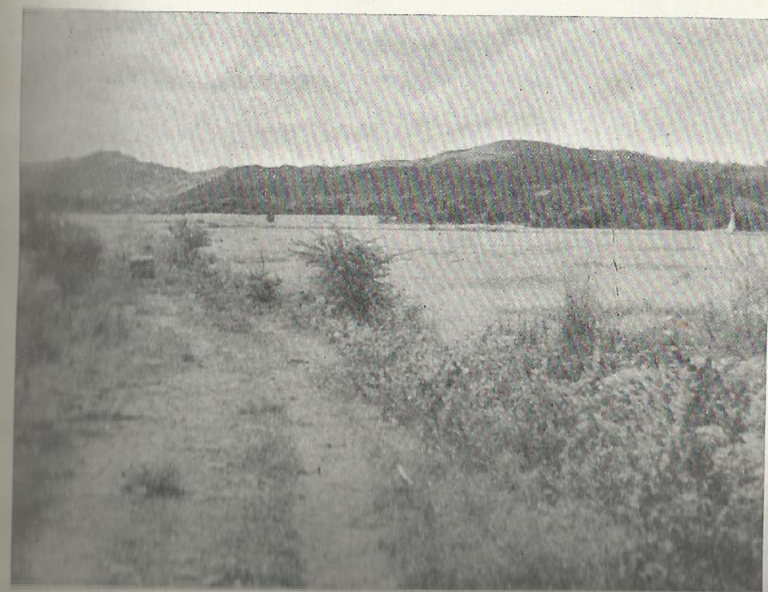

FIG. 2. A portion of the Tubao Valley at Barcelona, Tubao (looking South). The Barcelona series was first defined in this region. Note the neglected state of the Aringay-Tubao sand.

Sinapangan clay.

Depth of soil. cm.	Characteristics.
0–35	Light brown to yellowish brown, loose, fine granular clay. Moderate amount of well-decomposed organic matter mixed well with mineral matter. Roots penetrate easily and are abundant in this layer. Boundary between surface and subsoil is smooth abrupt.
35–70	Dark grayish brown to almost black, compact to almost massive clay. Sticky to plastic when wet. Brittle and hard when dry. Some roots penetrate down to 60 centimeters from the surface. Gradual boundary between this and the lower horizon.
70–200	Yellowish brown to light brownish red, very loose to loose clay.

SOILS OF THE ROLLING AREAS, STEEP HILLS, AND MOUNTAINS

The soils occupying the rolling areas, steep hills, and mountain regions are the Annam, San Fabian, Bolinao, Bauang, and Burgos series, and the mountain soils. They occupy an area of 103,229.59 hectares equivalent to 75.21 per cent of the total soil cover of the province. These soils have developed from the weathering of various rocks, such as conglomerates, shale, high-lime shale, coralline limestone, basalt, and andesite. The Annam, the San Fabian, and the Burgos series have developed from the residual material of conglomerate, basalt, and andesite; the Bolinao from coralline limestone, and the Bauang from high-lime shale. The general properties of these soils are closely related to the character of the soil material weathered from the underlying rocks.

Occurring in rolling areas and steep hills, most of these soils are dissected by numerous V-shaped drainage-ways. The rivers are shallow and short and the water flows swiftly, especially during the rainy season when the water swells into floods. Many of the soils are planted to clean-cultivated crops regardless of the steepness of the slope, and because of this improper agricultural practice these soils are badly eroded. This is especially true in the case of the Bauang soils which constitute the largest type in the province.

Based on their natural productivity, Bolinao clay rates first in upland palay, Bauang clay rates second, followed by San Fabian clay loam, and Burgos clay. For corn, Bolinao clay rates first also. For camote and cassava, Burgos clay ranks first followed by Bolinao clay, and Bauang clay.

The pH value or reaction of these soils are generally acidic, except Bolinao clay which is alkaline with an average pH 7.65.

Annam clay loam (*98*).—In cultivated areas the surface soil ranges in depth from 25 to 30 centimeters. In areas still covered with second-growth forest, the surface soil is deep reaching sometimes as deep as 50 to 60 centimeters (Plate 7, fig. 2). It is loose to moderately compact, fine to coarse granular clay loam, rich in organic matter, and consequently, darker than the subsoil. The roots of plants can readily penetrate down owing to the loose condition of the surface soil.

The subsoil at a depth of from 30 to 125 centimeters from the surface is brown to reddish brown, slightly compact, granular clay loam. The lower subsoil which gradually merges with the substratum consists mainly of an unconsolidated mixture of rounded gravel, pebbles, coarse sand, and clay.

The bedrock is conglomerate consisting of smooth, waterworn, roughly spherical gravel, pebbles, cobblestones, and boulders embedded in a matrix of coarse sand cemented by clayey materials. In certain areas notably the low-lying hills in the vicinity of San Fernando, this bedrock is 20 to 30 meters thick.

The surface soil and subsoil are easily eroded and in some areas the bed rock has been exposed due to severe erosion.

This soil occurs in the hilly to mountainous regions of Rosario, Sto. Tomas, Agoo, Tubao, and San Fernando (Plate 8, fig. 1). The aggregate area of this soil type is 7,520.25 hectares representing 5.47 per cent of the total area of the province. The external drainage is good to excessive. Internal drainage is fair.

A large part of this soil type is open land and is at present utilized for the production of crops. Upland rice, corn, cassava, bananas, and fruit trees are grown on the more gentle slopes, while the steeper slopes are covered with second-growth forest.

A normal profile of this type examined on the northern part of San Fernando has the following characteristics:

Annam clay loam.

Depth of soil. cm.	Characteristics.
0–30	Brown, slightly compact, granular, gravelly loam to clay loam. Consistency varies from sticky, plastic, friable to hard with decreasing moisture content. Moderate amount of organic matter present. Roots abundant down to 25 centimeters. Boundary between surface soil and subsoil is diffuse.
30–50	Light brown granular clay loam heavier in texture than the above layer. Boundary between subsoil and substratum is smooth and clear.

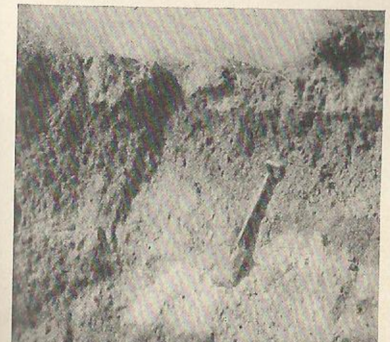

FIG. 1. Sinapangan clay profile from a cut at Sinapangan, Balaoan. Note the light colored surface soil and the dark subsoil. The subsoil is underlain by a light colored soil at a depth of 60 to 80 centimeters.

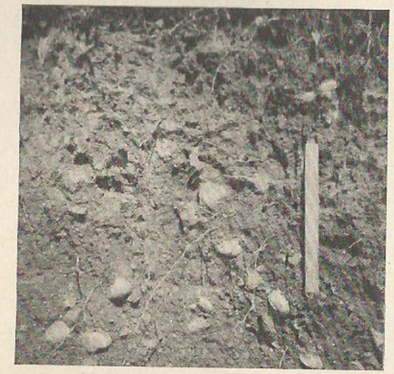

FIG. 2. Annam clay loam profile from a fresh "trail" cut on one of the low-lying hills of San Fernando. The surface soil is unusually thick (about 50 cm.). Vegetation of second-growth forest has been left intact for a considerable time.

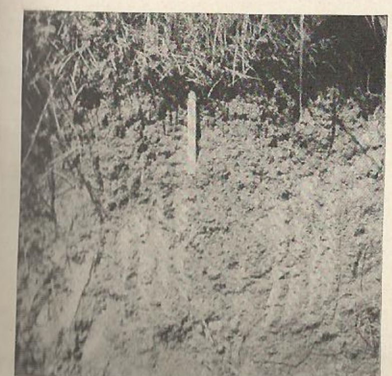

FIG. 3. A San Fabian clay loam profile exposed by an excavation at Rabon, Rosario. Note the dark topsoil rich in organic matter underlain by material of lighter color.

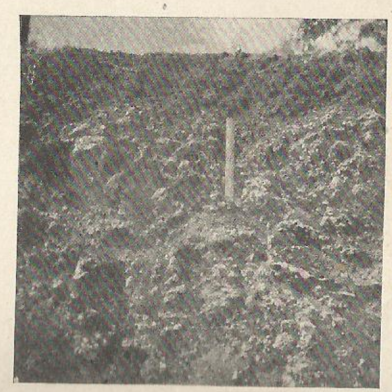

FIG. 4. A Bolinao clay loam profile from a road cut at Linsat, San Fernando. Note the mixture of clay and partially weathered coraline limestone which underlie the surface soil.

50–80	Reddish brown, coarse granular, clay loam with water-worm gravel averaging 3 centimeters in diameter imbedded in it. The gravel is about 50 per cent of the soil mass. Boundary is gradual.
80–160	Bed rock. A conglomerate consisting of smooth, waterworn gravel, and cobblestones set in finer grained matrix of clayey material.

San Fabian clay loam (*102*).—This soil types occupies about 131.98 hectares on the southern part of the province. It is a continuation of the same soil type found in Pangasinan.

The area (Plate 8, fig. 2) is rolling to hilly. Rain water flows readily on the surface but less readily through the soil below.

A greater part of this soil type is used for growing upland rice. Coconut, corn, sugar cane, and beans are also grown in limited areas. The uncultivated areas are presently covered with cogon.

A typical profile (Plate 7, fig. 3) examined at Damortis has the following characteristics:

San Fabian clay loam.

Depth of soil. cm.	Characteristics.
0–25	Dark brown to dark gray, granular, gritty clay loam. Plastic to very sticky when wet. When dry it is hard, compact and cracks into big clods. Roots abundant. Plenty of organic matter present. Boundary is gradual.
25–45	Grayish brown, granular, sticky clay loam. Same consistency as above. Roots penetrate down to this layer. Boundary between this and the next layer is gradual.
45-125	Light yellowish to whitish gray, soft, powdery clay loam to clay with highly weathered chalklike soft rocky material.

BOLINAO SERIES

Bolinao series was established in Pangasinan in 1941. As early as 1935, however, Pendleton (28) of the College of Agriculture, mentioned in passing but did not describe in detail, the "rather unusually dark red and brown soils of the red elevated coral reef which now forms the tied island or tombolo of Porro at San Fernando." This rather unusually dark and red brown soils have been identified by the Division of Soil Survey, Department of Agriculture and Natural Resources, as belonging to the Bolinao series.

Bolinao clay (*153*).—To a depth of 20 to 35 centimeters Bolinao clay is light to dark reddish brown slightly to moderately compact clay which is sticky to friable when wet and hard when dry (Plate 7, fig. 4). Below this layer the soil is heavier in texture and contains a large amount of yellowish gray to brownish gray highly weathered coralline limestone. At a depth of 80 to 120 centimeters this material rests on coralline limestone rock.

This soil which is confined to the peninsula of Porro, San Fernando; the coastal area between San Fernando and San Juan; and a narrow coastal strip between the mouth of the Maragayap River and Barrio Nalvo, Luna, has a total area of 1,761.47 hectares.

The topographic feature of the area is undulating to moderately rolling uplands, where the rain water flows off readily, and nearly flat upland where the run-off is relatively slow. The internal drainage is fair.

In some areas, especially the hills along the shores of Bacnotan, limestone outcrops are common. The gently rolling uplands are usually covered with ipil-ipil and madre cacao. The nearly level to slightly undulating areas are planted to upland rice, maguey, papayas, and pineapples.

A typical Bolinao clay loam profile studied in Barrio Lingsat, San Fernando, is described as follows:

Bolinao clay.

Depth or soil. cm.	Characteristics.
0–25	Reddish brown, fine granular slightly compact clay. Consistency varies from sticky, plastic, friable to hard with decreasing moisture content. Roots penetrate easily and are abundant in this layer. Limited amount of well-decomposed organic matter. Boundary between this and the layer below is wavy and clear.
25–90	Reddish brown fine to coarse granular clay heavier in texture than the above layer, intimately mixed with yellowish gray to brownish gray partially weathered coralling limestone. Very few roots go beyond 30 centimeters deep. Boundary is gradual.
90–120	Bed rock of coralline limestone.

Mountain soils undifferentiated (*45*).—The soils of the roughly mountainous regions (Plate 9, fig. 1) along the eastern border of La Union, which are difficult to survey because they are hardly accessible and therefore of no immediate agricultural value, are classified as undifferentiated soils. They cover 28,722.57 hectares, which is 20.92 per cent of the total area of the province. Most of the areas are in forest. The cleared areas are cogonal lands.

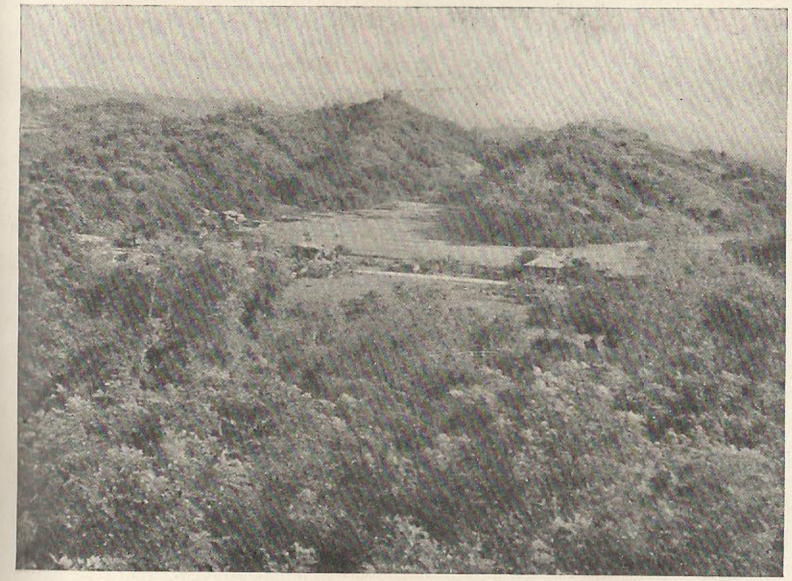

FIG. 1. A portion of San Fernando (looking South). Low-lying hills in the foreground and background are covered with second-growth forest. This is typical of the Annam series.

FIG. 2. Rabon, Rosario (looking Southwest). This hilly region is characteristic of the landscape of the San Fabian series.

PLATE 8

BAUANG SERIES

The soils of the Bauang series consists of loose to fairly compact, fine to coarse granular, light brown, yellowish brown to reddish brown surface soils and clay loam to clay subsoils. The substratum consists of highly weathered stratified high-lime shales, and sandstones cubical to hexagonal in shape. They are easily shattered and become powdery when pulverized. The stratified shales are found in many angles, ranging from horizontal to 90 degrees. The thickness of the strata varies from a few centimeters to two meters (Plate 11, fig. 1). The stratification of this parent material is the distinguishing feature of this series.

This series is the largest in the province (Plate 9, fig. 2; Plate 10, figs. 1 and 2). The general topographic features consist of the rolling uplands, hilly, and mountainous areas. In fact, nearly all the hills and mountains of this province belong to this series. External and internal drainage is good to excessive. During the dry season of the year this soil is so dry that cogonal areas easily catch fire. The vegetative cover of the area is generally cogon grass. In the cultivated areas, rice, corn, bananas, vegetables, and fruit trees are grown. Boho bamboo is a characteristic vegetative cover in rough rolling areas.

Because of the loose characteristic of the surface soil, accelerated erosion has made headway. There is only one soil type classified in this series.

Bauang clay (*121*).—The surface soil of this type ranging in depth from 10 to 35 centimeters is brown to light brown, very friable, loose, and coarse granular to slightly cloddy clay. In the badly eroded areas, the surface soil is sandy in texture. The subsoil consists of highly weather yellowish brown high-lime shales ,and sandstones. This usually crumbles easily into roughly cubical-shaped particles ranging in size from 10 to 50 millimeters in width. The depth of the subsoil varies from 60 to 100 centimeters from the surface soil. The substratum consists of stratified high-lime shales and sandstones. The stratification varies from horizontal to vertical in position.

The important crops grown on this type are upland rice, coconuts, bananas, maguey, fruit trees, and vegetables. Boho bamboo is found in rugged and desiccated areas. Areas that are not cultivated are either cogonal land or covered with forest or second-growth forest. The area covered by this type is

54,955.60 hectares representing 40.05 per cent of the total area of the province.

A typical profile of this type studied in Santol is as follows:

Bauang clay.

Depth of soil.	Characteristics.
0–35	Light yellowish brown to brown, slightly compact, coarse granular to cloddy clay. Hard when dry; becomes friable, plastic and then sticky as the moisture is increased. Fair amount of organic matter. Roots very abundant down to 30 centimeters. Boundary between horizons gradual.
35–60	Highly weathered yellowish brown high-lime shales and sandstones. Crumbles into roughly cubical sharp-edged particles 1 to 50 millimeters on an edge. Some of the particles that are further weathered exhibit exfoliation.
60–150	Alternate layers of yellowish brown shales and sandstones.

BURGOS SERIES

The soils of the Burgos series consist of dark brown, reddish brown to brownish red, friable, and granular surface soils underlain by slightly granular and friable clay loam to clay subsoils. The substratum consists of friable clay loam to clay with occasional fragments and boulders of igneous rocks especially andesites and basalt. The depth of the surface soil varies from 20 to 30 centimeters, while the subsoil is 45 to 60 centimeters from the surface. The boundaries are diffused. Coarse skeleton is practically absent except in the substratum.

The topographic feature of the series is generally hilly and mountainous dissected by several deep ravines and rivers. Because of the rough mountainous terrain, terraces are constructed for rice production. Steep hillsides are planted to bananas, camote, cassava, and corn.

The natural vegetative cover is generally cogon grass, but at high altitudes the dominant vegetation is forest trees of the dipterocarp type. On still higher elevations pine trees dominate.

This series is similar to the Baguio series established by Pendleton and Aquino (29) in the Bokakeng Forest Area, Mountain Province. There is only one type classified in this province.

Burgos clay (151).—This type covers an area of 10,137.72 hectares, which is 7.38 per cent of the total area of the province. It occupies the mountains east of Naguilian and the areas around Burgos municipality, up to the mountainous western border of Mountain Province.

FIG. 1. Difficult of access and of no immediate agricultural importance this heavy-forested region of La Union along the eastern border is designated as Mountain soils, undifferentiated.

FIG. 2. Bagulin (looking Northwest). Gently sloping hillsides are terraced and planted to lowland rice.

The internal drainage is good, but the external drainage is excessive. In cultivated areas erosion has made headway. However, in terraced hillsides where rice is planted erosion is not a problem.

A profile examined at Burgos is described as follows (Plate 11, fig. 2):

Burgos clay.

Depth or soil. cm.	Characteristics.
0–20	Light brown to dark reddish brown, medium coarse granular, fairly compact clay. Friable when dry but sticky when wet. Moderate organic matter is present. Boundary is diffuse.
20–45	Slightly lighter in color than the surface soil, coarse granular, friable to sticky clay loam to clay. Few roots penetrate this horizon. Boundary is diffuse.
45–90	Same as above with some highly weathered fragments of igneous rocks such as basalts and andesites.
90–below	Consolidated bedrock of basalt.

MISCELLANEOUS LAND TYPES

Lands which possess little or no definite soil characteristics are all included in this group.

Hydrosol(1).—These are areas under water most of the time (Plate 11, fig. 3). They are found in patches, too small in most cases to be delineated, all along the coast near the mouths of big streams. When the areas are extensive, as in the vicinities of San Fernando and Sto. Tomas, they are converted into fishponds (Plate 11, fig. 4). The vegetation is usually made up of nipa and mangrove. The soils in the fishponds are a mixture of sand, silt, and a small amount of clay. In places where the Bolinao series predominate, the subaqueous horizons of the hydrosol consist of a mixture of silt, clay, and fragments of marine shells and coralline limestone. The aqueous horizon is usually brackish and varies in depth from 5 to 100 centimeters.

Beach sand(118).—Beach sand designates the areas all along the coast covered with marine deposits of sand. These areas vary in width from 10 to 500 meters (Plate 12, fig. 1), the widest portions occurring in Barrio Narvacan, Sto. Tomas, and in San Juan, Bacnotan, and Luna. In San Juan and Luna the dry beach sand has been redeposited by the wind into mounds and ridges called sand dunes. There is very scarce vegetative cover (Plate 12, fig. 2).

Gravel deposits (*149*).—This is an extensive deposit of gravel and pebbles which covers the coastal areas of the barrios of Victoria and Magallanes, Nalvo, and Barrientos, Luna (Plate 12, fig. 3). This deposit has accumulated on the beach by the action of the surf and the waves. The gravel is used as material for road surfacing. At about 1 to 2 kilometers inland the gravel is intimately mixed with soil material. Although these areas are difficult to till, they are planted to rice, sugar cane, and vegetables.

River wash (*152*).—A considerable amount of level agricultural land is lost in the river beds. During the rainy season the water from the mountains rushes down into the comparatively short rivers and curves out into wide channels. But during the dry season there are only small easily forded streams, flowing through the beds which are then wastes of stone and sand 1 to 5 kilometers wide (Plate 12, fig. 4). In limited areas enough silt and clay is deposited to permit cultivation during the dry season.

GENESIS OF LA UNION SOILS

"Soils are mixtures of fragmented and partly or wholly weathered rocks and minerals, organic matter, air, and water in greatly varying proportions, and have more or less distinct layers or horizons developed under the influence of climate and living organisms. The cross section of horizons from the surface to the parent material is known as the soil profile. The degree of profile development is dependent on the intensity of the activity of the different soil-forming factors and on the length of time they have been active. Soils are dynamic in character—they are constantly undergoing change—but they normally reach a state of near equilibrium with their environment, after a long period of exposure to a given set of conditions" Bryers et al. (8)

The five factors of soil formation are (1) parent material, (2) climate, (3) biological activity (living organisms), (4) relief, and (5) time. These soil-forming factors are interdependent, each modifying the effectiveness of the others.

The parent material of La Union soils consists mainly of primary materials derived from the weathering of rocks in place, and secondary material or materials removed from its original position and deposited on upper and lower river terraces, valleys, and flood plains. The primary soil materials

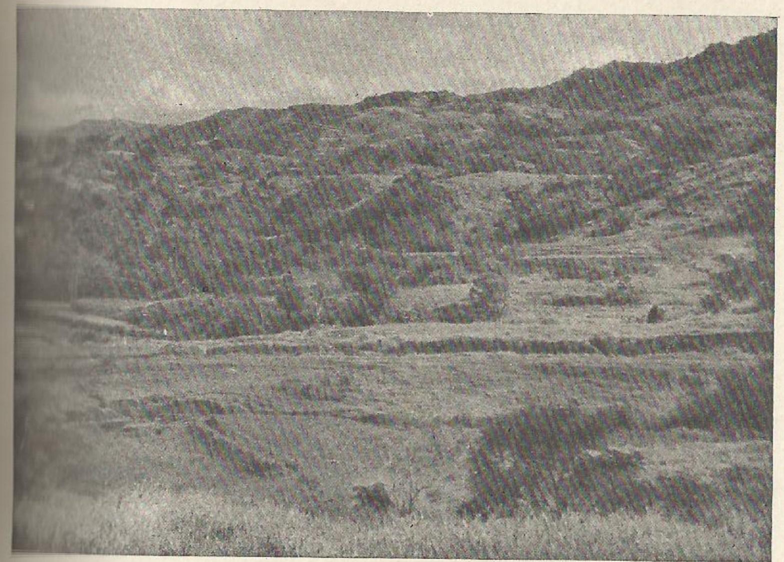

FIG. 1. Santol (looking Southwest). The soils of these hills belong to the Bauang series. Most of the area is denuded of trees and is now covered with cogon.

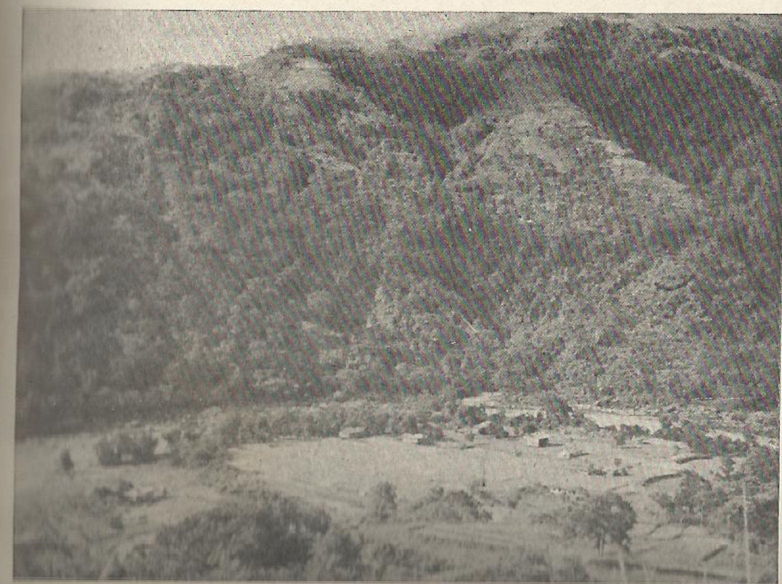

FIG. 2. Bagulin lies on a small river valley (looking North). The soils of the mountain in the background is of the Bauang series. It is covered with forest of the dipterocarp type.

PLATE 10

include those derived from the andesitic rocks underlying the Burgos area; those derived from the Tertiary sediments of limestones, shales, sandstones, and conglomerates found on most of the hills and mountains of La Union; and those from the raised coralline limestone rocks along the coast. The secondary soil materials include alluvial materials derived from the upland soils that have been formed from the primary soil materials.

Climatic elements such as rainfall, temperature, and relative humidity bring about certain physical, chemical and biological processes which act on soil materials so modifying them that after a considerable period the natural media for plant growth, we call soil, is formed. The vegetation of the province besides the forested area consists of second-growth forest, cogon grass, and permanent fruit trees. The topography of the province is generally rolling to hilly and mountainous, except for a narrow coastal plain.

The soils of La Union due to the diversity of the factors involved in their formation vary greatly in their characteristics as reflected in their profile development.

Storie, of the University of California, classified California soils into nine profile groups based on topography, mode of formation, and the kind of profile. Based upon the same method of classification, La Union soils fall under five of the nine groups set up by Storie as follows:

- Profile Group II
  - San Manuel sand
  - San Manuel silt loam
  - Umingan clay loam
- Profile Group III
  - Maligaya clay loam
  - Barcelona clay
  - Bigaa clay loam
  - Sinapangan clay
- Profile Group VI
  - San Fabian clay loam
- Profile Group VII
  - Burgos clay
- Profile Group VIII
  - Bauang clay
  - Annam clay loam
  - Bolinao clay

Profile group II includes soils on young alluvial fans, flood plains, or other secondary deposits underlain by unconsolidated material. Soils belonging to the San Manuel and Umingan series have been derived from materials deposited by flowing waters. That there have been variations in the rate of flow of these running waters due to changing slopes, is indicated by the different sizes of material deposited as shown in the profile which ranges from silt to cobblestone.

Profile group III includes soils on older alluvial fans, alluvial plains or terraces having moderately developed profiles (moderately dense subsoils) underlain by unconsolidated material. Soils of this group include the Maligaya series, Barcelona series, Bigaa series, and Sinapangan series which have moderately compact subsoils. Their parent materials have been deposited by comparatively slow moving waters for long periods of time as shown by their fine texture and great depth. The denser subsoils show that the processes of alluviation have been going on for some time.

Profile group VI is represented only by one soil type, the San Fabian clay loam, which lies on older coastal terraces and upland areas having dense clay subsoils resting on moderately consolidated material. This soil developed from soft chalklike rock under parang type of vegetation.

Soils belonging to Profile group VII are on upland areas developed on hard igneous bed rocks. Soils of the Burgos series are classified under this group. They have developed from the andesitic rocks found on the mountainous region around Burgos. The surface soil is fairly deep, being 15 to 20 centimeters. The red color of the soils is characteristic of Philippine soils formed under similar topographic and climatic features like the Antipolo soils of Rizal and the Luisiana soils of Laguna. All these soils have been derived from hard consolidated rocks.

Profile group VIII is represented by the Bauang series, the Annam series, and the Bolinao series. These are soils on upland areas developed on consolidated sedimentary rocks. Bauang clay has been derived from alternate layers of sandstones and high lime-shales found on most of the mountainous regions of La Union. Closely associated with it is the Annam clay loam which has been developed from conglomerates. On some of the hilly areas near the coast Bolinao clay has developed from the underlying hard and compact coralline limestone.

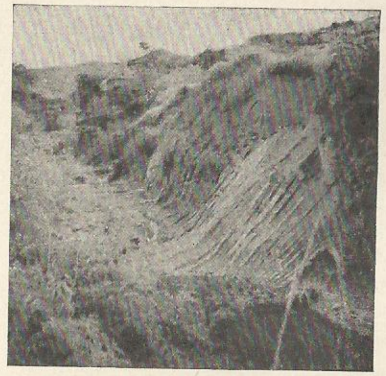

FIG. 1. A dry river bed at Rosario exposes alternate layers of sandstone and shale. Note the sandstone layers that stand out prominently.

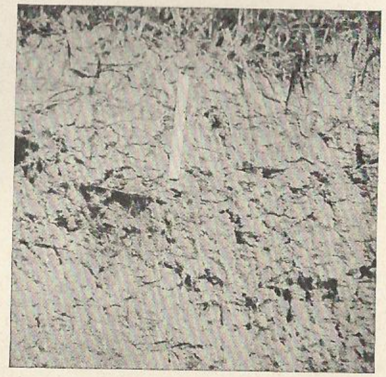

FIG. 2. Burgos clay profile exposed by an excavation at Burgos. Note the coarse granular structure of the surface soil and subsoil.

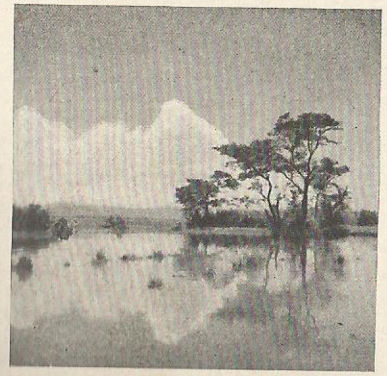

FIG. 3. A swampy area along the coast at Luna designated as hydrosol. The native vegetation is mangrove and nipa.

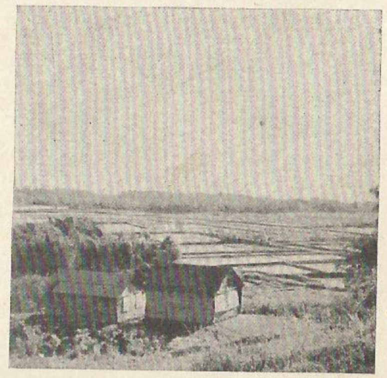

FIG. 4. At Carlatan, San Fernando, the hydrosol areas have been converted into fishponds.

PLATE II

Mechanical analyses of the four soil types (Table 16) representing the four soil series established in La Union shows that the soils contain a high percentage of clay. Sinapangan has the lowest with 35.09 per cent and Burgos the highest with 65.45 per cent. The high clay content of these soils is due mainly to the influence of the parent rocks. Sinapangan, Barcelona, and Bauang series have interbedded shale and sandstone as their parent rock, while Burgos has igneous rocks, mostly andesites. Sinapangan and Barcelona are secondary soils derived from the upland soils of the area, the Bauang clay. Together with the soils of the upland are highly weathered shale and sandstone and finely ground rocks. All these are deposited by the streams and from which were developed the Sinapangan and Barcelona series. The Bauang soils are of primary origin derived from the weathering of the interbedded shale and sandstone. These strata contain more shale than sandstone which on weathering give a large amount of clay. Burgos clay is a primary soil derived from the weathered igneous rocks, mostly andesites.

TABLE 16.—*Mechanical analysis and pH values*[a] *of four new soil series established in La Union Province.*[b]

Soil type and laboratory number.	Depth of horizon.	pH value.	Sand per cent.	Silt per cent.	Clay per cent.
	cm.				
Sinapangan clay:					
225 ss	0- 60	6.77	17.74	47.17	35.09
226 ss	60-100	7.09	15.77	26.92	57.31
227 ss	100-200	7.30	33.21	30.02	36.77
Bauang clay:					
248 ss	0- 15	6.44	25.56	28.20	46.24
249 ss	15- 90	highly weathered shale			
250 ss	90-150	highly weathered shale			
Barcelona clay:					
271 ss	0- 35	6.49	16.86	29.30	53.84
272 ss	35- 65	6.67	15.52	36.10	48.38
273 ss	65-100	7.00	16.26	37.38	46.63
274 ss	100-150	7.08	20.00	18.69	61.31
Burgos clay:					
297 ss	0- 20	5.26	14.40	20.15	65.45
298 ss	20- 90	5.48	13.39	20.18	66.43
299 ss	90-150	5.07	14.56	21.07	64.37

[a] pH determined by Mr. Severino B. Etorma of the Soil Research Laboratory Section, Division of Soil Survey and Conservation.

[b] Mechanical analysis conducted by Mr. Isaac Aristorenas of the Soil Survey Section, Division of Soil Survey and Conservation.

The pH values (Table 16) of the surface soils of the four soil types are all below pH 7. The acid reaction of the soils may in large measure be due to the prevailing climate in the province. Leaching of the soils has removed the soluble bases, such as calcium, magnesium, potassium, and sodium. During the rainy season when heavy precipitation occurs a great amount of these bases is removed. Removal of these bases will cause the soil to be acid.

PRODUCTIVITY RATINGS OF LA UNION SOILS

The central objective of all soil studies is, as Kellogg (16, 17) puts it, "to determine the kind, yield, and quality of plants that can be produced under alternative, physically defined systems of management on the various types of soils and the influence of these systems upon the long time productivity of the soil types."

The work on productivity rating started by C. F. Marbut and C. P. Barnes early in 1933 represents the most important approach towards the attainment of this objective. A soil productivity rating designates in a single index figure the combined effects of many soil characteristics. It summarizes for a given soil type the effect on yield of surface and subsoil texture, of depth of surface soil, of fertility, reaction, topography, and drainage.

The use of productivity rating is still in the developmental stage, but significant strides have been made and a number of states of the United States, notably North Carolina, New York, Ohio, and Iowa have included productivity ratings in their reports.

The rating compares the productivity of each soil for each crop to a standard of 100. This standard index represents the approximate average hectare yield obtained without the use of fertilizers and other amendments on the more extensive and better soil types of the region in which the crop is most widely grown. Soils given amendments, such as lime or commercial fertilizers, or unusually productive soils of small extent may have productivity rating of more than 100 for some crops.

The crop productivity index is based on observations on the field; interviews with local farmers; information given by the municipal agricultural inspectors, provincial agricultural supervisors, specialists, and others experienced in the agriculture of the region; and data obtained from government publications. Because there are no crop yield data by soil types available the index represents estimates of yield rather than yield records.

FIG 1. The coastal beach which is widest at Sto. Tomas is 500 meters wide. The highest of the two ranges in the background is Mt. Sto. Tomas.

FIG. 2. Along the coast at Luna, the dry beach sand has been redeposited by the wind into mounds called sand dunes. Vegetative cover is very sparse.

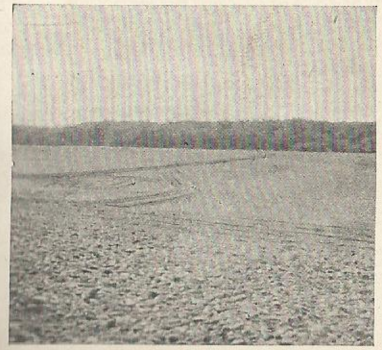

FIG. 3. At Luna there is an extensive deposit of gravel which covers the coastal areas of the barrios of Victoria, Magallanes, Nalvo, and Barrientos.

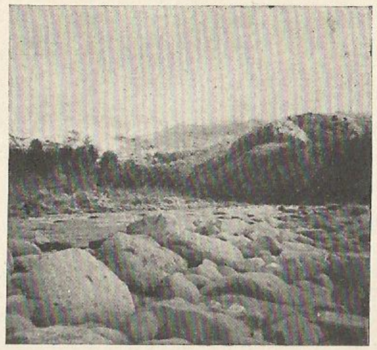

FIG. 4. During the dry season, most of the river beds are wastes of stone and sand, sometimes more than one kilometer wide. The picture shows one of the tributaries of the Naguilian River.

The productivity ratings of the different soils for these crops are shown in Table 17. The ratings in this table do not present the relative roles which soil types play in the agriculture of the province because of their extent and pattern of their distribution. The table gives only a general characterization of the productivity of individual soil types. Their total production of crops by soil areas cannot be pictured without additional information or knowledge of the hectarage of individual soil types devoted to such crops. No economic consideration has been placed in the determination of the ratings and therefore, these cannot be interpreted directly into land values, except in a very general way. Such factors as distance to markets, good roads, relative prices of the farm products, cost of production, and other factors that influence the value of the land have not been taken into consideration in these ratings.

TABLE 17.—*Productivity ratings of the soils of La Union.*[a]

Soil type [c]	Crop productivity index for [b]—									Remarks.
	Lowland rice.	Upland rice.	Tobacco.	Corn.	Coconut.	Sugar cane.	Camote.	Cassava.	Mungo.	
Bigaa clay loam	110	------	95	95	85	85	80	85	85	First class.
San Manuel silt loam	90	------	95	100	100	85	75	100	90	Do.
Umingan clay loam	80	------	90	110	95	90	80	85	80	Do.
Sinapangan clay	80	------	80	75	75	80	70	70	70	Second class
Bolinao clay	------	85	------	70	------	60	75	85	------	Do.
Burgos clay	------	70	------	------	------	------	80	95	------	Do.
San Manuel sand	45	------	------	50	105	------	------	------	------	Do.
Maligaya clay loam	70	------	85	70	65	75	70	70	75	Do.
Bauang clay	------	80	------	55	60	70	75	70	------	Do.
Barcelona clay	70	------	75	65	70	75	65	65	75	Third class.
San Fabian clay loam	------	70	------	50	------	60	70	60	------	Do.
Annam clay loam	------	60	------	------	------	------	50	70	------	Do.

a Absence of an index number indicates that the crop is not commonly grown on that particular soil type.

b Index for the different crops is given below.

c Classified according to productivity ratings.

Under present system of management the average yields per hectare of the following crops have been established as standards of 100:

Lowland palay	60 cavans per hectare.
Upland palay	20 cavans per hectare.
Tobacco	1,475 Kg. per hectare.
Corn	17 cavans per hectare.
Coconut	3,750 nuts per hectare.
Sugar cane	80 piculs sugar per hectare.
Camote	8 tons roots per hectare.
Cassava	13 tons roots per hectare.
Mungo	7 cavans per hectare.
Pineapple	7,500 fruits per hectare.

It must be known that the productivity rating as measured by yields of crops is not the only consideration that determines the relative worth of the soils for the crops. The ease or dif-

Owing to the foregoing poor farm-management practices, a marked decrease in crop yields every year has been reported by farmers. The farmers, however, believe that the low crop yields is due to insufficiency of soil moisture. There is no doubt that this is one cause, but there are many other contributing factors to the continued decreasing crop production. However, the fact cannot be overlooked that present soil-management practices are very faulty. Most farmers are so conservative that they stick to their old methods of farming which ordinarily consist of growing on the same land year in and year out soil depleting crops, such as rice, corn, or tobacco.

As a rule, after the rice is harvested the lands are left uncultivated until the next rice planting season. This system of farming is repeated every year without giving the land any means of replacing the plant-nutrients removed by the crops every year. The growing of certain soil improving crops, such as mungo, peanut, or soybean, which can be rotated with rice should be given immediate attention. These legumes fix atmospheric nitrogen in the root nodules and will greatly improve the organic matter content of the soil, especially when plowed under as green manure.

As yet there has been no study on the fertilizer requirements of the major soil types of La Union Province for the different crops grown in them. Heretofore, certain studies have been conducted on the fertilizer requirements of rice in some soil types in the Provinces of Nueva Ecija, Bulacan, Pampanga, and Tarlac. At best in the absence of data for La Union soils the work in these provinces may be used as guide especially in soils of the same or similar types delineated in La Union Province.

CONTROL OF RUN-OFF ON THE LAND

One of the problems in agriculture confronting the farmers of today is the control of water on the land, the neglect of which adversely affects to a considerable extent the productive capacity of the land. Failure to control the amount of water in the soil and the run-off on the land will not only result in poor crop returns but also increased soil erosion. The detrimental effects of soil erosion to every farmer, to the community and to the nation, are now well known and have been thoroughly discussed and illustrated in many papers.[a] It is

[a] Selga, Miguel, S. J. Observation of Rainfall in the Philippine Weather Bureau our Republic. D.A.N.R. Special publication (1948) 1-48. Alicante, M. M., and P. Mamisao. Methods of Conservation Farming. D.A.N.R. Tech. Bull. 17 (1948).

thus sufficient to mention here that every citizen should give the question serious thought and consideration.

Any effort exerted to control run-off on the land will give the dual effects of conserving both soil and water. The regulated removal of excess water by proper drainage will save the soil from washing and improve the productivity of the land. The regulated application of water on the land to satisfy the water requirements of the crops grown in a given soil type will produce a good vegetal cover on the land, which means not only better crop production but also better vegetal cover against soil erosion. The impounding of run-off water after heavy rains in natural depressions, or reservoirs which have been constructed for the purpose, will solve irrigation problems of the place.

Water is the most active agent of soil erosion in La Union Province. Soil erosion in this province is accelerated by incorrect land use and poor soil-management practices. The intensity of rainfall during the three or four months of rainy period is such that the plowed lands and the bare lands are easily eroded.

Large portions of the upland areas of La Union are greatly affected by soil erosion, not only because of irregular topography which is generally rolling, hilly, and mountainous, but because they are in most parts devoid of effective forest cover. Where the land is open, it is either in cogon grass or cultivated to some clean-cultured crops like rice and corn. The cultivated portions under the kaiñgin system of farming are usually abandoned after a couple of years, leaving the land to the washing action of the rain. Bauang clay loam is the biggest soil type seriously affected by erosion. It has a loose, friable surface soil and subsoil. It is not uncommon to see slopes greater than 30 per cent cleared and cultivated. While the other soil series in the uplands are not as susceptible to soil erosion as the Bauang series owing to a much better physical condition, they show evidence of erosion because of improper agricultural practices.

It is evident from the above findings on the erosional condition in La Union Province that the run-off should be controlled, not only to prevent soil erosion but also to conserve more water in the soil and in reservoirs for the sustenance of crops during the dry season. Reforestation in the steep slopes is badly needed. Such a step will not only return valuable timber from La Union Province, but will also provide the land with beneficial vegetal cover to regulate the flow of run-off. The moderate slopes which are used as croplands should be tilled employing suitable soil-conservation and soil-management practices so as to provide effective measures to regulate the flow of the run-off, thus preventing soil erosion and conserving soil moisture.

IRRIGATION

Rice is the principal crop of La Union. The culture of this cereal requires considerable amount of water. In many cases water becomes the limiting factor in rice production. Irrigation alone will double the yield of rice in many farms. In Bulacan and Pampanga an average of fifty cavans per hectare has been maintained for 20 years with the use of irrigation alone. In La Union the average production of irrigated fields is 33.3 cavans per hectare, while the nonirrigated fields average only 16.6 per hectare. At present only one-third of the irrigable lands of the province has been brought under cultivation pending completion of irrigation projects.

In 1912 the Philippine Assembly passed Act No. 2152, providing, among other things, the construction and maintenance of irrigation systems. This constituted the fundamental Irrigation Law of the land. In 1922 Act No. 2940 was passed, authorizing ₱20,000,000 bond issue as a revolving fund to finance the construction and maintenance of large irrigation systems. By the end of 1930, twelve large irrigation systems and three small ones had been constructed, serving 85,000 hectares of rice lands in 12 provinces of the Philippines.

The Amburayan Irrigation System in La Union is one of the 15 systems established by the Philippine Government through the ₱20,000,000 bond issue. The construction of this system, which includes 119.3 km. of canals, was finished in 1926 at a cost of ₱1,163,397. It irrigates 3,700 hectares of rice land representing 17.6 per cent of La Union's irrigable land of 21,000 hectares. The municipalities served are Sudipen, Bangar, Balaoan, and Luna. (See map in pocket.)

To supplement rain water, the farmers have established communal irrigation systems. They banded together, acquired water rights and built their own irrigation works through communal labor and funds apportioned among the members. Due to lack of funds and the necessary technical skill required in

building such projects, these communal irrigation systems are not so efficient as they ought to be. The farmers still lack water. During the soil survey of La Union, the survey of streams for purposes of irrigation was conducted with emphasis on possibilities of small irrigation projects. The construction of a number of such systems will go a long way towards solving La Union's rice shortage.

In 1947 government help was again extended to the farmers in the form of pork-barrel funds. With these funds and the technical assistance of the Bureau of Public Works personnel, irrigation water will be supplied to 4,605 hectares of rice lands. The systems to be constructed or improved are the following: Taragontong in Balaoan municipality; Paagao in Santol; Tankigan and Sevilla in San Fernando; Ayaoan Oeste in Luna; Quinabang in Bacnotan; and San Felipe, Sasilangan, and Bambanay in San Juan. It is hoped that the chain of communal irrigation systems will ease considerably the shortage of rice in the province.

CHEMICAL CHARACTERISTICS OF LA UNION SOILS

The soil survey of Philippine soils as carried out by the Division of Soil Survey and Conservation at present involves morphologic, genetic, and cartographic studies in the field, and laboratory investigations on the physical, chemical, and biological characteristics of the soil. The laboratory studies, especially those on the chemical properties, are distinct aids not only in tracing the genetic relationship of soils and parent materials and in studying the process of soil formation, but also in the laying out of the program for farm management and cropping system. Thus, comprehensive chemical studies reveal: (*a*) the reaction of the soil type which is a guide for determining the natural crop adaptability of the soil type, (*b*) the inadequacy, sufficiency, or excess of nutrient elements required by plants for their metabolism; (*c*) what toxic substances are present or what elements exist in toxic concentrations; and (*d*) the fertilizer requirements of the soil type for an increased crop production.

Plants need in relatively large amounts the essential elements carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, and iron. Very small quantities of boron, copper, manganese, and zinc have been found to be necessary also in the life processes of plants. The latter group of elements have been termed trace or rarer essential elements, because they are needed by plants in such minute quantities as one-fourth part per million in the soil solution. Of all the aforementioned fourteen essential elements, only three, namely, carbon, hydrogen, and oxygen, are derived by plants from the air and water, and the rest, from the soil. Deficiency of any one of the essential plant-nutrient elements in the soil adversely affects the quality and quantity of crop yields.

Tillage and cropping tend to deplete the natural supply of the essential nutrient elements in the soil, but the elements that usually become critical or inadequate in amounts first are nitrogen, phosphorus, and potassium. To replenish the supply or to replace what the crops take in from the soil and that lost through leaching or erosion, the application of manures and commercial fertilizers becomes necessary.

Excessive soil acidity which usually means deficiency in calcium and in magnesium is generally remedied with the addition of ground dolomitic limestone to the soil. A recent innovation in fertilizer manufacture is the incorporation of the rarer or trace elements in the mixing of certain brands of commercial fertilizers, in order to correct deficiencies of these elements in the soil.

METHODS OF CHEMICAL ANALYSIS

Total chemical analysis was followed for nitrogen to determine the potential amount of this important plant-nutrient element which under favorable conditions becomes available to plants faster than other essential elements. Preference was given to the determination of replaceable or readily available soil constituents because the results obtained with the rapid or availability tests correlate with plant growth or the response of plants to fertilizer treatment better than those obtained with total analysis.

Selected rapid chemical tests for available plant-nutrient elements found useful abroad are being calibrated under local conditions with actual results of fertilizer and liming experiments conducted in pots and in the field. While comprehensive data on local tests or experiments are not yet available, results of tests abroad are cited for comparison.

Soil reaction or hydrogen-ion concentration of the soils of La Union was determined with the use of a glass electrode pH meter. 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. (6) Ammonia and nitrates were determined by the methods of Spurway. (33) Data on the readily available phosphorus were obtained using the Truog method, (38) as modified by Marfori. (20) Available potassium, calcium, and magnesium were determined according to the methods of Peech and English. (27) For the interpretation of the results on available potassium, reference to the findings of Bray (10) and Murphy (24) was made.

INTERPRETATIONS OF RESULTS OF CHEMICAL TESTS

*Soil reaction or pH value.**—Soil reaction which affects the behavior and availability of plant-nutrient elements as well as those of toxic substances in the soil constitutes a very important limiting factor for plant growth and reproduction. Thus, in soils of high degree acidity or those with very low pH values, aluminum and manganese are rendered so soluble that their concentrations in the soil solution become toxic to the growing plants. On the other hand, in soils of very high alkalinity or those with very high pH values, iron, manganese, copper, and zinc are rendered unavailable to plants which in turn exhibit malnutrition or abnormal growth (Truog). (39)

Different plants have been found to have different optimum soil reaction requirements or pH preferences and different tolerance limits. Table 18 shows the pH requirements of some economic plants. One will note from this table that some plants like rice, pineapple, and tobacco, prefer medium acid

*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.

TABLE 18.—*The pH requirements of some economic plants.*[a]

[x, most favorable reaction; y, reaction at which plants may fare well or normally; o, unfavorable reaction.]

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
Bean, lima (*Phaseolus lunatus* Linn.)	----------	y	x	y	y	----------
Corn, or maize (*Zea mays* Linn.)	y	y	x	x	y	y
Lettuce (*Lactuca sativa* Linn.)	o	y	x	y	o	o
Onion (*Allium cepa* Linn.)	o	y	x	y	y	y
Orange, sweet (*Citrus sinensis* Osbeck) [b]	----------	y	x	x	x	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
Soybean [*Glycine max* (Linn.) Merr.]	y	x	x	x	y	y
Sugar cane (*Saccharum oficinarum* Linn.)	o	y	x	x	x	y
Sweet potato [*Ipomoea batatas* Linn.) Poir.]	y	x	x	y	o	o
Tobacco (*Nicotiana tabacum* Linn.)	y	x	y	o	o	o
Tomato (*Lycopersicum esculentu m* Mill.)	y	y	x	x	y	y

[a] Data taken mostly from Weir, Wilbert Walter. 1936. Soil Science, its principal and practice. J. B. Lippincott Co., Chicago and Philadelphia.
[b] From Spurway, C. H. 1941. Soil Reaction (pH) preferences of plants. Mich Agr. Expt. Sta. Sp. Bul. 306. Optimum range given was pH 6.0–7.5.

soils (pH 5.5 to 6.1), while other species like alfalfa, sugar cane, and orange prefer slightly acid to slightly alkaline reaction (pH 6.2 to 7.8). The pH tolerance limits for the first group of plants mentioned above have been estimated at pH 4.8 to 6.9, while those for the second group are pH 5.5 to 8.5. Certain plants, however, like corn and tomato have rather wide pH tolerance limits (pH 4.8 to 8.5), although their optimum pH requirements are of narrower range (pH 6.2 to 7.0).

Table 19 shows the average chemical analysis of the surface soil of the principal soil types in La Union Province. The soil types are arranged in the order of decreasing productivity ratings for lowland and upland rice (from Table 17) to facilitate the comparison of the data. The productivity ratings for rice were chosen from among the different crops presented in Table 17, because rice (either lowland or upland) is grown in all the soil types; it is the most important crop of the province and because, in the soil fertility studies underway at this writing in the Division of Soil Survey and Conservation, rice is used as the main crop indicator.

The pH values of the surface soils of La Union ranged from 5.55 to 7.65. As far as soil reaction is concerned, rice and

other similar acid-tolerant plants can be expected to grow fairly well or normally in all the soil types, except Bolinao clay which had a pH value of 7.65. This slightly alkaline reaction of Bolinao clay is probably due to its rather high available calcium content (Table 19).

The three most productive soil types in La Union, namely, Bigan clay loam, San Manuel silt loam, and Umingan clay

TABLE 19.—*Average chemical analysis of the surface soil of the soil types in La Union Province (arranged in the order of decreasing productivity ratings for lowland palay.)*[a]

Soil type	Productivity ratings for lowland rice (100=60 cav./Ha.)	pH value	Total nitrogen (N)
			Per cent
Bigaa clay loam	110	6.95	0.10
San Manuel silt loam	90	6.43	0.09
Umingan clay loam	80	6.74	0.11
Sinapangan clay	80	6.55	0.09
Barcelona clay	70	6.78	0.09
Maligaya clay loam	70	6.35	0.08
San Manuel sand	45	6.45	0.02
Bolinao clay	[b] 85	7.65	0.18
Bauang clay	[b] 80	6.43	0.10
San Fabian clay loam	[b] 70	6.95	0.08
Burgos clay	[b] 70	5.55	0.12
Annam clay loam	[b] 60	6.10	0.10

Soil type	Available constituents in parts per million (p.p.m.): Ammonia (NH_3)	Nitrates (NO_3)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)
Bigan clay loam	10	2	140	118	6,360	1,760
San Manuel silt loam	10	2	100	159	6,180	1,160
Umingan clay loam	2	5	97	273	5,480	1,180
Sinapangan clay	2	2	90	107	6,720	1,760
Barcelona clay	2	2	39	148	6,720	1,940
Maligaya clay loam	2	2	31	149	4,200	3,600
San Manuel sand	2	2	82	264	1,320	640
Balinao clay	2	10	18	139	38,625	740
Bauang clay	2	2	35	143	8,000	1,940
San Fabian clay loam	2	2	20	88	6,880	5,400
Burgos clay	2	2	8	255	1,420	1,500
Annam clay loam	2	2	20	134	4,500	1,400

[a] Productivity ratings as reported by the fieldmen who identified and classified the soil types (table 17).
[b] Productivity rating for upland palay, lowland palay being not commonly grown on this soil type. For upland palay, rating of 100 = 20 cavans per hectare.

loam have been rated in productivity for corn from 95 to 110 (Table 17). This is possible so far as soil reaction of these soil types is concerned, which varied from pH 6.43 to pH 6.95, because the optimum pH requirement of corn is pH 6.2 to pH 7.0.

Nitrogen.—A constituent of the protoplasm of every living cell, nitrogen is vitally needed for growth and reproduction by both plants and animals. In plants nitrogen is used largely in their vegetative growth, although it functions also in the development of fruits, grains, and seeds. An ample supply of available nitrogen in the soil may stimulate plant growth and hasten maturity, but the presence of excessive amounts tends to cause excessive vegetative growth and delay in maturity. In soils sufficient in nitrogen plants produce dark green leaves, while in those deficient in nitrogen, chlorosis or yellowing of the leaves develops and in advanced or severe cases, stunted growth results.

Besides delaying the maturity of crops, excessive supply of nitrogen in the soil causes other adverse effects such as: (*a*) Lodging in rice, wheat, oats, and other small grains, (*b*) decreased resistance of plants to diseases, (*c*) lowering of the purity of cane juice in the case of sugar cane, and (*d*) decreased tensile strength of bast fibers in fiber plants. However, for certain crops like leafy vegetables and forage grasses where succulence is desirable, an abundance of nitrogen in the soil is doubly an asset.

Soil nitrogen is found chiefly in the organic matter, which consists of the decaying plant and animal residues and the complex substances synthetized by 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; its conversion first into ammonia, then into nitrites, and finally into nitrates. For the production of nitrates through nitrification, moist warm soils which are well aerated, the proper microorganisms and a sufficient supply of nitrogenous organic matter are needed.

It is known that most plants assimilate their nitrogen from the soil as nitrates, while rice and other members of the grass family can absorb ammoniacal nitrogen. In the latter form, 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 the use of commercial fertilizers to correct the nitrogen deficiency of the soil, the choice of the kind of nitrogen-carrier will depend on the cost of the fertilizer and its application, and the crops grown. For short-season crops such as vegetables where immediate effect is desired, nitrates are preferable to ammoniacal nitrogen. In combination with calcium or sodium, nitrates tend to reduce soil acidity, while the ammoniacals generally increase soil acidity. However, for long-season crops like sugar cane, and irrigated crops

like rice, ammoniacal nitrogen is preferable to nitrate as far as efficiency and lower cost are concerned. The average total nitrogen content of Philippine cultivated soils so far analyzed in our laboratory was about 0.14 per cent. With this as basis, it can be seen from Table 19 that, with the exception of Bolinao clay which has a total nitrogen content of 0.18 per cent, the principal soil types identified and studied in La Union Province are generally low in total nitrogen contents, varying from 0.02 to 0.12 per cent.

In spite of its relatively high available phosphorus and potassium contents, San Manuel sand has very low productivity ratings for rice, 45, and corn, 50, (Table 17). Its very low total nitrogen content (0.02 per cent) may account for this very low productivity.

With the methods of Spurway for determining both ammonia and nitrates, 2–5 parts per million (p.p.m.) of soil are considered low, 10–25 p.p.m. as medium or normal supply, and 100 p.p.m. or more as very high or excessive. Low ammonia tests accompanied with a medium or normal supply of nitrates are normal for many soils where nitrification proceeds to completion, or where the ammonia is converted into nitrites and then into nitrates right away. Low tests may also mean that the ammonia is used up by plants as fast as formed, or that it is fixed in the base-exchange complex of the soil. Comparatively high tests for ammonia may mean that the soil has a high content of decaying organic matter, or that it was recently fertilized with ammoniacal compounds.

To be of some diagnostic value regarding sufficiency or deficiency of nitrogen in the soil, the results of the three nitrogen tests must be interpreted together. Low results with the three tests mean nitrogen deficiency. Low tests with chlorotic and stunted plants are positive indications of deficiency in available nitrogen. High content of ammonia with a low test for nitrates may indicate that some unfavorable soil conditions are interfering with nitrification. Low nitrate tests, however, may also indicate that the nitrate is absorbed by the plant as fast as produced, or that it is lost from the soil through leaching.

Table 19 shows that among the soil types identified and studied in La Union Province, only three, namely, Bigaa clay loam, San Manuel silt loam, and Bolinao clay, may be considered to have a medium or normal supply of available nitrogen. The rest of the soil types had quite low available nitrogen contents. In general, the La Union soils, especially those with high available phosphorus and potassium contents, may be expected to respond to nitrogen fertilization.

Phosphorus.—Like nitrogen, phosphorus is a constituent of every living plant and animal cell. Without phosphorus, cell division cannot take place and, therefore, growth is suspended. Phosphorus is needed in the formation of seeds and has a marked influence on the maturity of crops, especially grain crops. Being needed in the production of nucleo-proteids and fats and albumin, as well as in the conversion of starch into sugar, phosphorus hastens the ripening processes in plants in general.

Plants grown on phosphorus-deficient soils are of inferior feeding value. 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. Another very important effect of phosphorus on plants is the stimulation of the development of the root system. Phosphorus-starved plants have stunted root systems which mean decreased feeding zones.

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

According to the method of Truog,(38) at least 37.5 p.p.m. of available phosphorus are required for good crop yields under Wisconsin conditions for heavier or clayey soils and about 25 p.p.m. for lighter or sandy soils. Truog suggests 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(20) 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 on this subject 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 not be far from the minimum requirement for a good crop of rice.

From Table 19, it may be seen that the four most productive soil types in La Union Province, namely, Bigaa clay loam, San Manuel silt loam, Umingan clay loam, and Sinapangan clay have very high available phosphorus contents, varying from 90 to 140 p.p.m. and that Bigaa clay loam which had been rated highest in crop production has the highest available phosphorus content, 140 p.p.m. Compared with the analysis of the soil types in other provinces so far analyzed, the soils of La Union Province are generally high in available phosphorus contents, with the exception of Burgos clay, which has only 8 p.p.m. of available phosphorus. The low crop productivity ratings (meaning below 90) of most of the soil types of the province, may be ascribed to insufficiency of plant-nutrient elements other than phosphorus, most probably nitrogen. Only a few soil types of the province may then be expected to respond to phosphatic fertilization.

Potassium.—Plants usually need and contain more potassium than any other essential nutrient element derived from the soil. Plant ash usually contains about 40 per cent of potassium as potash (K_2O). Potassium, unlike phosphorus, is not localized in any part of the plant, although 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 by plants of carbohydrates and proteins. 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). (22)

A deficiency of potassium 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, shrunken, or misshaped flowers, pods, fruits, tubers, and roots.

Potassium occurs in both the organic and mineral matter of the soil, but it is found chiefly in the mineral portion and becomes available to plants through solution in soil water, action of weathering, and base exchange. 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 difficulty available or nonreplaceable form, principally 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 a blessing to agriculture, for it is the water-soluble potassium that is easily lost by the soil in drainage or through leaching.

In soils where the base-exchange capacity is rather large and the total exchangeable-base content is low, part or all of the potassium added as fertilizers is fixed in the clay mineral exchange complex and may be considered stored for the future use of plants.

The available potassium contents of the principal soil types in La Union Province were determined according to the method of Peech and English.(27) 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 and only meager results have been so far obtained, the data of Bray(10) and of Murphy(24) for available potassium which were obtained with similar procedures are referred to for estimating roughly the potassic fertilizer requirements of La Union soils. Unpublished results of fertilizer experiments so far obtained showed that a rice soil which contained as much as 132 p.p.m. of available potassium responded to potassic fertilization, while one that had 161 p.p.m. of available potassium gave no crop response to a similar fertilization using a certain variety of rice as the indicator.

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 potassic fertilization. The minimum requirement of replaceable potassium for soybeans was estimated at 100 p.p.m., while that for wheat and oats was about 65 p.p.m. However, he recommends 100 p.p.m. of available potassium as the minimum requirement for the principal Illinois crops to be grown in a 4-year rotation (Linsley).(18)

Murphy(24) found that 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 reports that on Oklahoma soils with 100 to 124 p.p.m. of replaceable potassium, 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 potassic fertilization.

From the findings cited above, it may be tentatively assumed that about 100 to 150 p.p.m. of available potassium is the average minimum requirements of most crops of the province, especially of rice and corn. Table 19 shows that most of the soil types in La Union Province, though not quite high in available potassium content may be considered not deficient in this plant-nutrient element. Some soil types, principally San Fabian clay loam and Sinapangan clay, and even Bigaa clay loam, may be expected to respond to potassic fertilization, especially for fiber crops and sugar cane.

Table 17 shows that Umingan clay loam has the highest productivity rating for sugar cane (90), which requires relatively much more available potassium (about 460 kg. of K_2O per hectare) than those required by other crops (about 132 kg. of K_2O for corn, and about 98 kg. of K_2O for rice) (Handbook of Philippine Agriculture.(4) For corn, Umingan clay loam has also the highest productivity rating (110). The relatively high productivity of Umingan clay loam for these crops may be attributed to the fact that among the soil types of the province, it has the highest content of available potassium (273 p.p.m.).

Calcium.—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. According to Thatcher,(37) experiments with algae have shown that in the absence of calcium salts mitotic cell division takes place, showing that the nucleus functions properly, but the formation of the new transverse cell-wall is retarded. This is one direct evidence that calcium is needed in cell-wall formation. Another is that calcium deficiency in the soil often results in the death of the terminal bud.

Calcium 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.

Besides being one of the essential plant-nutrient elements, calcium performs many important functions in the soil, affecting the latter physically, chemically, and biologically. The calcium content of the soil affects its physical structure. Soil colloids saturated with calcium are flocculated, while those defficient in calcium are generally deflocculated. This is why soils rich in calcium are usually in better tilth, more granular and porous, and less easily puddled than soils poor in this element. Soils with good tilth are easier to cultivate and have better aeration and drainage than those with poor tilth.

As a liming material, calcium neutralizes the acidity of acid soils and corrects the toxic conditions usually caused by soil acidity. Thus, calcium affects the solubility of soil mineral elements as already explained under the topic "soil reaction." Below pH 6.5, the availability of phosphate is very much affected by the calcium content of the soil. In calcium-deficient soils, phosphorus is usually comparatively unavailable to plants although the total phosphate content may be relatively high. Especially below pH 6.0, the tendency to form calcium phosphate, which is soluble in carbonic acid and therefore readily available to crops, decreases and increasing amounts of phosphate combine with hydrated oxides of iron and aluminum, forming compounds with very low phosphate availability. Liming, therefore, not only increases the pH value of the soil, but also increases the availability of phosphorus through the formation of calcium phosphate which has greater availability than the phosphates of iron and aluminum.

In nitrification occurring in the soil, "the oxidation of ammonia to nitrous acid by *Nitrosomonas* and other related species, and of nitrite into nitric acid by *Nitrobacter* is markedly retarded—by soil acidity. This is due to the sensitivity of these organisms to the acidity which develops when the nitrous and nitric acids are not neutralized, as is the case naturally in an acid soil. That is why the application of lime to distinctly acid soils often greatly stimulates nitrification and thus the production of readily available nitrogen."—Truog. (39)

Among the many soil types analyzed so far for available calcium by the Peech and English method in our laboratory, those that rated high in crop productivity gave about 2,000 to 6,000 p.p.m. of available calcium on the average. A rather low content of available calcium and a quite low pH value indicate the need for liming the soil especially for such "high-lime" crops as sugar cane, alfalfa, and other legumes. Referring to Table 17, the

soil types of La Union which gave fairly high productivity ratings for sugar cane (85 to 90), and mungo (80 to 90), are Bigaa clay loam, San Manuel silt loam and Umingan clay loam. The available calcium contents of these soil types varied from 5,480 to 6,360 p.p.m.

Table 19 shows that most of the soil types in La Union have fairly high available calcium contents, that is, much more than 2,000 p.p.m. Bolinao clay has rather an excessive amount of available calcium, which is corroborated by its quite high pH value.

Magnesium.—Another essential element for plant growth, magnesium is a constituent of chlorophyll and of most seeds. It appears to be needed in the translocation of starch, and in the formation of fats and oils, and "to function as a carrier of phosphorus." Magnesium deficiency in plants is shown by characteristic discoloration of leaves—purplish-red leaves with green veins in cotton, chlorotic leaves in legumes, and stripped leaves in corn, with the veins remaining green and the other portion becoming yellow.

In citrus "symptoms of magnesium deficiency occur on mature leaves at any season of the year. Irregular yellow blotches start along the midrib of leaves near the fruit and eventually coalesce to form an irregular yellow band on each side of the midrib. This area rapidly enlarges until only the tip and the base of the leaf are green, the base showing a more or less inverted V-shaped area pointed on the midrib. In more advanced stages the entire leaf may become yellow." Findings at the Citrus Experiment Station in Florida, U. S. A., have shown that in citrus, magnesium deficiency causes a reduction in total crop, in the size of the fruit, and in the sugar, acid, and vitamin C contents of the juice.—Camp et al. (11)

On the magnesium-deficient soils of Florida, the addition of magnesium-bearing fertilizers, principally dolomitic limestone and magnesium sulfate is now a common practice. The increase in crop yield due to the addition of magnesium is so great that the standard fertilizer for citrus in Florida contains a certain percentage of magnesium (Anonymous). (5) A state survey of the fertilizer practice in Florida in 1944 showed that in 41 cases or estimates, proper fertilization had increased the average yield of citrus more than fourteen times as compared with that of the control: estimated yield of citrus fruits per acre, without fertilizer, 24.4 boxes; with fertilizer, 358.5 boxes (National Fertilizer Association). (26)

are Bigaa clay loam, San Manuel silt loam, Umingan clay loam, Sinapangan clay, and Maligaya clay loam.

The injudicious cutting of timber in the conversion of forest areas into kaiñgins has denuded the mountains, hills, and rolling area of the province, resulting in the destruction of the land due to erosion. The neglect from lack of appreciation of the importance of soil conservation measures has caused upland soils to be depleted of their fertility, vegetative cover, and organic matter, which would otherwise conserve the water on the land.

Irrigation water has, heretofore, been applied in the culture of rice in La Union. The farmers are supplied water through the Amburayan Irrigation System and a chain of communal irrigation systems. Communal irrigation systems have been established by the farmers to supplement rain water. Communal labor and funds are used in these projects. With government aid surveys of streams have been made with emphasis on small irrigation projects. In 1947 pork-barrel funds have been diverted to the construction and improvement of communal irrigation systems. Through a chain of these communal systems it is hoped to double production in many farms. Construction of more communal irrigation systems and continuous improvement of existing ones will partly solve the rice shortage of the province.

As far as soil reaction is concerned, rice, pineapple, tobacco, and other similar acid-tolerant plants may grow fairly well or normally in all the soil types of La Union Province, except Bolinao clay which had a pH value of 7.65. However, these crops cannot be expected to give maximum yields on most of the soil types, the pH values of which ranging from pH 6.35 to 7.65, because the optimum soil reaction requirements of the above-mentioned crops are pH 5.5 to 6.1. Considering soil reaction alone as a factor, sugar cane, corn, orange, most legumes and other crops, the optimum soil reaction requirements of which ranging from slightly acid to slightly alkaline, may be expected to give high yields on most of the soil types of La Union.

With the exception of Bolinao clay which has a total nitrogen content of 0.18 per cent, the principal soil types in La Union Province are generally low in total nitrogen contents, varying from 0.02 to 0.12 per cent. Only three soil types, namely, Bigaa clay loam, San Manuel silt loam, and Bolinao clay gave a medium or normal supply of available nitrogen at the time of the survey. The rest of the soil types had quite low available nitrogen contents. In general, La Union soils, especially those with high available phosphorus and potassium contents, may be expected to respond to nitrogen fertilization.

The four most productive soil types in La Union Province, namely, Bigaa clay loam, San Manuel silt loam, Umingan clay loam, and Sinapangan clay have very high available phosphorus contents varying from 90 to 140 p.p.m. as determined by the Truog method. Compared with the analysis of the soil types in other provinces so far analyzed, the soils of La Union are generally high in available phosphorus contents. Only one soil type, Burgos clay, has a quite low available phosphorus content, about 8 p.p.m.

Most of the La Union soil types may be considered sufficient in available potassium. Only one soil type, San Fabian clay loam, seems quite low in its content of this nutrient element. It is significant that Umingan clay loam which has the highest productivity ratings for sugar cane and corn (which require relatively much more available potassium than those required by other crops) has the highest content of available potassium (273 p.p.m.) among the soil types of the province.

With the exception of two soil types, namely, San Manuel sand and Burgos clay, all the soil types in La Union have fairly high available calcium contents, that is, much more than 2,000 p.p.m. Bolinao clay has rather an excessive amount of available calcium, which is corroborated by its quite high pH value.

For most crops, all the La Union soil types seem sufficient in available magnesium as determined by the Peech and English method.

GLOSSARY OF COMMON ECONOMIC PLANTS FOUND IN LA UNION

Common name	Scientific name	Family name
1. Acasia	*Samanea saman* Merr.	Leguminosae.
2. Achuete	*Bixa orellana* Linn.	Bixaceae.
3. Alibangbang	*Bauhinia malabarica* Roxb.	Leguminosae.
4. Ampalaya	*Momordica charantia* Linn.	Cucurbitaceae.
5. Anonang	*Cordia dichotoma* Forst.	Boraginaceae.
6. Anonas	*Anona reticulata* Linn.	Anonaceae.
7. Atis	*Anona squamosa* Linn.	Anonaceae.
8. Avocado	*Persia americana* Mill.	Lauraceae.
9. Balete	*Ficus benjamina* Linn.	Moraceae.
10. Bamboo	*Bambusa spinosa* Roxb.	Gramineae.
11. Banaba	*Lagerstroemia speciosa* (Linn) Pers.	Lythraceae.
12. Banana	*Musa sapientum* Linn.	Musaceae.
13. Boho	*Schizostachyum lumampao* (Blanco) Merr.	Gramineae.

	Common name.	Scientific name.	Family name.
14.	Bua	*Areca catechu* Linn.	Palmae.
15.	Buri	*Corypha elata* Roxb.	Do.
16.	Cabbage	*Brassica oleracea* Hort.	Cruciferae.
17.	Cacao	*Theobroma cacao* Linn.	Sterculiaceae.
18.	Caimito	*Chrysophyllum cainito* Linn.	Sapotaceae.
19.	Casoy	*Anacardium occidentale* Linn.	Anacardiaceae.
20.	Cassava	*Manihot esculenta* Crantz	Euphorbiaceae.
21.	Castor plant	*Ricinus communis* Linn.	Do.
22.	Chico	*Achras sapota* Linn.	Sapotaceae.
23.	Coconut	*Cocos nucifera* Linn.	Palmae.
24.	Coffee	*Coffea arabica* Linn.	Rubiaceae.
25.	Cogon	*Imperata cylindrica* (Linn) Beauv.	Gramineae.
26.	Corn	*Zea mays* Linn.	Do.
27.	Cotton	*Gossypium hirsutum* Linn.	Malvaceae.
28.	Dayap	*Citrus aurantifolia* (Christm) Swingle	Rutaceae.
29.	Daligan	*Averrhoa carambola* Linn.	Oxalidaceae.
30.	Duhat	*Eugenia cumini* Druce	Myrtaceae.
31.	Eggplant	*Solanum melongena* Linn.	Solanaceae.
32.	Gabi	*Colocasia esculenta* (Linn) Schatt	Araceae.
33.	Garlic	*Allium sativum* Linn.	Liliaceae.
34.	Ginger	*Zingiber officinale* Rose	Zingiveraceae.
35.	Guava	*Psidium guajava* Linn.	Myrtaceae.
36.	Guayabano	*Anona muricata* Linn.	Anonaceae.
37.	Ipil-ipil	*Leucaena glauca* (Linn) Benth.	Leguminosae.
38.	Calachuche	*Plumiera acuminata* Ait	Apocynaceae.
39.	Kalabasa	*Cucurbita maxima* Duch	Cucurbitaceae.
40.	Kaldis	*Cajanus cajan* (Linn) Millsp.	Leguminosae.
41.	Kamachile	*Pithecolobium dulce* (Roxb) Benth.	Do.
42.	Kamias	*Averrhoa bilimbi* Linn.	Oxalidaceae.
43.	Kamagau	*Citrus hystrix* DC. Cat. Hort.	Rutaceae.
44.	Kangkong	*Ipomoea aquatica* Forsk	Convolvulaceae.
45.	Kapok	*Ceiba pentandra* (Linn) Gaertn.	Bombacaceae.
46.	Katurai	*Sesbania grandiflora* (Linn) Pers.	Leguminosae.
47.	Kondol	*Benincasa hispida* (Thunb) Cogn.	Cucurbitaceae.
48.	Lauan	*Anisoptera thurifera* (Blanco) Blume	Dipterocarpaceae.
49.	Lumbang	*Aleurites moluccana* (Linn) Willd	Euphorbiaceae.
50.	Mabolo	*Diospyros discolor* Willd.	Ebenaceae.
51.	Madre cacao	*Gliricidia sepium* (Jacq) Steud.	Leguminosae.
52.	Maguey	*Agave cantala* Roxb.	Amaryllidaceae.
53.	Malungay	*Moringa oleifera* Lam.	Moringaceae.
54.	Mango	*Mangifera indica* Linn.	Anarcadiaceae.
55.	Mansanitas	*Zizyphus jujuba* (Linn) Lam.	Rhamnaceae.
56.	Molave	*Vitex parviflora* Juss.	Verbenaceae.
57.	Mungo	*Phaseolus aureus* Roxb.	Leguminosae.
58.	Mustard	*Brassica integrifolia* (West) O. E. Schultz	Cruciferae.
59.	Nangka	*Artocarpus heterophyllus* Lam.	Moraceae.
60.	Narra	*Pterocarpus indicus* Willd.	Leguminosae.
61.	Nipa	*Nypa fructicans* Wurmb.	Palmae.
62.	Onion	*Allium cepa* Linn.	Liliaceae.
63.	Pakak	*Artocarpus blancoi* (Elm.) Merr.	Moraceae.
64.	Papaya	*Carica papaya* Linn.	Caricaceae.
65.	Patola	*Luffa cylindrica* (Linn.) M. Roem.	Cucurbitaceae.
66.	Peanut	*Arachis hypogaea* Linn.	Leguminosae.
67.	Pechay	*Brassica chinensis* Linn.	Cruciferae.
68.	Pepino	*Cucumis sativus* Linn.	Cucurbitaceae.
69.	Pepper (Black)	*Piper nigrum* Linn.	Piperaceae.
70.	Pepper (Sili)	*Capsicum annum* Linn.	Solanaceae.
71.	Pineapple	*Ananas comosus* (Linn) Merr.	Bromeliaceae.

	Common name.	Scientific name.	Family name.
72.	Pine tree	*Pinus insularis* Endl.	Pinaceae.
73.	Potato (Irish)	*Solanum tuberosum* Linn.	Solanaceae.
74.	Raddish	*Raphanus sativus* Linn.	Cruciferaceae.
75.	Rattan	*Calamus* spp.	Palmae.
76.	Rice	*Oryza sativa* Linn.	Gramineae.
77.	Rimas	*Artocarpus communis* Forst	Moraceae.
78.	Sagu	*Maranta arundinacea* Linn.	Marantaceae.
79.	Santol	*Sandoricum koetjape* Merr.	Meliaceae.
80.	Saluyot	*Chorchorus olitorius* Linn.	Liliaceae.
81.	Siniguelas	*Spondias purpurea* (Linn) Urb.	Anarcadiaceae.
82.	Sincamas	*Pachyrrhizus erosus* Linn.	Leguminosae.
83.	Soybean	*Glycine max* (Linn) Merr.	Do.
84.	Sua (Lucban)	*Citrus maxima* (Burm) Merr.	Rutaceae.
85.	Sugar cane	*Saccharum officinarum* Linn.	Gramineae.
86.	Sweet potato	*Ipomea batatas* (Linn) Poir.	Convolvulaceae.
87.	Talahib	*Saccharum spontaneum* Linn.	Gramineae.
88.	Talisay	*Terminalia satappa* Linn.	Combertaceae.
89.	Tamarind	*Tamarindus indica* Linn.	Leguminosae.
90.	Teak	*Tectona grandis* Linn.	Verbenaceae.
91.	Tobacco	*Nicotiana tabacum* Linn.	Solanaceae.
92.	Tomato	*Lycopersicum esculentum* Willd.	Do.
93.	Tugue	*Dioscorea esculenta* (Lour.) Burkill	Dioscoreaceae.
94.	Ubi	*Dioscorea alata* Linn.	Do.
95.	Upo	*Lagenaria leucantha* (Duch) Rusby	Cucurbitaceae.

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