REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES
MANILA

Soil Report 21

SOIL SURVEY OF BUKIDNON PROVINCE PHILIPPINES

Published with FOA-PHILCUSA Aid

Manila
Adbureau
1955

DEPARTMENT OF AGRICULTURE AND NATURAL RESOURCES

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BY

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

BY

RICARDO T. MARFORI and IGNACIO E. VILLANUEVA

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HOW TO USE THE SOIL SURVEY REPORT

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

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

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

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

—Adapted from the U.S.D.A.

ILLUSTRATIONS

(Photographed by Juan A. Mariano)

TEXT FIGURES

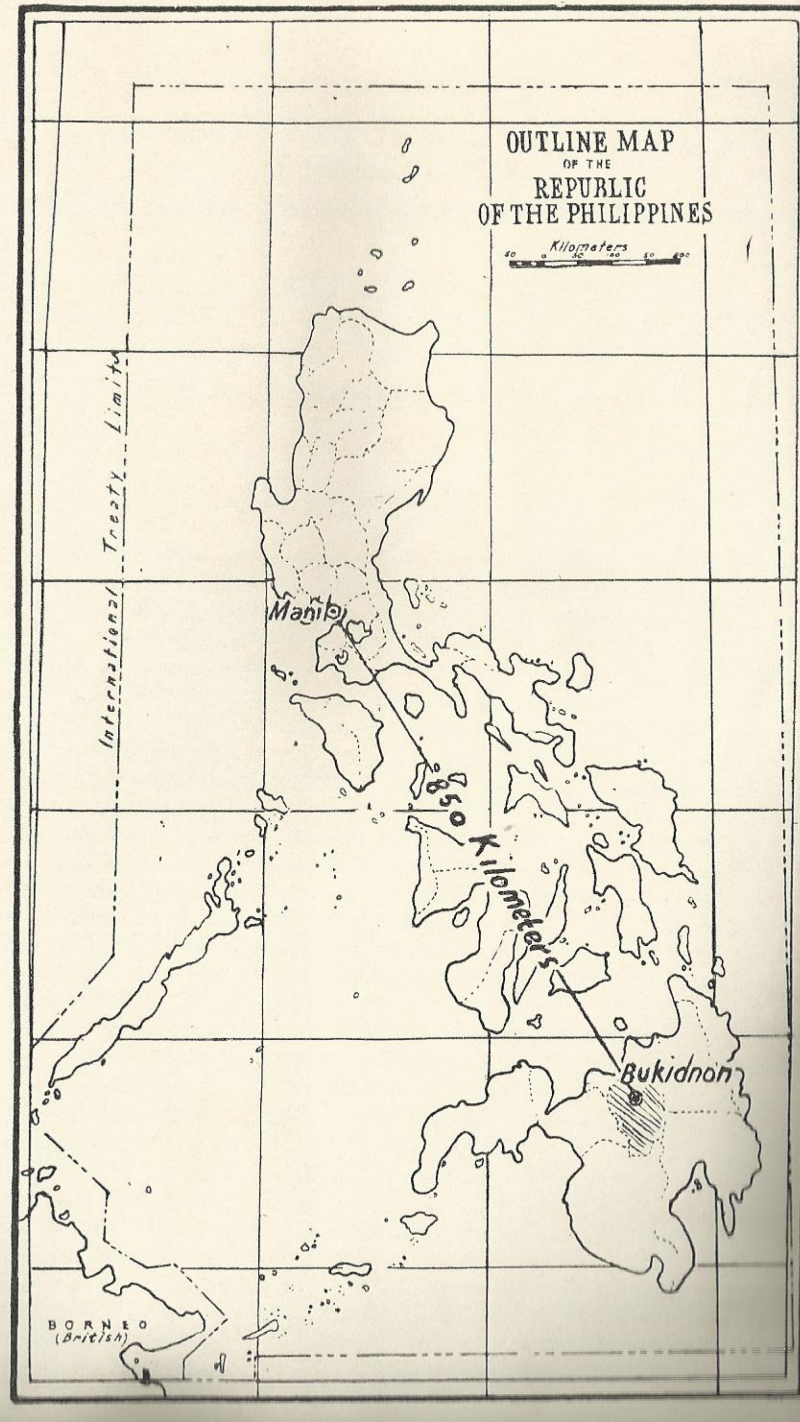

Fig. 1. Sketch map of the Philippines showing the location of Bukidnon Province.

SOIL SURVEY OF BUKIDNON PROVINCE PHILIPPINES

By Juan A. Mariano, Teodomero M. Yñiguez, and Eleuterio H. Aguas

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

By Ricardo T. Marfori and Ignacio E. Villanueva

SUMMARY

Bukidnon Province occupies the extensive plateau in Central Mindanao that is bounded on the north and west by Misamis Oriental; on the east by Agusan Province; on the south and southeast by Davao Province; and on the southwest and west by Lanao and Cotabato Provinces. Malaybalay, the capital, is about 850 kilometers by air from Manila and 104 kilometers by road from Cagayan de Oro City.

Although Bukidnon has a few lofty mountains, the greater part is gently rolling grassland plateau cut by deep and wide canyons of the Cagayan, Pulangi and Tagoloan Rivers and their branches and other rivers. At Mailag, 23 kilometers south of Malaybalay, the plateau begins to descend and gradually merges into the lowlands of Cotabato Province.

Except for the southern part, which is of sedimentary materials and the limited alluvial plains along the larger rivers, the whole of Bukidnon is of volcanic origin—lava and igneous rocks. The low grassy hills east of Malaybalay and those near Maluko and Dalirig, in the northern part, however, are mainly metamorphic (schist) rocks, some with cappings of limestone.

The drainage systems of Bukidnon are very complicated, some of the river basins flowing in opposite directions in the same general region.

The greater part of the plateau is under grassland and the mountains and hills are under primary and secondary growth forest.

Bukidnon is still an undeveloped province with a sparse population of only 7.89 persons per square kilometer. The lack of roads is the deterring factor in its settlement.

Parts of what is now Bukidnon had been part of Misamis beginning from about the middle of the nineteenth century until 1907 when Bukidnon was made a subprovince of Agusan Province, which was created that year. When the Department of Mindanao and Sulu was created in September, 1914, it became a province of the department with its capital at Malaybalay.

Two types of climate prevail in Bukidnon Province. The northern part falls under the third type or Intermediate A type, i.e., no very pronounced maximum rain period with a short dry season lasting only from one to three months. The southern part, beginning from Malaybalay, falls under the fourth type or Intermediate B type, i.e., no very pronounced maximum rain period and no dry season. Rains are very frequent, almost daily for most of the year. Though the province is nearer the equator than Luzon Island, the climate is pleasant due to its altitude and the usual extreme of heat of a tropical region is lacking. The province is outside the path of typhoons.

Agriculture is the main industry of the province with corn, rice, abaca, and pineapple as the main crops and root crops, bananas, coffee and vegetables as the secondary crops. The plateau is well suited to the growing of fruit trees. Bukidnon was the foremost cattle province in the Philippines before World War II but the industry has not been rehabilitated as yet. Corn grows very well, the average production per hectare being slightly over 25 cavans of shelled corn. Bukidnon has the largest pineapple plantation in the Philippines, at Del Monte, owned by the Philippine Packing Corporation.

Of the 88,555 hectares of farm area in the province in 1948 only 30,523 hectares, or 34.5 per cent, is cultivated. The average size of farm in the whole province is 10.68 hectares .

The soils of the province have been classified into fourteen soil types and two miscellaneous land types. Based on the topographic position they occupy on the landscape, they are grouped into three broad groups—(1) Soils of the alluvial plains, (2) soils of the plateau, and (3) miscellaneous land types.

The soils of the alluvial plain cover 26,441 hectares, or 3.29 per cent of the area of the province. They comprise those along streams that are or may be subject to flooding. This group includes the soils of the San Manuel series, Maapag series, and Mailag series. All of them, excepting the Mailag soils, are good croplands.

The soils of the plateau have an aggregate area of 490,582 hectares, or 61.03 per cent of the whole area of the province. Under this group are soils of the Adtuyon, Kidapawan, and Jasaan series and those of lesser extent and importance such as the Calauaig, Faraon, Bolinao, Alimodian, La Castellana, Tacloban, and Macolod series. The Adtuyon and Kidapawan soils are good for cropland and general farming. They have to be handled with care, however, because they are quite erosible when cultivated.

The miscellaneous land types have a total area of 286,817 hectares, or 35.67 per cent of the area of the province. A large portion of the land classified under "rough broken land" is suitable for pasture land.

Soil erosion is the washing away of the soil brought about by the interference of man with the "normal equilibrium between soil building and soil removal." It is an accelerated process that commences the moment man cultivates the soil.

The factors affecting the rate of erosion are slope, amount and intensity of rainfall, land use, and type of soil. Any cultivated soil will

erode depending upon the kind, degree or intensity of each factor and their varying interrelationships.

The degree of erosion is estimated by comparing the present depth of soil profiles with those of the comparable virgin profiles of the same type under the same or similar topographic conditions. If such profiles cannot be found, the best available information is used such as plant succession, erosion history, and visible evidence of erosion history.

The main factors responsible for erosion in the province may be mentioned as follows:

(1) Faulty soil management and cropping system have been used for some time on most of the farms.

(2) The grasslands have been frequently burned over and overgrazed.

(3) Plowing and planting up and down with the slope instead of across it.

Slight erosion (less than one-fourth of original surface soil lost or eroded) has affected 287,620 hectares, or 35.78 per cent of the province; moderate erosion (one-fourth to less than one-half of original surface soil lost) has taken place on 157,700 hectares, or 19.61 per cent; serious to severe erosion (three-fourths or over three-fourths of surface soil eroded) has covered 62,960 hectares, or 7.84 per cent; and severe to excessive erosion (all surface soil and over three-fourths of subsoil eroded) has affected 12,700 hectares, or 1.58 per cent of the whole province.

Reforestation is the most feasible method of controlling soil washing on the severely eroded areas. While the trees are establishing themselves, all protection from fires as well as from animals should be exercised.

The areas under serious erosion are mostly suitable for pasture. Their carrying capacity for livestock could be increased by preventing further wastage of the soil. Burning of the grasses, which often happens yearly or oftener, should be entirely stopped.

The soils under moderate erosion comprise the cropland on the plateau. A system of cropping should be adopted whereby the corn crop should be limited to not more than two crops a year or only one crop, if possible. Some kind of a legume crop should be grown at least once a year to be used as green manure. All cultivated lands with slopes should be tilled and planted on the contour. Any erosion control program on the Adtuyon and Kidapawan soils resolves itself into a combination of a good rotation system of farming (with less corn), terracing, and contour farming (perhaps considerable strip cropping). With the addition of small amounts of lime and in some cases, phosphatic fertilizers, practically any farm crop can be grown. Terracing should play an important part in the agriculture of the province. With or without terraces, less corn must be grown in the future than is raised at present if the fertile soils are to be completely saved from losses due to erosion.

In the chemical analysis of the soil samples collected from the province, the following methods were used:

For degree of acidity expressed as pH, the Leeds and Northrup Universal pH meter with a glass electrode was used. The organic matter was determined by the modified method of Peech and English

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

The interpretation of the chemical tests on the soils and the lime and fertilizer recommendations are given at the last part of the report.

INTRODUCTION

The current interest being manifested in populating sparsely-settled provinces like Bukidnon demands proper guidance to settlers if the mistakes committed in past settlement projects are to be avoided. While the causes of such failures are many and varied, doubtless one of them is the maladjustment between the new settlers and their soil. A considerable change in the type of use to which soils are put may be made by the new occupants of a region. The greater part of Bukidnon Province is upland country with a very small area of lowland or plain. It is but proper that before new immigrants move to Bukidnon Province, they should be apprised of the nature of the land and its possibilities so that they can decide for themselves whether or not it is the proper place for them to settle.

This soil survey report may be useful not only to prospective settlers but also to those already engaged in agriculture, land appraisers, prospective purchasers and tenants, farm loan agencies, real estate agents, agricultural technicians concerned in general land use planning as well as those interested in planning operations in communities or on individual farms, and students and teachers of soil science and allied subjects.

DESCRIPTION OF THE AREA

Bukidnon Province occupies the extensive plateau in Central Mindanao that is bounded on the north and west by Misamis Oriental, on the east by Agusan, on the south and southeast by Davao, and on the southwest and west by Lanao and Cotabato. The province lies between the parallels 7° 25' and 8° 38' north latitude and the meridians 124° 31' and 125° 16' east longitude, and has an area of 803,840 hectares. Malaybalay, the capital, is 60 kilometers by air (104 kilometers by

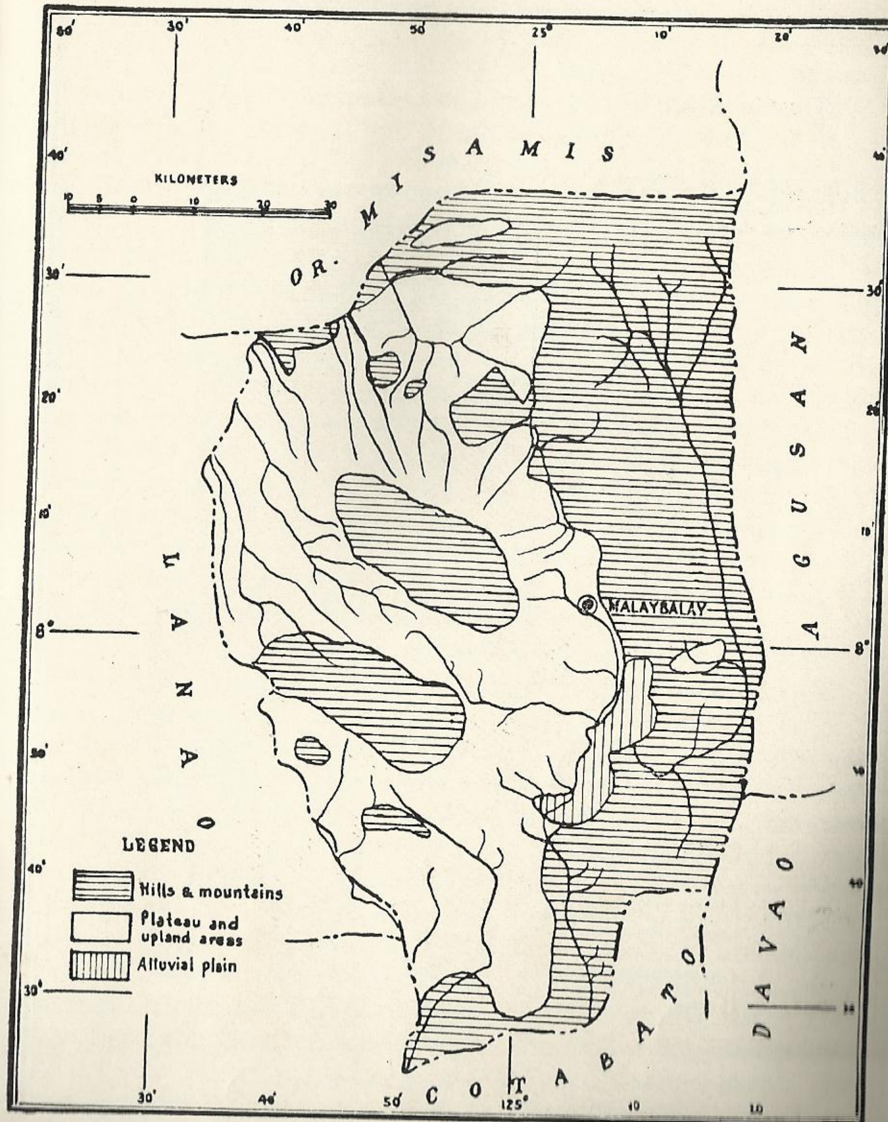

Fig. 2.—Sketch map of Bukidnon Province showing general topography and natural drainage system.

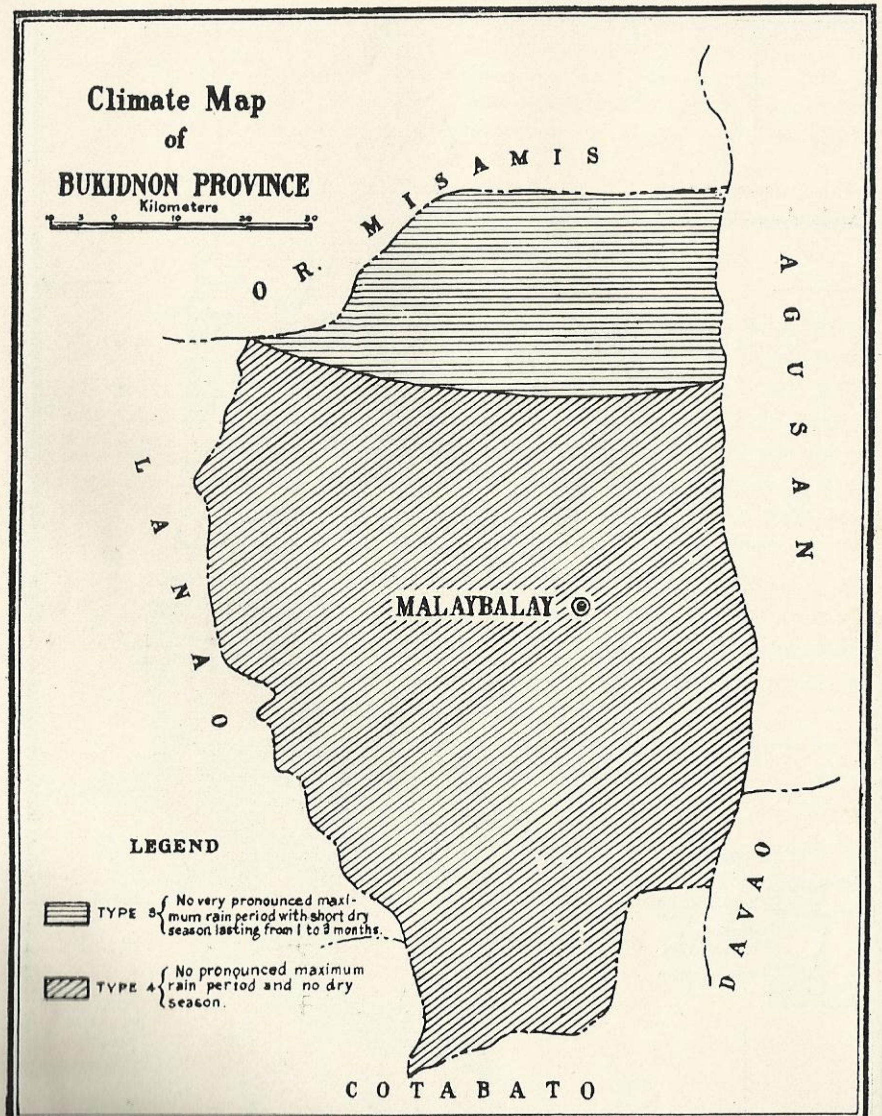

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Fig. 3.—Sketch map of Bukidnon Province showing areas under the two types of climate.

road) southeast of Cagayan de Oro, Misamis Oriental, and about 850 kilometers by air from Manila.

Bukidnon is the only province in Mindanao that does not have a coast line, it being in the northcentral part of the island. Mount Kitanglad (2,380 meters), an extinct volcano, occupies the center of and dominates the Bukidnon Plateau. Mount Kalatungan (2,287 meters) and Mount Tangkulang (1,678 meters) are the highest peaks in the southern part. The whole eastern and southeastern border adjoining Agusan, Davao, and Cotabato are lofty, densely forested mountains. The greater part of the province, however, is gently rolling grassland plateau cut by deep and wide canyons of the Cagayan, the Pulangi, and the Tagoloan Rivers and their branches and other rivers. The canyons have precipitous, often vertical walls of great heights. At Mailag, 23 kilometers south of Malaybalay, the plateau begins to descend and gradually merges into the lowlands of Cotabato.

Except for the southern part, which is of sedimentary materials, and the limited alluvial plains along the rivers, the whole of Bukidnon is of volcanic origin — lava and igneous rocks. The low, grassy hills east of Malaybalay and those near Maluko and Dalirig in the northern part, however, are mainly metamorphic (schist) rocks, some with cappings of limestone.

The drainage systems of Bukidnon are very complicated, some of the river basins flowing in opposite directions in the same general region. From the slopes of Mount Kitanglad spring all of the streams that flow northward into Macajalar Bay, as well as those that flow eastward and southward across the plateau. Cagayan and Tagoloan Rivers and their tributaries are the main streams draining the northern part. The divide reaches its highest elevation at Dalwangan (2,600 feet) where the streams on the south side flow towards the south. In the eastern section, separated by hills and mountains is the Pulangi River, which starts far to the north. The Manupali River, which springs from Mount Kalatungan, and the Sawaga River both join the Pulangi River near Mailag. The Maladugao and Muleta Rivers and their tributaries drain the southeastern part. Due to the frequent rains, especially in the high mountains, there are numerous permanent streams, some with falls. Only the Pulangi River is navigable with small, flat-bottomed craft and rafts and is often used by the natives in Cabanglasan and other settlements along it to float down their products to Mailag or Valencia.

Bukidnon is a province with abundant perennial streams which are often utilized as sources of water for drinking and domestic purposes by the greater part of the population. Although the people use such water with no ill effects, to insure safety, it should be chemically treated before using. Some of the streams have turbid and sometimes polluted water, hence filtering and chemical treatment are both necessary to render such water potable. The difficulty often encountered in the utilization of some streams is the great depth of their beds from the surface, sometimes reaching 300 to 500 feet. Piped-water systems supply water to the inhabitants of Malaybalay, Impasugong, and the different camps of the Philippine Packing Corporation at Del Monte. An artesian well supplies the water requirements of the people of Mailag, while dug wells, rain water tanks and drilled pumps are used in other places.

The greater part of the plateau is under grassland and the other smaller portion is planted to cultivated crops. Due to such vegetation, the province is naturally adapted to cattle raising. Cogon is the dominant grass but other grasses such as bagukbok, Johnson grass, redtop, orchard grass, gusa, cattail, silibon, talahib and many others are also found. Of these grasses, bagukbok, which grows better on poor soils than the rest, is relished most by cattle. Redtop, silibon, and cattail are next in desirability on pastures while Johnson grass, gusa, and talahib are coarse grasses. Tigbao grows luxuriantly along river bottoms.

The mountains such as the Kitanglad, Kalatungan, and the Pantadun Mountain Range and all of the southern part of the province beginning from Lake Pinamaloy are covered with primary forest. Only very small scattered areas of secondary forest are found in Bangahan, Omonay, Kiokong near Maramag, and the mountains east of Valencia. The primary forests are usually mixed forest with a lot of clinging vines and epiphytes. In some areas, rattan also abound. In secondary forests, boho, bikal, and bamboo are localized. Rivers are easily recognized on the plateau even at a distance by the presence of forest which usually line their banks or beds.

Although the climate and edaphic conditions are favorable for the growth of trees on the plateau as well as in the other parts of the province, the forest area cannot expand or invade the grasslands due to the practice of yearly or more frequent burning of the grasslands.

A considerable portion of Bukidnon remained unexplored up to as late as 1908 hence very meager knowledge about the province was known in the early years. Malitbog was founded in 1849, the first permanent settlement in the province.

Bukidnon is the home of the Bukidnons or the so-called "people of the mountains" who are known as peaceable farmers. There are some Manobos and a few Moros but the greater part of the population consists of immigrants from the Visayas and Luzon and their descendants. Besides, there has been an influx of settlers into the province during the last few years continuing up to the time of the survey.

Parts of what is now Bukidnon had been part of Misamis beginning from about the middle of the nineteenth century until 1907 when Bukidnon was made a subprovince of Agusan Province, which was created that year. Bukidnon, as a part of Misamis, came under the Revolutionary Government in December, 1899. When the Department of Mindanao and Sulu was created in September, 1914, it became a province of the department with its capital at Malaybalay.

The average population of the province is 7.89 per square kilometer according to the census of 1948. The population is fairly evenly distributed on the plateau, but a number of the non-Christian inhabitants are also found in the interior mountainous area.

Transportation facilities in the province are inadequate for the needs of the inhabitants. The province has 139.28 kilometers of first-class roads, 114.79 kilometers of second-class roads, and 71.56 kilometers of third-class roads. The Sayre Highway, which connects Northern and Southern Mindanao, bisects the province from north to south. The only lateral branches of this road are those going westward to Adtuyon from Maramag, to Alanib at kilometer post number 12 south of Malaybalay, and the road to Libona and Sta. Fe from Alae near the Bukidnon-Misamis Oriental boundary. Most of the towns and important settlements in the province are along this main road. The inhabitants in the interior areas away from the road have to depend on their beasts of burden for transportation or lug their products along muddy tortuous trails, some through and across canyons and deep rivers, to reach the road.

Passenger buses of the Mindanao Bus Company, Bukidnon Bus Company, Oning Transportation Company, and International Bus Company provide transportation between Bukidnon and Misamis Oriental as well as within the province. No transportation company in Bukidnon operates between Bukidnon and Cotabato or Davao. However, the International Transportation Company of Davao City and the Pulido Transportation Company of Kabacan, Cotabato make weekly trips or oftener to Malaybalay.

Abaca, the most important export, is sold mainly at Cagayan de Oro City and some of it are sold in Kidapawan, Cotabato or Davao City. Corn is sold at Cagayan de Oro City, and canned pineapple is exported at Bugo, Misamis Oriental. Pork and poultry products are sold at the local markets as the province is still not self-sufficient in such commodities.

Schools and churches are situated at convenient places in the barrios and towns. There is a total of 95 elementary schools with an enrollment of 14,804 pupils. Most of these schools are settlement farm schools. At Malaybalay are the Bukidnon Provincial High School and the Bukidnon Secondary Normal School and at Mosuan, Maramag is the Central Mindanao Agricultural College, all public schools. Two private schools, the San Isidro High School and the Mindanao Central Colleges, are in Malaybalay. The latter school provides instruction from kindergarten to college level. A provincial hospital is maintained at Malaybalay and municipal sanitary inspectors are stationed in the larger towns. There is no telephone line except the line which connects the Philippine Packing Corporation pineapple plantation at Del Monte and the cannery at Bugo, Misamis Oriental. A telegraph station is in operation at Malaybalay. Mail is dispatched and received daily except Sunday at Malaybalay, which serves as the distributing center for the different towns and barrios.

Almost half of the province is under commercial forest. Lumbering is the only important industry with three companies in operation—the Bukidnon Lumber Company, at Pinamaloy, Maramag, the Kitanglad Lumber Company at Tulonga-on, Imbatug, and the Pugahan Lumber Company at La Fortuna, Malitbog. The first is capitalized at ₱200,000 and the other two at ₱80,000 and ₱60,000 respectively. Boards of split white lauan locally called **talisayan**, which are used for walling, ceiling, and sometimes flooring of buildings, are made in Kibawe. Mat-weaving from **sud-sud**, a local rush growing on the marshy areas, is a home industry of the Bukidnons of Malaybalay. Ropes

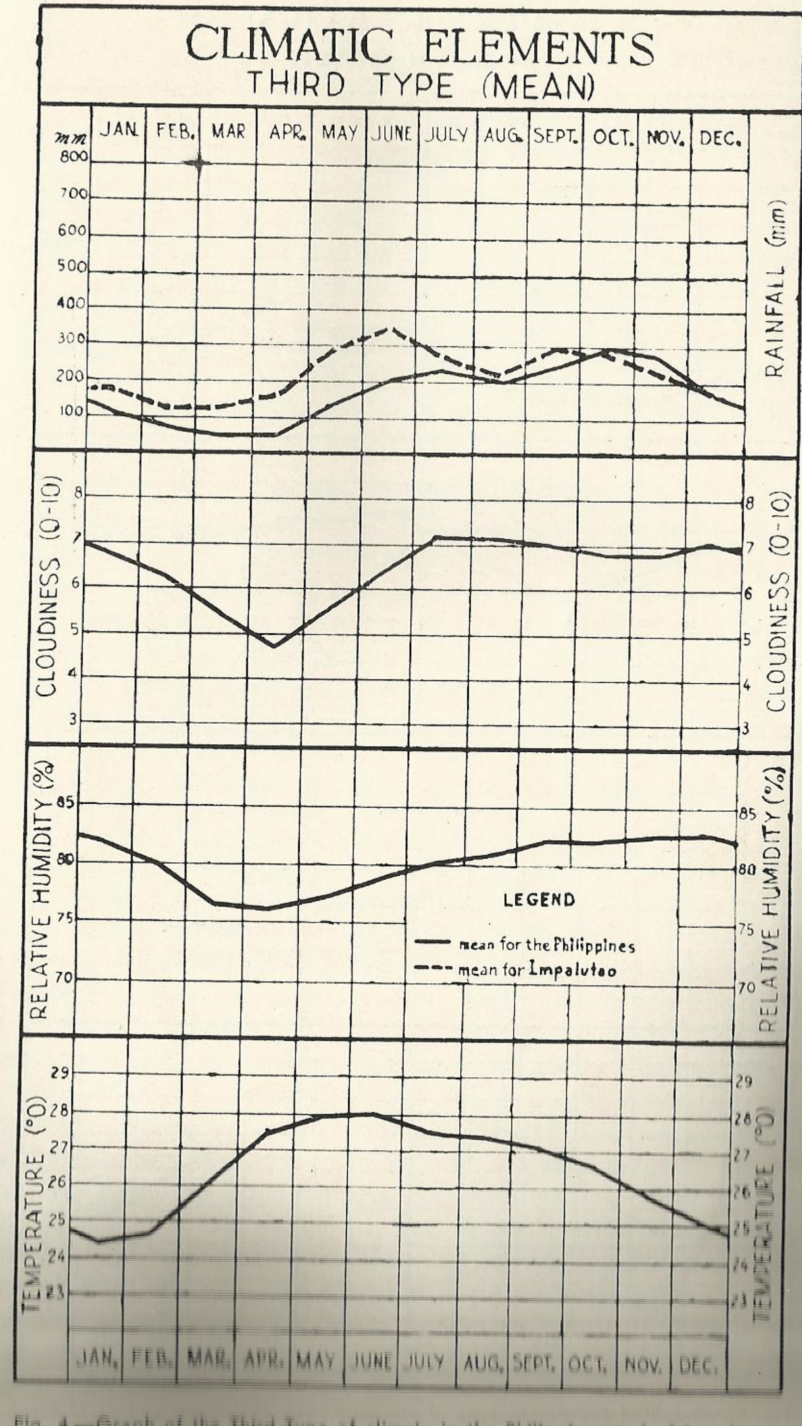


Fig. 4.—Graph of the Third Type of climate in the Philippines and of Impalutao, Bukidnon.

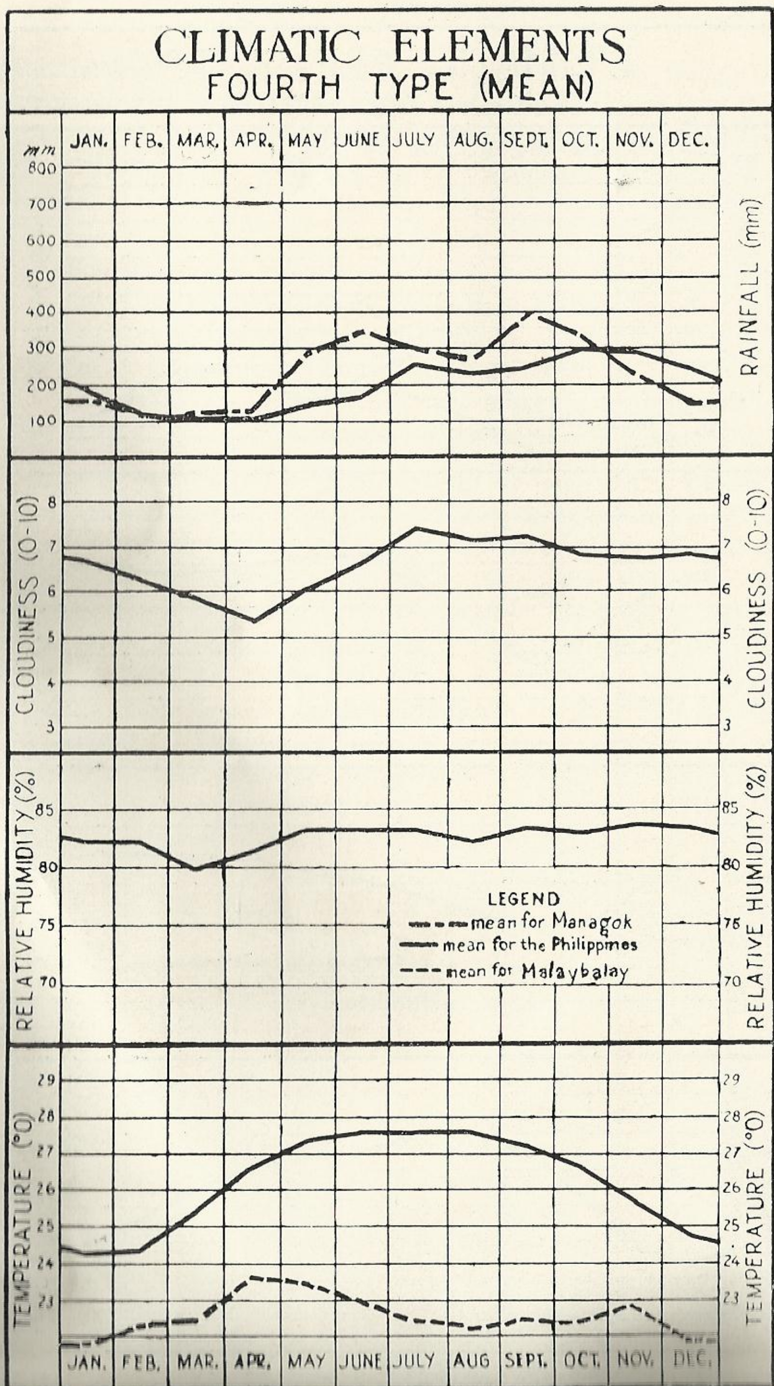


Fig. 5.—Graph of the Fourth Type of climate in the Philippines and of Malaybalay and Managok.

from abaca are manufactured at Bancud and are sold locally or sold at Cagayan de Oro City.

CLIMATE

The significant role of climate in soil formation and in the growth of plants can hardly be overemphasized. There is a close relationship between soil and climate, partly direct, but more largely indirect. The indirect effect of climate as it acts through the vegetation, for example, is probably greater than its direct effect on the soil. The three main elements of climate, temperature, moisture, and light are the factors that have the most power over plant life.

Two types of climate prevail in Bukidnon Province. The northern part falls under the third type or Intermediate A type, i.e., no very pronounced maximum rain period with a short dry season lasting only from one to three months, and the southern part falls under the fourth type or Intermediate B type, i.e., no very pronounced maximum rain period and no dry season. The dry period usually occurs from February to April. While there is no pronounced rainy season, the period of heavy rainfall is usually from June to October. Rains are very frequent, almost daily for most of the year, though usually light.

Though the province is nearer the equator than Luzon Island the climate is pleasant due to its altitude and the usual extreme of heat of a tropical region is lacking. An American official who visited Bukidnon in the early 1920's states that "the climate is relatively cool, resembling that of parts of southern California near the coast, and at night one needs substantial covering." Table 1 shows the average monthly and mean annual rainfall and average monthly number of rainy days for three places in Bukidnon, and table 2 shows the average monthly and mean annual rainfall and the maximum, average, and minimum monthly temperatures for one and a half years of observation at Malaybalay. The province is outside the path of typhoons. From table 2 it can be seen that the hot months of the year are April and May and the cold months are December and January. No mention could be made of the relative humidity, cloudiness, and most prevalent wind direction due to the absence of data in any of the observation stations about these elements.

TABLE 1. *Average monthly and annual rainfall and number of rainy days in three weather stations in Bukidnon Province.*[a]

Month	Managok Agricultural School 1921-1933		Impalutao 1927-1933		Diklom 1919-1924	
	Rainfall (mm.)	Number of rainy days	Rainfall (mm.)	Number of rainy days	Rainfall (mm.)	Number of rainy days
January	161.5	15.4	175.3	21.2	125.5	13.8
February	111.0	11.7	121.7	12.8	94.8	7.6
March	109.0	12.1	123.7	15.8	124.0	10.0
April	129.0	11.8	161.2	13.7	64.7	6.8
May	296.1	18.8	289.2	23.0	210.9	14.0
June	341.2	22.2	441.2	29.2	281.3	18.0
July	300.1	21.5	267.3	28.8	141.6	17.2
August	270.9	19.7	209.7	26.2	183.4	16.8
September	391.5	22.5	295.5	25.8	207.9	17.0
October	333.5	22.5	274.2	27.1	241.3	16.8
November	214.0	17.8	220.0	24.3	176.3	14.0
December	169.6	17.0	166.0	22.0	100.1	9.2
Mean Annual	2,827.4	215.4	2,744.9	269.1	2,051.8	161.2

a Data from Census of the Philippines, 1918.

TABLE 2.—*Average monthly rainfall and monthly average maximum and minimum temperatures of Malaybalay*[1]

Month	Rainfall (mm.)	Temperature		
		Average (F.)	Maximum (F.)	Minimum (F.)
January	42.4	71.5	88.5	57.3
February	45.7	72.0	88.8	57.4
March	105.6	72.6	89.8	53.6
April	99.8	74.7	91.3	59.3
May	183.8	74.1	89.5	61.0
June	350.2	73.4	87.6	62.0
July	430.5	72.5	86.7	63.4
August	425.9	72.1	86.0	63.0
September	331.2	72.6	87.0	62.0
October	395.7	72.4	87.8	63.3
November	181.3	73.0	88.0	61.2
December	267.9	71.4	85.0	61.0
Mean Annual	2,860.0	72.7	88.0	60.3

[1] Data furnished by the Weather Bureau Office at Malaybalay, Bukidnon. The observations are for one year only—1949.

AGRICULTURE

The early settlers of Bukidnon Province were the Bukidnons who, according to some people, formerly inhabited the region of northern Mindanao but later retired into Bukidnon when Visayan immigrants settled the country. They practiced the kaingin system of agriculture hence the deforestation of the

country at an early date and the concomitant change into grass vegetation. The Manobos still continue the practice up to the present time.

The fertile lands along the rivers, such as that in Malitbog, were cultivated first by the immigrants but soon after the lands of the plateau in the northern part such as those around Talakag, Libona, Tankulan, Impasugong, and Sumilao were utilized for the growing of crops. The lack of roads and transportation facilities to the southern part was the main reason for the slow development and settlement of that section of the province.

The adaptability of the extensive grasslands of the plateau for cattle raising was recognized by a number of the early settlers hence cattle raising became a major agricultural enterprise to the extent that the province became the largest producer of beef cattle and Indian buffaloes in the Philippines until the outbreak of the war in 1941.

The planting of cereals and other crops was not neglected, however. The census of 1918 mentions rice, corn, abaca, tobacco, copra, and camote as the main crops grown. Coffee and abaca had been exported as early as 1918 or earlier. The suitability of the soils of the plateau to pineapple was soon recognized, after which the Philippine Packing Corporation established the pineapple plantation at Del Monte, Tankulan.

Table 3 gives the hectarages of the principal crops for 1948. Diversified farming is practiced with corn, rice, and abaca as the principal crops and coffee, fruit trees, peanuts, camote, and cassava as the minor crops.

TABLE 3.—*Area planted, total production, and value of produce of the leading crops of Bukidnon Province.*[1]

Crop	Area planted in hectares	Total Production	Value in pesos
Corn	18,341	241,526 cavans	2,219,000
Rice	5,968	121,071 cavans	1,345,645
Abaca	5,946	3,167,704 kilograms	1,386,001
Pineapple	3,805	13,381,089 fruits	1,560,860
Camote	3,278	5,614,007 kilograms	335,394
Cassava	1,198	2,201,922 kilograms	129,405
Bananas	768	635,773 bunches	534,957
Coffee	321	329,330 kilograms	316,981

[1] Data obtained from the Bureau of the Census and Statisitcs, 1948 census.

CORN.—Corn is the staple food of the people and for this reason it is planted throughout the province. It does not require thorough land preparation as other crops more intensively grown. Two or three crops are grown in a year, hence it affords a quick source of food and income especially for new settlers.

The census of 1948 shows that 18,431 hectares were planted to the crop that year. The records of the office of the Provincial Agricultural Supervisor at Malaybalay give the average yield per hectare for the entire province as 25 cavans of shelled corn. The principal corn-producing municipalities are Talakag, Malaybalay, Maluko, Libona, and Baungon with yields of 30 to 35 cavans being obtained in those places. The Native Yellow Flint varieties are commonly planted. The rainy season planting is March to May and the dry season planting is August to October.

RICE.—Rice is gaining in importance as a staple food of the people, and this is the reason for the trend of increased planting of the crop. Due to the scarcity of work animals, especially immediately after liberation, however, the area planted in 1948 was only 5,968 hectares. The use of modern agricultural machinery in upland rice culture is increasing thus rendering possible the cultivation of larger areas with less farm help.

The area planted to upland rice is nine times that of lowland rice. Palawan, a standard high-yielding variety, and Malooy are the most common varieties planted with yields ranging from 20 cavans to as high as 70 cavans per hectare according to farmers' estimates. Malaybalay, Maluko, Kibawe, and Talakag produce the greater part of the upland rice crop.

Lowland rice is planted at Simaya, Nabago, and Minlawaan plains, 15 kilometers southeast of Malaybalay poblacion. Standard high-yielding varieties such as Wagwag, Quezon rice, and Elon-elon are exclusively grown with yields ranging from 40 to 60 cavans a hectare. The lowland rice fields are rainfed, but a few are irrigated from communal irrigation systems operated by the farmers. The planting season for lowland rice is June to September and that of upland rice is May to June.

ABACA.—The areas planted to abaca are along rivers and creeks for the reason that the plant does well along bodies of water. There is an increase in area planted to the crop during the decade from 1938 to 1948 from 4,744 hectares to 5,946 hectares due to the rising interest in the crop.

Due to the inducement of continued high price for the fiber since liberation up to the present, however, interest in the industry is being revived. The old plantings are being

Abaca is an important crop of Bukidnon Province. While most of the crop is planted along the rivers and creeks, there are also good abaca grown on Kidapawan clay loam and Adtuyon clay of the plateau.

PLATE I

renovated and new areas are being planted to the crop. Jalaijai is the most popular variety. Other varieties planted are Liboton, Tangongon, Irag, and Halogan. The plantings are almost wholly small holdings, averaging a hectare or less in area.

The production per hectare is relatively low because of the poor culture and little care given the plants. After planting, the plants are left on their own to compete with the weeds thus resulting in stunted growth and few suckers, and ultimately low yields. Hand stripping is still the most common method employed but a few stripping machines like those used in Davao and Cotabato are already in operation.

PINEAPPLE.—With respect to hectarage, pineapple ranks fourth as the most important crop in the province but second in value. Almost all of the plantings are those of the Philippine Packing Corporation at Del Monte and Libona. The few hectares of pineapple outside of the plantation are backyard or home lot plantings for home use or for the local market. Most of these are in Malaybalay and Maramag. Smooth Cayenne is almost exclusively the only variety planted.

SWEET POTATO (CAMOTE).—This is the most widely grown crop in the province especially among the native population—Bukidnons, Manobos and few Moros—who plant it in **kaiñgins.** It is the most popular supplementary food crop because of its short period of growth and the little or no land preparation necessary except clearing before planting the crop. There is a little increase in area planted in 1948 over that of 1938 as shown by census reports for those years. The crop does best on light soils. The yield is relatively low possibly because of the heavy nature of the soils, most of them being clay, and the little care given the plants. Talakag, Malaybalay, and Maluko are the largest-producing towns in the order named.

CASSAVA.—This crop, like bananas, is grown usually in backyard and home lots as well as in the fields and kaiñgins. It is the second best food supplement or substitute especially in the homes of the native population. Being a root crop, it prefers loamy soil. The production is only fair because of the heavy soils on which the crop is grown. Poor cultural methods also account for the low production.

BANANAS.—Although this crop is one of the easiest to grow, there is no large scale planting in the province. It is grown only in backyards or along fences and farm boundaries.

Weeding or cultivation is nil, hence production is quite low in spite of the suitability of the soils and climate to the crop. The crop is planted solely for home consumption and for sale in the local markets but never as an export crop. The census of 1948 shows that only 768 hectares were planted to the crop that year. Saba, Morado, Bungulan, Latundan, and Lacatan are the most common varieties planted. Malaybalay, Talakag, and Maluko are the largest producers of the crop.

COFFEE.—Coffee is one of the crops well suited to the province and has been exported as early as 1918. The cool climate, evenly-distributed rainfall, and deep well-drained soils all account for the adaptability of the province to the crop. Arabica, is the most popular variety planted, but Robusta and Excelsa are also found. This is one of the crops that gives the best promise for expansion considering the present needs of the country and price being paid for the commodity. Talakag, Impasugong, Maluko, and Sumilao produce most of the crop.

FRUIT TREES.—Almost all kinds of fruit trees do well in Bukidnon. Most of them are planted in backyard or home lots and are grown mostly for home consumption or for sale in the local markets. A few citrus orchards produce for export, Avocado, caimito, marang, jackfruit, papaya, lanzon, mango, soursop, cacao, santol, and pummelo are the fruit trees commonly grown.

VEGETABLES.—Vegetables are often raised in home gardens for home consumption and for the local market. Due to the even distribution of rainfall, crops can be planted all the year round. Sitao, habichuelas, upo, squash, eggplants, cabbage, pechay, onions, and tomatoes are the vegetables mostly planted. Irish potato is grown in Miarayon, a cool high place in the northwestern part of the province. The product is sold in Cagayan de Oro City.

AGRICULTURAL PRACTICES

Centuries-old agricultural practices still commonly prevail, but modern methods are also followed to a slight extent. The planting of crops in **kaiñgin** is still a common practice among the Manobos, who seldom have work animals for cultivating the land. The all-iron plow has replaced the wooden plow in most farms, and agricultural machinery is being used in some

farms. The level to slightly undulating terrain of the plateau and other parts of the province is suited to mechanized farming.

Simulated crop rotation is a common practice among the farmers. After the harvest of the main crops (rice and corn), secondary crops such as beans, peanuts,and vegetables usually follow. There is no regular succession of specific crops planted each year, however. Intercropping of upland rice and corn, corn and beans, or corn and peanuts is sometimes practiced. The use of fertilizers and soap solution sprays for the control of mealy bugs on pineapple is a common practice at the plantation of the Philippine Packing Corporation at Del Monte. During the survey, results of experiments on lime and fertilizers on upland rice at the projects of the defunct RCPA in Maramag and Pangantocan have convincingly demonstrated the benefits from such practices with the result that the people are now receptive to the practice. Ammonium sulfate and Warnerphos are the most common fertilizers used.

The growing of lowland rice in paddies under irrigation is practiced in the lowland plains southeast of Malaybalay. The levees or terraces incidentally help control erosion. In some localities, corn is planted year in and year out enhancing the loss of soil through accelerated erosion.

LIVESTOCK AND LIVESTOCK PRODUCTS

Before the last war, Bukidnon was the premier cattle province in the Philippines but the stock has been depleted so much during the war and the industry has not been rehabilitated up to the present. Most of the cattle raised were grades of Indian Nellore, an imported breed. Manila was the main market. Indian buffaloes and race horses were also raised for export to other provinces and Manila, respectively.

The carabao has been and still is the mainstay of the farmer. Hogs and chickens are raised by every family in backyards for home use and the local market. Goats and ducks are raised to a lesser extent. The local supply of eggs is insufficient for the needs of the people. Livestock and poultry raising could be expanded easily with enough markets for the products. Table 4 shows the number and value of livestock and poultry in 1948 as shown by census figures for that year.

TABLE 4.—*Number and value of livestock and poultry in Bukidnon Province*[1]

Livestock or poultry	Number	Value
Carabaos	6,084	1,688,275
Cattle	1,381	402,447
Horses	777	107,826
Buffalo	120	46,074
Goats	171	2,596
Hogs	15,237	603,836
Sheep	25	470
Chickens	1,787,472	167,744
Ducks	18,382	2,275

[1] Data obtained from the Bureau of the Census and Statisitcs, 1948 census.

LAND-USE CHANGES

The census of 1948 shows a total cultivated area of 30,523 hectares or an increase of 8,785 hectares over that of 1938. Almost all the newly cultivated lands were grasslands that were utilized as cattle ranches before the war. Small scattered areas were forested lands south of Maramag which were cleared. The increased use of farm machinery and the inducement from high prices for rice and corn especially, are the main incentives for the increase in area planted.

Abaca is another crop that is coming to the fore. Not only are the old plantings being renovated but new areas, most of which were former ranch lands, are being planted to the crop. The continued high price since liberation is the main cause for renewed interest in the crop.

The area devoted to upland and lowland rice is continually increasing and the same is true with corn and pineapple. While tobacco has been listed as one of the early crops grown, the area planted has been considerably decreased of late from 65 hectares in 1938 to only 30 hectares in 1948.

The forest lands in the southern part of the province are being cleared slowly but surely as more immigrants continue to settle in the province.

FARM TENURE

According to the 1938 census, the farm area in the province for that year was 126,969 hectares and the average size of farm was 19.35 hectares. Of the 6,561 farms, 1,270 had areas ranging from 2 to 2.99 hectares; 994 had areas of 5 to 9.99 hectares; 825 had areas of 3 to 3.99 hectares; 724 had areas of 10 to 19.99 hectares; and 672 had areas of 20 hectares and over. Seven farms had areas of 900 hectares or more.

In the same census (1938), of the 6,561 farms, 4,240 or 64.6 per cent were operated by owners; 1,325 or 20.1 per cent

by share tenants; 852 or 13 per cent by cash tenants; 73 or 1.1 per cent by part owners; and 67 or 1 per cent by farm managers, and only 4 farms were operated by share-cash tenants.

Under one system of rental in vogue in the province, the landlord furnishes work animals, seeds, and implements and the tenant receives one-half of the product. Under another system, the tenant furnishes everything and he gets three-fourths of the crop while the landlord gets one-fourth.

Labor is quite scarce and it is almost exclusively the Manonos and Bukidnons who are available. A wage per day of three pesos with food being provided is still shunned by them because they can earn more by stripping abaca.

FARM INVESTMENT

The property in a farm consists of the land, buildings, implements, domestic animals, and poultry. Most of the farmhouses are small, semi-permanent wood and bamboo structures, and some are temporary, improvised or makeshift types. The latter kind belongs usually to the new immigrants who have not had enough time to improve their farms. Some of the better farmhouses were destroyed during the war and have not yet been rebuilt.

The outbuildings on many farms include a granary, a corncrib, and a poultry house. Farms with machinery have machine and tool sheds in addition. Implements on the average farm consists of all-iron or wooden plow, wooden harrow with iron spikes, carts, and sleds. Farms with machinery have tractors, disc plows, disc harrows, a grain drill and a few with combines and driers.

The work animals are carabaos, cattle bulls, and buffaloes, with carabaos predominating. The number of work animals is increasing through importation from the Visayas and other parts of the Philippines.

TYPES OF FARMS

The system used by the Bureau of the Census and Statistics in classifying the types of farms was adopted in this survey. This system classifies a farm as belonging to a certain type if 50 per cent or more of the area of cultivated land is planted to the crop; a livestock farm if it has an area of 10 hectares or more, more than 10 head of cattle, horses, goats, and sheep, and less than 20 per cent of the total farm area is used for the production of crops, fruits or nuts; and a poultry farm if it has more than 300 chickens or 200 ducks and less than 2 hectares of the land is cultivated.

According to the above classification, the census of 1938 shows that of the 6,561 farms in the whole province, 2,071 or 31.5 per cent were corn farms; 1,398 or 21.3 per cent were abaca farms; 1,284 or 19.5 per cent were rice farms; 132 or 2 per cent were fruit farms; 107 or 1.6 per cent were vegetable farms; 94 or 1.4 per cent were livestock farms; and 1,424 or 21.7 per cent were other kinds of farms which could not be classified under any of the types enumerated.

SOIL SURVEY METHODS AND DEFINITIONS

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

The soils, their landscapes and underlying formation, are examined in as many sites as possible. Borings with the soil auger are made, test pits are dug, and exposures, such as road and railroad cuts are studied. An excavation or road-cut exposes a series of layers called collectively the soil profile. These horizons of the profile as well as the parent material beneath are studied in detail, and the color, structure, porosity, consistency, texture, and content of organic matter, roots, gravel, and stones are noted. The reaction of the soil and its content of lime and salts and other plant food constituents are determined either in the field or laboratory. The drainage, both external and internal, and other features such as the relief of the land, climate, natural and artificial features are taken into consideration, and the relationship of the soil and the vegetation and other environmental features are studied.

On the basis of both external and internal characteristics, the soils are grouped into classification units, of which the two principal ones are (1) soil series and (2) soil type. (3) A phase of a soil type is defined on the basis of soil characteristics that are of importance in land use. When two or more of these mapping units are in such intimate or mixed pattern

that they cannot be clearly shown on a map, they are mapped as a (4) complex. Areas of land that have no true soil such as river beds, coastal beaches, or bare rocky mountain sides are called (5) miscellaneous land types. Areas that are inaccessible, like mountains and great forest areas the classification of which is of no agricultural importance for the moment, are classified as (6) undifferentiated soils.

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

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

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

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

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

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

SOILS AND CROPS

The greater part of the Bukidnon Plateau is underlain by volcanic mudflows, or lahars, mainly from the two mountains —Kitanglad and Kalatungan. The rest of the province are underlain by other kinds of igneous materials and a few local areas by metamorphic rock (schist). The southern part adjoining Cotabato is of sedimentary materials such as limestone, calcareous shale, and recent alluvium along the rivers. Through weathering processes, the upper parts of the various rocks have broken down into soft materials, which in turn have been acted upon by soil-building forces and transformed into soils different in chemical composition and physical characteristics. Eroded and transported materials, which are usually fine, deposited along streams and at the base of slopes have developed into mellow rich soils that are some of the most fertile in the province.

The different degrees of resistance of the various rock formations to weathering forces has given rise to the present

form of the land surface that ranges from flat and gentle slopes to hilly and mountainous. The less resistant volcanic mudflows have produced deep, well-drained soils that are level but dissected deeply by a number of canyons; the schist with limestone cappings are responsible for the low hills and knobs east of Malaybalay and between Kisolon and Dalirig; and to the hard igneous materials which comprise the mountains are attributed the lofty, steep slopes of the mountains.

The soils overlying the schist and limestone are not so deep as those overlying basalts and andesites. Likewise, the soils on steep and rolling areas are thinner than those on level or gentle areas. The more intense erosion acting on the slopes and the less amount of organic matter that accumulates also give rise to lower mineral plant nutrients for those shallow soils.

In a few areas of the province the presence of stones on the surface is the limiting factor for crop use. Such areas are in Alae and Guisok sitio near Misamis Oriental and the stony areas of Maramag poblacion. Forests have always occupied the rough and steep lands. In general, the structure of the upland soils are conducive to good penetration of roots, good percolation of water, good drainage, and a fairly high water-holding capacity. With fertilization and care, these soils produce fair to good yields of general crops where the surface stones are not sufficiently numerous to interfere with cultivation.

The soils on the alluvial plain are free of stone; the surface is level, resulting in poor external drainage. Because of the occasional inundation, however, the soils are more fertile than some of the upland soils.

All the soils are acid, as shown by nitrazine paper tests in the field. The surface soil ranges from very strongly acid to slightly acid, and the subsoil is slightly less acid. The Adtuyon soils are the most acid and the Faraon soils the least acid. Although the Bolinao and Faraon soils were derived from calcareous material (limestone), the parent material seems to have had little or no effect on the development of the soils as the soils are also acid.

The census of 1948 shows that 88,554 hectares or 1.1 per cent of the total area of Bukidnon Province was farm land, including cultivated land, idle land, pasture land, forest land, and other kinds of land. Malaybalay, Talakag, Maluko, and Inpasugong have higher percentage of improved farm land than the other towns of the province. Over a large part of the province, the agriculture consists of patch farming; i.e., the farms are scattered and the improved farm land is generally in small tracts.

There is a little correlation between the soil types and the type of agriculture followed or crops grown. The soils on the plateau are planted usually to corn, upland rice, fruit trees and pineapple; the soils along the creeks and rivers are usually planted to abaca; and the soils of the alluvial plain along the Pulangi River and its branches are planted to lowland rice and partly to corn.

For convenience in discussing the agricultural relationship of the soils of Bukidnon Province, they have been placed in three broad groups based on the topographic position they occupy on the landscape. Some of the soils are relatively unimportant due to small extent, unfavorable use adaptation, or both.

These groups are (1) soils of the alluvial plains, (2) soils of the plateau, and (3) soils of the hills and mountains. In the following pages, the groups of soils and individual soil types are described and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map, and their hectarage and proportionate extent are given in table 5.

TABLE 5.—*Hectarage and proportionate extent of the soils mapped in Bukidnon Province.*

	Hectares	Per cent
Maapag clay	20,001	2.49
San Manuel silt loam	4,576	.57
Mailag clay loam	1,864	.23
Adtuyon clay	205,124	25.52
Adtuyon clay, stony phase	3,642	.45
Kidapawan clay loam	139,189	17.31
Alimodian clay	15,726	1.97
Jasaan clay	7,668	.95
Macolod clay	52,921	6.58
La Castellana clay	45,254	5.63
Tacloban clay	4,447	.55
Calauaig clay	4,363	.54
Faraon clay	1,952	.25
Bolinao clay	10,296	1.28
Rough broken land	41,905	5.21
Mountain soils, undifferentiated	244,912	30.47
Total	803,840	100.00

SOILS OF THE ALLUVIAL PLAIN

The alluvial plain lands comprise those along streams that are or may be subject to flooding. These are water-laid soils.

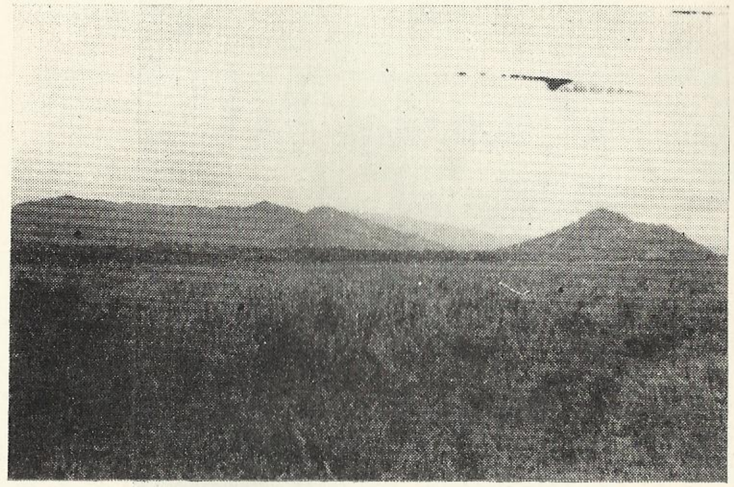


Fig. 1.—The Maapag Plain east of Valencia is level, hence well suited to mechanized farming. Lowland rice is the crop most suited to this area. Note the thick grass cover.

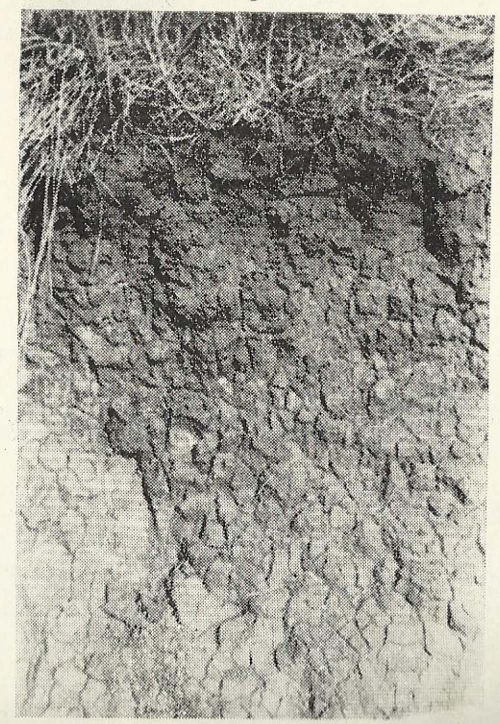


Fig. 2—Profile of virgin Maapag clay. Note the heavy clay surface soil and subsoil with well-defined structure. This soil is well suited to lowland rice.

virgin land with grass cover and negligible or no erosion occurring, the soil contains a fair amount of organic matter, especially the surface soil.

Lowland rice is the only crop being grown on this soil with yields ranging from 40 to 60 cavans per hectare being obtained. Under proper management, this soil can be built up easily and maintained in a productive state. The relief is favorable for all farming operations, and the fields are large enough to allow the use of improved machinery. Drainage appears to be the problem on this soil because of its heavy subsoil and substratum as well as its more or less level relief. The structure may also need to be improved to secure good tilth, and this can best be done by increasing the organic matter content of the soil through green-manuring. Corn cannot be raised during the rainy season on this soil because of its poor drainage condition. The growing of lowland rice under irrigation would undoubtedly increase the yield. The rivers and creeks that traverse the plains could be tapped for irrigation purposes in order to obtain maximum yields from this soil.

San Manuel silt loam.—This soil is one of the best agricultural soils of Bukidnon Province, but it is limited in area.

There is no distinct profile development and the gradation from one layer into the next is very gradual or indistinct. The surface soil consists of brown to grayish brown friable fine granular silt loam 30 to 35 centimeters deep underlain by a yellowish brown to grayish brown very fine to fine sandy loam subsoil that reaches to a depth of 70 to 110 centimeters from the surface. The substratum is reddish brown to grayish brown fine sandy loam to fine sand.

This soil type is found in small areas along the Pulangi River near Valencia and southeast of Dulogon. It is of recent alluvial origin with the rivers as the agents of deposition. The soils occur in low-lying areas and are subject to floods during the rainy season. The surface drainage is somewhat restricted, but internal drainage is fair to good.

The native vegetation consists of talahib, tigbao, and a very coarse sugar cane-like grass. The soil contains a fair amount of organic matter.

This soil is quite productive for most any crop, but those most commonly planted are corn, abaca, rice, peanuts, and vegetables. The corn plants in Valencia are often two-eared, stocky, tall, and dark green with yields reaching to 35 cavans per hectare. The abaca at Mailag grown on this soil is likewise tall and vigorous.

San Manuel silt loam is easy to work and it does not need special management to maintain its productivity. Very little or no erosion occurs on this soil due to its level or nearly level relief. Surface or external drainage may be the only problem of this soil.

Mailag clay loam.—This soil type occurs in the barrio of Mailag and part of the plain southwest of Maramag poblacion. It is level with few depressions where water collects during the rainy season.

The 20 to 25-centimeter surface soil consists of dark grayish brown granular clay loam when moist that changes to grayish brown, crumbly clay loam when dry. There are plenty of grass roots in the first foot or so of soil. In a few small patches of the area, some waterworn cobblestones are present on the surface. The subsoil is a gray plastic and sticky clay with plenty of concretions of round and angular forms of 2 to 5 millimeters diameter mixed with gravels of different sizes. The color of this layer changes to light gray when dry with a blocky structure. It reaches to a depth of 50 to 55 centimeters from the surface. The substratum is composed of light gray, somewhat loose clay containing concretions and gravels like the subsoil.

Due to the level relief and the presence of slight depressions, the surface drainage is poor and internal drainage is likewise poor due to the clay subsoil. Waterworn pebbles and cobblestones are found on the surface in some portions of the area at Mailag giving the impression that it might have been an abandoned river bed at some prior time. In the low portions are microrelief of small hills of 15 to 25 centimeters diameter and 15 to 20 centimeters high.

The native vegetation is grass consisting mostly of velvet grass, redtop, silibon, and others. The cultivated plants being grown on this soil are corn, bananas, cassava, and lowland rice. This soil is low in natural productivity as shown by the stand of the crops.

The greater part of the area under this type is idle land, but lately a few farmers have started to cultivate some portions of the area. To increase the productivity of this soil, the organic matter needs to be increased so as to improve the structure and other related physical properties as well as to add or facilitate the increase of mineral plant nutrients. External and internal drainage likewise need to be improved to get best results. This soil is not important agriculturally because of its small extent and low natural productivity.

SOILS OF THE PLATEAU

The soils of the plateau include the Adtuyon, Kidapawan, and Jasaan series. A large proportion of the area covered by these soils is under cultivation, and agriculturally they comprise the most important soils in the province. Adtuyon clay and Kidapawan clay loam are the more extensive and productive soils in the group while the Adtuyon clay, stony phase and Jasaan clay are both inextensive and of lesser productivity.

The relief ranges from nearly level to strongly rolling with the slope ranging from 2 to about 20 per cent. External drainage is good to excessive and internal drainage is fair to good. Although all of the soils are of heavy texture, the structure and consistency are such that percolation of water is not restricted.

All of the soils of the group are suited to general farming. Jasaan clay and Adtuyon clay stony phase have enough stones on the surface as to interfere with cultivation unless removed but not so numerous as to preclude the practicability of their removal. Special conservation practices may have to be adopted in the cultivation of these soils because they are all erosible to some extent. Since all of them are acidic the use of lime to raise the pH up to near the neutral point seems to be a necessary practice. Ammonium phosphate and sulfate of ammonia are known to increase the yield of upland rice and corn on these soils.

Adtuyon clay.—This is the most extensive soil type in the province, with a total area of 205,124 hectares or 25.52 per cent of the area of the province. It covers almost exclusively the entire Bukidnon Plateau. The relief ranges from flat to strongly rolling, but the slopes are fairly long and smooth with gradients of 3- to 10-per cent being the most common.

The 10- to 25-centimeter surface soil is light brown, brown to dark brown clay loam to light clay that is granular and friable. In cultivated areas, this layer is slightly heavier. There are plenty of grass roots and it is easy to penetrate. This horizon merges gradually into a dark reddish brown to brown clay with a prismatic structure in place that changes to granular under pressure in the hand. It is sticky and plastic when wet but brittle and hard when dry. This horizon reaches to a depth of 70 to 80 centimeters from the surface. This layer is underlain by a dark yellowish brown to light reddish brown clay that is hard and cloddy when dry. This substratum is slightly compact and is quite deep being over two meters in some places. In some places, some partially weathered igneous rocks are present in this layer.

Adtuyon clay is developed from parent material that originated from volcanic lava or mud-flows (lahars) composed of mixed boulders but chiefly andesites and basalts. These rocks are deeply weathered sometimes reaching to four and a half meters.

External drainage is good to excessive, and generally the soils have good internal drainage. Even if the subsoil and substratum are clay in texture the chemical nature of the colloids is such that the soils are granular thus promoting easy water movement in the soil mass.

The greater part of the area covered by this soil type is under grass. A few areas are forested with second growth such as along rivers and creeks. Before the war, when a large number of cattle was being raised in the province, some portions of the plateau were used for pasture. The more or less even distribution of rainfall enhanced the continuous growth of the grasses which thus furnished the livestock with verdant pasture.

This soil is perhaps the most important soil in the province agriculturally. The highest yields of corn in the province are obtained from this soil such as in Salimbalan, Talakag, Sankanan, and Malaybalay. Yields of 25 to 35 cavans of shelled corn are common on this soil. Upland rice yields as high as 60 to 70 cavans in some places and 99 cavans a hectare with fertilization using ammo-phos. at the rate of 200 kilograms per hectare and lime at the rate of 4 tons. Even with corn, fertilizers are known to increase the yields. In the higher altitudes, abaca is known to grow well, and even on the open parts of the plateau some new plantings are being started. Fruit trees such as avocado, caimito, marang, and coffee, cacao, peanuts, camote, cassava, and many other crops are grown on this soil, with fair to high yields being obtained.

On a large number of farms where this soil exists, there is a tendency to "bleed" the soil of its natural fertility. Corn is planted continually every year with as many as three crops a year being planted. While the decrease in yield is not so noticeable during the first few years after the land is opened, the decline in yield is quite apparent after a long period of cultivation. This the farmers also realize. Concomitant with the opening of the virgin grasslands, the problem of accelerated erosion commences to operate. This soil is erosible mainly because of its long slopes and the undulating to strongly rolling topography of some of the areas under this type. The frequent and copious rains that characterize the climate of the province render the subsoil and substratum saturated with moisture most of the time thus slowing down the internal drainage. In spite of the fact that this soil is relatively well drained, run-off still occurs carrying with it the fertile topsoil. To minimize or control erosion on this soil entails the practice of soil conservation measures such as contour cultivation and planting, strip cropping, terracing or a combination of these practices. Lime may need to be applied to correct the soil reaction or to supply calcium direct as a plant nutrient element.

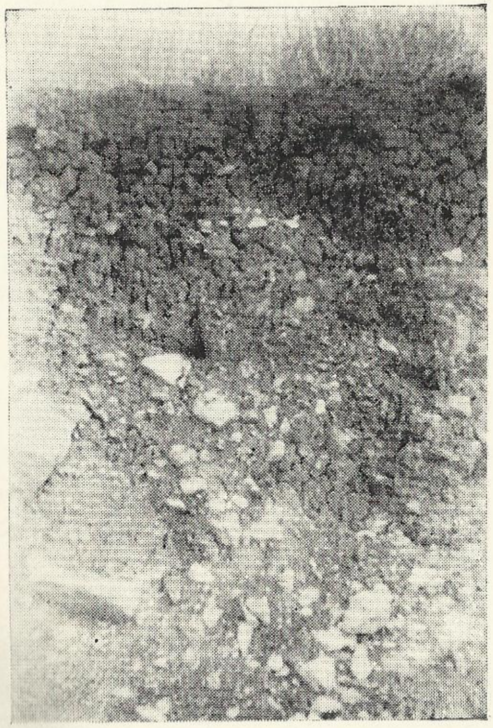
Adtuyon clay, stony phase.—Adtuyon clay, stony phase is inextensive and unimportant agriculturally. It occurs in two separate areas — a narrow strip west of the Mosuan Volcano and another at Panadtalan, northwest of Maramag poblacion. It occupies a total area of 3,642 hectares, or .45 per cent of the province.

The profile characteristics of this soil are essentially the same as that of the Adtuyon clay with the difference that pebbles, cobblestones, and boulders occur on the surface of the former making it less desirable for agricultural use. While it is not impracticable to remove the stones to render the soil more suitable for cultivation, the labor involved is already a deterrent to its utilization. Only a small portion of this soil is cultivated. Corn is the principal crop grown with cassava, camote, bananas, and fruit trees as secondary crops. It can be best utilized as range for livestock since it supports good growth of grasses. A few patches of second growth forest are also growing on this soil.

Kidapawan clay loam.—Kidapawan clay loam is the second most extensive soil in the province with a total area of 139,189 hectares, or 17.3 per cent of the province. Like the

Corn on newly-cultivated Adtuyon clay at Salimbalan, Tankulan. Yields of 35 to 45 cavans of shelled corn are common in such areas.

PLATE 4



Profile of Faraon clay showing the very dark gray to black soil and the weathered limestone parent material.

Adtuyon clay, it is one of the important agricultural soils and is closely associated with the latter. Generally, it occupies higher elevations than Adtuyon clay and has steeper and shorter slopes.

The surface soil consists of reddish brown to brown prismatic clay loam 15 to 20 centimeters deep. A virgin soil of the type under forest cover has a very mellow and crumbly surface soil with a much lighter texture. The upper subsoil is reddish brown slightly compact and brittle columnar clay when dry but plastic and sticky when moist. The lower subsoil is yellowish brown columnar clay that reaches to a depth of 120 centimeters from the surface. The substratum resembles the lower subsoil but it is more compact than the upper layers. This layer is sometimes mottled with red. In some places, boulders are found on the surface but not numerous enough to interfere with cultivation.

This soil occurs on the lower slopes of Kitanglad and Kalatungan Mountains and in the southern part of the province around and west of Kibawe. Generally, the relief ranges from gently undulating to steeply sloping and mountainous, but the greater part of the area is gently rolling to strongly rolling with slopes of 10- to 20 per cent being the most common. Owing to the steep gradients external drainage is free to excessive, but internal drainage is good.

The parent material of Kidapawan clay loam originated from volcanic materials similar to that from which the Adtuyon clay developed. The greater part of the area under this soil type is under secondary growth forest, but some portions are under primary forest and few patches of grassland. Part of the forests are of commercial importance.

The Kidapawan clay loam is utilized mostly for the growing of corn and upland rice and to a lesser extent for abaca, and coffee. The high altitude of the greater part of the area under this type makes the soil very suitable for those crops — abaca and coffee. Upland rice yields as high as 60 cavans a hectare while corn produces 20 to 25 cavans around the Kibawe area. Abaca yields 1,000 kilograms, or 16 piculs, a hectare at Kitaotao.

This soil is one of the soils in the province that are very suitable for general farming. The steep slopes in some areas, however, restrict the use of this soil for cultivated or annual crops. Perennial or permanent crops such as abaca, fruit trees, coffee, cacao, and coconuts are best for such places. Or, if such areas have to be planted to clean-tilled crops, appropriate erosion control measures have to be practiced to control soil erosion.

This soil is one of those soils related to the Luisiana, Antipolo, Alaminos, Tugbok, and Adtuyon soils. These soils are somewhat lateritic in their characteristics and are easy to manage. The greater part of the area covered by this type is still uncultivated because of the lack of roads and partly to the hardship of clearing the forest cover. When opened, this soil promises to be one of the best soils in the province. Liming to correct soil acidity and the application of fertilizers may increase crop yields on this soil.

Jasaan clay.—This soil is an extension of the same soil type in Masamis Oriental. It is not an extensive soil and is unimportant agriculturally. It is more adapted for pasture rather than for annual crops.

The 20- to 35-centimeter surface soil is light brown to brown clay slightly friable and somewhat mellow when moist. It has a columnar structure and affords easy penetration of roots. In some places, stones and boulders are on the surface and also imbedded in the soil profile from the surface down to the substratum. This horizon is underlain by a light brown to reddish brown columnar clay, subsoil soft and friable when just moist and slightly sticky when wet. The lower part of the subsoil has few gravels and stones. This horizon reaches to a depth of 80 to 100 centimeters from the surface. The substratum consists of light brown to reddish brown clay loam to clay that is very friable and very slightly loose. Few gravels and stones are also present in this layer like that in the lower subsoil. Roots penetrate the different layers easily.

This soil occurs in Alae and its vicinity in the northcentral part adjoining Misamis Oriental. As found in Bukidnon Province, this soil type has gently undulating relief with slopes of less than 5 per cent predominating.

Like the other soils of the plateau, this soil is developed from parent material originating from volcanic materials. Drainage, both external and internal, is fair to good. The native vegetation is grass with binayuyo trees scattered at random simulating a "parang" type of forest.

Some portions of this soil are cultivated to corn, upland rice, bananas, fruit trees, pineapple, and vegetables. This soil is of medium productivity for the cereals but it supports a good growth of fruit trees and pineapple. The presence of stones and boulders on the surface is a drawback to the utilization of this soil for cultivated crops. Permanent crops like fruit trees should be planted or it could be used as grazing land for livestock.

The slopes are not steep hence erosion is not so serious as on the Adtuyon clay or Kidapawan clay loam. Contour cultivation and the use of cover crops may be needed as erosion control measures on this soil.

Calauaig clay.—This soil occurs on the low grassy hills east of Malaybalay. These hills are presently idle lands although some parts have been utilized as grazing lands before the war. It is inextensive with an area of 4,363 hectares or .54 per cent of the province. The relief ranges from gently rolling to hilly with slopes ranging from 8 to 100 per cent.

The 10- to 15-centimeter surface soil consists of brown to light brown clay that is friable and granular when dry but mellow when moist. It is underlain by a light brown to yellowish brown clay which is plastic and sticky when moist but blocky and hard when dry. This upper subsoil reaches to a depth of 30 centimeters from the surface. It merges very gradually into the lower subsoil which has almost similar characteristics except for its slightly lighter color and less developed structure. The lower subsoil reaches to a depth of 55 centimeters from the surface. The substratum is a layer of weathering schist which looks like fragmental coal. In other places, the bedrock of schist which is usually in slab form is encountered in the lower part of the substratum.

External drainage is free to excessive, but internal drainage is slow. The native vegetation is a rank growth of grass. A small portion near Malaybalay is being reforested by the Impalutao Reforestation Station of the Bureau of Forestry.

Due to its unfavorable topography, this soil is not adapted to cultivated crops or seasonal crops. Parts of it may be utilized for growing coffee, fruit trees or other perennial crops or for grazing, but the greater portion is best adapted for forestry purposes. If ipil-ipil, madre cacao or other fast-growing trees are planted on those hills, they make a good source of firewood for Malaybalay later on.

Faraon clay.—This soil occurs on the low limestone hills between Kisolon and Tankulan in the north-central part of the province and in three separate places along the Sayre Highway south of Kibawe in the southern part. It has a total area of 10,296 hectares, or 1.28 per cent, of the province. It is not an agricultural soil because of its unfavorable relief, which is strongly rolling to hilly.

The 25- to 30-centimeter surface soil consists of dark gray to black heavy and plastic clay that becomes hard and cloddy when dry. The subsoil is similar to the topsoil in most respects except that it is of a lighter color, being gray or yellowish gray. This layer reaches to a depth of 40 to 45 centimeters from the surface. Fragments of limestone are sometimes found in this layer. The substratum consists of weathering limestone.

Although this soil is derived from limestone the soil reaction or pH is slightly acid. The grass or forest vegetation furnishes the soil a fair content of organic matter, but because of the eroded state of the soil, its organic matter content is much reduced as a result of the loss of the surface soil. In some places some pebbles and cobblestones of limestone are present on the surface.

External drainage is free to excessive, but internal drainage is poor or slow.

This soil is developed from parent material orginating from limestone. The hills between Kisolon and Tankulan have schist for a base, and the limestone rocks which overlie it are cappings over the schist.

This soil, as it occurs in Bukidnon, is non-agricultural. The more gentle slopes may be used for grazing or may be planted to perennial crops but not to seasonal or cultivated crops. It may even be best to reforest the area in order to increase the forest area in the vicinity and concomitantly the size of the streams, which are dry in some parts of the year.

Bolinao clay.—Bolinao clay occurs in the northwestern part of the province and is an extension of the same soil type mapped in Misamis Oriental. It is inextensive, occupying an area of only 1,952 hectares, or .25 per cent of the province. It is not an important agricultural soil like the Faraon clay. The low small hills that comprise it have gently rolling to hilly relief with slopes of 15 to 60 per cent at the most.

The 20- to 30-centimeter surface soil is a light to dark reddish brown friable and granular clay underlain by a brownish gray to light reddish brown clay which is heavier and more compact than the surface soil. This layer, which reaches to a depth of 45 to 70 centimeters, from the surface, has a blocky structure

and becomes hard when dry but plastic and sticky when moist. Some weathering coralline limestone is sometimes found in this layer. The substratum consists of coralline limestone rocks.

This soil differs from the Faraon clay mainly in the color of the surface soil. Both soils are derived from limestone residues and both have slightly acid reaction. External drainage is free to excessive, but internal drainage is fair. The native vegetation is grass with shrubs and small trees along the streams.

A few patches of this soil are planted to corn. The steep slopes do not warrant the planting of this crop, and it would be better to stop the practice and plant ipil-ipil or madre-cacao instead.

Alimodian clay.—This soil comprises the low smooth hills north and northwest of Tankulan and the hills east of Kiliog in the northwestern part of the province. Like the other hill soils such as the Faraon clay and Bolinao clay, the Alimodian clay is likewise non- agricultural. It covers 15,726 hectares, or 1.97 per cent of the province.

The surface soil of 20 to 25 centimeters is a brown friable clay with good granular structure. This layer contains a fair amount of organic matter and allows deep penetration of roots. This layer is underlain by a light brown clay subsoil with prismatic structure, slightly compact and brittle when dry that reaches to a depth of 50 to 60 centimeters from the surface. The substratum consists of gray or grayish brown weathered sedimentary rocks such as sandstone or shale.

This soil is non-agricultural and no agricultural crop is planted on any portion of the soil. Before the war, this soil was utilized as grazing land for cattle because of the rank grass vegetation to the extent that some areas were overgrazed with the result that catstep erosion occurred. This soil may be best utilized for forestry purposes by reforesting the hills with fast-growing trees such as ipil-ipil or madre-cacao.

La Castellana clay.—This soil covers the whole Mousan Volcano and similar hills, west of Mararag poblacion. It is a primary soil developed from the weathering of igneous materials, mainly basalts and andesites. Like the other hill soils in the province such as the Faraon clay, Alimodian clay, and Bolinao clay, this soil is non-agricultural because of its unfavorable relief and stoniness.

The 15- to 25-centimeter surface soil is a brown to dark brown clay when moist that changes to light brown or grayish brown when dry. It has a good coarse granular structure that permits easy penetration of roots; has a fair content of organic matter but is quite stony on the surface as well as within the profile. This layer is underlain by a reddish brown to brown clay loam, slightly compact with a granular structure; plenty of stones and boulders in the soil that obstructs root penetration. This layer reaches to a depth of 50 to 70 centimeters from the surface. The substratum consists of gray to dark brown clay loam which is compact and hard.

This soil is strongly acid like the Adtuyon clay and other soils of the province. This type covers 45,254 hectares, or 5.63 per cent of the area of Bukidnon. The strongly rolling to hilly relief renders the external drainage free to excessive but with fair internal drainage. The native vegetation consists mainly of grass with binayuyo trees. Patches of second growth forest also are found on the top and leeward side of the hills.

No crop is planted on this soil, but it may be utilized to advantage as pasture land. Some portions were used for such a purpose before the war. The abundance of better lands in the province for agricultural purposes other than this soil militates against its demand for such use.

Tacloban clay.—This soil is derived from the weathering of shale and associated rocks. Owing to its small extent and unfavorable topography, it is considered non-agricultural. It covers a total area of 4.447, or 0.55 per cent of the province. It occupies the southern part adjoining Cotabato Province.

The 20- to 30-centimeter surface soil consists of light brown, brown to dark brown good coarse granular clay, sticky and plastic when moist, and hard and slightly compact when dry. This layer is fairly penetrable by roots. It is underlain by a yellowish brown good coarse granular loam which is slightly sticky when moist and slightly hard when dry. There is a very gradual boundary between the two layers. The subsoil reaches to a depth of 65 to 80 centimeters from the surface. The substratum is a yellowish brown, poor coarse granular loam derived from shale, that reaches to 150 centimeters from the surface. Below this layer are igneous rocks, predominantly andesites.

The relief of this soil ranges from gently rolling to strongly rolling and hilly, which accounts for the good to excessive external drainage. Internal drainage is fair. This soil is almost entirely under virgin forest with only negligible portion under secondary growth forest, cogonal, or kaingins. Only small

portions along the Sayre Highway are cleared and planted to crops such as cassava, bananas, corn, and camote.

This soil is not considered agricultural except to permanent crops such as fruit trees, abaca, coffee, etc.

Macolod clay.—This soil occupies the southern part of the province on both sides of the Pulangi and Muleta Rivers. The lay of the land ranges from strongly rolling to hilly and mountainous. It covers an area of 52,921 hectares, or 6.58 per cent of the province. It is associated with the Kidapawan clay loam in some places. The soil is developed mainly from the weathered products of volcanic materials.

The 10- to 15-centimeter surface layer of Macolod clay consists of brown to grayish brown tenacious clay with mixture of rounded and angular gravels. This layer is underlain by a light reddish brown slightly compact clay that reaches to a depth of 60 to 65 centimeters from the surface. This material gives way to a layer of weathered igneous materials, generally andesites.

In badly eroded areas and on steep slopes, the surface soil is thinner and in some places the andesite boulders are exposed. This soil is considered non-agricultural except when planted to permanent crops like fruit trees, abaca, coffee, etc. The steep slopes and generally unfavorable relief render this soil unfit for cultivated crops. The presence of stones and boulders is another undesirable feature of this soil. The native vegetation, consists mostly of primary forest, but some portions are under secondary growth forest and cogonals.

External drainage is free to excessive, and internal drainage is good to fair. Run-off from the steep slopes is swift hence the danger from soil erosion is great the moment the native vegetation is cleared.

The cultivated areas of this soil are the few kaiñgins of the Manobos and Bukidnons, where bananas, upland rice, camote, gabi, and cassava are planted.

MISCELLANEOUS LAND TYPES

Although the soil map is primarily concerned only with soil, other areas of land that are without a definite soil must be indicated on the map. Rough broken land and Mountain soils, undifferentiated are two miscellaneous land types classified in Bukidnon Province.

Rough broken land (Adtuyon and Jasaan soil materials) — Rough broken land includes areas having steep or very steep relief, which in many places may be badly gullied or broken by intermittent drainageways and may include narrow winding ridges and steep knobs.

This land type occurs east of the town of Impasugong continuing up to and including a large portion of the municipal district of Malitbog in the northern part of the province. Because of the nature of the lay of the land it is non-agricultural, but it may be utilized for pasture. The grass vegetation can furnish a fair enough carrying capacity for livestock.

The soil materials of this land type are generally more of the Adtuyon clay and smaller areas of the Jasaan clay. In favorable places, the depth of the normal soil types of these soils are somewhat approached.

Mountain soils, undifferentiated. — These represent areas that are inaccessible like the mountainous and great forest areas, the classification of which is of no agricultural importance for the present. These occur in the west-central part of the province (Mounts Kitanglad and Kalatungan) and the whole eastern portion bordering Agusan and Davao Provinces (Pantadon Mountain Range and Mount Malambo). These mountains are covered with virgin or primary forests of such density that they are inaccessible.

MORPHOLOGY AND GENESIS OF THE SOILS

"Soils are natural media for the growth of plants." They are complexes of mineral and organic substances. Soils were not created in the beginning the way they now appear but are rather the product of development or evolution. They are evolved from a parent material, or regolith.

There are five general factors of soil formation: (1) Parent material; (2) climate; (3) biological activity (iiving plants and animals); (4) relief; and (5) time. These soil-forming factors are interdependent, each modifying the effects of the others. The character of the parent material modifies the effects of the others. The character of the parent material modifies the effects of rainfall and relief of an area. The character of the vegetation, is, in part, determined by temperature and rainfall and in turn modifies the effects of these, particularly of rainfall. The character of the relief influences, through drainage and run-off, the effects of rainfall and of time.

The Philippines falls under the great soil group known as the "Tropical and subtropical red and yellow soils". The mature soils of humid regions of which the Philippines is a part, generally, have developed under natural vegetations of forest or woodland. The greater part of the soils of Bukidnon, however, have developed under grass. As already stated in the early part of this report, the greater part of the province is of volcanic origin and smaller areas are of sedimentary and alluvial formations.

The soils of the province are predominantly brown or different shades of brown in color with reddish tinge and a few are dark gray to gray. The subsoil ranges from reddish brown to yellowish brown. The surface soils generally are fine-textured with clay predominating and a few clay loams. The subsoils range from clay to loam. On some hills, ridges, and steep slopes some stones and boulders are present on the surface. Bluffs of limestone bedrocks are exposed on some hills. The surface soil is friable in most places and rather heavy and plastic in others.

The climate is relatively cool and humid. The mean annual temperature at Malaybalay is 72.7 F with a mean annual maximum of 88 F and a mean annual minimum of 60.3 F. As the elevation ranges from 500 feet above sea level at the lowest valley floor to 7,278 feet at the highest mountain top, the differences in elevation cause differences in temperature and rainfall which in turn cause slight differences in the character of the soil profile within the province. The average annual rainfall at Malaybalay is 2,860 millimeters (112.5 inches) which is well distributed throughout the year although it is somewhat greater from June to October than at other months of the year. Because of leaching, the soils are generally acid with pH ranging from 5.0 to 6.3. Even the soils developed from limestone have acid reaction.

Undoubtedly forests originally covered practically all of the province. During the process of soil formation, very little organic matter is accumulated in the soil. The pernicious **kaiñgin** system of agriculture, which persists up to the present, has, however, resulted in the deforestation of the whole Bukidnon Plateau and the supplanting of the original forest with grassland or secondary growth forest. More organic matter seems to be accumulated under grass than under forest, but even at that erosion and overgrazing of the grassland in the past has reduced the amount of organic matter in the soil considerably. The alluvial soils appear to be fairly supplied with organic matter. Here, erosion is nil and the rank growth of grass enhances the accumulation of the material.

The parent materials of the soils are of two classes based on source of material; namely, residual material derived from the decomposition of rocks in place and secondary material or material removed from its original position and deposited on lower areas or valleys or along streams. The first class of soil material is from weathered igneous, metamorphic, conglomerate and shale rocks and the residue of dissolved limestone. Material of the second class includes alluvial material derived from upland slopes and deposited near streams by running water.

Soils derived from rock material weathered in place belong to the Adtuyon, Jasaan, Macolod, Alimodian, La Castellana, Kidapawan, Tacloban, Calauaig, Faraon, and Bolinao series.

In an outline of profile studies and classification used by the Division of Soil Conservation Survey, patterned after the system used by the California Agricultural Experiment Station, nine profile groups are recognized based on togopraphy, mode of formation, and kind of profile. The factors of soil formation have produced varied kinds of soils in Bukidnon that can be grouped into the following:

- Profile group II
  - a. San Manuel silt loam
- Profile group IV
  - a. Maapag clay
  - b. Mailag clay loam
- Profile group VII
  - a. Adtuyon clay
  - b. Kidapawan clay loam
  - c. Jasaan clay
  - d. La Castellana clay
  - e. Calauaig clay
  - f. Macolod clay
- Profile group VIII
  - a. Alimodian clay
  - b. Bolinao clay
  - c. Tacloban clay
- Profile group IX
  - a. Faraon clay

Soils under profile group I are soils on recent alluvial fans, flood plains or other secondary deposits having undeveloped profiles underlain by unconsolidated material. Most of our so called "alluvial soils" fall in this group. None of the soils in Bukidnon fall under this group.

Profile group II are soils on young alluvial fans, flood plains or other secondary deposits having slightly developed profiles, underlain by unconsolidated material. These have profiles with slightly compact subsoil horizons. The San Manuel silt loam falls under this group.

Profile group IV are soils on older plains or terraces having strongly developed profiles underlain by unconsolidated material. These are soils with dense clay subsoils, or secondary claypan soils to which the Maapag clay and Mailag clay loam belong. The Mailag clay loam differs from the Maapag clay not only in the texture of the surface soil but also in the presence of gravels in the subsoil of the former. The subsoil of Maapag clay is yellowish brown or light brown in color while that of Mailag clay loam is gray or light gray. Besides the soil of Maapag clay is deeper than that of Mailag clay loam.

Under *profile group VII* are members of the Adtuyon, Kidapawan, Jasaan, La Castellana, Calauaig, and Macolod series. These are soils on upland areas developed on hard igneous bedrock. These soils are formed from the underlying rocks and occupy generally a rolling to steep topography. The greater part of the soils of the Bukidon Plateau which fall under the Adtuyon series, have flat to gently rolling topography, however.

Within *profile group VII* are some so called *zonal* soils. These soils owe their characteristics primarily to the combined effects of climate and vegetation on various rocks which have lain in a well-drained position long enough for a dynamic equilibrium to be reached between the decay and accumulation of organic matter and beween the rates of erosion and rock weathering. In actual fact the equlibrium may be maintained only for limited but variable periods of time. Such soils have reached their full structural profile development, and the resultant profile appears to be in accord with that which the climate and vegetation are expected to produce. Soil without such dynamic equilibrium are not classified as zonal. The Adtuyon clay, Kidapawan clay loam, and Jasaan clay may be said to belong to this order.

Profile group VIII are soils on upland areas developed on consolidated sedimentary rocks. These are soils that have been formed on stratified rocks such as sandstone, shale, or limestone. The topography is generally rolling to steep. Examples of such series are the Alimodian, Tacloban, and Bolinao. The Alimodian clay is developed from shale and sandstone while the Tacloban is formed from shale. The Bolinao clay is formed from the residue of dissolved hard limestone rocks.

Under profile group IX is the Faraon clay. Soils of this group are soils on upland areas developed on softly consolidated material. The topography is generally rolling to steep. The Faraon clay is the soil formed as a residue of the dissolution of soft coralline limestone.

Intrazonal soils (soils within soil zones) have more or less well-developed soil characteristics that reflect the dominating influence of some local factor or relief or parent material over the normal effect of the climate and vegetation. The profile development may be influenced by or due to excessive calcium or sodium in the parent rock, to excessive moisture in the soil, or to excessive time during which some soils have been forming. The characteristics of the Alimodian, Tacloban, Bolinao, and Faraoan soils are attributed mainly to the effect of relief and the soil material. The rolling or hilly topography has induced erosion and retarded normal profile development. The high content of clay in the subsoils is derived from the weathering of the shales and sandstones and apparently is not due to illuviation processes.

Azonal soils owe their simple profile characteristics to their youth, and individual types are not necessarily limited in distribution to any one zone. One azonal soil type may occur in one or more soil zones.

In general, almost all the soils are characterized by a high clay content. This condition retards the rapid deterioration caused by leaching. Such deterioration as has taken place is largely due to erosion. The agricultural soils are responsive to good management and can be brought to a higher stage of productiveness. They are retentive of moisture and generally have a good tilth or structure. This latter condition makes for easy cultivation, but it also makes the soils more susceptible to erosion.

The texture, color, and other properties of the alluvial soils reflect the character of the upland soils from which they

are derived. The Maapag clay has some of the characteristics of the adjacent Faraon clay and Alimodian clay from which it is derived. They are normally deep, dark, and productive and show only slight evidences of profile development.

PRODUCTIVITY RATINGS AND PHYSICAL LAND CLASSIFICATION

A recent development in the field of soil science is the soil productivity rating which "designates in a simple index figure the combined effect of many soil characteristics." This feature of the soil survey report is of great aid to prospective purchasers and tenants, farm loan agencies, land appraisers, and real estate agents.

The rating compares the productivity of each soil for each crop to a standard of 100. This standard index represents the average hectare yield obtained without the use of fertilizers and soil amendments on the more productive soils of the Philippines where the crop is most widely grown. Unusually productive soils may have productivity indexes of more than 100 for some crops. The standard yield for each crop shown in table 6 is given at the head of each respective column.

Record of yield over a long period is the best indicator of productivity. In Bukidnon Province most of the productivity ratings are based largely on information from farmers, the provincial agricultural supervisor, published bulletins and statistics. For soils without yield data and other information, the indexes in the table are inductive estimates for those soils taking into consideration factors such as climate, soil, slope, drainage, and management.

The primary objectivve of a productivity rating table is to give an idea of the probable productivity of individual soil types. Such a table cannot be the basis of determining land values directly since economic considerations have not been taken into account.

LAND USE AND SOIL MANAGEMENT

For agriculture to be permanent, proper land use and soil management has to be based on the use capabilities and needs of the respective soils. The term "land use" as used in this section means the broad uses of land on the farm, such as (1) cropland, (2) permanent pasture, and (3) forestry. By soil management is meant such practices as (1) choice and rotation

TABLE 6.—*Productivity ratings of soils and physical land classification of land in Bukidnon Province.*

	Crop Productivity Index For—								
	Corn 100=17 cavans	Abaca 100=15 piculs	Pineapple 100=7,500 fruits	Rice (lowland) 100=60 cavans	Rice (upland) 100=20 cavans	Camote 100=8 T	Banana 100=900 bunches	Coffee 100=800 Kgs.	Physical land classification
San Manuel silt loam	200	130	—	—	200	90	90	—	First-class soils (good to excellent crop land)
Adtuyon clay	175	100	90	—	150	50	110	100	
Kidapawan clay loam	85	120	80	—	130	45	100	105	
Maapag clay	60	—	—	100	75	—	—	—	Second-class soils (fair to good crop-land)
Jasaan clay	90	80	75	—	105	40	80	70	
Bolinao clay	70	—	—	—	70	45	70	60	
Faraon clay	70	—	—	—	70	45	70	60	
Adtuyon clay, stony phase	60	75	75	—	70	40	75	80	Fourth-class soils (generally best suited to pasture)
Tacloban clay	65	80	—	—	65	45	70	70	
Calauaig clay	—	—	—	—	—	—	85	80	
Mailag clay loam	40	—	—	50	—	30	40	—	
Alimodian clay	—	—	—	—	—	—	50	40	
La Castellana clay	—	—	—	—	—	—	55	45	
Macolod clay	—	—	—	—	—	—	50	50	Fifth-class soils generally best suited to forestry
Rough broken land	65	70	65	—	100	—	65	70	
Mt. soils, undifferentiated	—	—	—	—	—	—	—	—	

of crops, (2) application of fertilizers or lime or other soil amendments, (3) tillage methods, and (4) mechanical and vegetative means of controlling runoff.

The use capability of any land is determined wholly on the basis of physical characteristics of the land, i.e., the soil and its climatic environment. The four groups of factors to be considered are: (1) Permanence of the soil if cultivated (susceptibility to erosion); (2) productivity of the soil as conditioned by native fertility, capacity for retention and movement of water, salt content, aeration, or other factors; (3) the presence of any factor that would interfere with cultivation, such as stoniness or a hardpan layer; and (4) the climatic environment, particularly temperature and rainfall.

Bukidnon is one of the few sparsely-populated provinces in the Philippines, hence large areas of agricultural lands are still uncultivated. As it is, however, the good and better lands are not always utilized first because accessibility to roads and transportation facilities are given more weight than the productivity or suitability of the land in the choice of a farmstead. Added to this is the presence of nomadic *kaingineros* who prefer to clear the forested sloping areas than settle for good on level open lands. Besides, the greater part of the province consists of upland areas with very few and inextensive river valleys. Although a large portion of the uplands have level to very gentle slopes, the greater portion has slopes that necessitate the application of special practices if they are brought under cultivation and agriculture has to become a permanent paying enterprise. The pernicious habit of planting corn continually every year on the same soil has been going on for some time that the effects are beginning to be felt in the form of decreased yields. Since sooner or later all the presently available virgin lands will have to be cultivated, and the soil being exhaustible as it is, it devolves on the present users of the land to practice soil conservation and soil-improvement practices in order to maintain, if not increase, the productivity of the soils.

The lands of the province have been classified into three broad groups according to their topography into: (1) hills and mountains (45.35 per cent of the total area of the province), (2) the rolling and plateau area (51.36 per cent), and (3) the alluvial lands or river valleys, (3.29 per cent).

The mountains, which are heavily forested have been used for forestry. A number of the hilly areas have been used for pasture before the last war to the extent that some were overgrazed. Such hilly areas are under the Alimodian, La Castellana, Faraon, and Calauaig soils. A large area of the plateau soils (Adtuyon, and Kidapawan soils) were used also for pasture although they are suited for cultivated crops. Some areas of these soils were also overgrazed resulting in the formation of catsteps in local areas of Adtuyon and Dagumbaan in Pangantocan and Maramag districts. Parts of the Maapag and Mailag soils of the river valleys were likewise used for pasture before the war. Those agricultural lands which were used for pasture, although suitable for the growing of crops, were not then needed at the time and the returns from livestock farming for which they were utilized compared favorably, if not more, than that which could have been realized had they been devoted to agricultural crops. Because of the post-war increase in population and the fact that the lessees of the cattle ranch lands have not renewed their leases, however, the agricultural areas are already being planted to crops. Such areas as the Adtuyon project of the defunct RCPA (Rice and Corn Production Administration), the present site of the Araneta Research Farm at Maapag Plain, and the site of the Central Mindanao Agricultural College at Mosuan are examples of agricultural lands which were formerly used as pasture land but which have been lately cultivated. The soil of the Maapag Plain (Maapag clay) is best suited for lowland rice, but upland rice has also been grown successfully. Corn may be raised during the dry season on this soil. The San Manuel silt loam, another river valley soil, is best suited for corn, although other crops such as abaca, upland rice, beans, vegetables, and root crops, or any other crop, could be grown just as well.

It is encouraging to note that generally, the soils of the province have been used according to their use capability. Poor soil management prevails, however, in Bukidnon Province just like in most provinces of the country. The continual planting of corn on the same land, with sometimes as many as three crops a year, is one of the practices that needs to be stopped, if not modified. Because corn is a heavy feeder, it depletes the soil so fast of its plant nutrient elements. For this reason other crops, preferably legumes if possible, should be grown in rotation with corn in order to replenish part of the nitrogen element used by the corn or other crops. It would be better still if the legume were used as a green manure, that is, the crop is plowed under as soon as it starts to flower. With this method, the organic matter content of the soil is increased and the available mineral plant nutrients may also be increased.

As yet no exhaustive experiments or studies have been made on the more important soil types of the province as to their lime or fertilizer requirements in relation to the common crops grown on them. Soil reaction, or pH determination, of the Adtuyon clay (this is the soil of the whole Bukidnon Plateau) shows that it is very strongly acid (pH 4.5 to 5.0). For crops to do best on this soil, lime has to be applied in order to "sweeten" the soil. A few field experiments on this soil type indicate that two to three tons of agricultural lime a hectare suffices to correct the soil acidity when upland rice is grown. Higher applications may be necessary if legumes like soybeans, cowpea, or mungo are grown. The same experiment furnished evidence that ammonium phosphate fertilizer gave significant increase in yields of upland rice with applications of 100 to 300 kilograms a hectare. Higher applications have not as yet been tried, hence the best rate of application cannot be stated. Field trials on the same soil type with ammonium sulfate on corn showed marked increase in the growth of the plants but no data was available on the yield of the crop.

Results of field trials on Maapag clay using ammonium sulfate fertilizer for Palawan (upland rice variety) gave increased yields but figures for the optimum rate of application and the amount of increase in production were not available.

EROSION SURVEY OF BUKIDNON PROVINCE

Soil erosion is the washing away of the soil brought about by the interference of man with the "normal equilibrium between soil building and soil removal." It is distinct from normal or geologic erosion, the kind that occurs in the natural undisturbed environment of the soil. Geologic erosion is imperceptible because the rate of removal of the surface soil is generally no faster than the rate of formation of new soil from the parent material.

Soil erosion is an accelerated process that commences the moment man cultivates the soil. Because of the removal of the protective cover the processes of detachment and transportation of the soil body proceeds more rapidly than soil formation.

The active agents causing erosion are water and wind. In this country, erosion by wind is negligible, hence in this discussion we shall limit ourselves to erosion caused by water.

Erosion is classified into three types, i.e., sheet erosion, rill erosion, and gully erosion. Sheet erosion is defined as "the more or less even removal of soil in thin layers over an entire segment of sloping land." This is the most insiduous type of erosion because it is the hardest to detect, and it has already gone far enough when the average farmer notices it.

When the runoff from sloping land collects in furrows or depressions forming "rivulets" we have what is called rill erosion. The small furrows are easily obliterated by cultivation. When the rills of runoff from the sloping land are of sufficient volume and velocity to generate enough cutting power to produce deep cuts or gullies, we have what is known as gully erosion. This kind catches the attention of the farmer readily because the incisions give a striking picture of the landscape.

FACTORS AFFECTING SOIL EROSION

The factors affecting the rate of erosion are slope, amount and intensity of rainfall, land use, and type of soil. With the other factors remaining constant, long steep slopes accelerate erosion more than gentle and short slopes. Heavy and frequent rainfall likewise promote accelerated erosion. Heavy torrential downpours, the kind that we have most often in the Philippines, cause heavy impact of the rain drops upon the bare ground dislodging soil particles from their places causing rapid suspension in the runoff. The soil has a rate of absorption which may be high at the start of the rainfall but decreases with the increasing degree of wetness of the soil. The dislodged silt soon clogs up the pores retarding further infiltration of water with a consequent increase in the runoff. Light, protracted rains are less destructive because of the less amount of runoff formed.

Experiments in the soil conservation experiment stations in the United States conclusively show that bare plots or fields lose much more soils than fields with vegetative covers, and that close-growing crops afford greater protection from erosion than row or cultivated crops, such as corn. Some soils erode faster than others even when under the same set of conditions. Soils differ in their susceptibility to erosion as conditioned by their characteristics such as structure, texture, organic matter content, character of the profile (presence or absence of hardpan, claypan, or dense subsoil) and the nature of the colloidal materials. Heavy impermeable subsoils limit the depth of water penetration and consequently the amount that can be absorbed, hence soils with such subsoils are apt to be more erosive than soils having good internal drainage. On the other hand, soils with loose or sandy subsoil or substratum are also quite vulnerable to gully erosion once those layers are exposed in a cut because of the caving-in that usually takes place during heavy rains.

METHOD OF CONDUCTING EROSION SURVEY

In the determination of the types and degrees of existing erosion as well as in the designation of present land use, the procedures and system used were those outlined in Soil Conservation Survey Handbook by Norton.

The degree of erosion is estimated by comparing the present depth of soil profiles with those of the comparable virgin profiles of the same type under the same or similar topographic conditions. If such profiles cannot be found, the best available information is used such as plant succession, erosion history, and visible evidence of active erosion. In places where the virgin topsoil is shallower than the average plow depth, the position and depth of the lower part of the solum may be used in estimating the degree of erosion.

The term "topsoil" as used in this report, means the surface layer of soil, that is, the surface soil to average plow depth or the A horizon if this is deeper than the plow depth. "Subsoil". as used here means the B horizon or that part of it not included in the topsoil as defined above. An area was mapped as belonging to a certain erosion class when more than one half of that area were eroded to the extent indicated for that class. The various types and degrees of erosion that are recognized and used in this survey and the symbols used to designate them are as follows:

Sheet erosion:

1 — Less than 25 percent of original topsoil removed. Erosion of class 1 is mapped if the effects of erosion can be identified, but the average removal has been less than 25 percent of the original topsoil. No gullying.

2 — 25 percent to less than 50 percent of original surface soil removed.

22 — 50 percent to less than 75 percent of original topsoil removed.

3 — 75 percent or more of the topsoil removed, or all the topsoil and less than 25 percent of the subsoil removed.

4 — All the topsoil and 25 to 75 percent of the subsoil removed.

5 — All the topsoil and 75 percent or more of the subsoil removed; parent material may be eroded.

Miscellaneous classes:

O — No apparent erosion. This is mapped on nearly level cultivated land, and on land that is protected by vegetation and shows no evidence of erosion.

\+ — Recent alluvial or colluvial deposits.

\- — Undifferentiated erosion. Urban areas and farmyards, where degree of erosion cannot be readily determined.

The system used in classifying the degree of erosion is as follows:

TABLE 7.—*System used in classifying the degree of erosion.*

Erosion class	Description	Degree of erosion
0	No sheet erosion, no gullying	No apparent erosion
1	Small extent of sheet erosion and no gullying. Less than 1/4 of original surface soil eroded.	Slight sheet erosion
2	Moderate sheet erosion. 1/4 to less than 1/2 of original surface soil eroded.	Moderate erosion
22	Moderate sheet erosion. 1/2 to less than 3/4 of original surface soil eroded.	
227	Moderate sheet erosion with shallow gullies. 1/2 to less than 3/4 of surface soil eroded.	
3	Serious sheet erosion. 3/4 or over 3/4 of surface soil eroded.	Serious to severe erosion
38	Serious sheet erosion with frequent gullies. Over 3/4 of surface soil eroded.	
4	Severe sheet erosion. All surface soil and 1/4 to 3/4 of subsoil eroded.	Severe to excessive erosion
5	Excessive sheet erosion. All surface soil and over 3/4 of subsoil eroded.	

It can be seen from the above table that slightly over one half of the soils of the province are under slight to excessive erosion. Of this area subjected to accelerated erosion, less than one half is subject to erosion varying from moderate to excessive in severity.

Soil losses from erosion are usually stated in terms of tons of soil lost per hectare. A hectare of soil to a depth of 17 cen-

EXTENT OF SOIL EROSION IN BUKIDNON

TABLE 8.—*Nature and extent of erosion in Bukidnon Province.*

Erosion group	Erosion class	Description	Are (Hectares)	Per cent
I No aparent erosion	0	No sheet erosion, no gullying.	282,860	35.19
II Slight erosion	1	Small extent of sheet erosion and no gullying. Less than 1/4 of original surface oil lost or eroded.	287,620	35.78
III Moderate erosion	2	Moderate sheet erosion. 1/4 to less than 1/2 of original surface soil lost.	135,720	16.88)
	22	Moderate sheet erosion. 1/2 to less than 3/4 of surface soil eroded.	21,980	2.73
IV Serious to severe erosion	3	Serious sheet erosion. 3/4 or over 3/4 of surface soil eroded.	62,960	7.84
V Severe to excessive erosion	4	Severe sheet erosion. All surface soil and 1/4 to 3/4 of subsoil eroded.	2,560	0.32
	5	Excessive sheet erosion. All surface soil and over 3/4 of subsoil eroded.	10,140	1.26)

timeters weighs approximately 2,470 tons. Since a depth of around 17 centimeters has been lost from approximately 233,360 hectares, it is estimated that around 576 million tons of soil have been lost since they were cultivated or pastured. An average analysis of Bukidnon soils shows that they contain 5,928 kilograms of nitrogen, 31 kilograms of phosphorus, and 412 kilograms of potassium to a hectare to a depth of 17 centimeters. Converting those figures from the total amount of soil lost, we get the following: a total of 1,382,400 tons of nitrogen, 1,497 tons of phosphorus, and 96,192 tons of potassium. When we reduce these figures to their equivalents in some common fertilizers, Bukidnon has lost 6,912,000 tons of ammonium sulfate, 17,147.5 tons of superphosphate, and 192,384 tons of potassium chloride. A bag of 45 kilos (100 pounds) of ammonium sulfate costs ₱6.50, so from this basis, from nitrogen alone the province has lost ₱898,560,000. Add to this the amount of ₱1,714,750 for superphosphate and ₱26,933,760 for potassium sulfate and you realize that the province has already lost almost a billion pesos worth of fertilizers.

FACTORS RESPONSIBLE FOR EROSION IN THE PROVINCE

The factors responsible for the occurrence and degree of erosion have to be evaluated in order to be able to determine the control measures necessary and the priority or degree of emphasis for each measure. Observations during the course of the survey between the relationship of the present use and management of the soils to the degree or severity of erosion and information obtained from interviews with farmers suggest a number of factors that have caused accelerated erosion in the province. These may be mentioned as follows:

(1) *Faulty soil management and cropping system have been used for some time on most of the farms.* Corn has been grown continuously on the same land every year, with as many as three crops a year being planted. The depletion of the fertility of the soil has been brought about by such a system of cropping and especially so when no attempt or provision is made for the replenishment of the organic matter content of the soil. Corn also affords very little, if any, protection of the soil from the beating action of the rain and subsequent washing.

(2) *The grasslands have been frequently burned over and overgrazed.* The almost yearly burning of the grasslands destroyed the organic matter and leaf litter which when left intact, absorb the rainfall and thus prevent or lessen runoff. The large number of cattle in the province before the last war resulted in the overgrazing of certain areas. The catsteps often seen on hillsides and gently rolling areas attest to such a fact. The livestock make paths up and down the slopes especially near the creeks where they go for water, trample the ground, and destroy the grass cover causing heavier than normal erosion.

(3) *Plowing and planting up and down with the slope instead of across it.* A large portion of the cultivated areas in the province is in slopes with gradients of 1 to 5 percent being the most common. The slopes are long in most cases, and the longer the slopes, the greater the danger from erosion because of the increased acceleration of the runoff. The greater the speed of the runoff, the greater is the carrying capacity or erosive power. When a sloping land is plowed or planted up and down with the slope, the furrows help promote accelerated erosion by serving as miniature gullies, whereas if the plowing is across the slope the furrows function as miniature dams that check the flow of the runoff.

AREAS UNDER THE DIFFERENT EROSION GROUPS

Different degrees of erosion occur in one general region so a comprehensive discussion of soil erosion by regions does not seem to be in order. We shall then treat the subject by erosion groups and mention the areas under each group.

Severe to excessive erosion. — The areas under this erosion group occur in the northwestern part of the province adjoining Misamis Oriental. They comprise the low hills and rolling areas west of the national highway at Alae and north of the same road along the Bukidnon-Misamis Oriental boundary. The soils are undifferentiated mountain soils. While they are not cultivated, the vegetal cover consists only of very sparse growth of grasses that can hardly maintain a foothold. The protection that the grasses afford to the soil is almost nil. Trees or shrubs cannot establish themselves due to the yearly or more frequent burning of the grasses.

In the greater part of the area boulders and cobblestones are already exposed on the surface. When it rains there is no impediment for the runoff to run down the slopes carrying with it all the dislodged and suspended materials to the rivers and ultimately to the sea.

Reforestation is the only feasible method of controlling soil washing on this area. While the trees are being helped in establishing themselves all protection from burning as well as from animals should be exercised. During the period of short dry season, it may even be necessary to water planted trees that have not yet established themselves.

Serious to severe erosion. — Soils falling under this group are those that have lost 3/4 or over 3/4 of their original surface soil. Faraon clay, La Castellana clay, Alimodian clay, and a large area of rough broken land (a miscellaneous land type) are under this erosion group. Most of those areas are hill lands with slopes. The vegetation is generally grass, but a few patches of second growth forest are also found.

These soils are not cultivated but some areas have been used as pasture land before the last war. As previously mentioned elsewhere in this paper, the grasses have been frequently burned thus destroying all the organic matter on the surface of the soil. For the same reason, the growth or mantle of grass is not thick enough to give adequate protection to the soil. Some of the grazed lands have been overgrazed. Besides, the slopes are likewise steep, imparting speed to the runoff giving it great erosive power.

Boulders and cobblestones are exposed on the hillsides in some places. On the overgrazed areas, catsteps are quite prevalent. The preponderance of clay texture of the surface soils is one of the causes of accelerated erosion. Ordinary clay soils are tight that not long after the first drops of rain the tiny pore spaces soon get clogged up with silt preventing further infiltration of water. Most of the rains then become runoff.

While these soils are not agricultural they are suitable for pasture. Their carrying capacity for livestock could be much increased by preventing further wastage of the soil. This can be accomplished by stopping altogether the burning of the grasses. Since the livestock industry has not been rehabilitated as yet, the danger from overgrazing no longer exist. The grasses will then stabilize the land much faster than it would be possible under normal conditions under pasture.

Moderate erosion. — Under this group are the soils which have from 1/2 to less than 3/4 of their original surface soil eroded. All the cultivated upland areas and a former cattle ranch at Salawagan fall in this group. The soils in this group deserve special attention for two reasons: (1) almost all of the soils in this group are the productive agricultural soils of the province, and (2) it is much easier to control erosion on those soils now than it will be years later when the degree of erosion shall have advanced far enough. The costs necessary to control erosion in this group at the present time are low as compared to the costs that will be necessary in the future to assure permanent utilization of these same areas if they are allowed to go on unprotected for a much longer period.

The Adtuyon soils, which make up the greater part of the soil in the group, belong to the family of soils with deep reddish brown to brown soils to which Luisiana, Tugbok, Kidapawan, and Alaminos soils belong. The subsoil of these soils could give moderate yields after the topsoil has been removed. But even on such deep soils, moderate degree of erosion should be checked because it may indicate the present state under a rate of erosion that may destroy the whole soil profile within another 50-year period of cultivation.

One very distinguishable characteristic of the Adtuyon soils is their depth with almost uniform characteristics of the subsoil and substratum. It is for this reason that the farmers do not seem to realize the severity of erosion occurring on their fields. While some of them are already farming on the subsoil, they may be thinking that it is still the original surface soil they are cultivating. Even at the pineapple plantation of the Philippine Packing Corporation where scientific methods of farm-

ing are being practiced, the soils are being eroded just as fast as in the areas cultivated by the small farmers. The corporation is able to maintain continued production only through the use of fertilizers and by increasing or maintaining the organic matter content through green manuring with crotalaria. They are also careful to return all crop residues back into the soil by chopping all the leaves, stems, roots, and all parts of the pineapple plants in the field before plowing. While tillage is on the contour, planting of the pineapple plants is not on the contour but in straight rows that sometimes run up and down with the slopes. The runoff is drained off the fields through a system of small, shallow drainage ditches of about a foot wide and half a foot deep.

Erosion occurs on those soils mainly because of the abundant rainfall and faulty soil management. It is apparent that some kind of vegetative cover should be provided especially during the months of heavy rainfall such as June to October. A system of cropping should be adopted whereby the corn crop should be limited to not more than two crops a year or only one crop, if possible. Some kind of a legume crop should be grown at least once a year to be used as green manure. All cultivated lands with slopes should be tilled on the contour and planted along the contour. Any erosion control program on the Adtuyon soils resolves itself into a combination of a good rotation system of farming (with less corn), terracing, and contour farming (perhaps considerable strip cropping). With the addition of small amounts of lime and in some cases, phosphate fertilizers, practically any combination of farm crops can be grown. Terracing should play an important part in the agriculture of the province. Inasmuch as large areas of corn are now being planted on the Adtuyon soils, it is likely that terracing will permit the use of a rotation which includes more corn than should ordinarily be planted on unterraced land. With or without terraces, less corn must be grown in the future than is raised at present if the fertile soils are to be completely saved from losses due to erosion.

On the range lands subject to moderate erosion, the most effective erosion control measure to adopt is controlled grazing. The different parts of the range should be pastured in rotation so as to allow the grasses to recover. If necessary the amount of stock on the range should be reduced.

Slight erosion. — Under this group of erosion are the soils that are subject to accelerated erosion but have lost only less than 1/4 of their original surface soil. The areas falling in this group are the former cattle ranches and kaingined areas which are now under secondary growth forest. The lands are gradually being stabilized as a result of the non-rehabilitation of the cattle industry and the increasing education among the native population. So long as the grasslands are no longer burned yearly or overgrazed as they were before the war, there is all the possibility of complete stabilization of the soils, a few years hence. The areas now under secondary growth will also continue to be stabilized as the trees grow larger and approach that of the virgin forest. No erosion control measures are necessary on those soils except to let nature take its course without the least disturbance.

The greater part of the soils in this group belong to the Kidapawan series with lesser areas of Adtuyon clay and Macolod clay. The Kidapawan soils make good abaca soils due to their high elevation with increased rainfall and cooler climate. Fruit trees such as coffee, avocado, marang and other trees also do well just as they do on the Adtuyon soils. These crops can be planted on those soils without danger from erosion because they are permanent crops, especially so if some legume cover crop is planted in the orchard.

No apparent erosion. — Under this group are soils on level or nearly level cultivated land, and on land that is protected by vegetation showing no evidence of erosion. Active normal erosion — that is, erosion that has not resulted from activities of man or natural destruction of plant cover is also included in this group. The level or nearly level lands are those under Maapag clay, San Manuel silt loam and Mailag clay loam. The areas under normal erosion are the undifferentiated mountain soils. The soils of the plain mentioned are not eroded mainly because of their level or nearly level topography. The mountain soils on the other hand have rough topography but they are well protected with forest vegetation.

EFFECTS OF SOIL EROSION IN THE PROVINCE

Physical effects—To the average layman or farmer, the physical effects of erosion are not very apparent. Yields of corn are already on the decline on those farms that have been farmed for a decade or so. The ordinary farmer however, does

not always notice his diminishing production for the reason that hardly any records are kept about the farm operations.

Sheet erosion, the insiduous type, is the most prevalent type that occurs in Bukidnon. Most of the cultivated soils belong to the Adtuyon and Kidapawan series, two soils both deep and almost uniform in color, texture, and structure from the surface down to the substratum. People do not realize the severity of erosion occurring on their farms because of these imperceptible differences in the soil profile so that even when they are already farming on the subsoil they may believe that it is still the more productive surface soil that they are working on. And because sheet erosion is not as spectacular as gully erosion, it does not often catch the eye of the farmer.

The burning and overgrazing of the grasslands resulted in the thinning of the stand of the grasses and in some places other species less desirable for the livestock have supplanted the more palatable ones. The reduction or near extinction of the cattle industry during the Japanese occupation until the present is affording those former pasture lands time to stabilize their grass cover and ultimately normal erosion.

Perhaps the most destructive outcome of accelerated soil erosion is the removal of the physical body of the soil including everything that is in it—plant nutrients, soil minerals, organic matter, and beneficial organisms. While poor or infertile soils can be improved by the addition of soil amendments and organic matter, soil erosion leaves nothing to be improved but rather transports everything from the usable cropland to the bottom of the seas and mouths of rivers. The damage is not only confined to the eroded land but it also affects the adjacent lower areas where the eroded materials are finally deposited. Some of the materials are deposited along rivers and creeks thus decreasing their water-carrying capacity and increasing the possibility of floods.

Economic effects. — The economic effects of soil erosion are not as apparent as the physical effects. They are nevertheless important and far reaching. It is but natural to expect that the continued operation of a system that undermines the basic industry of the province, agriculture, can have only an adverse effect on the people.

The decrease in yields could be temporarily staved off through the use of fertilizers but even this is only a palliative and cannot go on indefinitely if agriculture is to be permanent.

If erosion is allowed to go on unchecked, the time may come when the farmers may be farming on the parent material or bedrock in which case no amount of fertilizer will then be effective because one cannot simply farm on bedrock. Fluctuations in prices and social ills are closely interrelated with erosion conditions. High prices are usually incentives for agricultural practices which in the long run are unsound and conducive to promoting accelerated erosion. Likewise, low prices have the unwholesome effect of inducing exploitative farming because of the necessity of producing enough to meet current operating expenses and overhead.

The adoption of sound land use and conservation program may necessitate the retirement of part of the cultivated lands in a farm resulting in a reduction of the farm income. With normal prices, the retirement from cultivation of eroded or poor lands enables one to concentrate operations on the better lands with little or no reduction of the farm income. Ordinarily, however, the adoption of soil conservation measures usually entails decrease in immediate returns. The long time benefits that accrue from such measures, however, offset those possible early losses in income. Some kinds of tenants and land speculators are averse to the adoption of conservation measures since they have only a short term interest on the land.

Cultural effects. — The adverse effect of erosion can be felt by the people in a number of ways. Eroded soils are poor soils; poor soils mean low yields; low yields give low income; low income of the people means low tax collections for the government. When the coffers of the government are depleted, it (the government) cannot build good roads, schools, or markets. Hospitals and dispensaries are inadequately provided and other public services may be wanting. This is true whenever agriculture is the basic industry or source of livelihood of the people like in Bukidnon Province.

METHODS OF PREVENTION AND CONTROL OF EROSION

The conservation survey. — The typical productive unit nearly everywhere is the family farm. At the outset, the soil conservationist should recognize that even the well established farmer must weigh many things before changing his business to incorporate the desired soil and water conservation measures.

The guiding principle in conservation farming is the "effective prevention and control of soil erosion and adequate

conservation of rainfall in a field, on a farm or ranch, over a watershed, or on any other unit or parcel of land, requires the use and treatment of all the various kinds of land comprising that area in accordance with the individual needs and adaptabilities of each different area having any important extent."

The real objective in conservation farming is to have the farmer make a creditable living for himself and his family, and at the same time treat his land in such a way as to assure continued economical production.

Before anything is started on the farm, the *farm conservation plan* must be formulated. This plan is the "outline of a course of operations designed to safeguard the producing capacity of the land, hold the soil in place, and insure a going business." It is not an end in itself, and the farmer should take part in its formulation. A practical plan will adapt itself to the hard realities and call for a sensible sequence of changes. It should permit all likely contingencies. The plan is not rigid and unchangeable. It takes four or five or even eight years to install the necessary measures depending upon the degree or degrees and extent of erosion on the particular farm. As the plan takes form, revision and refinements may be necessary.

The usual procedure in the formulation of a farm conservation plan is to take three factors into consideration. These are: (1) conservation survey (inventory); (2) farm organization, (economic aspects, present cropping programs, equipment, buildings, water supplies, fences); and (3) the farmer and his family (experiences, likes and desires, and abilities).

Four major land factors are mapped in a conservation survey — soil type, slope, type and degree of existing erosion, and present land use. Soil types are mapped according to accepted standards as contained in Soil Survey Manual (pp. 65-100) by Kellogg.

In the establishment of slope groups and the determination of the types and degrees of existing erosion as well as in the designation of present land use, the procedures and systems used are those of the Soil Conservation Survey Handbook by Norton.

Slope classes are established to indicate the maximum degree of cultivation that can be carried on with satisfactory control of erosion. Slope group A are the areas which are nearly level on which little or no erosion occurs regardless of the kind of tillage. Slope group B are those that are subject to erosion when cultivated but may be controlled satisfactorily provided the proper practices are employed. Slope group C are those that are too steep for clean cultivation but could be planted to close-growing crops for protection during critical erosion periods. Slope group D are those too steep for any cultivation and should be kept under permanent cover to either grass, shrubs, or trees.

Four land use classes are mapped in a conservation survey — cropland, idle land, pasture, and woodland. Their definitions and symbols are as follows:

L. *Cropland.* — This class includes all land planted to crops and, in addition, fallow land and orchards.

X. *Idle land.*—Land either void of vegetation or maintaining plant growth of little economic or agricultural value is mapped under this class.

P. *Pasture.* — This class includes grazing land or range other than pastured woodland, and land in grasses or legumes that is devoted primarily to grazing.

F. *Woodland.* — Woodland includes land with 40 percent of the ground covered by the spread of woodland or forest species of any age and land devoted to forest plantations.

Land-use map (*Land capability classes*). — From the conservation survey, one can determine the land capability classes on the farm. These classes indicate the most intensive tillage that can be practiced safely with permanent maintenance of the soil, or in regions where cultivation is not practiced, the most intensive utilization for range or forestry that at the same time preserves the soil and its plant cover. The classes are determined wholly on the basis of physical characteristics of the land, together with the climatic environment, at the time of mapping. Where an uneroded or but slightly eroded cultivated area is sufficiently steep to be susceptible to destructive erosion, this susceptibility is in itself a present condition.

In the formulation of the general definitions of use capability, the number of classes are reduced to a minimum.. In cultivated regions, four classes are recognized—I, II, III, and IV ranging from areas wherein the land could be cultivated safely (I) to those in which permanent vegetation for protection should be maintained (IV). The classes and the land they designate are:

I. Land suitable for cultivation without special practices.
II. Land suitable for cultivation with simple practices.
III. Land suitable for cultivation with complex or intensive practices.
IV. Land not suitable for cultivation.

The groups of factors used in the determination of the above classes are: (1) Permanence of the soil if cultivated (susceptibility to erosion); (2) productivity of the soil as conditioned by native fertility, capacity for retention or movement of water, salt content, aeration, or other factors; (3) the presence of any factor that would interfere with cultivation, such as stoniness, or a hardpan layer, and (4) the climatic environment, particularly temperature and precipitation.

In the general definitions of the classes, the soil requirements of different crops were not considered. In like manner, the profitableness or unprofitableness of cultivation was not taken into account since the profit factor is usually governed by such factors as accessibility to markets or prevailing prices rather than by the nature of the soil or its climatic environment.

Mention must also be made of the fact that frequently the dividing line between any two classes necessarily is somewhat arbitrary. The Adtuyon clay, stony phase would be classed lower than the Adyuton clay, even if it were more level or more productive than the latter, because of the presence of stones. A sloping area of Kidapawan clay loam, assigned to class III, may be much more productive than a level area of Adyuton clay, although the latter would be assigned to class I because it needs no erosion-control measure or other special practices in order to produce moderate yields. Productivity is only one factor in the determination of land use capability and is considered only in those instances where it is a limiting factor.

In every instance, the capability appraisal of the land is based on conditions existing at the time of mapping. Classes of land according to use capability may not be permanent. The removal of topsoil by accelerated erosion, increased availability of irrigation water, accumulation of toxic salts, and artificial drainage may necessitate reclassification later. Introduction of new crops or of farming methods not previously known to be applicable may have a similar effect. Experience may show that some established practices may not afford adequate protection of the land, so that a reclassification or reappraisal of the former classification may be necessary.

When the land-use capabilities of the soils are determined, they are marked on the field sheets or map. The planning technicians who use the maps can then tell at a glance, by looking at the classes of land according to use capability, the maximum intensity of agricultural use that can be practiced safely. An understanding of the reasons for placing a specific tract in a given class can be had by an examination of the separate factors expressed in the conservation survey symbol. The technician then considers, in addition to the physical resources, the preferences of the farm owner or operator as well as the economic feasibility of any system of cropping or any practice recommended.

CONTROL OF EROSION

Erosion-control measures designed to slow down or minimize soil erosion may be grouped under two headings — mechanical and vegetative. The measures under mechanical control may be mentioned the following: (1) contour tillage, (2) terracing, (3) contour furrowing in pasture land, and (4) gully control. Those under vegetative control are (1) contour strip cropping, (2) contour buffer strip planting, (3) planting orchard trees in contour rows, (4) cover cropping, and (5) use of grassed waterways.

Not all of these measures may be necessary for adoption on each farm. The measure to adopt in a certain area depends upon a number of factors such as (1) slope, (2) degree of erosion, (3) kind of crop to be grown, and (4) erosibility of the soil.

Erosion control on cropland — Under a system of contour farming, all plowing and furrows are on the level. The furrows and rows of plants under contour tillage function as small dams or terraces that retard the flow of water.

The practice of contour strip cropping functions under the same principle as contour farming — it retards the flow of water through the use of close-growing vegetation. Under this system of cropping, row crops like corn or peanuts are planted in bands between bands of close-growing crops. Runoff from land in row crops, even under contour cultivation, is more rapid than runoff from land in close-growing crop, the movement or flow is slowed down, part of the soil load is deposited and more moisture enters the soil.

Strip cropping is the growing of crops by dividing the field into blocks or strips so that each strip of clean-tilled crop like corn is protected by a non-cultivated strip of small grain like upland rice or a legume such as mungo. While this system of growing crops is new in this country and has not been practiced to any great extent, experiments and demonstrations in the United States conclusively show that, when combined with other erosion-control measures where necessary, it is very economical and effective and one of the most practical means of conserving soil and water on cultivated land.

Contour strip cropping divides the length of the slopes, checks the momentum of runoff water, filters the soil being carried off, and increases the absorption of rain water by the soil. It encourages the use of proper crop rotation and helps maintain a balance between soil-building and harvested crops. It can be installed at practically no expense and the maintenance is low. The strips do not require the same degree of engineering exactness as terraces. Strip cropping conserves time and energy. Usually the rows are long, hence fewer turns, and less power are required for operations on the same level, which is obtainable only in contour cultivation. The effectiveness of strip cropping depends on the production of the right kind of vegetation in an amount adequate to offer resistance to water. It is a purely vegetative control. Grass is probably the most effective, but small grains like upland rice sown broadcast and most of the legumes are good substitutes. When planning a strip cropping system, advantage should be taken of the erosion-resistant crops best adapted to the locality.

In laying out of the strips, no hard and fast rules could be laid down for all conditions. Practicability and soundness of the conservation measures is of utmost importance. This may necessitate change or changes in the farming system or land use to fit those soil-conserving methods. It may be the relocation of fences, retirement of some of the steeper slopes from cultivation and putting them to pasture or trees, and adjusting rotations to meet the variations in erosibility of the soil. Long, steep, impervious slopes naturally require a much larger proportion of close-growing erosion-resistant crops than short, gentle pervious slopes.

Generally, the width of the strips depend on type of soil, slopes, length of slope, amount of normal rainfall, kind of crops, rotation, use of cover crops, amount of soil humus, degree of erosion and type of farming followed. Under the most favorable conditions, the strips should not be more than 65 meters nor less than 15 meters. The kind, density, and amount of vegetation used in the control strips are other determinants of width. On soils of low fertility that will produce only scant vegetation, control strips will not be so effective and should be reinforced with terraces.

Mamisao (1949) recommended, under the rainfall intensities in the Philippines, the following figures to serve as guide in determining widths of contour strips:

Slopes from level to 5%	— 40-50	meters measured along the slope
5% to 8%	— 36-45	" " " " "
8% to 10.5%	— 32-40	" " " " "
10.5% to 13.5%	— 28-35	" " " " "
13.5% to 16.5%	— 24-30	" " " " "
16.5% to 19.0%	— 20-25	" " " " "
19.0% to 22.0%	— 16-20	" " " " "
22.0% to 25.0%	— 12-15	" " " " "

"When the soil is permeable with good internal drainage and when the crops to be planted are close-growing, the upper limit of the width is chosen. For big, tall crops, such as sugar cane and ramie, the upper width limit may also be chosen but additional conservation measures may have to be practiced if the soil is tight and internal drainage is poor."

Slopes between 1 per cent and 2 per cent are usually strip-cropped in addition to contour cultivation. With higher slopes up to 3 percent, the same methods of control are used but the widths of the control strips are increased and those of the strips of row crops are decreased. Slopes between 4 per cent and 6 per cent should have strip cropping reinforced with terracing where necessary. Slopes higher than 6 percent should be terraced, and all terraced lands should be strip cropped. All severely eroded lands should be retired from cultivation and seeded to grass or legumes if possible.

Mechanical measures of erosion control — In planning an erosion control program, proper management of the cultivated vegetal cover to simulate natural conditions as nearly as possible is given primary attention. In addition, mechanical measures are often used in a supplementary or complementary manner.

The season of cultural practices such as the plowing of fields or seedbed should be timed so that it is not too far in advance than what is necessary before planting. It is during the periods

when the soil lacks vegetal cover that mechanical measures of erosion control are needed most. "Terrace" as used in this discussion refers to the broad-base terrace as distinguished from the "bench" terrace common in sloping fields devoted to lowland rice. The broad base terrace can be cultivated and planted on top as well as on the sides.

Terracing as a means to control erosion should be resorted to only when the measures previously described do not suffice. Terracing requires a certain degree of engineering skill and usually a trained soil conservation technician or agricultural engineer is needed to supervise its construction. Terraces intercept the runoff and impound it temporarily thus giving the soil more time for absorption, or it drains the water off slowly to natural drainageways. When improperly constructed they may do more harm than good. The presence of well protected waterways is essential in terraced fields otherwise one would be starting the formation of gullies. Terraces are expensive to construct and maintain.

There are two types of broad-base terraces — absorption type and drainage type. The former has little or no grade along the channel and is designed to hold the water until it is absorbed by the soil. For this reason the channel is as little as possible in order to give greater area for the water to spread out hence greater absorbing surface. This type is for permeable soils or those with high rate of absorption.

The drainage type is slightly graded, and its main use is to conduct the runoff slowly from the field to the protected drainageways. This type is used on soils with slow or poor internal drainage.

It must be mentioned that these terraces must be so constructed and spaced so that they function under the maximum rainfall intensity of the area. They would be worse than useless if breaks occur during heavy rains since the concentration of the runoff would give it more destructive power than if allowed to flow on the unterraced field.

The soil on gullied lands can be held in place only if it is planted to trees, shrubs, and vines. In such places, it is often necessary to construct in the gullies inexpensive soil-saving dams made of native materials to aid the plants in getting started.

Bukidnon is one of the few provinces in the Philippines well adapted to fruit growing. It seems propitious to state that should orchards be established it is best that the trees be planted on the contour. Should it be desired to irrigate the trees during periods of low rainfall the application of water will be greatly facilitated by the presence of rows on the contour.

Cover cropping of orchards is also advocated for a number of reasons. Cover crops keep down weeds, provide organic matter for the soils, and minimizes soil erosion. If legumes are used, the nitrogen supply or content of the soil is increased through the fixation of nitrogen from the air.

Erosion control on pasture land or grassland.—The problem of erosion control on pasture land is not acute now as it was before the last war. The only control measure for range land is controlled grazing or reducing the number of stock on the range. This gives the grasses enough time to reestablish themselves.

The pernicious habit of burning grasslands must be stopped altogether if the soils are to accumulate organic matter so essenial in increasing infilration rate and water-holding capacity of the soils.

Erosion control on woodland or forest areas. — The destructive system of *kaingin* agriculture on steep slopes being practiced by the native population should be stopped and discouraged. The benefits derived from a year or two of cropping on a kaingin do not compensate for the irreparable damage done to the land.

It should also be mentioned that selective logging by forest concessionaires be practiced in order that enough vegetation remains in logged-off areas to provide partial protection to the soil. "Clean" cutting removes practically all natural curbs on waterflow.

In summarizing what has been said about controlling runoff and erosion, it is neither suggested nor implied here that lands should be returned to a state of nature merely for the sake of runoff and erosion control. Generally speaking, such an idea is absurd. Over most of the thousands of hectares of agricultural, range, and forest lands, the problem is one of management—management with the end in view to keep to a minimum the wastage by runoff, erosion, fire, and flood. Land management for conservation is a means to an end; it is not an end in itself. We conserve natural resources and plan their more effective use for aid in erosion control and drought alleviation in order to promote human welfare. We advocate it so that we may produce continuously the food, fiber, and timber that we require. Each program of erosion control must take into account the people living on the land and their well-being. Whether land is cropped, forested, or pastured, whether it is operated by owners or tenants, it must, if privately owned, yield a fair return. The public should keep in mind that food comes from productive land and nowhere else and that productive land in the Philippines, or around the world for that matter, is already scarce and getting scarcer. Teamwork or cooperation of those who use the land is essential. Land use practices and conservation measures will not function without the day-to-day attention and interest of the person who is making his living from the land.

Irrigation comes second in importance among the water control practices in Bukidnon Province. While it is true that there is only a short dry season in the northern half of the province, there are times when droughty periods occur, as it happened during the time of the survey in 1950, in the southern part such as in Maramag and Kibawe. The very low yield of upland rice in those places mentioned that year was partly due to the lack of rains during the heading period of the crop.

In one sense, all irrigation is supplemental since rainfall provides some part of the water required by crops. It is most needed during droughty years.

The Maapag soils in Managok, Minlawaan, Simaya, Nabago, Maapag, and Dagatkidavao plains and the plain in Maramag and Mailag are all suitable for irrigation, and can be devoted to lowland rice. The almost flat relief of those plains promote an economical and even distribution of the water. The many rivers and creeks in those areas have enough discharge for the purpose. Since under irrigation, water supply is no longer a problem, the late maturing varieties of rice, which are also high yielders, could be planted. Or if it is desired to plant two crops of rice a year, it is only through irrigation that it can be made feasible.

Irrigation in other parts of the province like the plateau is possible but the excessive depth of the rivers necessitate the construction of expensive dams. The smaller and, incidentally shallow streams, however, can be used without the construction of costly structures.

If irrigation is developed in the province, the development of drainage is a natural concomitant in the irrigated areas. This is especially true on the Maapag soils previously mentioned if harvestors (machinery) are used in harvesting. Even under present conditions of rainfall obtaining in the province, drainage of the Maapag soils appears to be a necessity. Experience at the Araneta Research Farm in Maapag Plain shows that drainage facilities must be provided if the rice crop is to be harvested in time with the use of machinery.

Due to the high elevation of the greater part of the province, the streams have generally high grades giving speed to the streams. For this reason over-all drainage is adequate and the chances of floods or overflow are very few.

CHEMICAL CHARACTERISTICS AND FERTILIZER REQUIREMENTS OF THE SOILS OF BUKIDNON PROVINCE

By Ricardo T. Marfori [1] and Ignacio E. Villanueva [2]

The province of Bukidnon has been reportedly popularly known and advertised because of the famous cattle ranches pioneered by Messrs. Cruz, Roces, Sanvictores, Guingona, Fortich, Cudal, etc. and the Philippine Packing Corporation. The company leased several thousand hectares of good agricultural lands devoted to the growing of pineapple for sale in the Philippines and abroad. These alone brought the province of Bukidnon to its present economic importance to the whole country.

With vast rolling lands and extensive grasslands of the plateau, early settlers were induced to engage in the ranch business. Only quite a few succeeded in this ranch business, and up to this writing only one has been rehabilitated. The kaingin system of agriculture which has caused the deforestation of the areas led to the transformation of the forest area into grasslands, or grazing lands. Nevertheless, the much travelled Ilocanos, Tagalogs, Pangasinans and Visayans who believed in the pioneering work in the Mindanao jungles arrived and settled there. With increasing number of settlers from Luzon encouraged by the Administration, the agricultural potential of the province should be known. A soil survey was conducted sometime ago to identify and classify the soil types based on their morphological and genetic characteristics, as they are found in the field. In conjunction with these, studies of the chemical characteristics of these soil types were made in the laboratory. The results of the analysis of the soils brought from the fields are interpreted and are presented in the succeeding pages, which the writers believe serve as a guide in adapting an efficient soil management and in formulating systematic cropping practices.

The laboratory furnished the following information: soil reaction (or pH value) denoting acidity or alkalinity as a

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guide to crop adaptation, deficiency or sufficiency of the nutrient elements needed for plant growth; toxic substances—present, to what extent are they toxic; lime and fertilizer requirements of the soil types for a maximum crop yield.

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

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

Agricultural soils are mostly acid in reaction. Sometimes very unusual and excessive acid reaction of the soils occur and may be due to calcium deficiency. Hence, the necessity of liming the soil with a view not only to correct the acidity but also to supply the calcium ions needed by the plants. Agricultural lime usually contains considerable amount of magnesium, hence, the application of lime includes magnesium as in the dolomitic limestone and magnesium sulfate. The progress of research and the rapid advancement in scientific work in the U.S., have led to the inclusion in the compounding of feeds and fertilizers the elements calcium and magnesium. Much and many more are to be known as years go by through extensive experimentation.

METHODS OF CHEMICAL ANALYSIS

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

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

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

The degree of acidity of the soil expressed as pH was determined by using the Leeds and Northrup Universal pH meter fitted with a glass electrode. The organic matter was determined by the modified method of Peech and English (30).

The 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 (12). The ammonia and nitrates were determined by the methods of Spurway (34). The available phosphorus was determined by the methods of Truog (37), and the available potassium, calcium, magnesium, iron and manganese were determined according to the methods of Peech and English (30). The Leitz photoelectric colorimeter with light filters was used in the determination of the readily available nutrient elements.

INTERPRETATION OF CHEMICAL TESTS

Soil reaction or pH value.—Soil pH assumes an important place in soil research, in plant physiological investigations and in the diagnosis of field agricultural problems. The soil reaction denotes the degree of acidity or alkalinity affecting fundamentally the behavior and availability of the plant nutrient elements essential to plant growth. Soils that are highly acid or those with very low pH values render the soluble aluminum ions to accumulate in concentrated forms thereby becoming toxic to plants. Soils of high pH values or of high alkalinity makes the iron, manganese, copper and zinc unavailable to plants, thus causing abnormal growth.

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

"The influence of reaction on availability of each nutrient element is expressed by the width of the band (the wider the

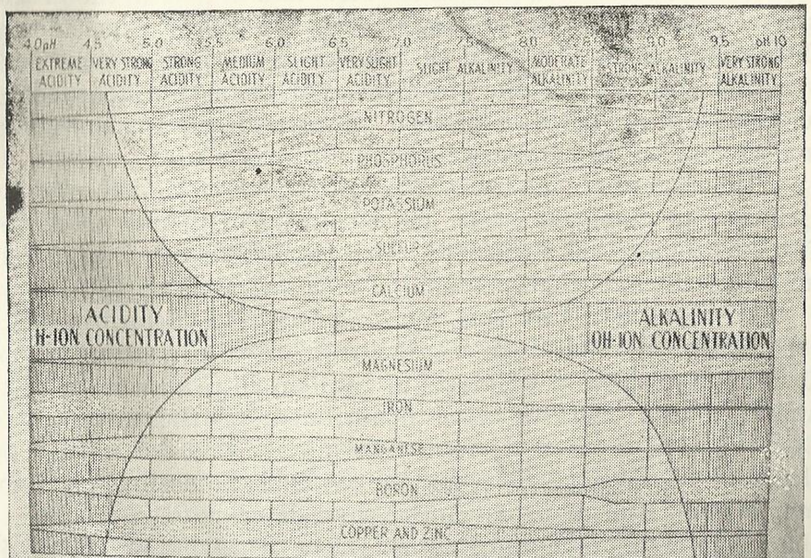

FIG 2 CHART SHOWING GENERAL TREND OF RELATION OF REACTION TO AVAILABILITY OF PLANT NUTRIENTS

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

Fig. 6/2.—Width of bands indicates "favorableness of reaction influence" to the presence of adequate "amounts necessarily present"; these amounts are influenced by many other factors.

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

The soil reaction or pH value of the surface soils of the fourteen different soil types of the province of Bukidnon ranges from 5.0 to 6.3 (from strongly acid to slightly acid.)

Table 9 shows that different plants have different pH preferences and different tolerance limits. Some species like pineapple and tobacco grow most favorably under slightly acid soil condition (pH 5.5 to 6.1). Other crops like alfalfa, sugar cane and orange prefer less acid or even slightly alkaline conditions (pH 6.2 to 7.8). The pH tolerance limits for the first group of plants mentioned above have been estimated at pH 4.8 to 6.9 while those of the second group are pH 5.5 to 8.5. Some plants however, like corn and tomato can tolerate a wider range (pH 4.8 to 8.5) although the best growth of these plants had been observed between pH 6.2 to 7.0.

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

TABLE 9. *The pH requirements of some economic plants*

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

Plant	Strongly acid pH 4.2-5.4	Medium acid pH 5.5-6.1	Slightly acid pH 6.2-6.9	Neutral reaction pH 7.0	Slightly alkaline pH 7.1-7.8	Medium alkaline pH 7.9-8.5
Abaca, *Musa textiles* Nee [1]	Y	X	X	X	Y	O
Caimito, *Chrysophyllum caimito* Linn [1]	Y	X	X	Y	O	O
Coffee, *Coffea arabica* Linn [1]	Y	X	X	Y	O	O
Cowpea, *Vigna sinensis* (Linn.) Savi [2]	Y	Y	X	Y	Y	—
Corn, *Zea mays* Linn. [2]	Y	Y	X	X	Y	Y
Durian, *Durio zibethinus* Linn [1]	Y	X	X	Y	O	O
Peanut, *Arachis hypogaea* Linn [2]	Y	Y	X	X	Y	—
Pe-tsai [4] *Brassica pekinensis* Rupr [4]	Y	Y	X	X	X	X
Rice, *Oryza sativa* Linn [1]	Y	X	X	Y	Y	O
Sugar cane, *Saccharum Officinarum* Linn [2]	O	Y	X	X	X	Y
Tobacco, *Nicotiana tabacum* Linn [2]	Y	X	Y	O	O	O
Sweet potato, *Ipomoea batatas* (Linn.) Poir [1]	Y	X	X	Y	O	O
Cassava, *Manihot esculenta* Crantz.	Y	X	X	X	Y	Y
Pineapple, *Anonas comosus* (Linn.) Merr [1]	Y	X	Y	O	O	O
Banana, *Musa sapientum* Linn. [1]	Y	X	X	X	Y	O
Tomato, *Lycopersicum esculentum* Mill [2]	Y	Y	X	X	Y	Y
Onion, *Allium cepa* Linn [2]	O	Y	X	Y	Y	Y
Soybean, *Glycine max* (Linn.) Merr [2]	Y	X	X	X	Y	Y
Orange, *Citrus auratium* Linn. [3]	—	Y	X	X	X	Y

[1] Based from the soil reactions where they are grown with the productivity ratings of the soil types in 11 provinces. A pH ranges of 5.7 to 6.2 was found to be most suitable for the growth of upland rice, variety Inintiw. by Rola, Nena A., and N. L. Gavlez. 1949. Effects of soil reaction on the growth of upland rice and on its nitrogen, calcium, phosphorus and iron content. Philippine Agriculturist 33: 120-125.

[2] Data taken mostly from Weir Wilbert Weir. 1936. Soil Science. Its principles and practice. J. B. Lippincott C. Chicago and Philadelphia.

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

[4] From Arciaga, Antonio N., and N. L. Galvez. 1948. The effect of soil reaction on the growth of pet-sai plants and on their nitrogen, calcium and phosphorus content. Philippine Agriculturist 32: 55-59. Normal growth reported was in pH 4.2 to 8.6; optimum range was pH 5.9-8.6.

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

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

Most plants assimilate their nitrogen from the soil in the form of nitrates, and to effectively produce this available nitrogen, the soils must be moist, warm and well aerated for the activity of the microorganisms. This is known as nitrification. Rice and other grasses of the same family absorb the ammoniacal form of nitrogen. This ammoniacal form can be fixed in the soil and not easily lost through leaching. The nitrate form of nitrogen however is very soluble and easily lost by leaching and therefore cannot be fixed.

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

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

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

So far analyzed in the laboratory, the average total nitrogen content found in Philippine cultivated soils is about 0.14 per cent as against 0.25 per cent average for Bukidnon province. The total nitrogen content ranges from 0.15 to 0.43 per cent, having an average of 0.25 per cent. All of the soil types identified and analyzed are presented in table 10 which are all above average for total nitrogen. The available NH_3 is medium although NO_3 nitrogen is rather low, ranging from trace to 10 p.p.m. Seven of these soil types have traces of NO_3. The surface soils in Bukidnon have a high total nitrogen, low ammonia and nitrates. For crops mostly growing on moist soils the ammonia form is mostly used, while on a well-drained soil the nitrate form is mostly used. In spite of the high total nitrogen content, some of the soils require nitrogenous fertilizer.

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

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

Because of its relatively small quantity as found in agricultural soils and being a major plant nutrient, its depletion or exhaustion from the soil should be carefully minimized. The stunted growth is the most characteristic symptom of plants grown in soils deficient in phosphorus. The growth symptom that serves to identify a phosphorus shortage is not however clearly defined. The plants usually appear dark green, but corn and some of the small grains sometimes show purplish tints on the leaves and stems when grown on phosphorus-deficient soils. Legumes show bluish green color of leaves and appear stunted.

TABLE 10.—*Chemical analysis of the surface soils of Bukidnon Province.*

Soil type	Productivity ratings for corn 100=17 cavans	pH value	Total nitrogen	Available constituents in parts per million (p.p.m.)							
				Ammonia (NH_3)	Nitrates (NO_3) trace	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Manganese (Mn)	Iron (Fe)
			%								
1. San Manuel silt loam	200	5.60	0.19	10	trace	36	125	1700	1050	27	1
2. Adtuyon clay	175	5.30	0.26	25	10	4	83	300	80	87	2
3. Jasaan clay	90	5.70	0.21	10	2	13	170	1600	1060	60	1
4. Kidapawan clay loam	85	5.40	0.23	10	2	3	254	900	140	55	2
5. Bolinao clay	70	6.30	0.41	10	10	77	166	1800	500	90	1
6. Faraon clay	70	5.50	0.23	10	trace	3	44	1100	730	23	1
7. Tacloban clay	65	5.55	0.16	10	trace	15	254	4300	1400	205	2
8. Adtuyon clay, stony phase	60	5.55	0.21	10	trace	2	163	700	310	23	trace
9. Maapag clay	60	5.00	0.29	10	5	4	103	700	480	53	10
10. Mailag clay loam	40	5.30	0.43	10	trace	4	96	900	50	81	2
11. Calauig clay	—	5.80	0.30	10	trace	6	71	1500	780	108	trace
12. Alimodian clay	—	5.40	0.20	10	trace	4	227	2000	1060	185	1
13. La Castellana clay	—	5.30	0.21	10	10	7	299	1100	500	24	trace
14. Macolod clay	—	5.60	0.15	10	5	5	106	1700	640	11	trace

Tobacco manifests a dark green color and a delay in maturity. Citrus fruits are deep green and later fading to bronze, followed by development of necrotic areas and shedding. In rice, it may delay maturity for as much as two months.

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

Table 10 shows the analysis of the different soil types for available phosphorus. It ranges from 3 p.p.m. to 77 p.p.m. with an average of 13 p.p.m. for the province of Bukidnon. Only 2 of these soils gave over 30 p.p.m. represented by San Manuel silt loam and Bolinao clay which gave 36 p.p.m. and 77 p.p.m. respectively. Most of them have below 10 p.p.m. of available phosphorus. For all crops, excepting the two soil types mentioned, the soils of Bukidnon show a deficiency of phosphorus and therefore require phosphatic fertilizer.

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

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

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

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

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

Marfori et al. (23) of the Bureau of Soil Conservation in their study of the fertilizer requirements for lowland rice on some Philippine rice soils found that where the soils are highly deficient in available potassium, small applications of potassium fertilizers generally will not give immediate significant increases in crop yields because of the fixation of the added potassium in the base exchange complex of the soil. However, large initial applications of potassic fertilizers on such a soil will satisfy or saturate its potassium fixing capacity and leave enough available potassium for immediate use by plants, thereby increasing yields. With larger applications on the Buenavista silt loam and Maligaya clay loam containing 9 p.p.m. and 50 p.p.m. of available potassium, it was found that larger application gave a significant increase in the crop yield with Guinangang rice variety as the plant indicator. Of the Marikina clay loam and San Manuel silt loam containing 132 p.p.m. and 161 p.p.m. of available potassium, respectively, repeated large applications of potassic fertilizers did not give any significant increase in yields using Guinangang also.

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

It might be expected that rice and sugar cane will have greatly varying minimum available potassium requirements when one considers that amount of potash removed from the soil by a good crop of sugar cane has been estimated to be about 460 kg. of K_2O per hectare, while that removed by rice has been estimated to be about 98 kg. of K_2O per hectare (Phil. Agriculture Field crops) (8). More fertilizer experiments must be made in places where the nutrient contents vary gradually from soil to soil to establish more definite limits for the nutrient requirements.

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

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

From the results obtained in the Philippines and from abroad it may be safe to assume tentatively that 100-150 p.p.m. is the average minimum potassium requirement of most Philippine crops such as rice and sugar cane. The available potassium contents of the 14 soil types in Bukidnon are shown in table 9 ranging from 44 p.p.m. to 299 p.p.m. with an average of 154 p.p.m. There are four soil types which have their available potassium below 100 p.p.m. and are considered very critical for any crop. These four soil types require application of potassic fertilizer while others have fairly enough or sufficient.

Calcium. — This element is one of the essential plant nutrients which affects the soil physically, chemically and biologically. For plant growth, this element is required in the translocation of carbohydrates and certain mineral elements. It appears to stimulate root growth and adds strength to cell walls. It helps in regulating acid-base exchange within the plants. It also remains in the leaves and stalks as the plant matures. The calcium content of the plants is an index of their feed value, because of its effectiveness in the development of bones and teeth of animals. According to Sherman (32), calcium is the outstanding element of the mineral matter which gives shape and permanence to the body's framework and endows our bones with strength, and our teeth with hardness that they need. Thatcher (36) also in his experiment 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, evidencing therefore that calcium is needed for cell wall formation.

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

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

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

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

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

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

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

The results of analysis for available calcium content of the various soil types in Bukidnon are shown in table 10 ranging from 300 p.p.m. represented by the Adtuyon clay to 4,300 p.p.m. represented by the Tacloban clay. The minimum is represented by the former and maximum by the latter with an average of 1450 p.p.m. of available calcium. Excepting Tacloban clay and Alimodian clay, the calcium contents are quite low and very critical. The soils in Bukidnon require the application of agricultural lime to raise the available calcium from 200 to over 2000 p.p.m. for optimum crop production. The range of pH indicate that the soils are strongly acid and should be adjusted to medium acid or slightly acid for the best growth of numerous economic crops.

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

The symptoms of magnesium deficiency occur on mature leaves of citrus at any season of the year. The irregular yellow blotches start along the midribs of the leaves near the fruits 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 V-shaped area pointed on the midrib. In more advanced stage, the entire leaf may become yellow. Other findings at the Citrus Experiment Station in Florida, U.S.A. have shown that magnesium deficiency causes a reduction in the total crop size of fruit and in the sugar, acid, and vitamin C contents of the citrus juice (Camp et al), (15).

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

The soils of Bukidnon as shown in table 11 have their available magnesium contents ranging from 50 p.p.m. represented by the Mailag clay loam to 1400 p.p.m. of the Tacloban clay, with an average of 627 p.p.m. Our findings show that the soil types that were rated high in crop productivity ratings and which were analyzed so far by the Peech and English method in our laboratory gave about 600 p.p.m. to 1700 of available magnesium on the average. However, for certain species of citrus (pummelo) symptoms of magnesium deficiency had been observed on soils that contained even as much as 950 p.p.m. of available magnesium. Seven of all of the soil types in the province have magnesium deficiency (below 600 p.p.m. of available magnesium) and these soils therefore require the application of dolomitic limestone.

Iron. — Iron plays an important part in the leaves of green plants, although only needed in very small or limited quantities. Different soil types from various places in Luzon which, according to their productivity ratings were rated high or at least medium, were analyzed for available iron content in this laboratory. Following the Peech and English method the results obtained ranged from about 2 p.p.m. to 30 p.p.m. of available iron. The iron present must be in soluble form. Table 9 shows the available iron contents of the diferent soil types of Bukidnon province ranging from trace to 10 p.p.m. Four of them have traces.

Manganese. — Most agricultural soils contain very small amounts of total manganese less than 0.1 per cent (1,000 p.p.m.) but the requirements of plants are very small. The literature reports that the cabbage leaves contain 23 p.p.m. of manganese; radish roots, 29 p.p.m.; rice grains, 23 p.p.m.; and tomato fruits, 46 p.p.m. Some soil types from various places in the Philippines that were rated high or at least medium in crop productivity were analyzed in this laboratory for available manganese content following the Peech and English method. The manganese content of these soils are found to vary from about 15 p.p.m. to 250 p.p.m. The soils in Bukidnon excepting the Macolod clay which contains only 11 p.p.m. have sufficient manganese content ranging from 23 p.p.m. to 205 p.p.m. with an average of 74 p.p.m.

The leaf symptoms of manganese deficiency had been observed on Ladu and Zinkom mandarin orange (citrus nobilis, Linn.) growing on a certain soil type in Batangas province which was found to contain traces only of available manganese. The unpublished data of the experiment on the effect of the manganese-treated citrus trees on the yield of vitamin C content of the juice over the untreated reveals that there is an increase in yield as well as the vitamin C content of those manganese treated trees over the control but as far, not statistically significant

FERTILIZER AND LIME REQUIREMENTS OF BUKIDNON SOILS.

The crops grown mostly in the province which have been rated for crop productivity are corn, abaca, pineapple, rice, camote, banana and coffee. Cassava, fruit trees and vegetables, although not raised extensively, are usually grown in backyards for local market and home consumption. Table 13 gives the lime and fertilizer recommendation for the crops of rice, corn and abaca, based on the chemical analysis of the soil types on which these crops are mostly grown. If one examines the results of the chemical analysis of the fourteen different soil types in Bukidnon province as presented in table 9 a majority of them are found to be deficient in many of the nutrient elements especially available phosphorus, potassium and calcium. While the total nitrogen appears high, the nitrate nitrogen appears deficient because of the very irregular topography of the agricultural lands and as mentioned earlier, plants growing on well drained soils use more of the nitrates than the ammonia form.

The agricultural lime needed for any of the crops of rice, corn and abaca varies from an application of 0.50 ton to 8.5 tons per hectare. The application of commercial nitrogenous fertilizer like ammonium sulfate analyzing 20 per cent nitrogen are 100 kilos for rice, 150 kilos for corn and 250 kilos for abaca. Rice, corn and abaca require from 50 kilos to 300 kilos of single superphosphate analyzing 20 per cent P_2O_5. For potassium requirement, the application of 50 kilos to 100 kilos of muriate of potash per hectare seems sufficient depending on the amount of available potassium contents of the various soil types on which any or all of these crop are grown.

For information and guidance, the unpublished results on the preliminary fertilizer and liming experiments of upland rice in Bohol, conducted by the Division of Conservation Operations are cited here. The yield of the control was 10.51 cavans of palay per hectare. With an application of 300 kg. ammophos (16% N and 20% P_2O_5) per hectare the yield become 28.36 cavans with an increase of 17.85 cavans over the control. However, with another application of not only 300 kg. ammophos but also with 2 tons of lime per hectare the yield was 41.91 cavans Another treatment was made in which 300 kg. ammophos and 4 tons lime per hectare were applied, the yield was 42.41 cavans. From the data presented, there was an increase yield of 17.85 cavans of palay from the ammophos-treated over the control. The application of ammophos and 2 tons of lime gave an increased yield of 13.55 cavans of palay per hectare over the ammophos treatment alone. Increasing the application of lime to 4 tons with the same amount of ammophos gave only an increased yield of 14.05 cavans over the ammophos treatment alone, or 5 cavans increase from 2 to 4 tons lime applied. This shows therefore, that the 2 tons application of agricultural lime per hectare is more profitable and economical than 4 tons. The crop responses to the nitrogenous and phophatic fertilizers and to lime

may be expected due to the low contents of nitrogen and available phosphorus and calcium of Ubay sandy loam in Bohol province. The total nitrogen is only 0.09 per cent and 15 p.p.m. NH_3 and 10 p.p.m. NO_3 The available P is only 6 p.p.m., available K is 53 p.p.m. and available Ca is 1800 p.p.m. The available K is low, so that it should have been added and tried but potassic fertilizers were not available from the market at the time the experiment was conducted. The total increase in yield due to liming and fertilization would have been greater had the potassic fertilizers been included in the treatments.

TABLE 11.—*Fertilizer and lime requirements of the surface soils of Bukidnon Province.*

Soil type	Agricultural lime b	Ammonium sulfate (20% N)	Superphosphate (20% P_2O_5)	Muriate of potash 60% K_2O)
	Tons/Ha.	Kg./Ha.	Kg./Ha.	Kg./Ha.
For Corn				
San Manuel silt loam	1.50	150	50	50
Adtuyon clay	8.50	150	300	200
Jasaan clay	2.00	150	200	50
Kidapawan clay loam	5.50	150	300	—
Bolinao clay	1.00	150	—	50
Faraon clay	4.50	150	300	200
Tacloban clay	—	150	200	—
Adtuyon clay, stony phase	6.50	150	350	50
Maapag clay	6.50	150	300	150
Mailag clay loam	5.50	150	300	100
Calanaig clay	2.50	150	300	150
Alimodian clay	—	150	300	—
La Castellana clay	4.50	150	300	—
Macolod clay	1.50	150	300	150
For Upland Rice				
San Manuel silt loam	1.50	100	50	50
Adtuyon clay	8.50	100	300	150
Jasaan clay	2.00	100	200	50
Kidapawan clay loam	5.50	100	300	—
Bolinao clay	1.00	100	—	50
Faraon clay	4.50	100	300	200
Tacloban clay	—	100	200	—
Adtuyon clay, stony phase	6.50	100	350	50
Maapag clay	6.50	100	300	100
Mailag clay loam	5.50	100	300	100
Calanaig clay	2.50	100	300	150
Alimodian clay	—	100	300	—
La Castellana clay	4.50	100	300	—
Macolod clay	1.50	100	300	100
For Abaca				
San Manuel silt loam	0.75	250	50	100
Adtuyon clay	4.25	250	300	300
Jasaan clay	1.00	250	200	50
Kidapawan clay loam	2.75	250	300	—
Bolinao clay	0.50	250	—	50
Faraon clay	2.25	250	300	400
Tacloban clay	—	250	200	—
Adtuyon clay, stony phase	3.25	250	350	50
Maapag clay	3.25	250	300	200
Mailag clay loam	2.75	250	300	200
Calanaig clay	1.25	250	300	300
Alimodian clay	—	250	300	—
La Castellana clay	2.25	250	300	200
Macolod clay	0.75	250	300	—

b Limestone ($CaCO_3$) pulverized to 20 mesh and about 50% to pass 100 mesh.

The four best soil types in Bukidnon are the San Manuel silt loam, Adtuyon clay, Jasaan clay and the Kidapawan clay loam. While these soils are considered the best soils basing from their crop productivity ratings for corn and other crops, they have not however, shown sufficiency of the essential nutrient elements, in fact these soil types are very deficient in phosphorus and calcium. It is therefore necessary that for a good and profitable crop it is recommended that the nutrient or fertility level of these soils be raised for an efficient cropping system. All of these fertilizers are available from the market now and are not very costly. If applied properly and correctly, these fertilizers will boost for a very conservative yield, but one thing sure is that for every peso of investments in commercial fertilizers, there will be a corresponding increase in profits from the increased yield in cavans of palay per hectare in the case of rice. The San Manuel silt loam, Kidapawan clay loam and Adtuyon clay are the best abaca soils in Bukidnon. The first two soil types seemed to have better crops of abaca in Bukidnon than when grown on the same soil types in Davao province, as revealed by their crop productivity ratings for abaca. Of course as to fertility level, the Davao soils are better, much more so the available potassium for Davao soils are very high while that of Bukidnon soils are deficient. Similarly with phosphorus, the Bukidnon soils are very deficient in this nutrient element. It should not however be overlooked, the fact that so many hectares of grazing lands in the province are, if not now, were devoted to pasture. If still true today, fertilization of such pasture is essential to provide a good and succulent and nutritious feeds for the healthy animals grazing there to make them grow faster and give more and better quality of beef.

GLOSSARY OF COMMON ECONOMIC PLANTS FOUND IN BUKIDNON PROVINCE

Common name	*Scientific name*	*Family name*
Abaca	*Musa textilis* Nee	Musaceae
Achuete	*Bixa orellana* Linn.	Bixaceae
Agingai	*Rottboellia exaltata* Linn.	Gramineae
Ampalaya	*Momordica charantia* Linn.	Cucurbitaceae
Atis	*Anona squamosa* Linn.	Anonaceae
Avocado	*Persea americana* Mill.	Lauraceae
Bamboo	*Bambusa spinosa* Roxb.	Gramineae
Banana	*Musa sapientum* Linn.	Musaceae
Bangkal	*Nauclea orientalis* Linn.	Rubiaceae
Batao	*Dolichos lablab* Linn.	Leguminosae
Binayuyo	*Antidesma ghasembilla* Gaertn.	Euphorbiaceae
Boho	*Schizostachyum lumampao* (Blanco) Merr	Gramineae
Cabbage	*Brassica oleracea* Linn. var. *capitata* Linn.	Cruciferae
Cacao	*Theobroma cacao* Linn.	Sterculiaceae
Caimito	*Chrysophyllum cainito* Linn.	Sapotaceae
Camote	*Ipomoea batatas* (Linn.) Poir	Convolvulaceae
Cashew	*Anacardium occidentale* Linn.	Anacardiaceae
Cassava	*Manihot esculenta* Crantz	Euphorbiaceae
Cinchona	*Cinchona* spp. Linn.	Rubiaceae
Coconut	*Cocos nucifera* Linn.	Palmae
Coffee	*Coffea* spp.	Rubiaceae
Cogon	*Imperata cylindrica* (Linn.) Beauv.	Graminae
Corn	*Zea mays* Linn.	Gramineae
Cowpeas	*Vigna sinensis* (Linn.) Savi.	Leguminosae
Crotalaria	*Crotalaria juncea*	Fabaceae
Eggplant	*Solanum melongena* Linn.	Solanaceae
Fern	*Acrostichum aureum* Linn.	Polypodiaceae
Gabi	*Colocasia esculenta* (Linn.) Schott.	Araceae
Ginger	*Zingiber officinale* Rosc.	Zingiberaceae
Guayabano	*Anona muricata* Linn.	Anonaceae
Ipil-ipil	*Leucaena glauca* (Linn.) Benth.	Leguminosae
Jackfruit	*Artocarpus heterophyllus* Lam.	Moraceae
Kapok	*Ceiba pentandra* (Linn.) Gaertn.	Bombacaceae
Lanzon	*Lansium domesticum* Correa	Meliaceae
Lettuce	*Lactuca sativa* Linn.	Compositae
Libato	*Basella rubra* Linn.	Basellaceae
Macopa	*Eugenia malaccensis* Linn.	Myrtaceae
Mango	*Mangifera indica* Linn.	Anacardiaceae
Marang	*Artocarpus odoratissima* Blanco	Moraceae
Mungo	*Phaseolus aureus* Roxb.	Leguminosae

Mustard	*Brassica integrifolia* (West) Schultz	Cruciferae
Onion	*Allium cepa* Linn.	Liliaceae
Orange	*Citrus aurantium* Linn.	Rutaceae
Papaya	*Carica papaya* Linn.	Caricaceae
Patani	*Phaseolus lunatus* Linn.	Leguminosae
Patola	*Luffa cylindrica* (Linn.) M. Roem.	Cucurbitaceae
Peanut	*Arachis hypogaea* Linn.	Leguminosae
Pechay	*Brassica chinensis* Linn.	Cruciferae
Pine	*Pinus insularis* Endl.	Pinaceae
Pineapple	*Ananas comosus* (Linn.) Merr.	Bromeliaceae
Irish potato	*Solanum tuberosum* Linn.	Solanaceae
Pummelo	*Citrus maxima* (Burm.) Merr.	Meliaceae
Radish	*Raphanus sativus* Linn.	Cruciferae
Rice	*Oryza sativa* Linn.	Gramineae
Rubber	*Hevea brasiliensis* (HBK) Muell.-Arg.	Euphorbiaceae
Santol	*Sandoricum koetjape* Meer.	Meliaceae
Sitao	*Vigna sesquipedalis* Linn.	Leguminosae
Squash	*Cucurbita maxima* Duchesne	Cucurbitaceae
Sugar cane	*Saccharum officinarum* Linn.	Gramineae
Talahib	*Saccharum spontaneum* Linn.	Gramineae
Tobacco	*Nicotiana tabacum* Linn.	Solanaceae
Tomato	*Lycopersicum esculentum* Mill	Solanaceae
Ubi	*Dioscorea alata* Linn.	Dioscoreaceae
Upo	*Lagenaria leucantha* (Duch.) Rusby	Cucurbitaceae

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