

ADEQUACY OF SOIL STUDIES IN PARAGUAY, BOLIVIA AND PERU

November-December, 1963



FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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1. Report of the First Meeting of the Advisory Panel on the Soil Map of the World, Rome, 19-23 June 1961.
2. Report of the First Meeting on Soil. Survey, Correlation and Interpretation for Latin America, Rio de Janeiro, Brazil, 28-31 May 1962.
3. Report of the First Soil Correlation Seminar for Europe, Moscow, U.S.S.R., 16-28 July 1962.
4. Report of the First Soil Correlation Seminar for South and Central Asia, Tashkent, Uzbekistan, U.S.S.R., 14 September-2 October 1962.
5. Report of the Fourth Session of the Working Party on Soil Classification and Survey (Subcommission on Land and Water Use of the European Commission on Agriculture), Lisbon, Portugal, 6-10 March 1963.
6. Report of the Second Meeting of the Advisory Panel on the Soil Map of the World, Rome, 9-11 July 1963.
7. Report of the Second Soil Correlation Seminar for Europe, Bucharest, Romania, 29 July-6 August 1963.
8. Report of the Third Meeting of the Advisory Panel on the Soil Map of the World, Paris, 3 January 1964.

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BOLIVIA AND PERU.

Report of FAO Mission, November-December 1963

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FOREWORD

The first meeting on Soil Survey, Correlation and Interpretation for Latin America,* which was held in Rio de Janeiro from 28 to 31 May, 1962, and was attended by delegates from eleven Latin American countries, requested the Director General of FAO to "designate a mission of specialists whose objectives would be an appraisal of the adequacy of the soil studies actually being undertaken by the various countries of the Region in relation to their needs, and to put forward suggestions and recommendations". This request to the Director-General of FAO constitutes the terms of reference of the Mission whose findings are here reported.

In compliance with this request, the World Soil Resources Office of the Land and Water Development Division in cooperation with the Soil Survey and Fertility Branch, and Land Use and Farm Management Branch organized the first mission to visit Paraguay, Bolivia and Peru during November and December 1963. These three countries of the Region which have received comparatively little technical assistance from FAO in the field of soils.

The Mission was comprised of the following members:-

A.C.S. Wright, FAO Soil Specialist, Mission Leader
Luis de Leon, Professor of Soils, University of Uruguay
Rafael Pacheco, Instituto Nacional de Colonización,
Quito, Ecuador
W.G. Miller, Land Use Planning Specialist, FAO, Rome.

In addition to the aforementioned duties, the Mission was requested to carry out an exploratory study of the major soils of the less known regions of the countries visited, in cooperation with the Governments concerned. This is the first of two reports and deals with the Mission's findings on the enquiry into the adequacy of soil studies in the three countries visited, in relation to their needs. This report contains a number of suggestions and recommendations which are of paramount importance for the countries' development program. Some Expanded Program of Technical Assistance and Special Fund projects are herein defined. It is hoped that as a result of this Mission a closer cooperation in the field of soils will be established between the countries concerned, FAO, EPTA and the United Nations Special Fund in order to obtain the most urgently needed information on soils which is required for the efficient utilization of the countries' land resources.

The Mission acted as an experimental "task force" and endeavoured to speedily obtain information on the distribution of the major soils from areas where very little soil information existed. The second report will discuss at length the technical and scientific facets of the soil studies undertaken by the Mission.

The success of the Mission was largely due to Professors de Leon and Pacheco, the Latin American members of the Mission, and the excellent cooperation and help received from the Soil Scientists in the three countries. On behalf of FAO, I can assure them of our deep gratitude for the effort and experience they contributed. FAO is also indebted to the governments of Paraguay, Bolivia and Peru, for their generous hospitality and cooperation and to the FAO and TAB Resident Representatives who greatly helped to make the Mission a success.

D. Luis Bramao

* See World Soil Resources Report No. 2. Chief, World Soil Resources Office
Land and Water Development Division

I N T R O D U C T I O N

This report is a combination of three separate reports concerning the state of soil studies in three Latin American countries, - Paraguay, Bolivia and Peru. The information is presented in this form to facilitate reporting to each country individually.

The Mission achieved a considerable measure of success during its brief life, mainly because of the participation of the two Latin American soil scientists, Professor Luis de Loon and Ing. Rafael Pacheco, from Uruguay and Ecuador respectively, who very quickly established contact with scientific colleagues in each country visited by the Mission, opening the way for rapid collection of a liberal cross-section of pertinent data. The Mission experienced, to the fullest degree a particularly happy demonstration of the true Latin American capacity for acceptance without reserve with no accounting of time and trouble taken, and a noble generosity in the supply of information and advice. This is not always the fortune of official missions, and I believe that we were to a large measure favoured by the sincere and humble spirit of scientific enquiry exemplified in the bearing of our Latin American colleagues of the Mission. Our hosts accepted the Mission as a neighbourly gesture for closer cooperation and exchange of knowledge and experience in this vital field of Soil Resources. It was a successful thoroughly enjoyable, and scientifically stimulating Mission.

This prompts me to offer a suggestion: would it not be worth while to explore further this type of approach? If we take for instance, the case of Paraguay. It is relatively small in area and almost totally lacking in persons with training in soils. A 'task force' composed of soil scientists from the better equipped neighbouring countries, Uruguay, Argentina and Brazil, led by a soil specialist supplied by FAO, would have little difficulty in making a preliminary assessment of the yet unknown nature of the soil resources of Paraguay. This could be achieved in a space of about six weeks. It would be almost certain to disclose information about land use potentials of great significance to the future development of the Republic.

In each of the three countries visited by the Mission, there was an evident desire to deflect the purpose of the Mission into just these very channels: to utilize the combined expertise of the Mission personnel to explain the nature of the local soils, to advise on their classification, and to give an opinion on pressing local soil problems. Time did not permit us to give much help in those matters, but, as leader of the Mission I feel it incumbent to draw attention to the possibility of FAO acting as a simple catalyst in the promotion of soil studies where the political climate is favourable. Many of the present group of adequately trained soil scientists in Latin America have reached their current status with the help of FAO scholarships and study tours. As scientists they are surprisingly competent and their spirit of scientific enquiry is such that they are eager to meet new soils and test their interpretative powers. Soils do not stop or change at National boundaries; nor should soil scientists when opportunities are favourable. As Latin Americans, they welcome the fresh breeze of inter-American cooperation and are eager to put their skills at the service of their neighbours.

From the point of view of FAO, the scheme holds many potential advantages. It is relatively inexpensive since only the soil correlator has to travel any considerable distance. Travel within the host country is arranged by the appropriate government authorities. The results are satisfying to all concerned: the host country gets a very rapid expert appraisal of its soil resources, the participating soil scientists acquire a considerable amount of new soil experience, and the governments achieve a more ample and up-to-date picture of the background against which they may substantiate their requests for U.N. Special Fund or Freedom from Hunger development projects.

A.C.S. Wright
Soils Survey and Fertility Branch
F. A. O.

PARAGUAY

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Reliable soil information is possibly of greater importance to the Republic of Paraguay in its present stage of development than any other type of scientific information. Although small in area and relatively lightly populated, over 70% of the people live in rural surroundings, and agriculture is the mainstay of the country's economy. In general, the Mission found that relatively few soil surveys or related investigations existed, none are currently in progress, and those that are contemplated are incidental to other schemes. It is the opinion of the Mission that more and better soils information will be essential for the success of the development program already begun.

At this stage in the development of Paraguay, two important trends are apparent: the earliest farmed soils over a wide radius around Asuncion are showing marked signs of exhaustion, and the road construction program forging a link between Asuncion and Brazil has opened up large areas of new land for settlement. Both factors, acting together, have stimulated a strong movement of farmers in the direction of the virgin soils of eastern Paraguay. Soil problems requiring investigation are of two kinds. On the one hand they are needed to help devise economic methods for the rehabilitation of the 'worn-out' soils, probably involving consolidation of abandoned holdings and more emphasis on pastoral farming; and on the other hand soil studies are needed urgently in the newly settled areas which are at present mainly being farmed by traditional systems and which will surely deteriorate rapidly in fertility unless the farmers can be persuaded to adopt better soil management methods. Supplementary to the latter soil studies, there should be investigation to determine the economic size for farm holdings on the different kinds of soil; of the types of crops best adapted to each soil; and of conservation measures necessary to ensure that production will not decline because of gradual acceleration of soil erosion. The government intends to establish experimental and demonstration centres in the new settlement areas to determine those essential matters, but lack of soil information has introduced an element of uncertainty which is holding up the selection of appropriate sites for those stations.

The Mission found that very good work is being done on the existing experimental stations in the determination of the fertilizer requirements of crops but, again, the full value of this work is not being realised because there are no soil maps with sufficient details to show to what extent those results can be applied over the surrounding farmland. Similarly, the experimental stations provide excellent demonstration of soil erosion control measures, but these are not in general use by farmers although certain of the farmed soils are badly in need of such measures. Land use capability studies have been conducted for certain crops but, here again, the information is of only local significance in the absence of soil maps. No information was available concerning the different soil management practices suitable for use with specific crops in the different kinds of soils

A limited amount of soil survey is contemplated in the future, but only in connection with the access road construction program and the selection of new areas for settlement. There are hardly any Paraguayans* with adequate training in soil survey and future studies will be left largely in the hands of overseas experts hired by the organizations carrying out these projects. The Mission was able to gather very little information as to future needs and training of Paraguayan personnel. It is obvious that the future will bring a much greater need for local soil surveyors, and soil fertility and conservation staff, but the present rate of output of graduates from the University with adequate soil training amounts to only two or three per year. This seems totally inadequate in terms of the present and potential needs of the country.

In all, the Mission found that there was a persistent dearth of reliable soil information in Paraguay and, with the re-awakening of interest in national land development schemes in mind, the Mission offers the following recommendations:

1. That the Paraguayan Government seeks the assistance of a soil surveyor under the FAO Expanded Program of Technical Assistance (EPTA). The person for this post should have had wide experience in sub-tropical soil conditions and his most important duty would include the re-appraisal of the more important soils in the country to determine their correct classification and to correlate them with similar soils elsewhere, so that external soil knowledge can be brought to the aid of Paraguayan farmers. His duties would also include:
 - assistance in selecting sites for new experimental stations;
 - help with determination of development priorities in areas where new farm colonies are desired and where new access roads are planned;
 - help to provide an accurate basis for soil management studies in relation to farm planning, crop selection, and erosion control;
 - advise upon the possibility of developing irrigated farming and rice growing on the Chaco plains and other areas;
 - indicate alternative means of rehabilitating the depleted soils in areas where consolidation and grass-land farming is to be attempted, and
 - develop a scheme for the training of Paraguayans in the methods, techniques and art of soil surveying and, if required, give some assistance with the establishment of more ample soil courses at the University.

2. That there should be some strengthening of activity in the field of soil conservation studies, and that these should be carried out over whole watersheds rather than on individual farms. These studies should provide soil management data essential for both the land rehabilitation work and the land settlement programs; thus requiring at least two distinct study areas. Information from these studies will be particularly important for Paraguay

* See page 11 'Personnel'

as the density of the farm population increases. They are long term studies and so they should be commenced soon. A project should be formulated with the aid of the EPTA and submitted to the Special Fund of the United Nations.

3. That, when air photo coverage, ground control and the supply of reliable base maps for soil surveys are adequate, and when there is sufficient number of trained Paraguayan soil surveyors available, a further project be submitted to the United Nations requesting assistance with a natural resources survey to determine the true potential of important areas of the country. This information will be required, not only for agricultural and forest development, but also for selecting sites for new industrial developments. A soil survey team would be an integral part of this project.
4. That the Ministry of Agriculture investigate the possibility of bringing about the consolidation of all soil workers by creating a division for soil and fertility investigations, with units for soil surveying, for soil fertility, for soil conservation and management, and with a laboratory unit serving the whole division and the farming community in general.

I. SOURCES OF INFORMATION

In Paraguay, extremely useful information was obtained from members of the following organizations: Ministry of Agriculture, STICA (Servicio Tecnico Interamericano de Co-operacion Agricola); Meteorological Department of the Ministry of Defense; Military Geographic Institute; Inter-American Geodetic Survey and the Secretariat for Planning and Development. To informants of the above organizations, and to many others, the Mission is deeply indebted for the fine spirit of co-operation shown.

In addition to the study of material provided by informants, the Mission also reviewed published and unpublished reports and maps available in local libraries and, further, carried out a limited number of field investigations in the relatively densely settled region southwest of Asuncion, in the newly opened up agricultural region near the Parana river, and on the Chaco plains northwest of Asuncion.

II. PHYSICAL CHARACTERISTICS OF PARAGUAY

Geographic Location

Paraguay is one of the smaller countries of South America, with an area of 157,000 sq. miles (407,000 km²), or 40.7 million hectares. Surrounded by Bolivia, Brazil and Argentine, the country depends on the Paraguay-Parana river system for access to the sea. The capital and main shipping port, Asuncion, is more than 1,000 km distant from the main industrial centers of Montevideo, Buenos Aires, Sao Paulo and Rio de Janeiro.

Situated between latitude 19°S and 28°S, and with few mineral resources and little industrial development of its own, Paraguay is basing its economy on the production of sub-tropical crops and the exploitation of natural forest resources.

Topography and Landforms

Paraguay is characterized by landscapes of low relief. The mean elevation of the country is probably less than 100 m and the highest point is only slightly over 700 m above sea level. This more elevated part represents a low north-south anticline between the synclinal basins of the Chaco and Parana. From the anticlinal ridge, the rocks dip gently eastward toward the Parana basin; while to the west the rocks either dip steeply or are downfaulted into the depths of the Chaco basin.

This relatively simple geological structure gives the country two major and somewhat distinct physiographic regions:

- (1) An eastern region of mainly rolling to hilly relief, underlain by ancient rocks whose appearance at the surface marks the visible western limit of the great Brazilian shield. Although the rocks are very ancient, there are no distinct remnants of ancient land surfaces. It would appear that, in Paraguay, all the latter have been destroyed by a long series of erosion cycles, resulting in a subdued topography characterized by wide valleys filled by a great depth of alluvial and colluvial erosional materials.

- (ii) A western region consisting of a vast aggraded alluvial plain which has been the accumulation area for an enormous amount of erosional material since the Andean orogeny in Late Tertiary times. No major rivers now discharge across this old floodplain, but minor streams are intermittently active during the brief rainy season, sorting and redistributing the older surface sediments.

Geology

Along the north-south anticline that occupies the greater part of the eastern physiographic region, the following rocks appear close enough to the surface to form the parent materials of soils:

- (i) sandstones of Cretaceous, Triassic and Jurassic age, in part intruded by volcanic rocks, and varying widely in their content of mica, silica, haematite, feldspar, etc., and in their degree of consolidation or induration;
- (ii) granitic rocks of varying composition, of Devonian and Permian age; and
- (iii) Limestones and calcareous shales, probably of Silurian age.

Intruded within these sedimentary rocks are volcanic rocks of mainly basic composition but of varying ages. The most important single member of this group is a thick series of basaltic rocks that form the main soil forming parent material over much of the eastern part of the eastern physiographic region. These rocks are of Triassic or possibly of Jurassic age, and the landscape is less maturely dissected than the rest of the eastern region.

In the western, or Chaco, region, the underlying rock rarely approaches close enough to the surface to contribute to the soil pattern. The chief soil forming parent materials are unconsolidated sands, and clayey or silty sediments of comparatively recent depositional age. The lower beds are mainly continental in origin with some interlayering of marine sediments; the surface materials are mainly a resorting of these older materials as they gradually work their way down the gently sloping plain. There are indications that much of the older material was laid down under conditions more arid than at present, allowing the preservation of considerable quantities of salts, particularly those of sodium and magnesium. The total depth of the Chaco sediments is thought to be in excess of 600 m.

Climate

The present climatic regime of Paraguay represents an uneasy balance between cool sub-tropical, and very warm tropical conditions and is especially noteworthy for abrupt fluctuations in temperature. This is a reflection of geographical and physiographic conditions, for Paraguay is situated near the center of the continent with no well defined topographic barriers, and between two major climatic systems. Thus Paraguay lies open to invasion by masses of cold air coming from the south, and to warm air from the north. In total, the climate of the country can be broadly reckoned as continental sub-tropical.

There is a well defined seasonal rhythm during the year, but it is subject to distortions at any time: marked annual variability is a prominent characteristic of the Paraguayan climatic pattern. In general, winter months although mild are somewhat drier and considerably cooler than summer months; while summer months are inclined to be very hot and humid with intermittent heavy rains. Frosts occur with some regularity in the south-eastern sectors during the winter and are most frequent in July and August, but even here there is a frost-free interval of approximately eight months. The frost hazard diminishes northwards, except in the case of the Chaco region where several degrees of frost are not uncommon as early as April and as late as October.

The mean annual temperature gradient over the whole country decreases from 26°C in the northwest to about 21°C in the south and east; while the mean annual precipitation increases regularly from slightly under 500 mm in the western Chaco to over 1600 mm near the Parana river. This interplay of temperature and rainfall produces maximum mean potential evapotranspiration rates of about 1500 mm in the northern Chaco region, and minimum rates of about 1200 mm in the south and east of the country. The calculated mean annual water deficit is negligible near the Parana uplands, but increases towards the northwest where it exceeds 700 mm per annum. According to Thornthwaite's classification, the western half of the Chaco experiences a semi-arid regime (class 'D'); the eastern Chaco is dry sub-humid (class 'C₁'); the central and western part of the eastern physiographic region is moist subhumid (class 'C₂'), and the remainder of the country falls within the humid categories (classes 'E₁' and 'B₂').

In terms of conditions for soil formation, the current climatic regime indicates that over most of the Chaco region, leaching and, to some extent, weathering operate very weakly during 70% of the year, and the advent of rain produces temporary waterlogging leading to a sharp initiation of gley processes. In the central sector of the country, the same alternation of wet and dry conditions produces an interplay between leaching, gleying and weathering, but to a much lesser degree than in the Chaco. In the humid eastern sector, soil weathering is probably operative throughout the year; leaching is fairly continuous but not very strong, and gleying is of much less consequence.

Vegetation

The soils of the Chaco region are developing under a variety of plant formation, including xerophytic woodland, semi deciduous forest, palm forest and natural grassland. In the eastern region, the soils have developed under forest until comparatively recent times, although 'islands' of grassland amongst the forest have been known from pre-hispanic days. These were areas where indigenous tribes had repeatedly destroyed the forest to make food gardens. In time, the natural fertility of the soils declined to the point where the original forest was unable to regenerate.

There appears to be a fairly close ecological relationship between the kind of natural plant cover and soil conditions; to such a degree that where the original vegetation pattern is still intact, the approximate soil conditions may be often estimated from an inspection of air photographs. However, about 45% of the original plant cover of Paraguay has been modified by farming activities to an extent that it is now no longer possible to determine with certainty the nature of these original plant formations.

Soils in Relation to Environment

The variety of rock formations; the diverse history of landscape formation and destruction; the past and present climatic patterns, and the conditioning effect of different kinds of plant cover, have combined to produce a varied and interesting assemblage of soils.

Most of the quartz-rich rocks (which include most sandstones and all the granitic rocks) have given rise to Red-yellow Podzolic soils. These contain materials that have a long history of weathering and most soils show evidence of lateral drifting of soil material as a result of erosion, limited transportation and accumulation during previous geologic cycles. These soils are mainly associated with landscapes of subdued relief, - often low island hills rising out of wide plains deeply filled with quartz-rich alluvial and colluvial detritus. By contrast, most areas of basaltic rocks (including some arkosic sandstones of high feldspathic content) have given rise to soils similar to the 'terra roxa estructurada' of Sao Paulo and Parana States in Brazil. Areas of calcareous rocks located in the northern sectors of the eastern region have given rise to dark coloured clays related to Grumosols, and to associated calcareous hydromorphic soils.

The soils of the Chaco region are the product of a shorter but more consistent history of landscape building, yet nevertheless, they preserve some indication of a varied post-Tertiary climatic history. In many of these soils, weathering and clay movement from the surface downward has been sufficient to produce dense subsoil 'clay pans', which in turn are responsible for the formation of 'perched' water-tables during the brief wet season, leading to seasonal activity of gley processes followed by, in the western Chaco, some capillary return of soluble salts to the surface. This has led to the formation of extensive areas of halomorphic soils: particularly solonchaks and solodised-solonchaks soils. Many of the soils are Planosols, some showing salt enrichment due to evaporation; associated with these, in some areas, are more sandy soils that show more pronounced leaching of the surface soil. In other areas carbonate-rich heavy clays have given rise to grumosols. The soil pattern of the Chaco is undoubtedly complex and, as yet, incompletely known.

Finally, there are large areas of permanently swampy soils in the triangular lowland area where the Paraguay and Parana rivers join, and some extensive alluvial flat lands in the south-central part of the country. These are mainly soils of old floodplains, no longer subject to strong alluvial deposition, with acid 'planosolic' types of profiles. The majority are 'pseudo-gley' rather than true gley soils.

Over wide areas the soils of Paraguay are deficient in moisture for much of the year. This is particularly true of the western and northern Chaco region. Lack of water for agricultural purposes must be reckoned as a factor seriously limiting land development, although the situation cannot be accurately assessed until there are soil maps showing where availability of water coincides with areas of soil adapted for irrigated farming. Water of good quality for irrigation is available from both the Pilcomayo and Paraguay river systems where they traverse semi-arid or dry sub-humid territory.

III. SOILS AND THEIR UTILIZATION

Soil Genesis and Classification

Information of this nature can only be obtained from field soil surveys, followed up by specific soils studies. Unfortunately, there has been very little activity of this type in Paraguay. As far as could be ascertained, there have been no published reports of soil investigations nor detailed or semi-detailed soil maps prepared in the country. Only two broad reconnaissance soils maps are available. The first of these is very old but extremely good map, dated 1912, prepared by Moises S. Bertoni and entitled "Mapa Agrológico, Fisiográfico y Climatológico." This map expresses quite well the broad picture of the soil resources of the country.

The second map, available in photocopy in two sheets on a scale of 1:1,000,000 (2) was subsequently published on a scale of 1 cm = 5.8 km in a professional paper of the U.S. Geological Survey (3) by Edwin B. Eckel, dealing mainly with the geological and mineral resources of Paraguay. This soil map was made in 1952 by Pedro Tirado Sulsona, J.B. Hammon, and J.R. Ramirez of the Departamento de Ingeniería of STICA, approximately at the same time as the team of the U.S. Geological Survey were working in the country. It shows eleven soil 'series' in the eastern region, and delimits approximately six soil 'series' for the Chaco region.

Some additional general information about Chaco soils is available in the report of a German scientific commission prepared for the Government in 1960 (4). One member of the commission, Rudolf Lüders, gave a more detailed account of some aspects of the Chaco soils and analytical data in a paper published in Germany in 1962 (5).

Some additional recent information is available on the 1:2,500,000 preliminary soil map prepared by the World Soil Resources Office of FAO.

In summary, the Mission found that the information about Paraguayan soils available from surveys and related studies was extremely deficient as a basis for understanding soil genesis and preparing an accurate soil classification.

Soil Fertility

Although little has been published on this topic, a good deal of field experimentation has been carried out on the Experimental Stations at Caacupe, Encarnación and Filadelfia, and on farmers' soils in the vicinity of these stations. This work has been supplemented by the soil testing service of the San Lorenzo soils laboratory.

Experimental plots for each of the main cash crops (maize, cotton, tobacco, sugar cane, etc.) and for citrus and pastures have been maintained for a number of years for fertilizer trials with the three major nutrient elements and some of the minor elements. The experimental areas have been wisely chosen, hence the results are applicable to the main kinds of soil in southeastern and central eastern Paraguay, and to the central part of the Chaco. In addition to the field trials, some crop responses have been correlated with laboratory determination of available nutrients in the soils.

The records of the experimental program maintained by Ing. Hernando Bortoni show sites of all trials: a point of great value when accurate soil maps become available. The mean crop responses to fertilizer treatments applied to Red-yellow Podzolic soils of medium-to-high base status in the central and eastern part of Paraguay are of the order indicated in Table 1.

The extension service offering technical advice to farmers draws heavily on Ing. Bortoni's knowledge of the soils, but much of the available information on soil fertility cannot be made generally available until reasonably accurate soil maps are available to provide a sound basis for effective correlation of fertility data.

Soil Conservation

Again, in this field, little published information is available. The agricultural experimental stations are themselves excellent demonstrations of soil conservation practices but it is evident that few farmers are actually following sound practices.

Land Use Capability

Land use capability studies have been made in the past in respect of certain crops but the information is only of local significance in the absence of soil maps of the whole country. Nor is there any published information available concerning the different soil management practices suitable for use on the different kinds of soils.

Land Use and Agricultural Development

According to the 1950 census of agriculture, the major part of the cropland is located in the eastern physiographic region; while the main area of pastoral farming is in the western or Chaco region. The forested land is located mainly in the eastern and northern sectors of the eastern physiographic region.

Despite recent advances in agricultural technology, and changes in market relationships for farm products, there has been no corresponding marked change in Paraguayan agriculture. The allocation of land between the major land use classes has not changed substantially, although some change is discernible in respect of the cropping pattern due to an increasing amount of land being employed in cotton production. Changes in size of farm holdings, in use of farm machinery and in the use of other modern farm management practices are virtually imperceptible. Farmers still depend to a great extent on manual labour supplied by their own families, and lack capital in all its various forms.

Although the regional pattern of land use and colonization might have evolved somewhat haphazardly and spontaneously, its development is nevertheless partly related to land productivity and accessibility. There are striking differences in the soil resources of the two main physiographic regions, arising from the contrasting nature of their geomorphological history, and from past and present differences in their climatic regimes. These factors have played a major part in determining the present distribution of the population. The soils of the eastern region have proved more

attractive for settlement and more tractable for farming, to the extent that 96% of Paraguay's present population now live in the eastern region which represents only 37% of the total area of the country. The course of the river Paraguay roughly marks the division between the populous eastern region and the rather empty western region. With a total population of under 2 million, Paraguay has the lowest density of population of any country in South America.

No systematic drive has been made to reshape the pattern of land use on the basis of information pertaining to soils or related production factors, except for some extreme cases in the more accessible areas where a high degree of crop adaption has been achieved, - but by trial and error rather than as the result of application of scientific information. In the areas primarily used for crops, bush fallowing is quite commonly practised, hardly any fertilizer is being applied and conservation practices - cultural as well as structural - although badly needed in some instances, are virtually ignored.

The present trend in land development is a movement eastwards towards the Brazilian frontier and along the western bank of the Parana river; a movement facilitated by the highway at present under construction between Asunción and Brazil. This population drift is motivated by the improvement of accessibility of the rich virgin soils in the extreme eastern part of the eastern region. But, and herein lies the real tragedy of the situation, the inappropriate land use practices of the old region are being transferred to the newly developing region where they are grossly inappropriate and will rapidly deplete the fertility of the soil. Now roads are also being constructed westwards from Asunción into the Chaco Boreal, but the soils of this western region are proving less attractive to farmers, although several promising farm colonies have been established there.

The uneven land use pattern and the widespread addiction to unthrifty management practices are, however, not entirely due to lack of adequate scientific information about the soils or even to failure to recognise the problem; but they are certainly to be related to the system of land ownership. There are very many small landowners, with from 3 to 5 acres, and a considerable number of large landowners, with from 500 to 5,000 acres; but a great scarcity of farmers in the middle range. Both 'latifundios' and 'minifundios' present problems of readjustment. On the one hand owners of large tracts of land with soils ideally suited for crop production may prefer to engage in extensive pastoral farming, while, on the other hand, small uneconomic holdings do not lend themselves to the adoption of sound land use practices which must include crop rotation systems and some soil conservation measures. It is very evident that Paraguay is one of the few countries in South America where all who want land can easily acquire it; where the small farmer can, by his natural industry achieve freedom from hunger, and where there are very few outward signs of rural poverty. Yet this is being achieved at some expense of the soil resources, and, although not perhaps of great consequence at the moment, the cumulative effects of careless soil management will surely in the end create a difficult situation for these very pleasant and industrious people.

The agricultural development of Paraguay, whether by accelerated exploitation of resources in virgin areas or by the rehabilitation of worn-out land through acceptance of rational soil management practices, is hampered by the geographic location of the country. Much of the agricultural production is in direct competition with that of the tropical parts of the larger neighbouring countries; and within Paraguay there is very little specialization. Each of the small farmers tend to concentrate on the 'popular' crop of the moment.

Land Productivity

Crops. A number of investigations have been carried out with respect to crops by the Servicio Técnico Interamericano de Cooperación Agrícola, and the results have been made available to the public by means of stencilled leaflets. These cover management practices for most of the common crops, for suggested new crops, seed improvement programs, various aspects of phytopathology, animal husbandry; and economic studies on costs of production, availability of credit, marketing prices, and small farm processing plants. In total, some 250 of these leaflets have been issued and they appear to have a wide circulation. Soil management practices suitable for the different soils are often incorporated with other matters with reference to specific crops.

Pastures. Pastoral topics are the subject of several STICA leaflets but the range of investigations has been limited. Although some pasture introduction trials have been carried out in different parts of the country, little information appears to be available concerning pasture establishment and pasture management practices required for different soils. Especially noteworthy is the lack of information about use and management of the natural grazing lands of the Chaco plains. Also, ecological studies and analyses of the nutritional value of the different types of natural pasture still remain to be done, although taxonomic studies of those grasses were undertaken many years ago.

Forestry. STICA has also released a number of leaflets dealing with forestry matters; and FAO reports are available concerning the timber potential of the natural forests. The FAO reports were prepared by Mr. M. Gallant in 1955 and 1957.

Vegetation maps for the whole country were prepared in 1927, by Stiltenberg; in 1932, by Schnoider; in 1945, by Carabia and in 1950, by James. All of these are on a relatively small scale and somewhat general.

IV. CURRENT SOIL STUDIES AND EXPANSION CONTEMPLATED

Soil Surveys

General reconnaissance surveys. No general reconnaissance surveys are currently running and none are contemplated for the immediate future.

Specific soil surveys. Soil surveys for specific purposes or of special areas are not at present operating. A limited amount of soil survey work in connection with the access road construction program is expected to be undertaken by the International Bank of Reconstruction and Development and is referred to below under item 4: Integrated studies.

Soil Fertility Investigations

The soil fertility investigations that have been in progress for several years are intended to continue at about the same pace in the future since many of them are long term investigations. No expansion is possible owing to financial limitations, although some expansion would be highly desirable.

Soil Conservation Investigations

These are also continuing at a slow and regular pace. This pace is not expected to accelerate unless additional funds can be provided. As mentioned in the next section, some increase in soil conservation work is contemplated in connection with the Access Roads project to be administered by the IBRD.

Integrated Studies Connected with Land Development Projects

No studies of this type are currently operating but two are anticipated in the near future and a third is now under consideration. The first relates to a relatively small project for rural development in the vicinity of Puerto Stroossner. This project involves aerial photography of about 100,000 hectares and is being financed by the Banco Interamericano. The work of photo interpretation has been contracted to a private company.

The second project, known as the "Paraguay Road Survey Project", relates to a triangular area between Asuncion, Puerto Stroossner and Encarnacion. It was elaborated in 1961, and approved by the Special Fund of the United Nations in August, 1963. The Executive Agency will be the International Bank of Reconstruction and Development. The project calls for the aerial photography of some 50,000 kms² and photo-interpretation studies to determine the pattern for construction of access roads to foster colonization in the area. The area was selected on the basis of data shown on the 1952 soil map and also because it is occupied by 70% of the inhabitants of Paraguay. It is intended that the photo-interpretation studies will make use of soil data shown on this early soil map; but provision is made in the project for the employment of experts in agriculture, soil classification and colonization to assist with photo-interpretation, in order that the network of secondary and tertiary roads shall be designed to serve the areas with the best agricultural potential.

The third, and most recent project, still being elaborated by the Secretariat for Planning and Development, depends to some extent on the availability of air photographs taken for the previous project, but also requires new aerial photography of an additional 50,000 kms². The total area involved is about 100,000 kms². The purpose of the project is to provide a basis to guide farmers undertaking colonization of virgin forest land, and at the same time to plan the consolidation of the worn-out holdings abandoned by the farmers who have moved into the new colonization areas, and to devise new systems of agriculture for the abandoned farms. No indication can be given, at present, of the number of experts required for this project; but, in addition to soil surveyors and soil conservation specialists, the Mission urges that high priority should be given to the inclusion of experts in crop selection and farm planning to ensure that due attention is given to the selection of suitable crops, yielding products that can be economically marketed.

Other Investigations

Climatology. Early climatological maps and assessments were often based on inadequate meteorological records, but during the past four years the position has improved immeasurably through the efforts of Prof. Felix Alborni employed by the World Meteorological Office and his Paraguayan colleagues. The maps showing climatic data accompanying this report have been made available through the courtesy of these meteorologists, and it will be seen that a great deal of information of great importance for analysis of crop productivity and selection of potential crops has been analyzed and prepared in readily usable form.

Geology. Geological maps of Paraguay have been prepared by Harrington (1957, 1958); by Putzer and his colleagues (1958) and by Eckol (1959). Considerable geological and geophysical information is to be found in the report by the German commission headed by Dr. Putzer (6), and in a subsequent report on the Chaco region by a second German commission led by Dr. Flath (4). The latter report was released in 1960. The most complete geological information is to be found in the report by Eckol (2). A very early paper by Keith Johnson appeared in 1876 (7). This geological information has considerable relationship with land productivity for the soil pattern is closely allied to geological patterns, and the fertility of the soils is fairly closely related to the petrological composition of the rocks.

Hydrology. Background information on this important topic is very scarce and no data concerning stream flow or groundwater reserves are readily accessible. There are a large number of wells throughout the country but there are no reliable records of rates of recharge after pumping, of seasonal water levels, or of the quality of the water. The second German commission that investigated the Chaco region reported on potential aquifers that existed at depth in the Chaco sediments and on the probable quality of the groundwater supplies. Their general conclusion was that the water of better quality was likely to be found near the surface and that deeper bodies of groundwater were likely to be too saline for agricultural use.

Many areas of Paraguay have a seasonal water deficit and in such places agricultural development requires provision of water for irrigation. At the present time there is almost no development of irrigated farming, although in some regions there is river water of good quality which could probably be utilized for irrigation or other uses.

Personnel

Paraguayan personnel working on soil surveys and related soil investigations are currently contributing only 3.5 man/years: 2.5 man/years in soil fertility, and 1 man/year in soil conservation. There is no person actually engaged in soil surveys. It is anticipated that there will be some difficulty in finding an adequate number of Paraguayan counterparts with sufficient experience or training in soils or allied subjects for the integrated projects enumerated above.

No international personnel are currently working in Paraguay on soil surveys or other soil studies. However, it may be anticipated that several foreign soil experts will visit Paraguay in connection with the IBRD Road Survey project in the near future. For the small project in the vicinity of Puerto Stroessner, it is understood that the Banco Interamericano has contracted with 'Italconsult' for the employment of a soil surveyor and a soil classification expert, although it is anticipated that this assistance may be of relatively short duration.

Training Programs

From 1940 to 1955 technical training in agriculture, carried out in a secondary school, provided a course with five years of general agricultural subjects. During this period many Paraguayan students obtained university training in agriculture in foreign countries - mainly in Uruguay, Argentina and Puerto Rico.

Since 1955, studies at the university level have been organized at the Facultad de Agronomía y Veterinaria located in San Lorenzo, under the University of Asunción. This organization has received financial support from STICA in the provision of general and laboratory equipment and 60 scholarships during the past 5 years. There has also been a considerable amount of support from the Montana State University of U.S.A., with the provision of three professors. Technicians of STICA are also teaching courses in the Faculty. The curriculum for all students comprises five years of training in general agriculture and on the average there have been 15 graduates in agriculture in each of the past three years. About 25% of the graduating students join private firms; a proportion each year leave the country to seek posts in Argentina, and the rest find jobs with the Paraguayan Government services. Since there has been no expansion of the Government agricultural services during the past three years, there is a problem for graduates who wish to remain in their own country and continue to work with local agricultural problems. Some have sought graduate training in Costa Rica, Puerto Rico, Chile and the U.S.A. In some cases this training has been in the field of soils and fertilizers.

In the field of soils, the students in Paraguay have two courses: one of general soils in the third year of training, and one in the fifth year in soil fertility and fertilizers. Both of the present professors have had advanced study in foreign countries.

Although little information could be gathered as to future needs for agricultural technical training, it is evident that the proposals of the Secretariat for Planning and Development in respect of new agricultural development projects indicate that there must be considerable expansion of the Government agricultural services. This must include the employment of soil surveyors, soil conservation workers and soil fertility personnel as well as many others working in closely allied subjects.

It is worth mentioning that there was at one time a proposal to submit to the Special Fund of the United Nations a request for assistance for "Resources Appraisal, Training and Research for Agricultural and Forestry Development." That project had distinct but integrated aspects; collection of basic data on the natural agricultural resources, and improvement of agricultural training. However, this proposal did not move far

from the preliminary drafting stage and is currently dormant; but it is worth noting that in its original form it called for the services of one specialist in soil survey for a period of one year for appraisal of the national soil resources, one fellowship for one year for overseas training in soils, and one 'soils and soil survey specialist' for the training and research part of the program.

V. NEED FOR FURTHER SOIL STUDIES

General Observations

The lack of reliable soils information and maps showing the actual area of the different kinds of soil is apparently being widely felt, since many informants sought to divert the members of the Mission into discussion of their immediate soil problems which were posed variously on a regional or a district basis, or concerned with new farm colonies, individual farms and ovon gardens. Almost everyone brought into official contact with the Mission mentioned, at some point the need for reliable soil maps. There is thus some evidence of a widespread awareness of the need for further soil studies. To our Paraguayan informants, as to ourselves, the point at issue was not the evident need of such studies but the most rapid and efficient means of inaugurating them. To assess this point, a brief recapitulation of the strengths and weaknesses of the Paraguayan scene is perhaps desirable.

Paraguay is fortunate in that most of her farmers are industrious, have their own parcels of land; fortunate in that there is no population pressure forcing extreme measures of land utilization, and very fortunate to be endowed with soils available for settlement that are above average in quality for sub-tropical countries. Notwithstanding these very considerable advantages, the agricultural economy of the country has not developed far beyond the original subsistence stage. Moreover, farmers are already finding that their parcels of land are no longer providing them with a living as good as formerly. This is no reflection on the technical extension services of the Ministry of Agriculture, - a group that is better trained than in many other South American countries, and is strongly buttressed by U.S. technicians and experts - but it may be a reflection of the general lack of knowledge about Paraguayan soils. In many aspects, the technical services themselves are operating on a basis of trial and error, part of which could be eliminated if the soils had been scientifically studied.

The present rate of progress toward efficient agricultural production may be slow but there are definite signs of progress. This would be more encouraging were it not for the fact that the economic situation calls for a much more rapid rate of progress. The economy of Paraguay depends a great deal upon the sale of exported agricultural products. Many of the crops well adapted to Paraguayan soils and climatic conditions, even when grown most efficiently, are not likely to become economic export crops because of high transportation costs and the long haul to the consumer centers. To a very great degree, the future of the country may well depend on skillful selection and concentration on a few specific crops that can be widely grown and partially or completely processed within the country before exportation. Agriculture can expect little real help from increase in domestic consumption because any substantial expansion of the domestic market will depend primarily on the amount of expansion achieved in the development of non-agricultural resources and industries, which does not appear promising at present.

Paraguay is still largely an agricultural country with little industrial or urban growth. Almost 70% of the population lives in a rural environment, and thus the effective contribution from the urban population is relatively small.

All of this means that Paraguay falls into the category of the countries where economic progress, - synonymous with agricultural progress in this case - is extremely difficult to stimulate and to maintain. It will be necessary to plan the course of agricultural production very carefully and then ensure that the multitude of small farmers cooperate by growing the crops the country needs. Neither the initial planning nor the guidance of the farming community can be carried out successfully without a far higher standard of knowledge of the country's soils. Reliable long-term development plans cannot be formulated until the soil resources of the country have been evaluated and classified to provide a reliable index to the total productivity potential; reliable advice to farmers struggling with crops essential to the national economy cannot be provided without a thorough understanding of the soil characteristics.

There is also the matter of spending the limited amount of money available for agriculture as wisely as possible. It would seem that too great a reliance has been placed on the philosophy that a technique that has proved its value in one country can be applied with little modification in another country. This is usually far from true. As elsewhere, the soils of Paraguay have their individuality and inherent characteristics that are indigenous to the environment under which they have developed; they cannot be expected to react uniformly or predictably to imported technical tricks. Some part of the available money should be spent each year on a steadily expanding soil survey program, so that the data obtained from soil fertility experiments and the results from analyses of farmers' soils, fertilizer trials on farmers' lands etc. can be safely used as a guide by farmers on similar soils. In this way, each piece of soil knowledge has potential application over all areas with similar soils; but first you must know where those similar soils are located. This requires the preparation of soil maps in some detail. It was unfortunate that the initiative that led to the preparation of the first reconnaissance soil map in 1952 was never followed up by the necessary critical soil studies, and by semi-detailed and detailed soil surveys.

The above are general observations that apply not only in the case of current and planned soil studies, but apply, even more critically, to most of the current and planned agricultural development projects; in some of these expensive projects, a sound knowledge of the soil resources of the whole country may be critical to the success or failure of the scheme.

Other general weaknesses observed concern the degree of co-ordination and integration of activities in agricultural development. In particular, it was noted that the land colonization program in progress was based on a standard size farm holding; without critical investigations to determine the economic size of farms required for the different kinds of soil. Nor was there any evidence of desire to find out the types of crops best adapted to particular soils, nor the soil management practices and farm planning programs suited to particular soils; nor the minimal soil conservation measures necessary to ensure that any particular soil will remain fertile under colonization activities. In many cases the extension services operating in newly developed areas were, as yet, without an experimental or demonstration area.

The need for additional experimental areas is particularly acute in the Chaco region where some areas may prove to be quite suitable for rice and sorghum production.

Specific Observations

Soil identification, genesis, classification and correlation. So marked was the lack of information relevant to these topics that the Mission considered it advisable to pay special attention to the problem of the proper identification of soils while undertaking its field investigations. The Mission reached the following conclusions:

- i. None of the units shown on existing Paraguayan soil maps are series: some are soil associations, while others are soil assemblages relating to a particular land type of major extension, and some units are soil complexes.
- ii. There is insufficient difference between many of the map units shown on the soil map to justify their existence as discrete entities; the range of variation allowed within one 'series' overlaps excessively with that of another 'series' so that large parts of the map become meaningless for agricultural extension work or as a guide in more detailed soil investigations.
- iii. The soil descriptions in the report accompanying the 1:1,000,000 soil map are of no use for anyone wishing to make a precise identification of any soil.
- iv. Within the series belonging to the Red-yellow Podzolic soil group, the most important differentiation, - that of degree of leaching -, is not made. Thus, no separation is made between the soils of low natural fertility and those of medium-to-high natural fertility.
- v. No distinction is made between the intermittently dry soils of the western half of the eastern physiographic region and the more continuously moist soils of the eastern half, although this appears to show well in the profiles of the Red-yellow Podzolic soils. This differentiation is of importance in land use practices, soil management, erosion control, and in fertilizer programs.
- vi. In the Chaco region, the mapping units are extremely broad and, it is said, that in practice, these units have proved to be of very limited value.

Availability of basic information for soil studies. Basic information for soil studies is more or less adequate only in respect of climatic data. Geological data is deficient for the recognition of petrological differences in soil parent materials, and the geomorphic history of the different land forms. Ecological data of value to the understanding of soil-plant relationships is likewise largely lacking. These deficiencies are, however, insignificant alongside the acute lack of good base maps for soil mapping.

Topographic maps of the type needed for accurate soil mapping, are not available. Four quadrangles, of the area around Asunción, are the only ones yet available in the 1:50,000 topographic series planned for the whole country. These have contour lines at 10 m intervals. This work is largely in abeyance owing to lack of funds. An early topographic map of the whole country showing the approximate topography by means of form-lines is no longer available, and the aeronautical charts prepared during the last war from tri-metrogon photographs are likewise of little value for accurate soil mapping. The latter are on a scale of 1:500,000. Some Argentinian topographic maps on a scale of 1:500,000 include some useful data covering part of Paraguay. There is also a planimetric map on a scale of 1:500,000 giving the rough outlines of cultivated areas, prepared in about 1945. The region in the vicinity of the main river systems is rather better served, by maps on scales of 1:1,000 and 1:50,000, prepared by the Dirección de Hidrografía y Navegación. An atlas of the rivers of Paraguay was published in 1950. Responsibility for most of this class of work is in the hands of the Instituto Geográfico Militar which operates as best it can on a very limited budget. This Institute is doing excellent work but the rate of progress is extremely slow.

There is also a team of the U.S. Geodetic Survey working in the Instituto Geográfico Militar, currently engaged in preparing ground control plans of the area to be covered by forthcoming aerial photography. For lack of adequate funds, this group is also making very slow progress. Eventually, it is hoped to prepare a reliable topographic map on a scale of 1:100,000 for the whole country, but at the present rate of progress this will not be available until some time in the far distant future.

With respect to aerial photographs, none ideally suitable for soil mapping are available as yet. A limited area was covered by the USAF tri-metrogon photographs of 1945, but the quality was uneven and much of the landscape obscured by clouds. An area in the Chaco region was flown by the Brazilian "Pegasa" Company under contract to a private oil prospecting company and these are said to be available as a single set held by the Ministry of Public Works. An area of approximately 100,000 ha., is due to be flown in April or May of 1964 for the Puerto Stroessner development project, and a much larger area is to be flown (about 50,000 km²) for the Special Fund project connected with the planning of access roads to potential colonization areas. These will probably be on a scale of 1:25,000; and it is envisaged that controlled mosaics will be prepared from these photographs with a scale of 1:1,000,000. Even if all these plans are carried out, a very large part of the country will still remain without either air photographs or reliable topographic maps.

Training of personnel. There are serious weaknesses in this field. The present rates of output of graduates with adequate soil training amounts to only two or three per year. Some of the other general agriculture graduates could be given "on-the-job" training; but even with these, the number coming available each year will be scarcely adequate to meet the demand for this type of professional as the development and colonization projects get under way.

Financial limitations. The proportion of the National budget for agriculture, currently about 1.7% is apparently small, particularly for a country that must derive a large part of its income from agricultural products.

Furthermore there is a great shortage of agricultural credit and capital within the country to promote the adoption of sound soil management practices on the farms and to stimulate the use of fertilizers and farm machinery, and to promote efficient farm production and agricultural development generally.

VI. RECOMMENDATIONS

1. Expansion and Re-orientation of Studies

Expansion of activities in soil fertility, soil conservation, land use (especially small farm management studies), and related investigations are clearly necessary, but the most pressing needs at the moment are for soil surveys, soil classification and correlation studies and general assessment of soil potentials. Fulfilling these needs is a logical first step towards a full scale inventory of the soil resources of the country to evaluate their agricultural potential.

Specifically, the urgent need is for the expansion and re-orientation of soil studies in the direction of surveys that will:

- a. Enable the accumulated soil fertility data to have a much wider application than at present;
- b. Provide an accurate basis for crop selection, farm planning, soil management and erosion control, particularly in the new colonization areas;
- c. Serve to indicate the most desirable means of rehabilitating the depleted soils in areas where some consolidation of farm holdings is to be attempted;
- d. Help to establish development priorities in areas where new farm colonies are projected, and
- e. Assist in the selection of sites for new experimental stations and demonstration farms and projects;
- f. Suggest where irrigated farming might profitably be investigated and indicate the sites where pilot studies might be carried out.

As part of the general expansion in agricultural training, there needs to be considerable expansion in the teaching and training of professionals and technicians in soils, with heavier emphasis than at present on modern concepts of soil genesis and the importance of soil processes in the plant growth cycle.

2. Initiation of New Studies and Integrated Programs

Soil survey work should be initiated by the Ministry of Agriculture. The present structure of the Government agricultural organization is shown in Diagram 1, from which it will be seen that soil surveys could be fitted in under either the Institute of Agronomy or under the Natural Resources Section. It might, however, in view of the importance of soil studies to the future of agricultural economy, be better to consolidate soil work under a new section for soils and fertilizers, with units for soil survey and classification; for fertility investigations and fertilizer use; for soil conservation and management, and with a soil laboratory unit serving the rest of the section and the farming community in general. This proposal is explained more fully by Diagram 2.

Integration of soil survey and soil fertility programs would become automatic with the creation of the soils and fertilizer section, but in addition it is very important that the closest possible contact be maintained with groups undertaking farm colonization and land development projects. A new project that should be created as soon as air photographs become available, is a combined soil and ecological survey on a scale of 1:250,000 to determine the nature of the soil and plant resources of the country. During the initial stages, when only a limited area is covered by the air photographs, (those taken in connection with the road construction project) a team mainly of soil surveyors and plant ecologists can be trained for the day when it will become possible to extend operations over the rest of the country. In view of the relatively small area of Paraguay and the scarcity of trained local soil men, this type of project might well become the subject of an appeal for international assistance, - a Special Fund project for instance. The great advantage of linking soil scientists and plant ecologists and other specialists in common harness is that, for very little extra cost, one obtains a better appraisal of the natural and potential value of a region than is possible when any one group of specialists is working separately.

Let a third type of new study concerning the management of watersheds and erosion control should be considered for the not too distant future. The potential erodability of many of the main kinds of soils is very great, nowhere more so than in some of the areas now being colonized. The only convenient and practical natural unit for studies of this type is a complete watershed. This would involve soil and vegetation surveys in some detail, installation of instruments for measuring soil and water movement, and would necessarily be a long-term project. Since erosion is intimately related to farm prosperity in Paraguay, this type of project might find international support through the "Freedom from Hunger Campaign", but should also qualify for assistance from the UN Special Fund program.

3. Technical Assistance

Expanded Program of Technical Assistant (EPTA): The Mission is unanimous in recommending that a soil surveyor be assigned to Paraguay as soon as possible. The person selected should have had wide experience in sub-tropical soil conditions since his first activity would have to include reappraisal of the more important Paraguayan soils to determine their correct identification, so that accurate correlations could be

made with similar sub-tropical soils, in other countries, thereby placing a large body of new soil information at the disposal of the Paraguayan agriculturalists. Thus, in the initial stages, the soil surveyor would mainly function as a "soil assessor". His presence in Paraguay might be particularly appreciated by development planning authorities who are frequently confronted with the difficulty of comparing the relative merits of two or more competing projects.

An experienced soil surveyor would be of some assistance to the University authorities who will be faced with the problem of designing new and expanded courses in soils, and, if required, could assist with the selection and training of Paraguayan university graduates and technicians in the art of soil surveying. At an early stage it would be necessary to select a Paraguayan counterpart for the EPTA soils man.

An even more compelling reason why export soils assistance should be at the disposal of the Paraguayan authorities arises from the nature of many of the present land development projects. Most of these will have the soil work contracted out to private companies and the soil experts hired for a brief tour of duty in Paraguay will be varied in origin and quality. In order to derive the maximum benefit from the work of those experts and to assess the standard of the work, it may be of lasting value to the Paraguayan authorities to have independent assessors in the persons of their EPTA soil surveyor and his local counterpart. All the soil information gathered should be entered in a central filing system, against the day when a project can be launched to make a complete inventory of the soil resources of the country. The accumulated experience of the EPTA soils man and his Paraguayan counterpart will greatly assist the Paraguayan Government in the preparation of a project of this nature in a form readily acceptable to the Special Fund of the United Nations or other financing agency.

Special Fund of the United Nations. Although the present moment may not be appropriate for making an immediate start with a comprehensive survey of the land use potential of the whole country (owing to lack of Paraguayans trained in soils, ecology, forestry, land use appraisal, etc., and lack of adequate base maps), this will be needed in the future. Such information is needed to allow more accurate planning of agricultural and forestry development, and to provide a rational basis for land settlement schemes, access road planning, for locating future storage, refrigeration and processing installations, and even for the siting of future towns and cities. Such a survey would also indicate areas for agricultural development through irrigation, water storage by means of dams, afforestation, and for hydro-electric schemes. If carefully carried out, a land potential survey of this type provides highly acceptable data to interest agencies with money to invest in various aspects of the country's economy.

Yet another project, one concerning watershed and erosion studies on a scale too costly to be borne entirely by the Paraguayan Government, might be formulated for submission to the Special Fund of the United Nations, or might seek a sponsor through the Freedom from Hunger Campaign. In the preparation of these, and similar projects, the assistance of an EPTA soil surveyor with prior knowledge of Paraguayan soil conditions would be a decided advantage.

4. Coordination of Soil Studies with Other Activities

With the current resurgence of soil studies in Paraguay, the need to ensure proper coordination with other related activities will arise. This is particularly true in respect of the activities of STICA and other groups working in soil fertility and soil conservation. This essential coordination can probably be secured most easily through some re-organization of the Ministry of Agriculture in order to regroup together most of the personnel working in the field of soil investigations. Failing this, the next best solution would be to appoint a Paraguayan soil correlator with a roving mission, and facilities to visit freely all areas and organizations where soil work is being carried out. This man would naturally be the official counterpart for the soil surveyor stationed in Paraguay under the EPTA program.

TABLE 1 AVERAGE CROP YIELD WITH SELECTED FERTILIZER MIXTURES*

<u>Crop</u>	<u>Treatment</u>	<u>Average Yield (Kg/ha)</u>
Maize	Control	1,400
	40-0-0	2,300
	25-45-20	3,200
Sugar Cane	Control	36,000
	60-30-80	78,000
Cotton	Control	1,200
	35-15-15	1,800
Wheat	Control	600
	30-50-25	1,300

* Source: Interview with Ing. Hernando Bertoni, Paraguay.

DIAGRAM 1 : PRESENT STRUCTURE OF AGRICULTURAL SERVICES IN PARAGUAY

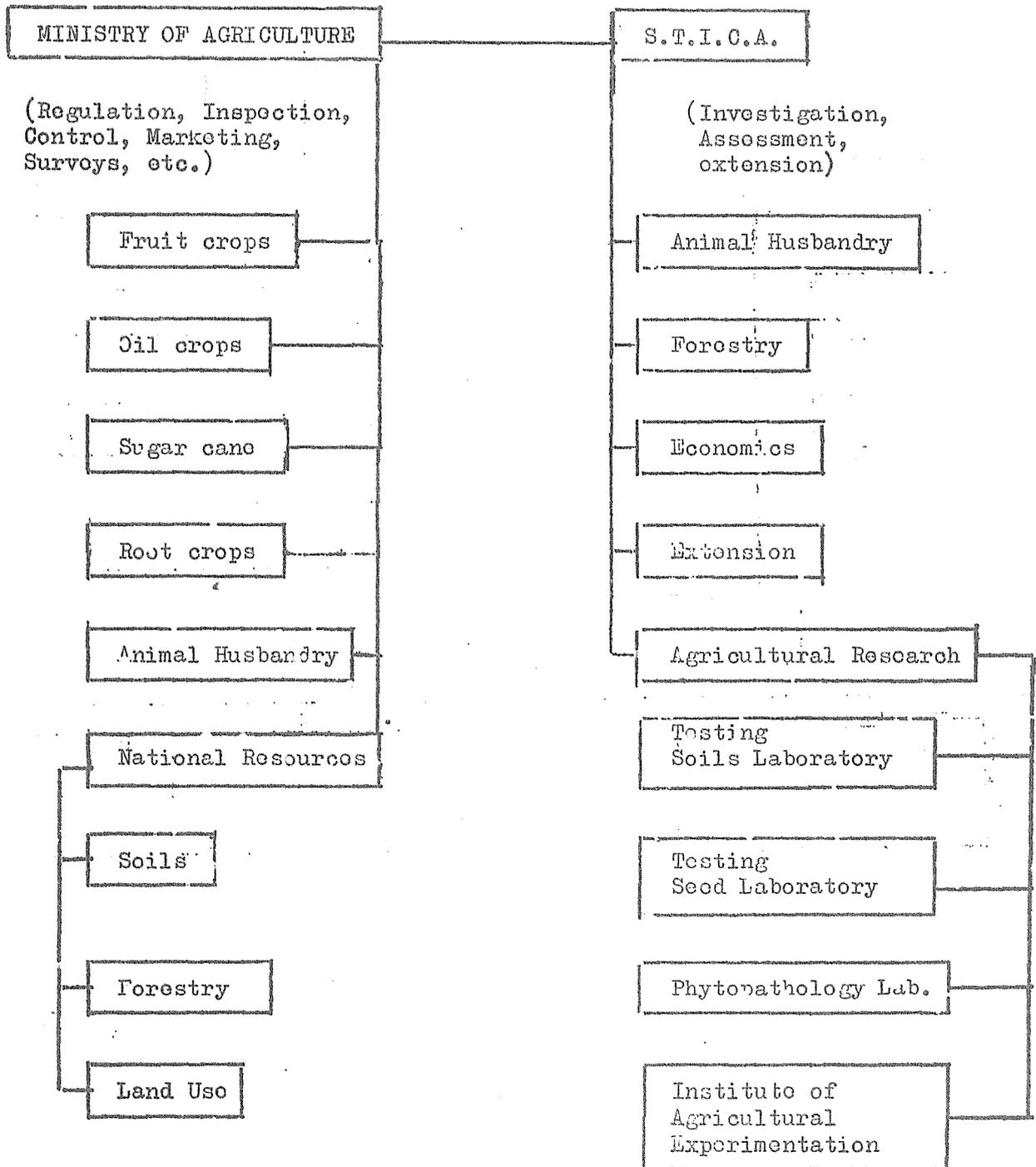
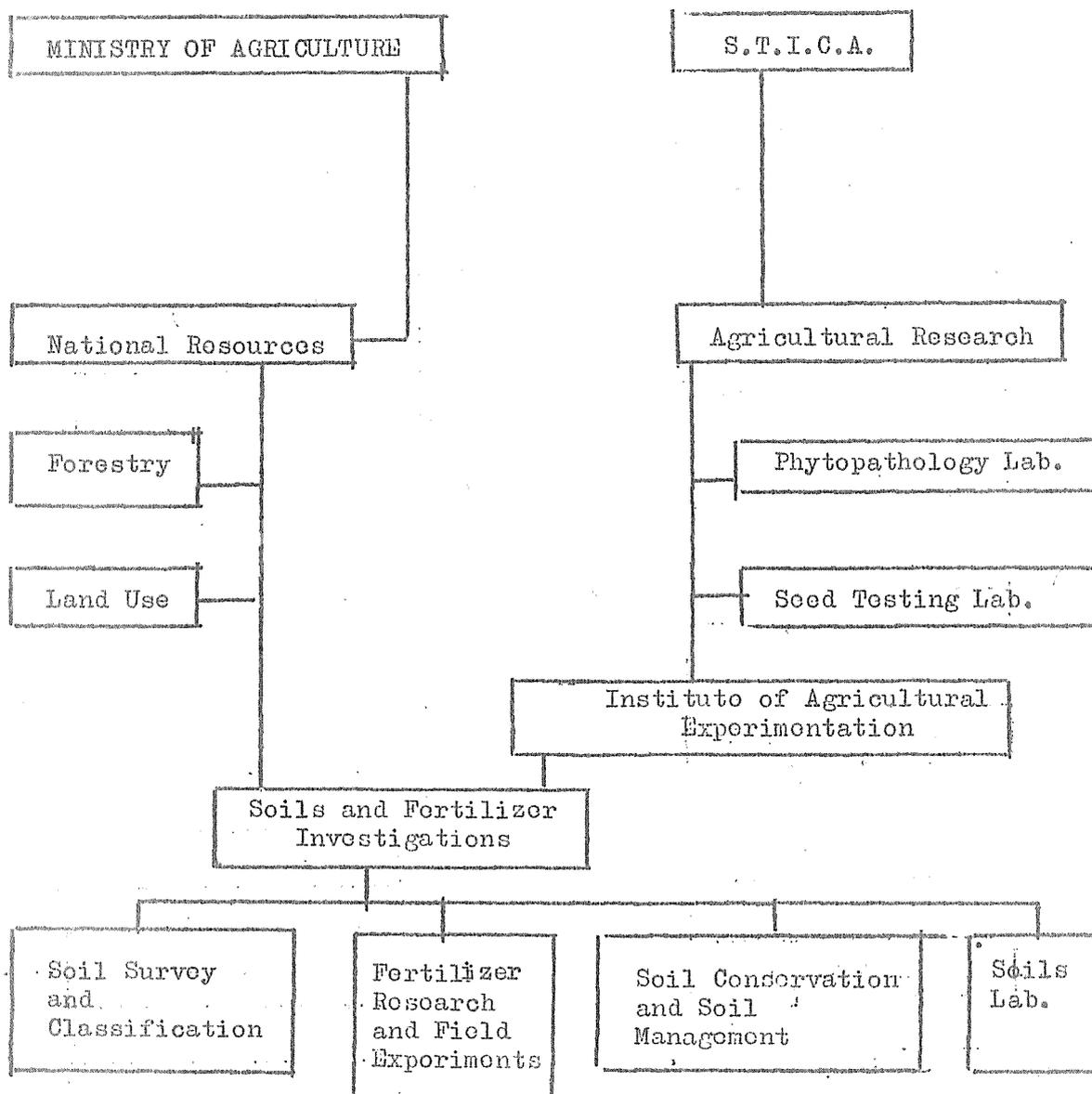


DIAGRAM 2 : SUGGESTED RE-ORGANIZATION FOR CONSOLIDATION
OF SOIL INVESTIGATIONAL WORK



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P A R T II BOLIVIA

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Bolivia has reached a critical stage in her economic development. Despite relatively massive international assistance, reflected by 63 United Nations experts currently working in Bolivia, the assistance of several unilateral aid groups - notably those from U.S.A., now joined by a British group, and soon to be joined by a Belgian group, and the very vigorous efforts of the Bolivians themselves, the situation is not entirely satisfactory.

The focal point of the problem was formerly considered to be the population explosion on the altiplano, but it is now becoming increasingly evident that equally serious aspects of the problem are to be found in the tropical lowlands which were destined to receive the surplus farmers from the highlands and adjacent intermontane valleys. Social services, to which the majority of the U.N. experts in Bolivia are dedicated, have made considerable progress in the highlands, while transport facilities and communications linking the highlands with the lowlands have improved immensely during the past 5 years; but the social services, communications and, above all, the technical agricultural services within the tropical lowland region are notably deficient. Visits by the Mission to the most accessible of the lowland settlements, revealed many conditions that would be certain to repel rather than attract farmers long accustomed to the rude but less oppressive environment of the altiplano. Moreover, the Mission found that many of the new settlers were imitating the agricultural practices of old established farmers, who, in turn had absorbed the subsistence practices of the indigenous Indian farmers, adding no technical improvements, and subjecting both the subsistence farming system and the soil to unfair strain by striving to grow cash crops in addition to the normal food requirements of the household. Already some of the colonists were complaining of soil exhaustion and were contemplating a move to fresh, virgin land. Basically, the rising agricultural problems of the lowlands stem from a lack of experience in tropical farming and a lack of soil knowledge. There is need to counteract this as rapidly as possible.

The total force of knowledgeable soil men in Bolivia amounts to only four: one U.N. Special Fund specialist in irrigated soils; one Bolivian specialist in soil management; two fully qualified soil surveyors, one Bolivian and one British. Of these, only the soil surveyors regularly visit the tropical lowlands. The Mission wishes to stress that if the lowland colonisation schemes are to be successful, there should be a senior soil scientist stationed in Bolivia to assist the soil survey groups with the proper classification and appraisal of the soil resources, and to assist the Ministry of Agriculture in selecting sites and arranging soil fertility trials and demonstration plots in the actual colonisation areas before the main stream of colonisation commences.

In regard to organisation of soil investigations in Bolivia, it is very fortunate that the Ministry of Agriculture is contemplating its reorganisation along lines suggested by Dr. Victor Bruce of F.A.O. This could permit a regrouping of all major soil investigations within a single unit of the Ministry, to replace the present scattering of minor soil studies being carried out by a variety of agencies; and will allow for a proper system of "in service" training so that a strong corps of soil professionals and technicians can be brought into existence. In view of the magnitude and urgency of the problems, the sooner a central bureau for soil studies can be formed, the better will be the agricultural progress of the country. It is not only the Bolivian farmers and the government organisations who are awaiting better soil information: many of the 63 United Nations experts are also hampered in their work by inadequate understanding of the properties of Bolivian soils.

The situation obviously calls for a major effort in the field of soils, yet, in view of the many commitments of the Bolivian government, which has to provide transport facilities, operating costs and trained personnel as counterpart contributions to the various United Nations field programmes already operating, the Mission reluctantly refrains from recommending at this time yet another UNCT project to "evaluate and promote the development of soil resources" on a major scale, but considers that, at the very least, there should be a highly qualified soils expert under the FAO Expanded Program of Technical Assistance made available to assist the Bolivian Government. The Minister of Agriculture expressed a strong desire that such an expert be found and sent to Bolivia at the soonest possible moment.

If this expert can be provided for Bolivia, his duties should include:-

- advising on the classification of soils in the areas destined for colonisation projects and, by drawing on world experience of agricultural endeavour in similar soils, further advise on the soil management procedures likely to give the best results;
- select areas for pilot trials and demonstration plots so that new farmers in the tropical lowlands will have visible evidence of the importance of safeguarding the store of natural soil fertility, of the economic advantages of correct fertilizer applications, of both the appearance and cultivation requirements of unfamiliar crops, of the system of crop/pasture rotation to maintain soil structure, of the desirability of planting a part of their land in permanent tree crops, and of the danger inherent in straying too far from the narrow path of adequate tropical soil management practices;
- assist with the organisation of a central soil service within the new framework of the Ministry of Agriculture, and with the training of staff for undertaking soil studies, including the training of a Bolivian soil correlator who would function as a counterpart to the expert;
- be at the disposal of the University authorities should they call for advice on the raising of the standard of soils teaching programmes;

- act as an assessor in soil problems for the Development Planning authorities; and advise on the selection of promising soil areas where efforts, both technical and capital investment, should preferably be concentrated;

- assemble gradually as complete a picture as possible of the genetic background of Bolivian soils, and from this venture with confidence into the field of planning a national soil survey of the whole country to be undertaken when adequate staff and funds are available, possibly obtaining the assistance of pedologists loaned by neighbouring Latin American countries in the form of a Regional Task Force, organised by the World Soil Resources Office and the Organisation of American States.

The list above is undoubtedly an impressive one, far beyond the means of any single person; but all these problems are very real ones in Bolivia today, and a start must be made to tackle them if the economic development programme is to continue on its planned course.

ADEQUACY OF SOIL STUDIES IN BOLIVIA

I. SOURCES OF INFORMATION

In Bolivia, extremely useful information was obtained from members of the following institutions and organizations: Ministry of Agriculture, Servicio Agrotécnico Interamericano (SAI), University of San Simon, Ministry of Economy and British Mission, United Nations Technical Assistance Office and FAO Technical Assistance Mission. To informants of the above organizations, and to many others the Mission is deeply indebted for the fine spirit of co-operation shown.

In addition to the study of material provided by informants, the Mission also reviewed published and unpublished reports and maps available, and further, carried out a limited number of field investigations in the region of the "Yungas", the central Andean ranges of Oruro - Cochabamba - Santa Cruz, and the northern part of the Altiplano.

II. PHYSICAL CHARACTERISTICS OF BOLIVIA

Geographical Location

Bolivia, the only completely land-locked country in South America, covers a total area of 415,000 sq. miles; situated astride the central sector of the Andean mountain system and extending down to the central lowlands. In the latter portion, Bolivia has common frontiers with Brazil, Peru, Paraguay and Argentina. In the mountainous sector it has common frontiers with Chile, Peru and Argentina.

Topography and Landforms

There are three obvious physiographic divisions to Bolivia: the Altiplano and adjacent highlands, representing about 14% of the country; the east facing Andean slopes and intermontane valleys, occupying about 29% of the country; and, finally, the eastern plains representing some 57% of the total area of the country. This broad analysis has only limited value in view of the very complex topographic pattern within the physiographic units, and the complex micro-climatic pattern. Within each of the broad physiographic divisions there are several important environmental regions and these are usually indicated by the pattern of the natural vegetation. These environmental regions provide a better physiographic basis for any analysis of Bolivian agricultural problems.

Unfortunately, the environmental regions of Bolivia have not yet received adequate study. In the simplest analysis Cardenas (1) recognizes seven major phytogeographical regions, which Arce (2) has described 13. For the purposes of the report of this Mission the country has been divided into nine broad environmental regions, representing northern, central and southern sectors of each of the three main physiographic divisions.

a. The Eastern or "Altiplano", physiographic division consists of wide flat plains of undulated to rolling glacial landforms, and a number of hills and mountains ranges elevated high above the main base level of the Altiplano. The mean altitude of the Altiplano is about 4000m, whereas some of the higher mountains rise to over 7000 m. Some of the landforms appear to have been preserved almost intact from early Tertiary time, before the great orogeny: but the greater part of the Altiplano landscape was modified extensively during four glacial periods in Quaternary time, and further modified by erosion and accumulation in recent time. A conspicuous feature of the Altiplano landscape is the wide, flat plain once occupied by a chain of lakes and lagoons. This western physiographic division has within it at least three distinct environmental regions:

i. Northern Altiplano region

The northern region has the higher proportion of land of rolling relief than the rest of the Altiplano, and enjoys a somewhat less rigorous climate owing to ameliorating influence of Lake Titicaca which forms its northern boundary. The climatic regime may best be described as "dry subhumid to moist subhumid, Altiplano". The landscape was probably once covered with dense tussock grassland and patches of xerophytic shrubs, although little of this now remains owing to centuries of intensive potato and quinoa cultivation and grazing by llamas and other indigenous livestock. Even today, practically every hectare of soil is used for crops of wheat, barley, beans, potatoes and other vegetable crops; only the most stony and shallow soils are uncultivated and used for grazing for sheep, cattle, llamas and alpacas. The present landscape is characterized by small cultivated plots surrounded by stone walls, and by larger strips of cultivated land separated by long heaps of stones and boulders. In this region, the mean annual rainfall is between 500 and 700 mm and mean annual temperatures are in the vicinity of 10°C. Occasional severe frosts do great damage to crops in the flattish basin areas, but are less of a hazard to crops on the rolling low-lands.

The soils range from shallow stony sandy loams to deeper gray and reddish-brown clays, and are locally calcareous in the subsoil. Saline soils are restricted to small areas in the centre of basin topography. There is a deficit of soil moisture from August to October, but over the whole year there is an excess of precipitation over evaporation.

ii. Central Altiplano region

The central Altiplano region is characteristically a region of wide, flattish plains, formerly occupied by lagoons, surrounded by a narrow fringe of rolling land, which in turn, is enclosed by a ring of mountains. The climatic regime is markedly drier (mean annual rainfall between 200 and 400 mm), with very strong and cold dry winds during much of the year. Frosts are intense during winter, spring and autumn months, so that cropping

is restricted mainly to the steeper slopes of the rolling downland and to the lower slopes of the mountains. The mean annual temperature is probably about 60°C. The total climatic regime can be described as "semi-arid Altiplano". The agricultural pattern is predominantly pastoral with llamas far more common than alpacas, and sheep more common than cattle. Although greatly modified by centuries of pastoral farming, enough remains of the natural vegetation to suggest that the original plant cover was mainly low tussock grassland with wind-sheared xerophytic scrub on the more bouldary and stony soils.

Soils range from bouldary loams to calcareous heavy clays with saline soils common on the plains. Evaporation rates are very high during most of the year and for five months of the year there is a marked deficiency of soil moisture; the total annual moisture deficit is of the order of 250mm. During the intense rains of January to March, there is much sheet erosion and mass flow of the topsoils. Wind erosion is also very active as an agency for redistributing topsoil materials, especially in the western sector where the soils are forming from fine pumiceous volcanic ash.

iii. Southern Altiplano region

The third and most southerly of the Altiplano environmental regions has a still drier climate, - best described as "desertic Altiplano". Over much of the region there is a marked moisture deficit throughout the year and the total annual rainfall is in the vicinity of 100 mm. In some years no appreciable rain is recorded. Owing to the very high evaporation rates, rainfall brings little relief to the dry soils. Very severe frosts are common and may occur at any time of the year, with the result that crop production is restricted to especially favourable sloping and sheltered locations. The mean annual temperature may be as low as 3°C, although the diurnal range is very wide. Much of the landscape is occupied by broad barren salt plains ("salars"); elsewhere the plant cover is scanty and restricted mainly to open, low tussock grassland. Agriculture is mainly pastoral; sheep and llama flocks being herded across the plains to localities where a little rain has freshened the natural tussock pasture. The soils are typically desertic in character.

b. The Central, or Andean ridge-and-valley, physiographic division.

This division consists almost entirely of steep slopes enclosing narrow intermontane valleys. In this division, there is a great complexity of micro-climates within different valleys, within sectors of the same valley, or even between opposite slopes of the same sector of a single valley. The chief factors involved in the formation of these local climatic conditions are the altitude of the valley floor, the general trend of the valley system, and the length and width of any particular sector. In about the centre of this physiographic division, the main axis of the Andean chain bends from its general north-south direction, and takes on a northwest-southeast trend. Thus, all the valleys carved in the flanks of the Bolivian Andes in the northern sector follow a general northeast direction and they become funnels whereby the hot, moist air from the Amazon climatic system can travel up to the edge

of the Altiplano. By contrast, the valleys carved in the flanks of the southern sector of the Bolivian Andes have an easterly or southeasterly trend, less directly affected by the flow of the Amazonian air masses, and much more affected by the advances of cold air masses from the south. Between the two regions lies the central sector of the Bolivian Andes which comes under the influence of both regimes but to only a moderate degree. This is the admittedly oversimplified basis for dividing the Central physiographic region into northern, central and southern "environmental" regions.

i. Northern Andean slopes and intermontane valleys

These are locally known as "yungas". They commence at the point where the warm, moist tropical air from the lowlands meets the colder drier air of the Altiplano system, forming an almost permanent cloud belt. This usually takes place at an altitude between 2300 m and 3700 m. depending on local topographic conditions. Above this point, the valley heads and mountain ridges have a cold, moist-to-dry subhumid environment.

In the majority of areas the cloud belt zone occurs at 3300 m. Here the air is cool and strongly charged with moisture; the vegetation is a dwarf forest of gnarled, wind-shorn trees thickly hung with lichen and epiphytes. The soils are shallow and strongly acidified beneath a thick layer of raw forest humus that increases in depth on the broader mountain ridges to form small peat bogs. The environment is unattractive, of little interest to farmers and foresters alike: - a matter of some importance, for if the natural vegetation should be extensively disturbed, massive sheet erosion would remove the whole of the thin soil mantle.

Immediately below the cloud forest belt, there begins an upper montane forest belt with taller and straighter trees of modest girth, draped with lichens, ferns and mosses, and interspersed with arborescent ferns. The climate is still cool and moist, but the air is less saturated and moisture condensation is diminishing. Here the mantle of soil and weathering rock on the steep slopes is somewhat deeper (averaging perhaps 30 cm); and even under natural conditions, long slip scars mark the places where some of the larger and older trees have torn loose from the mountainside and started debris avalanches. As with the zone above, the environment is fortunately unattractive to farmers and to commercial foresters.

The lower montane forest belt appears next, with trees of greater height and girth rooted in a mantle of soils weathering rock that often exceeds 50 cm. even on very steep slopes. The climate is warmer and locally somewhat drier (as on the north-facing lower slopes of some of the deeper valleys). Under natural conditions erosion is not particularly active, but accelerates rapidly when large-scale timber extraction is practised, and may become spectacular in places where pioneer farmers have tried to carve cropland from the forested steep slopes. In most areas, the lesson has been quickly learned, and few farmers have remained permanently in this belt.

Below this latter belt begins the true rain forest, passing successively from temperate to sub-tropical and tropical facies as the temperature increases with decreasing elevation. Concurrently with changes in the forest composition, the mantle of soil and weathered rock on the steep slopes increases in depth and both the colour of the soils and the nature of the soil clays show progressive change in the direction of reddish soils of predominantly kaolinitic composition. The sub-tropical belt appears to have been most attractive to pioneer settlers and from this zone they have spread upward into the temperate belt and downward into the tropical belt, commencing first on the lower slopes of the valley sides and extending upwards on to all but the most precipitous slopes. Under natural conditions, erosion is not very evident, but intensive cropping has reduced many areas to bare rock. Most farmers have been forced into a system of shifting agriculture, with increasingly long intervals between crops and an ever-lasting search for new forest land to balance declining crop yields. Shifting cultivation of indigenous Indian farmers in the humid tropics depends for its success on a nice balance between exploitation of accumulated fertility in forest residues plus some renewal of fertility through slightly accelerated erosion, and the modest demands of a purely subsistence economy. When the demands are increased by the need to grow crops in quantity beyond the immediate subsistence requirements of the farmer, shifting cultivation leads to greatly accelerated erosion and the ultimate ruination of the soils. In the "yungas" of Bolivia, this situation is compounded by the lack of inherited, indigenous skills for dealing with this type of problem: the farmers are, for the most part, recent immigrants into the region. The situation would be less serious if production was based from the outset on such tree crops as coffee, citrus, papayas and mangos and the land thenceforth kept permanently under their shade. However, a very high proportion of the land is used for maize, mandioca ("yuca"), coca, and other raw crops, and, as a result, large areas have passed out of production other than casual livestock grazing.

ii. Central Andean slopes and intermontane valleys

In this region, the belt of maximum condensation is less marked and there is rarely any true cloudforest. The zones of slightly higher humidity and precipitation at high altitudes are indicated usually by light shrubby forest of quchuina (*Polylopis incana*), and even this does not form a continuous belt but appears locally where cool and moist air conditions prevail. There is no true, regular, well-defined sequence of vegetation belts as in the northern sector of the Bolivian Andes.

The valley heads in this region extend back into the semi-arid region of the Altiplano, and the steep slopes are thinly covered with tussock grassland. Agricultural endeavour is restricted to nomadic pastoral grazing of the natural grassland. At first, with decreasing altitude and increasing precipitation, the tussock grassland thickens and small shrubs appear. Much of this belt has been overgrazed and periodically burned to promote new grass growth, with the result that much of the tussock grassland has been replaced by short turf of sedges and annual grasses. In this zone, indigenous farmers have exploited the lower valley sides for potato, quinoa and wheat production and have been forced by growing population pressure to extend their cropping activities to the steeper slopes, thereby causing greatly accelerated erosion. This occurs approximately in the zone of maximum humidity in the higher altitudes, and scattered remnants of *Polylopis* scrub-forest are common. The soils are shallow, somewhat

acid and range in texture from loams to clays depending on parent material.

With decreasing elevation, microclimatic differences become very marked: the change may occur anywhere from 3300 m to 3800 m; with some valleys, sections of valleys, or even opposite sides of valleys showing in swift succession changes from cool dry subhumid to warm dry subhumid, to very warm semi-arid conditions. In some areas, where warm, humid air from the "yungas" region impinges on the periphery of the central environmental region, the sequence of climatic conditions is even more spectacular, running the gamut from cool, very humid to very warm, semi-arid in a distance of less than 20 km and over an altitudinal range of less than 1500 m. The vegetation patterns are a sure guide to climatic conditions, and also fit well with soil categories; despite great textural range controlled by the nature of the soil parent materials. Decreasing rainfall and increasing temperature are paralleled by decreasing leaching of exchangeable bases and increasing movement of clay from the topsoil into the subsoil. This latter process reaches its maximum in the dry subhumid zones, and is less in evidence in the calcareous soils of the warm semi-arid zones.

At elevations approaching 100 m. and continuing down to the lowland plains, the environment becomes more uniformly humid and warmer. Here the vegetation pattern regains some measure of uniformity on all slopes, although variations in the soil pattern due to variations in soil parent material are somewhat more marked. This is a zone of semi-deciduous woodland growing in fertile soils showing distinct clay movement into the subsoil; a feature which is still retained to some degree when the forest changes to light tropical rainforest on the foothills in the immediate vicinity of the plains.

iii. Southern Andean slopes and intermontane valleys

The valley heads of the southern region of Andean slopes and intermontane valleys lead back into the saline and desertic region of the Altiplano. The upper montane slopes and high valleys are decidedly semi-arid and are used only for seasonal pasturage on the sparse *Stipa* tussock grasses. With decreasing elevation, a zone of dry subhumid xerophytic scrubland and tussock grassland appears, but soon gives way to semi-arid conditions generally with some valleys experiencing almost desertic conditions, with a strong development of saline soils on the valley floor. Conditions improve with further decreases in altitude and the lower foothill zone enjoys subhumid climatic conditions which permit the growth of semi-deciduous woodland and finally, near the start of the eastern plain, a mixed deciduous and evergreen forest. Soils of fair depth and natural fertility are to be found in this latter zone, but the long winter dry season has discouraged settlement.

c. The Eastern ("plains") physiographic division

The natural resources of this division are scarcely yet explored. Almost the whole of this natural unit consists of one vast alluvial plain built up as a wide apron of detrital material eroded from the flanks of the Andes after their uplift in Late Tertiary time. This material most fills the Chaco basin, extending right across the western limit of the Brazilian shield, and also contributes largely to the filling of the Amazon basin. In its final stages, the plain was built up by coalescing fans of rivers subject to seasonal flash flooding: their frequent changes of course can still be read in the anastomosing pattern of low sandy ridges and clay-filled shallow

depressions. As the accumulation process diminished, many of the larger rivers developed lightly incised channels running northwards to the Amazon basin; while those from southern valleys continued their southeastern trend across the Chaco plains to join the Parana river system.

Although derived from alluvium, most of the plain is no longer subject to deposition of fresh alluvium from outside the area. Today, the process is more one of local redistribution of superficial soil material during the short but intense rainy season. For the most part they are old soils with a very marked degree of clay accumulation in the subsoil. Rainwater can no longer penetrate readily and during the rainy season the surface of the plain becomes awash with ponded rainwater which moves slowly down the gentle slope of the plain, resorting and transporting some of the sandy material from the low ridges. In this process no new alluvial material is added. Only along the western margin of the plain are younger alluvial soils to be found, the centre and most of the eastern part of the plain are old soils with strongly differentiated profiles.

It is interesting to note that the nature of the sediments on this plain bear some relation to the river systems of the Central Physiographic Division. For example, the northern sector of the plain has been built up by rivers flowing from a somewhat acid, strongly weathering environment and the sediments are mainly acid and kaolinitic; while the southern sector of the plain has been built up by alkaline and saline rivers carrying less weathered clay minerals.

There are certainly more than three environmental regions in the plain, but for the purpose of this report, a very broad grouping into northern, central and southern regions will be sufficient.

i. Northern plains regions

This region experiences a tropical climate with a mean annual temperature in excess of 26°C and with a mean annual rainfall in excess of 1500 mm. There is a long rainy season (October to April) followed by a very hot, dry winter season. The soils become markedly moisture-deficient from July to August owing to the high rate of evaporation and transpiration. Much of this northern plain is covered with species of coarse grasses, well-adapted to survive the extreme oscillations of soil moisture conditions. The natural grasslands serve as rangeland for an extensive beef cattle industry.

ii. Central plains region

The central plain experiences a mean annual rainfall of about 1000 mm. falling mainly between November and March. The mean annual temperature is in the vicinity of 23°C, and the relative humidity of the air is lower than in the northern plains region. Most soils are markedly deficient in moisture from July to October but in the rainy season a large part of the plain is inundated with "perched" water for weeks at a time. The natural vegetation is a mixture of grassland, chaparral scrub, and light forest; each vegetation type being accurate indicators of specific soil conditions. In the western sector of the central plains there are extensive areas of sandy soil, locally heaped by the wind to form low dunes. In the northeast sector, where the soils are derived from ancient metamorphic rocks of the Brazilian shield, a type of dry subtropical forest grows on soils that are old and leached. In the southeastern sector, there is a more thickly forested belt that experiences an annual rainfall of about 1300 mm. and mean annual temperatures around 26°C.

iii. Southern plains region

This is in many ways comparable to the Chaco region of Paraguay. The mean annual rainfall is between 900 and 700 mm., falling mainly in the period January to March. Mean annual temperatures are thought to be in the vicinity of 27°C, with very hot summers and cool winters. The soils are subjected to a long period of moisture-deficiency followed by a brief period of inundation by "perched" water during the rainy season. The natural vegetation is mainly xerophytic woodland, with areas of open, grassy plains and many patches of swamp. Parts of the area are distinctly saline.

The nine broad environmental regions have been discussed at some length in order to give an idea of the diversity of the country, and because there is so little yet published on this subject. The above account is based largely on unpublished information available only in Bolivia, supplemented by some observations made during the field investigations of the Mission, and by information gathered in conversation with persons familiar with conditions in the different regions. Some background knowledge of the geographic diversity of Bolivia is quite essential for any reader interested in an assessment of the adequacy of soil studies in relation to the agricultural problems of the country.

Geology

With respect to geology insofar as it concerns the parent material of soils, the range of rocks is not unduly large. Contrary to popular opinion, the Bolivian Andes are mainly formed of sedimentary rocks; andesite and other volcanic rocks are relatively unimportant. The great majority of soils are formed from sandstones and shales (ranging from micaceous and arkositic sandstones to calcareous shales) and their derivative alluvial and colluvial products. Most of the soils on the flanks of the Andes are directly formed from the country rock, or from their immediate derivative materials. On the altiplano, and on some small plateau remnant amongst the dissected flanks, glacial activity and solifluction have transported soil parent materials for short distances. Over the eastern plains, alluvial activity has moved materials over much larger distances.

Climate

Bolivia has an enormously wide range of climate: rainfall ranges from near zero in parts of the southern Altiplano to more than 300 m. over parts of the northern plain; mean annual temperatures range from near 2°C on the Altiplano to over 27°C on the lowland plain; relative humidity of the air ranges from very low on the Altiplano to extremely high in the cloud belt of the Andean ranges.

Vegetation

The natural plant cover ranges from almost barren desert with scattered low tussock formation and halophytic plants, to luxuriant tropical rainforest. There are at least 30 important plant formations in the Bolivian ecological assemblage.

III. SOILS AND THEIR UTILIZATION

Soil Genesis and Classification

There is a great dearth of published information about soils but a certain amount of unpublished information is available at several centres within the country.

Most of the early investigations were of general or preliminary type (e.g. Storie), or were limited to specific areas for which irrigation projects were being considered (e.g. Report of the Mexican Irrigation Commission, 1940), but few of these were accompanied by maps or attempted to classify the soils on a systematic basis. Very few early soil maps are available. One soil map seen was that prepared as a result of the Mexican Irrigation Commission and covers part of the Cochabamba Valley showing the main soil series and their classification according to suitability for irrigation.

With respect to information of value to the compilation of a general inventory of the soil resources of the whole country, very little soil information is available. The Keenleyside 1951 Mission attempted an assessment for some regions and the British Mission Report (MacKenzie, Coulter and Wilson, 1962), contains comments concerning the probable classification of the soils seen in their travels.

Ing. Aroe, the only fully qualified soil surveyor remaining to serve in his country, prepared a phytogeographic map of Bolivia in 1962 and has available some comments about the soils of the different phytogeographic regions. In addition to this valuable map, Ing. Aroe and his team of relatively inexperienced soil surveyors have, during the past three years, mapped the soils of 15 areas considered potentially suitable for colonization, totalling some 19,196 square kilometers (see Table 1 and Fig. 1).

TABLE 1
SOIL SURVEYS COMPLETED UP TO 1963

	<u>Km²</u>	<u>Has.</u>
1. Covendo - Santa Ana	186	18,600
2. Chipiriri - Isinuta - Bomborajama	242	24,200
3. Quiquibey	347	34,700
4. Iquisivi	160	16,000
5. Chipiriri - Isiboro	600	60,000
6. Rurrenabaque - Río Cauchal	208	20,800
7. Piquendo - Suapi	43	4,300
8. Agrigente - Coni - Effe - Chimoré	180	18,000
9. Isiboro - Río Iohoa	2,400	240,000
10. Chimoré - Puerto Villarroel	900	90,000
11. Yapaoaní - Puerto Grether	920	92,000
12. Río Cauchal - San Borja	960	96,000
13. Santa Ana - Inioua	50	5,000
14. Estudio Exploratorio del Río Mamoré	<u>12,000</u>	<u>1,200,000</u>
Total -	<u>19,196</u>	<u>1,919,600</u>

Soil Fertility

Soil fertility investigations have been in progress in Bolivia for some considerable time. There are six main agriculture experimental stations located in different climatic regions, carrying out crop research (sugar, maize, rice, wheat, rubber, cacao, peanuts, soya beans, oats, potatoes, forage and truck crops), which in some cases has included fertilizer trials (Station Annual Reports). The Central Experimental Station "La Tamborada", located in Cochabamba, has recently commenced critical fertilizer studies as part of a FAO-administered Special Fund Project. These are under the guidance of Ing. Dulá and have demonstrated that for wheat, at present market prices, the best economic results were achieved with an application of 50 kg/ha of nitrogen in the form of sulphate of ammonia. No responses were obtained with potash, and not all soils responded to phosphate. Some soils showed no response to any fertilizer combinations due to their high natural fertility in some cases, and to interference of other limiting factors (e.g. salinity), in other cases. The widest application of these results is not possible in the absence of soil maps for the region. The same comment applies in the case of the other experimental stations. The soils of the actual station grounds have been mapped but funds and staff have not been available to map the soils of the surrounding areas in which extension work has to be carried out.

Soil Conservation

No information was obtained concerning previous soil conservation studies. In view of the seriousness of the erosion problem in Bolivia it seems incredible that none have been carried out.

Land Use Capability

Land use maps have been prepared, however, by the Natural Resources Section of S.A.I. for some areas.

Land Use and Agricultural Development

Agricultural activity is spread over the three major physiographic divisions of the country. A large body of information concerning agricultural production in these three regions is available but when summarised this data often fails to give an adequate picture of either the present land use pattern, or the current trend of agricultural development, because the physiographic divisions are too broad to serve usefully as an analytical framework. For instance, of the agricultural activity on the Altiplano, most of the crop production is concentrated in the northernmost sector, near Lake Titicaca, where the population density locally exceeds 127 persons per square mile and where almost every hectare is repeatedly under crop. Much of the rest of the Altiplano is only lightly cropped, and considerable areas have only a small permanent population. Similarly, crop production in the central physiographic division of Andean slopes and valleys is concentrated in certain localities but virtually absent in other areas. Thus analyses of statistics, on the basis of the broad physiographic divisions, are apt to be misleading: so far no analysis of agriculture on the basis of the natural environmental regions is available. In Bolivia, it is likely that agricultural economists are seriously hampered by the fact that neither the nature nor the approximate limits of the natural environmental regions are adequately known; a reconnaissance soil map of the whole country would clearly be of great assistance in defining these important boundaries.

However, experience in Latin America has shown that the actual land use pattern is not always related closely to the pattern of natural resources. In many instances the dominant and sometimes the controlling factors are ethnological, historical or even social. For example, it is difficult to understand how the Aimara Race came to select the harsh, cold regions of the Altiplano for their racial territory, and why they never migrated in great numbers but preferred a never-ending struggle to keep alive on the limited range of crops tolerant of the severe environment. This is a matter that appears to have no direct connection with the pattern of available natural resources, but it does have an important bearing on present trends of agricultural development. Over the centuries the rigorous environmental conditions of the Altiplano has enforced a very close relationship between people, plants and soil. The farming skills of the Aimara are highly specialized ones; within their own conditions their inherited farming skills are a liability. In some degree, the same comment is applicable to the Quechua-speaking farmers of the Andean slopes and valleys. These people have evolved their ideas about farming in an environment dominated by steep slopes and unstable soils. As subsistence farmers in their own environment they were exceedingly skilful in balancing production with the natural instability of the land. Both groups are now caught up in crucial and entirely new problems of existence. Modern hygiene and medical care have resulted in over-population of their customary territory and they have to accept a measure of migration; and modern customs require that they pay for these health, education and social benefits by producing more than the requirements for their immediate subsistence needs.

The effort to feed extra mouths and to grow surplus produce required by a "cash economy" has distorted their carefully adapted farming systems and led, in quite recent times, to greatly accelerated erosion and to accelerated depletion of soil fertility. A major problem in Bolivia is to find new land for their agricultural endeavours; persuade them to move, and to teach them an entirely new system of farming suited to their new environment. The magnitude of this problem cannot simply be measured by the fact that it involves somewhere about one million people; the real difficulty lies in the fact that the inherited farming instincts are very deeply ingrained and have almost the force of religious precepts. Re-adaptation must inevitably be a slow process. These are problems basically of an ethnological character; but there are other problems of a more recent, historical kind.

Prior to the Spanish Conquest, the individual was responsible to the head of the family, who in turn was responsible to the head of the clan, in turn responsible to the head of the tribe, and so on, and through this chain of responsibility the individual land use rights were safeguarded. When the land passed into the hands of Spanish landowners, many farmers lost their rights and became virtual slaves. This situation persisted until 1952 when the Bolivian Government commenced a land reform program which reinstated the land use rights of a large number of farmers, giving to each, title of land ownership. This release from centuries of uncertainty has presumably resulted in the farmer feeling a grim determination to permit no new interference with his land use practices. From the point of view of the farm extension worker, these recently-emancipated farmers are less susceptible to suggestions concerning land use management and are almost to a man, opposed to farm cooperative schemes; contrasting strongly with other farmers who hold less secure land use rights but who have never suffered so strongly the bonds of servitude.

These are some of the basic problems inherent in the agricultural situation in Bolivia today, and they will inevitably have a strong influence on the future of agricultural development. It is necessary to keep them in mind when considering the type of technical aid most appropriate for Bolivian agricultural progress.

The actual land use pattern, is one of very small, intensively cultivated farms in one corner of the Altiplano, whose further exploitation is limited by the climate controlling the range of crops that can be grown and by progressive soil fertility exhaustion which cannot be economically remedied by simple application of fertilizers; and of a vast number of small cultivated plots extending on to all but the most precipitous slopes of the intermontane valleys. In these latter farms the range of agricultural produce is wider, but erosion has been accelerated to such a degree that many fields have degenerated until they are largely bare rock, and the eroded debris has been steadily swept away by the rivers to produce grave flood problems on the lowlands. Notwithstanding this, probably 85% of Bolivian crop production still comes from these Aimara and Quechua farms. The remainder comes mainly from the recently-developed irrigation projects of the alluvial floors of the inter-Andean valleys; only a very small proportion yet comes from the tropical lowlands.

Pastoral production is likewise concentrated in the Altiplano, mainly in the central sector, where flocks of llamas, alpacas and sheep produce wool and a little meat; and in the higher valleys where the livestock population is augmented by cattle and goats for meat and milk production. In addition, the chief farming activity of the lowlands is cattle raising on the natural pastures and browse vegetation, but the number of farmers engaged in this industry is relatively small.

Large-scale farming activities are still in their infancy in Bolivia. Sugar, fibre and oil industries are developing on the lowlands near the foothills, and in some of the irrigated inter-Andean valleys. Milk production is becoming established in the Cochabamba Valley. Parts of the latter Valley have a population of 325 people per square mile, 70% of those being of European or mixed extraction. Some 30% of the nation's cattle are to be found in the Beni area. The total value of livestock production is about equal to that of crop production, owing to the fact that most of the latter is production for home consumption whereas more of the animal products are exported.

Forests still cover as much as 40% of the total area of the country and they are only exploited for timber in localities where they are readily accessible.

The development of a planned agricultural policy under the existing diverse land use conditions is exceptionally difficult, and is made a hundred times more difficult by the enormous transport problems across mountainous terrain to the main centres of consumption; or, in the case of exportable produce, across thinly populated plains and deserts for shipment from a foreign port.

Transport problems are being steadily resolved by the construction of trans-Andean roads and railways, but even when these are adequate, there still remains the deeper problem of how to modify strongly ingrained indigenous farming habits and inherited farming prejudices to create, from the existing indigenous farm population, a new kind of farmers willing and capable of undertaking the development of suitable areas of lowland soils and so becoming efficient participants in the economic growth of the Nation. This problem is

a fascinating one and an acute one. The excess population concentrated in the over-farmed areas of the Altiplano and Andean Valleys amounts to well over one million persons and their economic condition must surely deteriorate if they remain where they are. Meanwhile, there is unused land in abundance along the foothill plains suitable for skilful tropical farming. What propaganda, what gentle persuasion can be used to turn a very conservative Indian farmer from the cold highlands into a cooperative tropical lowland farmer, employing modern technical devices? It is a strange irony that Latin America's most enduring socialist republic must henceforth depend to an ever-decreasing degree on an effective re-orientation of much of her intensely conservative farming population to achieve the increase in agricultural production that her economy requires. This is the rub of the agricultural administrative problem, and the adequacy of soil studies and the need for increased soil investigations must be viewed against this background.

Land Productivity

Investigations relating to land productivity are of uneven quality and usually not of a coordinated nature. This is inevitable where such investigations are sometimes under national control, sometimes the result of an invited Commission, sometimes the work of an individual scientist, and sometimes the result of an international team.

With regard to crops and pastures, yield data are available for many but are usually not correlated with soil, climatic or moisture data. Forest productivity surveys have been made in specific areas in the past, but lack of ground control for air mosaics and lack of planimetric base maps will delay a complete forest inventory for some considerable time. Two FAO foresters are at present preparing for a forest survey of specific regions where suitable air photographs are available.

In the field of climatology, which is often particularly closely related to soil productivity in Bolivia, the available climatic records have been analyzed by Prada (1946) and Antesana (1958) for the whole country, so that the main features of the climatic regime are known in outline. (Some local micro-climates have also received attention (e.g. Urquidi, 1954, and Fernández, 1961 for the Cochabamba Valley. The unique Altiplano climate has been analyzed by Stenz (1950) and Yepes (1950)). Dr. Guerrini of the World Meteorological Office is currently working in Bolivia.

Presumably because Bolivia was formerly dependent chiefly on its mining industry, it is well supplied with geological data; although no complete recent geological map has been published for the whole country. The available data establishes that the chief soil-forming parent materials in Bolivia are the Quaternary alluvial sediments of the lowlands, and the glacial and related sediments of the Altiplano; followed by various sandstones and shales. These make up the bulk of the rocks of the Andean slopes. Calcareous rocks and volcanic rocks, quartzites and granites occur over a relatively minor extent of the country. The most complete account of geomorphological relationships is that of Ahlfeld and Branica (1960). An early geological map of the country was published in 1944 by Oppenheim. Useful data concerning sections across the Andes can be found in a paper by Douglas (1914); and concerning eruptive rocks in a paper by Smulikowski (1934).

With regard to water-supplies for agricultural purposes, little information is available concerning hydro-geological features and very few geophysical studies have been carried out. Since the visit of the Mexican Irrigation

Commission records have been kept of stream flow in certain rivers, but no complete watershed studies have been conducted for any length of time. There is no central authority for irrigation studies, but most of the irrigation work is in the hands of the Dirección General de Riego under the Ministry of Agriculture. A summary of irrigation projects in Bolivia was prepared by Ingenieros Fernández and Sanjines in about 1962. The two principal irrigation schemes currently operating are those of the Cochabamba Valley (4,500 has. with a possible extension over an additional 1500 has.), and the Tacahua Area (2700 has.). Three new irrigation schemes are under development: La Angostura, Department of Tarifa; Puna, Department of Potosí; and Chuma, Department of La Paz.

IV. CURRENT SOIL STUDIES AND EXPANSION CONTEMPLATED

Soil Surveys

No general reconnaissance surveys are currently in progress. Some general reconnaissance surveys of lowlands tropical areas are planned to begin in 1964 when the soil survey personnel of the British Mission are assembled.

Specific soil surveys are in progress in the area between the Chapare and Isiboro Rivers for colonization assessment, and will be extended in the next year to the Ichito River near Puerto Grethor. Other soil surveys will be undertaken for irrigation purposes in the Villa Montes Area.

The "Plan Bienal" for national development calls for soil surveys of some 250,000 to 300,000 has. during the period 1964-65.

Soil Fertility Studies

The fertilizer investigations of wheat responses will be followed by a similar investigation using other crops if continuing FAO and UNSF support can be obtained, mainly in the Cochabamba Area. Other fertilizer trials are continuing on the various experimental stations.

Soil Conservation Investigation

No studies of soil conservation are in progress, but proposals are being formulated to secure an expert in soil conservation for the continuation of the UNSF project centred at Cochabamba. The "Plan Bienal" proposes that said conservation studies be undertaken in Tarifa, and in the north and south "yungas" region.

Integrated Studies connected with Land Development Projects

A UNSF project administered through FAO in the Cochabamba area will terminate shortly, and proposals are being made to secure a follow-up project with additional attention to soil mapping and soil conservation investigations. This new project calls for an expert in soil fertility and mapping and another in soil conservation.

In 1962 a British Mission visited Bolivia to report on the technical assistance needed for the development of tropical agriculture in Bolivia. (MacKenzie, Coulter and Wilson, 1962). This commission recommended the establishment of a soil and land use survey team, one member of which has already arrived and commenced work in establishing a soil survey laboratory for analysis of soil samples taken in connection with the soil surveys. The complete team will consist

of a senior soil surveyor and two soil surveyors, with a forester or ecologist attached to it for a specific period. This team would concentrate initially on a broad reconnaissance of the lowland tropical soils to define areas worthy of more detailed investigation, in particular the San Javier-Concepción area: Riberalta, Yacuiba and the Tucuvaca Valley.

The soil survey laboratory of the British Mission will be integrated with the existing soil laboratory at "La Tamborada", Cochabamba, and the soil survey work of the British Mission plans to be operated in conjunction with that of Bolivian soil survey teams working in the tropical lowlands.

The "Dirección Nacional de Desarrollo" plans to carry out soil studies for irrigation project covering a total of 9,000 has., located at Mairana, Cuchu, Punata, Huarina Peñas and Villa Montes.

Personnel

At present there are 18 Bolivian soil surveyors (some are undergraduate students from the University of San Simon undergoing on-the-job training) under the direction of Ing. Arce. These operate as three six-man teams and the team leader is a graduate from the general soils course of San Simon University. There are thus 4 Bolivians engaged in full-time soil surveying.

Two U.S. soils experts (Drs. Englehorn and Hanson) have served in the past as field assessors to the Ministry of Agriculture (S.A.I.) soil survey program under Ing. Arce. There are, however, none of these experts in the country at the present time. The single soil surveyor of the British Mission, and Ing. Dulá of the FAO/UNSF project are the only two international experts with soil training currently serving in Bolivia.

A private Germany company, "Ingeria Global" is at present undertaking irrigation studies for the Bolivian Government but no soil survey personnel are employed.

Training Programs

There are seven universities in Bolivia, but only one, the University Mayor de San Simon, has a Faculty of Agricultural Sciences.

Agricultural training is carried out at three levels:-

- Elementary, taught in four high schools;
- Intermediate, taught at five schools of practical agriculture;
- Superior, taught only at San Simon in Cochabamba.

During the last five years, an average of 7 students graduated each year from the Faculty of Agricultural Sciences and of these only five joined the Government Agricultural Services. Many of the graduates seek employment in neighbouring countries where the pay and opportunities are better.

At San Simon, a student can acquire the title of Ing. Agronomo in General Agriculture. For this degree, the student has to take two compulsory courses in soils. The general soil course includes some information about soil classification and about soils and fertilizers. Students majoring in soils may elect to specialize in soil fertility, for which they are required to submit an original thesis based on soil and crop investigations; those specializing

in soils are also required to serve as a soil survey assistant on the Ministry of Agriculture S.A.I. soils teams. No post-graduate courses in soils are available in Bolivia.

The "Plan de Desarrollo" recognises that the lack of technicians in the middle and upper category is the principal "bottle-neck" in the agricultural development program. It would appear necessary to seek some system of scholarships to encourage students to enter the Faculty of Agricultural Science at San Simon. Approximately 10% of the present annual intake of students elect to join this Faculty.

V. NEED FOR FURTHER SOIL STUDIES

General Observations

As part of the social and economic development of Bolivia much of the national effort, and almost all the international technical assistance, is directed towards the agricultural sector of the economy through resettlement schemes in the tropical lowlands; through land development and irrigation schemes in the Andean Valleys and through improvement of social and agricultural extension services to the Altiplano farmers. With all these efforts, soil investigations are given far too little attention.

This situation is alarming for, as is well known, a sound agricultural development planning and implementation must be based on a knowledge of the country's soil resources and potentialities. The virtual neglect of soil surveys and soil investigations as basic and integral material for the agricultural development program, represents a very serious weakness in current and planned activities relating to the economic development of Bolivia. This fact is not overlooked by Bolivian development planners, but the severe shortage of Bolivian soil specialists and the slow development of soil science courses in the University, plus the annual drain of graduate students who prefer to work in neighbouring countries, all combine to force the economic planning group to go ahead without waiting for essential soil information. In this situation, Bolivia is strongly predisposed to seek additional international aid in the field of soil science.

There are already a formidable number of international experts working in Bolivia. It does not seem to be widely known that there are currently no less than 63 international experts supplied by the United Nations working in the country. Of this number, more than half are directly concerned in agricultural development. In addition to these, there have been a number of U.S. agricultural technicians; private agencies employing agricultural technicians and recently, a group of British advisers on tropical agriculture. Yet another group, from Belgium, is scheduled to arrive in the near future. This amounts to a very considerable intensity of external effort to improve Bolivian agriculture and it also means that the country has undertaken a heavy burden in the provision of counterpart personnel and finance. The volume of reports and economic analyses available for study is truly phenomenal for a country of this size, but throughout all these there is a conspicuous deficiency of soil information and a repeated call for soil studies.

There is an immediate need for reliable soil information to support major National development projects, such as:-

- Farm resettlement areas, where for lack of understanding of soil properties virgin land is being farmed by inappropriate methods that can only lead to rapid exhaustion of the natural fertility of the soil.

- New colonization areas, whose selection requires advance soil surveys and whose development requires careful checking of the changes in the soil properties and corroborating soil fertility investigations.
- Access road planning, which requires a very rapid reconnaissance soil survey of large areas to determine the broad agricultural potential of regions.
- The formulation and implementation of pastoral farming programs in the Altiplano, which requires accurate soil information to show where the soils have a greater pastoral rather than arable farming potential, and to assist in the selection of soils suited for extension of pasture trials already being carried out at the Altiplano Experimental Stations. The present production of wool on the Altiplano is about 0.8 kg. per sheep, trials have shown that local sheep crossed with improved varieties grazing on nutritious pastures and alfalfa plots, can produce far higher wool yields under Altiplano conditions. This program is in urgent need of soil survey data.

To handle all this work, there is at present in Bolivia only one Bolivian soil surveyor with adequate training, and one junior British soil surveyor. If the Belgian group arrives, they may be expected to bring an additional soil surveyor.

In addition, there is a need for reliable soil information to guide crop expansion studies, soil fertility investigations carried out by the Experimental Stations, fertilizer programs, and to determine the basis of future soil conservation investigations. There is at present only one fully-qualified expert in the field of soil-plant relationships in Bolivia, and he is attached to a Special Fund program of the United Nations and hence limited with regard to the territory that he can serve. A Bolivian specialist in soils has been added recently to the Extension staff (at Cochabamba) but for lack of essential soil data the effectiveness and progress of his work may be adversely affected.

The immediate needs for soil information is sufficiently formidable, but there are also some very important long-term needs; especially in such fields as soil erosion control, crop selection and plant breeding, use of fertilizers and afforestation. Standing out above all is the future need of a complete inventory of the soil resources of the country, and reliable soil information is urgently needed to assist analysis of the true productivity and competitive position of Bolivian agriculture.

Bolivia has received a massive injection of international aid and this has begun to produce an accelerated rate of agricultural development. Social and economic urgency required that this start without waiting for essential soil studies, but as the momentum of the movement increases the need for reliable soil information becomes increasingly acute. Already some failures due to lack of this information can be observed.

The "Plan Decenal de Desarrollo" recognizes the urgent need for better knowledge of the soil resources of the country, but also comments on the fact that one of the major problems is the weakness of administrative organization in the past, which has led to various parts of the agricultural program being divided amongst different ministries and institutes, without any subsequent coordination of the efforts.

Generally speaking, there is also a lack of any clear-cut organisation to undertake the essential soil studies. Many different groups are currently, or at one time have, engaged in soil studies. Amongst these are the following:-

The Ministry of Agriculture
Servicio Interamericano Agrícola
The Ministry of Public Works
The Universidad San Simón
The Corporación Boliviana de Fomento
The British Mission for Tropical Agriculture
"Alianza para el Progreso"
Various private organizations contracted for special development projects
The Technical Assistance Bureau of the United Nations through FAO, OIT,
UNESCO and others.

Each of these has, from time to time, discovered some important aspects of the properties of Bolivian soils and used the information successfully in some particular agricultural project. With so many persons working with applied soil science, using different methods and different standards, it is extremely important that there should be some central bureau responsible for the collection and analysis of soil data: a unit to collate and evaluate and maintain a growing record of Bolivian soil characteristics. This bureau should be developed within the structure of the Ministry of Agriculture, and should also be the seat of the soil survey service. Moreover, neither the soil surveyors nor the staff engaged in coordinating soil data will be able to function efficiently without some general picture of the total soil resources of the country; in short, this central soils unit must also eventually undertake a comprehensive soil survey of the whole country.

Although the need has been apparent for some time, financial limitations have prevented the Ministry of Agriculture from creating this highly desirable centralization of soil studies. Meanwhile, other ministries with fewer budget restrictions, have expanded their interests in the field of soils and brought about further decentralization. It is expected that early in 1964, there will be a re-organization to strengthen the Ministry of Agriculture and if the proposals of Dr. David Bruce of FAO are accepted, the new Ministry will have a Department of Land Use Capacity under the Investigation and Extension Branch which could serve as a home for a Soil Bureau. It might be even more desirable to create a specific Department for Soil Survey and Research.

Specific Observations

Apart from the above general observations, there are certain specific factors that may be expected to mitigate against the development of knowledge about Bolivian soil resources. These are grouped under the following:-

Soil identification, genesis, classification and correlation. No definitive studies have been made in this field in Bolivia. U.S. soils advisers working with Ing. Arce under S.A.I. programs have attempted to link some of the tropical soils with the U.S. 7th Approximation classification, and visiting soil scientists (e.g. Coulter of the British Mission, in 1962; and Arens of FAO in 1961) have briefly recorded their impressions of the approximate relationships of some Bolivian soils and the more widely accepted world soil groups.

In view of the paucity of correlation between Bolivian soils and the soils in other parts of the world, the present Mission paid particular attention to this aspect during its field investigations. No soil maps were available for

any of the areas visited (with the exception of a soil map of the irrigable area of the valley of Cochabamba prepared by the Mexican Irrigation Commission in 1948). From these field observations, supplemented by a study of all available ecological, meteorological and geological reports and maps, a very generalised rough soil sketch map for Bolivia will be prepared. Valuable advice was received from Ing. Arce of Bolivia and P. Arens of FAO in its preparation. A discussion of some of the major features in the Bolivian soil pattern follows:-

In the case of the Altiplano there are four main soil regions. The soils of the southern Altiplano are mainly desert soils (Regosols and Lithosols) which, under Altiplano climatic conditions, are subject to very little weathering and only a small amount of leaching which is repeatedly cancelled out by the upward movement of soluble salts. From south to north, there is a gradual increase in the amount of leaching, and some increase in the incorporation of dark-coloured humus compounds (melanisation), but weathering processes are exceptionally weak throughout the Altiplano. However, clay soils exist in abundance, but this clay is derived from ancient weathering processes (pre-weathering) that may have occurred in inter-glacial periods or even may relate back to the mantle of weathered material that was present on the landscape before the Andean orogeny. Almost none of the landforms escaped modification in glacial times, and many landforms are related to post-glacial lake and lagoon systems. The soils on these latter plains, in the vicinity of Lake Titicaca, are often dark gray montmorillonitic clays, with accumulation of calcium carbonate at various depths, or accumulation of gypsum crystals. Saline soils and salars are common on the southern and central Altiplano, but are rare and extremely local at the northern end of the Altiplano, although some soils have characteristics suggesting that they were perhaps formerly saline soils that are now leached. No classification of these Bolivian Altiplano soils has ever been attempted. In Chile, Brown and Gray Altiplano Desert and semi-desert soils are recognized; in Peru Altiplano Prairie soils ("Pradera Andina") and Altiplano Humic Gley soils ("Gley Humico Andino") have been recognized. In Bolivia, it is probable that both Gray and Brown Desert and Semi-desert Altiplano soils occur; as well as Brown and Gray Altiplano Prairie soils, together with their related hill and steep-land soils, and associated hydromorphic and halomorphous soils. At this stage it is desirable to retain the word "Altiplano" or "Andino" in the description, because the implications of the unique climatic conditions are as yet unexplored. No "Paramo" soils were seen on the Altiplano proper but Lithosols and steep-land related to the Paramo soils were found on the northeast-facing upper slopes of the Altiplano mountains at altitudes from 3900 m. upwards to the snowline. Amongst these soils are to be found small patches of Alpine Meadow soils. Soils derived from volcanic ash occur only in the western sector of the central Altiplano region, and there the climate is too dry for the development of allophane clays. These "volcanic soils" are mainly Regosols. Small patches of Altiplano bog soils (saline peats) occur along the foot of the western mountains.

The central physiographic division comprises mainly Lithosols and recent colluvial soils with only a relatively small proportion of the landscape developing steep-land and hill soils that show something of a zonal impress. The soils of most value for accurate determination of the current genetic processes, are those occupying the broader ridge tops and the few, very small, up-land plateaux representing a part of an older landscape that escaped severe dissection. Soil formation in these relics of old landforms seldom dates back beyond the last glacial period, for the soil parent materials show distinct evidence of solifluction and glacial deformation.

Summing up all the available field evidence from examination of the Lithosols, steepland soils and hill soils, as well as that from soils developed on more stable landforms, it is evident that two distinct sequences of soil formation exist. On the north-east facing slopes of the northern "yungas" region, where the warm, moist air of the Amazon lowlands reaches nearly to the top of the Andean mountain ranges, the sequence is from Podzols and associated Gley Podzols in the cloudforest belt; descending to Acid Brown Forest soils in the upper montane forest belt, then swiftly through Brown Forest soils showing increasing degree of weathering of parent materials in the lower montane forest and subtropical forest belts; until strongly weathered Reddish-Brown and Red soils are reached in the rain forests of the tropical foothills and lowlands. These latter soils are Red-Yellow Podzolic soils where derived from rocks rich in silica, and Red-Brown Lateritic soils where derived from rocks rich in basic minerals. Soils with somewhat intermediate characteristics also occur on parent materials that are not particularly acidic or basic: these have sometimes been described as "Tropical Brown Forest Soils". Most of these foothill and lowland soils appear to be of moderate to high base status under natural conditions but soils of low base status appear on the older alluvial terraces.

By contrast, on the southeast-facing slopes of the southern sector of the central physiographic region, where the influence of the air mass of the Amazon basin is relatively weak and the influence of cool and relatively drier polar air is strong, the soil sequence is very different. With decreasing altitude, the thin dark, very weakly weathered soils of the Altiplano mountains gradually increase in clay content and show clay eluviation. At first this is little more than a slight increase in subsoil compaction. Under moist sub-humid conditions in the middle altitudes, soils from sandy parent materials are weakly podzolised and those from clayey parent materials (shales, etc.), are very harsh-structured acid clays. Within this belt, there are several major enclaves with dry subhumid and semi-arid climatic conditions. Here the soils show strong clay eluviation, but are not at all leached of bases. The accumulation of clay in the subsoil is in the nature of a "fragipan", very hard when dry but quite friable when thoroughly moist. With decreasing altitude in these dry enclaves, the soils show strong accumulation of calcium carbonate and occasional gypsum; in the valley bottoms the alluvial soils are often saline. It is difficult at present to place all these soils in accepted World Soil Groups. The soils of the semi-arid sectors appear to be Calcisols and Calcio-Brown soils while those of the dry subhumid areas have a resemblance to Non-Calcic-Brown soils and Chestnut soils. However, the soils are developed under a climatic regime which has summer rainfall. This summer rainfall increases over the whole of the lower foothill sector; here, under a moist subhumid regime, semi-deciduous appears. The soils still show a pronounced degree of clay eluviation but the base status is kept high by re-cycling of nutrients through the forest system. These soils have some of the features of the Grey Wooded soils of Western Canada, but they are of a more reddish-brown colour. These soils need further study before their true genetic relationships can be assessed.

Over the eastern plains a wide variety of soils can be found. In the northern sector Gley soils and Pseudo-Gley soils are developed under tropical conditions many of these are strongly leached and some are with ferruginous pans or with plinthite. In the southern sector, saline hydromorphic soils are more common and some have a distinct resemblance to degraded Solonetz (Soloth, Solodi). Most soils usually show strong accumulation of clay in the subsoil which promotes seasonally waterlogging and are light reddish gray in colour and slightly mottled. Most soils show some measure of leaching, and under deciduous forest

the surface few centimeters are occasionally bleached, although the pH does not indicate any development of strongly acid conditions. Further study is needed before those soils can be adequately classified; they have some resemblance to Planosols, but also many points of difference.

From this brief description of some of the more obvious features of Bolivian soils, it will be seen that a great deal more work needs to be done in the field of classification. The present situation is such that anyone venturing on serious soil studies in Bolivia virtually will be starting from scratch.

Availability of basic information for soil studies. With the possible exception of geological information, there is rather deficient analysis of climatic data; lack of ecological data and deficiency of agronomic data that can be employed safely in the construction of future soil maps.

Nor is the position much better in respect of base maps suitable for soil maps. Reliable topographic and planimetric maps exist only for parts of the Altiplano area. Elsewhere, the available topographic maps with form-lines and somewhat inaccurate planimetric maps would be quite inadequate for precise soil mapping. A considerable proportion of the country has been covered by air photographs (see Fig. 2) but many different aerial survey companies have been involved and each has to be approached individually, to obtain prints. Some of the photographs are of poor quality while some contain large areas obliterated by clouds. Copies of all negatives flown are supposed to be held by the Instituto Geodésico Militar in La Paz, but this organization was unable to provide the Mission with either pertinent information or copies of maps. In general, it would appear that much of the Andean foothills and adjacent lowland has been flown, as well as some of the northeastern and northern plains, and most of the Altiplano. This leaves only part of the Andean slopes, all the northeastern and eastern (Brazilian boundary) area and much of the Chaco area without air photo coverage. Many of the photographs taken are at a scale of 1:40,000.

Few of the areas flown have ground control and almost all the mosaics made from the air photos are uncontrolled. The majority of these uncontrolled mosaics are on a scale of 1:50,000 or smaller.

Training of personnel. Very little formal training for soil personnel is available in Bolivia, apart from the soil courses given as part of the General Agricultural syllabus at San Simon University. Most of the present junior soil surveyors have only on-the-job training, and some are students working on soil survey teams as part of their university training.

Far too few university students are showing interest to specialize on soils and allied subjects, and the annual output of such students is woefully small in relation to the needs of the country. Also, as mentioned earlier, an unfortunately high proportion of graduates with some interest in soil science leave Bolivia.

This situation makes it almost impossible to visualize any rapid expansion of a soil survey and investigation centre within the Ministry of Agriculture, and virtually precludes the immediate preparation of a major project to map the soil resources of the country even with international assistance, since an inadequate number of Bolivian counterparts would not be forthcoming.

Financial limitations. These are probably very serious in Bolivia where the national income is strictly limited, and where much of the money allocated to agriculture is already tied up in the provision of counterpart services to international, and other, projects already operating.

VI. RECOMMENDATIONS

1. Expansion and Re-orientation of Soil Studies

Much is needed in this field but little seems possible under the present organization. If more money was available in the local budget for agriculture and if the Ministry of Agriculture completes its reorganization and creates a central soil service, then there could be expansion of soil survey work in connection with land settlement schemes, and a re-orientation of soil studies in the direction of better classification and correlation of soils. Pre-colonisation soil surveys are urgently needed; it is vitally important that these virgin soils be properly classified, and their true fertility status and proper soil management regimes be accurately assessed before large-scale settlement commences.

2. Initiation of New Studies and Integrated Programs

New soil surveys and investigations are badly needed, but again, recommendations must be qualified according to the amount of local finance likely to be available, and the success of the proposals for reorganisation of the Ministry of Agriculture. It is particularly desirable that some watershed studies be made to determine the extent to which soil erosion is damaging the national economy, and to devise practical control measures. It is also desirable to initiate some soil investigations of the declining fertility so evident in newly colonized areas, and to lay down some simple soil management rules for the main kinds of soil. In the present circumstances, the Mission does not feel that these projects can be unduly emphasized.

3. Technical Assistance

If a serious attempt is made to create a centralized soil unit for the whole country, under control of the Ministry of Agriculture, and if funds are set aside to assure that a Bolivian counterpart with adequate mobilization will be available, then the Mission strongly recommends the appointment of a soil surveyor under the EPTA program.

The duties of this soil surveyor will be many and varied, and the situation will certainly be a demanding one. He may be expected to:-

- i. Assist in the formation of a Department of Soil Survey and Research, in the creation of a central soils laboratory, in the organization of a soils information centre, and the setting up of a filing system for recording the characteristics of all the major soils.
- ii. Act as a soils assessor in colonization and land settlement projects, in selection of routes for new access roads and land valuation studies.
- iii. Advise on the nature and scope of soil fertility trials in areas where newly colonized soils are showing signs of declining fertility; advise on soil fertility problems generally, and select soils for future soil fertility investigations.

- iv. Draw up soil management "blue-prints" for problem soils and select areas for soil conservation studies.
- v. Assist with the promulgation of a "soil education" program in conjunction with soil specialists attached to the Extension services, to ensure that the farmers become increasingly aware of their duty as stewards of national soil resources.
- vi. Assist the lagging field of University soils teaching, by providing material for classes and by giving occasional lectures by invitation.
- vii. Assemble as complete a picture as possible of the genetic background of Bolivian soils, and from this venture with confidence into the field of soil classification; to classify soils for persons and projects needing such information; to correlate soils between projects, and to advise experimental stations.

Depending on the advice of the EPTA soil surveyor, it might be possible to consider an integrated soil and land use survey project at some future date. Such a project would certainly require UNSF or other support.

The fertilizer trials program at present being carried out by Ing. Dulá (under a UNSF project) is due to terminate in 1964. This work has proved highly successful and it would be desirable to see it continued and extended to embrace crops other than wheat, and to cover regions other than the Cochabamba Valley. The presence of an EPTA soil surveyor in Bolivia would enable better correlation of fertility results with soils and allow better identification and selection of important soils for such a project. This type of work is sometimes carried out with FEEC support in other countries, and the possibilities here should be explored.

The World Soil Resources Office, through its efforts to compile a soil map of Latin America, is gradually bringing about a measure of co-operation between the soil surveyors of the various Latin American countries. The stage will soon be reached where it may be possible to organize a team of Latin American soil scientists to carry out urgent general surveys for countries yet lacking in training soil technicians. This could probably be arranged by cooperation between FAO and the Organization of American States, with some financial backing from a third source.

Should this suggestion find favour, the Mission strongly recommends that such a "task force" of Latin American soil scientists be given as their first assignment, the preparation of a general soil map of Bolivia on a scale of 1:1,000,000, using existing topographic maps and striving, not for accuracy of soil boundaries, but for accuracy in soil classification. Such a team should be under the general direction of the FAO EPTA soil surveyor in Bolivia, or a Regional Soils Expert.

4. Co-ordination of Soil Studies with Other Activities within the Country

The demand for assistance with soil classification and correlation in Bolivia is so great that the EPTA soil surveyor will inevitably find himself deeply involved in many of the agricultural projects operated by different organizations. In particular he should seek an opportunity to co-ordinate his work with the FAO team engaged in making a Forestry Inventory, and with FAO personnel engaged in soil fertility studies. These are two fields for which FAO has taken a major responsibility in Bolivia, and reliable soil information is essential to their success.

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LIST OF FIGURES

Fig. 1 Progress of soil surveys (1959-1963)

Fig. 2 Air-photo coverage as of December, 1963.

P. A. R. T. III - PERU

SUMMARY OF FINDINGS AND RECOMMENDATIONS

Peru has embarked on a realistic program of agrarian reform which will result in a new epoch of agricultural development. The technical services at the disposal of the Peruvian government during its vigorous drive to resolve the social and political problems of the rural population are relatively highly organized and are composed of comparatively highly trained professionals and technicians. Furthermore, the technical aspects of the agrarian reform program appear to be getting very careful analysis. The Peruvian Government is also receiving considerable foreign assistance from many sources.

To a very large measure, the eventual success of this reform program will depend on the correct use of reliable soil knowledge. Unfortunately, in recent years, soil surveys and related investigations have not kept pace with growth of agriculture and the need for information for planning purposes. Although a number of small and scattered areas have had soil studies, there is nothing approaching an overall picture of the true nature of the soil resources of either the whole country nor of many of the important agricultural regions where reform programs are currently going into operation. There are now, however, soil survey teams at work in some of the 'key' agrarian reform regions. It is further proposed to undertake a stocktaking of soil resources as part of a country-wide assessment of natural resources. There are also proposed projects to carry out more detailed soil mapping as part of pre-colonization surveys.

There is thus a considerable amount of activity - present and planned - in the field of soil studies. Weaknesses in the present situation, however, include a virtual absence of personnel familiar with modern concepts of soil classification and experience in soil correlation, and a growing shortage of professional staff with adequate training in soil investigation techniques, particularly in soil surveying. The Mission understands that the Agrarian University of "La Molina" intends to seek support for the amplification of the Soils Department in its Faculty of Agronomy with a view to stepping up the turnout of graduates with advanced training in soils, but it appears certain that Peru will have to seek outside assistance in work on soils.

An additional weakness in the situation lies in the fact that soil studies are being carried out more or less independently by many different organizations. The Mission enquired into the possibility of the creation of a central Soils Institute but reached the conclusion that, whereas highly desirable, it should be postponed and studied further. The Peruvian authorities, however, are not unaware of this weakness and, with commendable forethought, have already established a Department of Soil Co-ordination in the grounds of the Central Agricultural Experimental Station at "La Molina" alongside the main soils teaching centre of the University and with a modern building including offices, draughting rooms and laboratories.

The Mission urges that this centre for co-ordinating soil work be given a stronger operative role in the Agrarian Reform program. This could be done by making it the centre for all Peruvian soil correlation and soil classification studies. To do this would necessitate the provision of an expert in soil classification and correlation to the centre and the appointment of a Peruvian counterpart who would become the National Soil Correlator.

The Mission considers that an appropriate expert in soil classification and correlation should be made available, on request from the Peruvian Government, under the FAO Expanded Program of Technical Assistance (EPTA) and further urges that high priority be given to this recommendation. The duties of an EPTA expert in soil classification and correlation would be :-

The training of a counterpart as the National Soil Correlator;

An immediate investigation of all soils currently employed for soil fertility trials and correlation of these soils with those of the surrounding region where the local extension services are operating;

An early visit to all soil survey parties currently working in the field to resolve the more pressing problem of soil classification;

The inauguration of a central index system for recording the significant morphological, chemical, physical, biological and agricultural characteristics of all named and adequately identified Peruvian soils, employing a logical and natural system of soil classification;

The early preparation of a broad schematic map showing Peruvian soils classified tentatively under major soil groups to act as background for advisory work in connection with natural planning programs (early maps of this type are in existence but the Mission feels that recent advances in soil science now permit the construction of far better maps);

A gradual assembling of soil data to assist the national stocktaking of soil resources and participation in this latter program when it begins to ensure that the soils are uniformly correlated throughout the country;

Assessment of regional and local soil problems as required by the Institute of Planning, the Institute of Agrarian Reform, Irrigation agencies and similar fiscal, semi-fiscal or private corporate bodies;

Promotion of co-operation between all groups engaged in soil studies and so start to lay the foundation for a National Soils Institute which should grow naturally from the activities of the Department of Soil Co-ordination.

The Mission feels that the pressure to implement agricultural development programs gives urgency to the appointment of an EPTA expert in soil classification and correlation. It would also be highly advantageous if a Peruvian counterpart could be selected promptly and a short-term scholarship arranged for him to visit soil correlation centres in Europe and North America as well as the World Soil Resources Office in Rome.

The Mission considers further that soil erosion problems have been too long neglected in Peru and that a project designed to initiate soil conservation research and application of soil erosion control measures to an experimental watershed area should be given high priority. The Mission therefore recommends that careful consideration should be given to the proposals being prepared by Mr. Law for soil conservation and watershed management projects under the United Nations Special Fund program.

I. Sources of Information

In Peru, extremely useful information was obtained from members of the following institutions and organizations: Ministry of Agriculture, Institute Nacional de Planificacion (Direccion de Planificacion Regionales, Estudios de Recursos Nacionales), Universidad Agraria "La Molina" (Facultad de Agronomia, Facultad de Economia y Facultad de Ingenieria Agraria), Servicio de Investigacion y Promocion Agraria (SCIPA, Division de Experimentacion Agropecuaria, Dept. de Correlacion de Suelos), U.S. Agency for International Aid, including members of Missions from North Carolina State University and the Iowa State University, Corporacion de Fomento y Promocion Social y Economica de Puno, (CORPUNO), (Seccion Ejecucion de Planes Regionales de Reforma Agraria; Grupo de Reconocimiento de Suelos en Juliaoa), Instituto Geografico Militar, Lima, Sociedad Geologica del Peru, Lima. To informants of the above organizations, and to many others, the Mission is deeply indebted for the fine spirit of co-operation shown.

In addition to the study of material provided by informants, the Mission also reviewed published and unpublished reports and maps available and further carried out a limited number of field investigations along a short transect from Desaguadero, on the Bolivian frontier, to Puno; from Puno, northwards to the limit of Puno Department, on the road to Cuzco; from the limit of Puno Department to Cuzco, Cuzco to Maaohu Pooohu; and from Lima to Oraya, a west to east transect across the desert coastal plain and Rimac alluvial soils.

II. Physical Characteristics of Peru

Geographic Location

Peru is the third largest country of the continent, covering an area of 1,284,000 km², and extending from near the equator to about 18° south latitude.

Topography and Landform

Customarily, Peru is divided into four major physiographic divisions: the Pacific coastal lowlands covering 145,000 km² (11.3%); the Andean Cordillera, 405,000 km² (31.5%); the Amazon foothills, 201,000 km² (14.6%), and the Amazon plains, 533,000 km² (42.8%). Within this simplified picture there are a very large number of distinctive environmental regions (for example, the Altiplano), each with its particular combination of climate, topography, rock formations, land forms, plant cover and hydrogeologic regime.

Taking the natural plant formations as a guide, Tosi (1) has identified no less than 35 natural climatic ecological zones: many of these can be further subdivided on a geomorphological and edaphological basis, giving a complex pattern of over 100 distinctive environmental regions. To give even a brief summary of these is beyond the scope of this Mission's report.

Natural Resources

Although the information is far from complete, Peru is in an incomparably better position than most other Latin American countries in respect of preliminary assessments of the national agricultural resources. Some of these preliminary surveys have been published, and in other cases, this material is carefully preserved in Ministerial archives and in institutes and is available

for consultation. It would serve little or no purpose to list this information anew in this report or to attempt a summary description of the conditions that vary so widely in respect to geology, climate, soils, vegetation, water supplies and other characteristics.

III. Soils and Their Utilization

Soil Genesis and Classification

The Instituto Nacional de Planificación has recently completed an 'Inventario de Estudios de Suelos del Perú' (2) which gives details of 77 soil surveys carried out between 1949 and 1963, covering a total area of 91,606,21 km², equivalent to 7.1% of the whole country. The scales of the maps range from 1:2000 to 1:5,000,000. However, even this imposing list of work is not entirely complete in that it omits some soil studies carried out by different university groups. (see Fig.1).

In the surveys referred to in the "Inventario", a total of 154 soil associations have been identified; 327 soil series have been defined, as well as 101 soil types and 44 phases of either associations, series or soil types. Reference is made to about 12 of the World Great Soil Groups. In many cases the soils are also grouped into land use capability classes.

Additional soil information is available in a large number of publications ranging from geographic text-books to reports on scientific investigations, but in many instances the soil identifications are too general to be of much value.

Soil Fertility Investigations

These have been going on for at least 30 years, and the volume of information available is impressive. Much of the early work, and some of the later work, however, cannot be given really wide practical application because the soils used in the investigations have never been properly classified.

Many of the major crops (maize, potatoes, barley, sugar cane, rice, cotton, etc.) have been investigated in respect of their reaction to fertilizer applications, pasture grasses and legumes (especially alfalfa) have been included in fertilizer trials. Probably well over 1000 fertilizer trials are carried out each year amongst all the different agencies. A large number of technicians are employed by SCIPA and the Agrarian University for soil fertility investigations at the present time; the total number wholly or partially engaged in this field approaches close to 500, of which half are of the professional or sub-professional level. The information available concerning these investigations is comprehensive and often accompanied by statistical analyses, but in many cases correlation between sites of experiments is made on a basis of climatological or phytological data because most of the soils used in the work are still not adequately identified. The Division de Experimentación Agropecuaria issues a comprehensive report containing the results of soil fertility investigations carried out during the year(3).

Soil Conservation

A considerable number of land use capability maps are available for special areas, and in 1962 a land use map for the whole of Peru was prepared by the "Servicio de Investigación y Promoción Agraria" on a scale of 1:3,000,000 (4) in this map the soils are grouped into 8 use-capacity classes.

Land Use Capability

A map on a scale of 1:400,000 showing the four land slope categories in central Peru, was prepared by the Organization of American States in 1961 (5). A map showing areas subject to soil erosion for the whole country was prepared, on a scale of 1:300,000, by SIPA in 1962 (6). This map shows broadly the degree of erosion according to four grades. There are no maps showing potential erodability of the soils.

Land Use and Agricultural Development

It is estimated that Peru has 20 million hectares of potential farmland of which only 2.2 million hectares are cultivated; and of this 0.5 million hectares lie fallow yearly. Thus, the area actually in cultivation each year to feed the 10.5 million inhabitants of Peru is 1.7 million hectares, or 0.16 hectares per capita. At the current rate of population growth (2.7% per annum) there will inevitably be a sharp decrease in the proportion of cultivated land per capita in the future unless some readjustment is made in the pattern of agricultural development.

The greatest part of the agricultural production comes from the coastal region which grows nearly half the total of agricultural exports. This agricultural region depends essentially upon irrigation for its productivity, and on the whole, it is a region of intensively developed alluvial valleys separated by long stretches of barren desert. Present water-supplies are inadequate to permit irrigation of these desert stretches, and there are severe technical problems inherent in the nature of the soils as well.

Unlike the coastal area, the sierra region (about one-third of the total area of the country) has a long agricultural history but the level of technology is relatively low. The average size of the farms is probably less than 1 hectare in the case of indigenous farmers, although there are still some very large landowners amongst the non-indigenous population. The pattern of agriculture is uneven, with some of the inter-mountain valleys crowded with minute farm properties, and others controlled by one or two large proprietors who seldom actually live on their estates.

In the region of the selva, the eastern Andean foothills and the Amazon lowlands, organized agricultural endeavour is a comparatively recent innovation. This vast area, which represents more than half the total area of Peru, is still largely a region of scattered subsistence farming carried out by forest tribes who derive a large part of their food supplies from hunting and fishing. Organized timber exploitation is handicapped by lack of access, and is largely confined to the vicinity of the larger, navigable rivers. More intensive agricultural exploitation is seriously limited by lack of tropical farming experience in Peru: most settlers are quite unaccustomed to tropical farming conditions. Probably less than 200,000 hectares are regularly employed for agricultural production in the whole of this vast region.

In recent years, in the coastal region, the chief trend in land use has been towards increasing the areas devoted to monoculture crops such as cotton, sugar cane, rice, maize and coffee. It is reported that there is still great scope for raising agricultural production substantially by further expansion

of the irrigation network, by employing better soil management systems (including more widespread use of fertilizers), and by more attention to the use of high-yielding crop varieties. These measures for raising production are mainly restricted to the coastal lowland valleys.

The agricultural trends in the sierra region have been rather different. Here the population explosion, triggered in part by penetration of medical, social and education services in recent years, is forcing the pace of land reform. Many large estates are being parcelled out amongst local farm labourers, so that the trend is towards the creation of a vast number of small holdings. Initially these are essentially subsistence farms, and only a very small proportion of the farm produce finds its way to local markets. Eventually, it is hoped that this multitude of new farm properties, with their proud but highly individualistic owners, can be organized for the production of crops needed to support the national economy; but for a long time yet they will probably remain basically subsistence farmers. Here there is great need for erosion control and soil conservation measures, but these are extremely difficult to enforce in the present circumstances.

Finally, there is the trend towards establishing agricultural settlements in the Amazon foothill region. In part this trend is related to the population explosion in the sierra region, a voluntary migration of landless people into unfamiliar but not inhospitable terrain; in part it is a calculated policy of the Peruvian Government to encourage farm settlements along the tropical fringe. Whether spontaneously, or officially inspired, these pioneer farmers of the subtropical and tropical humid foothills and lowlands are encountering many problems. Most of them are still in the first stage of agricultural endeavour, clearing virgin forest and planting subsistence crops. Problems of access, and problems of transportation across the high walls of the Andes are inevitably delaying the development of more highly organized forms of agriculture. Nor is all the land equally adapted for agricultural development. Many farmers are finding that the first season's crops are no true indication of the fertility of the soil: and some have become little better than the forest Indian, moving each year on to a fresh portion of virgin land.

It is to prevent this tendency that the Peruvian Government is organizing pre-colonization surveys, to establish the limits of the more fertile soils in the region and, on the basis of this information, plan the orderly growth of agriculture in the most favourable sectors. The population pressure is too acute for this policy to operate effectively everywhere along the Andean foothills, but by steady attention to certain key colonization areas, the Government hopes to maintain a measure of control over the situation. Even in the selected areas, the problems are formidable. Little is known about the soil management practices necessary to ensure sustained crop production in these areas. Experiments and field trials are needed to establish which of the crops needed to support the national economy can best be grown: to establish economic rates of fertilizer application; to establish essential crop rotation systems. Above all, much work is needed to educate the farmer in these new techniques, or to restrain him from ruining the soil before the colonization schemes are fairly started.

The above paragraphs are but a very brief summary of the more striking aspects of the land use and agricultural development pattern in Peru. They provide however, essential scenery for the stage on which the story of soil and related agricultural investigations is being enacted.

Land Productivity

Land productivity in respect of crop and pasture production is comparatively well understood, and a considerable volume of published and unpublished information is available. From these sources certain inferences can be made concerning soil conditions, but for the lack of a general soil map of the whole country, much of this information has only local application.

Land productivity is less well understood with regard to natural and planted forests. Local forest inventories have been made, but only a few of these include correlations with soil conditions. It would appear that little attempt has yet been made to evaluate the soils from the point of view of forest production.

Climatic maps and reports on regional climatology are available, in some aspects analysis of climatological data is deficient. A map showing the climatic regions of Peru was prepared by Nicholson and published by the Universidad Mayor de San Marcos, in 1962, on a scale of 1:3,000,000 (7). Information on the hydrologic balance in the soils throughout the year in the different regions is notably deficient. A rainfall map of Peru by Andacocha was prepared in 1962 (8).

A good general geological map, on a scale of 1:200,000 has been published by the Geological Society of Peru (9), and a large number of more detailed geological maps are available for certain parts of the country.

With regard to water resources, the Servicio de Agrometeorología e Hidrología of the Ministry of Agriculture has accumulated a great deal of data, and in some areas published reports are available.

IV. Current Soil Studies and Expansion Contemplated

Soil Surveys

General reconnaissance surveys: No general reconnaissance survey is in progress at the moment; all survey work is concentrated in specific areas where soil information is needed urgently for agrarian reform and land settlement projects.

A project for an 'Inventory and Evaluation of the Natural Resources of Peru' (10) has been elaborated by a National Committee under the direction of Ing. José Lizárraga, Director of Regional Planning and Studies of Natural Resources of the National Planning Institute. This project envisages the use of modern photo-interpretation techniques and rapid ground surveys to establish the nature of the natural resources (geology, geomorphology, hydrology, soils, vegetation, forestry, present land use, land use capability) in a series of 13 study areas covering 989,640 km², leaving only some 294,360 km² of the more remote part of the Amazon lowlands outside the scope of the project. Priority will be given to those areas where information is most greatly needed and where basic information (existing aerial photography, ground control and topographic base maps) are already available. It is anticipated that the project will utilize the services of all available trained soil surveyors in Peru (some 20 in all) for a period of 4 years and will require an investment of about 13,000,000. A loan sponsor for this project is at present being sought. It is currently being reviewed by U.S. A.I.D.

Specific soil surveys: Semi-detailed soil surveys are at present operating in the Department of Puno and in the Department of Pasco in connection with agrarian reform and resettlement schemes. These soil surveys are organized through an agreement between the local Development Cooperation (CORPUNO) and the Instituto Nacional de Planificación. Other soil surveys are in progress in the Tingo María (11) and San Lorenzo areas.

Soil Fertility Investigations

Field experiments related to the testing of soil fertility are chiefly under the control of the agency administering joint U.S. Peruvian Technical Co-operation Group (SCIPA) through the Division of Experimentation in the Ministry of Agriculture. This Division operates 4 experimental stations, 7 sub-stations and 12 experimental farms located in nine of the 12 agricultural regions of the country. Regional experimental centres are lacking only in the Trujillo, Ica, and Puno agricultural regions, although in the latter case there is an experimental station (Chuquibambilla) operated by the Universidad Técnica del Altiplano, located in the City of Puno. In addition, there are some experimental stations operated by agricultural societies in the different regions where fertilizer experiments are carried out.

The Division of Experimentation operates five regional soil laboratories located at the Regional Experimental Stations. In addition, small soil laboratories are operating in other centres.

The Central Experimental Station is located adjacent to the Agricultural University "La Molina" and has a Department of Soils and Fertilizers. It employs 10 Peruvian professionals and has the services of a consultant supplied by U.S. A.I.D. contracted from the University of North Carolina. There is also a Department of Statistical analysis with two Peruvian technicians attached to the headquarters of the Division of Experimentation at "La Molina". The other experimental stations have smaller departments of agronomy and soils, employing a total of 12 professionals and sub-professionals. The Agrarian University of "La Molina" participates in these studies by an agreement with the Ministry of Agriculture. In the past, these organizations have received assistance from U.S. A.I.D., the Rockefeller Foundation and from the "Esso" Research Organization.

Current soil fertility investigations are mainly being carried out by the Division of Experimentation of the Ministry of Agriculture, under the direction of Dr. Grobman. In these trials, a standard experimental design is employed, with varying rates of different fertilizers applied to different kinds of crops, to study the effects of different fertilizer balance, rates of dosage, times of application, methods of application, etc., with the ultimate objective of establishing the broad economic level of fertilizer applications in specific regions of the country. It is intended that this information will serve as a basis for applications to commercial banks for loans to farmers. The current work is part of a continuing five-year program.

In connection with the expansion and intensification of this fertilizer investigation program, Dr. Grobman has elaborated a project for pilot studies of a more intensive nature in areas where the Peruvian Government is interested in land reform and accelerated land settlement. Included in the project are proposals for the enlargement of soils teaching courses at "La Molina" Agrarian University, and in-service training within the investigations to be carried out under the project.

Soil Conservation Investigations

There are no soil conservation investigations in progress at the present time. Mr. Low, the FAO/UNSF expert in soil conservation attached to the University Agraria "La Molina", Lima, and engaged in teaching soil conservation courses in the Facultad de Ingenieria Agraria, is elaborating a project for pilot watershed studies that includes soil conservation investigations and erosion control demonstrations. Peru has no soil conservation service, and yet it is one of the most seriously eroding countries in Latin America.

There is hope that, out of collaboration between the Agricultural Engineering Faculty of the Agrarian University of "La Molina"* and the Department of Experimentation of SIPA and the Ministry of Agriculture, will appear the first steps towards setting up a national soil conservation service. Already, the University is preparing soil conservation courses for the agricultural extension workers; and if the project for pilot watershed studies eventuates then there will be valuable additional facilities for experimental work and training personnel and for demonstrating practical erosion control techniques.

At the same time, it is very evident, that much of the Peruvian soil erosion problem has its roots in land tenure, social and economic problems. Hence, landscape engineering techniques cannot be expected to solve the problem alone. For their full effect, such techniques require a level of agricultural skill at least adequate to assure that the cost of the engineering works will be ultimately repaid through substantially increased production. In all probability the success of a soil conservation service in Peru will inevitably be closely bound with the success of the land reform, and related social and economic development programs.

Integrated Studies connected with Land Development Projects

A number of integrated studies connected with land development are currently operating but, as far as could be ascertained, none of these directly involve soil investigations.

From 1961 to 1963, a pre-colonization survey was carried out in the northern sector of the Department of Puno under FAO/UNSF agreement. Mr. Arens was the FAO Soil Surveyor attached to this project. The report on this project was completed early in 1963 (12) but no immediate action was taken to initiate follow-up studies necessary before colonization could begin.

The situation has now changed, and the Peruvian Government is anxious to proceed with the follow-up studies of selected areas in the Madre de Dios River Valley. This will probably be advanced as a prospective Special Fund project during 1964, and at least one soil surveyor will be required for the project. Another land development project, in the northern part of the Department of San Martin and the southern part of the Department of Amazonas (Chachapoyas Area), has reached a more advanced stage of preparation. This proposal will also be put forward for Special Fund support, and it calls for the services of a soils expert for a period of two years.

Yet a third land development project is being formulated for the coastal region of Peru, where a survey of the surface and groundwater resources is proposed. It is likely that this survey of agricultural water resources will be linked with some assessment of soil potentials, requiring the services of at least one soil surveyor.

* Strengthened by a current United Nations Special Fund Project.

Personnel

Approximately 16 Peruvian soil surveyors are currently engaged in field work, and about 50 professional agronomists currently engaged in soil fertility studies. International assistance, at the present time, consists of one consultant in soil fertility (University of North Carolina) and one expert in soil conservation (FAO), primarily occupied with teaching. The total force engaged in soil and closely related studies is around 300.

The proposed inventory of natural resources already referred to requires the participation of 5 Peruvian soil specialists and 20 soil technicians; with six foreign soil specialists and 5 foreign soil technicians.

The project for soil conservation research and watershed management which is being formulated for submission to the Special Fund of the United Nations, envisages the employment of two Peruvian soil surveyors and a senior soil conservationist counterpart; along with a soil conservationist project manager, a soil scientist and soil conservation engineer to be supplied by the international executing agency.

Other potential land development projects itemised in section 4 (above) call for an additional 3 international soils experts with their Peruvian counterparts.

Training Programs

In Peru there are 9 Faculties of Agronomy located in two of the universities of Lima, in Lambayeque, Piura, Huancayo, Ica, Cuzco, Arequipa and in Puno. Of these, only the Agrarian University of "La Molina" has a long history of agricultural teaching. This institution commenced as an Agricultural High School in 1902, and became a university in 1959. The Catholic University in Lima was founded only four years ago, and many of the other universities also teaching agriculture are even younger. All the above universities have courses in soils (general) and in soil fertility and fertilizers, but the number of students taking these courses is small. Soils teaching in Peru is centred on the University of "La Molina" where the soils department offers six courses: soil physics, soils chemistry, soil genesis, soil microbiology, soil morphology and classification, soil fertility and soil management as part of their general studies. Students specializing in soils are required to take all six of the soils courses and also to prepare a thesis on some aspect of soil research. There is also a graduate school offering advanced lectures in soil chemistry, soil physics, genesis, morphology and classification, soil microbiology and soil fertility. In the Faculty of Agricultural Engineering of the same University (supported by a FAO/UNSF project from 1961 until 1965) there are courses in soil conservation engineering.

In the case of "La Molina" University, approximately 300 students enter each year, and of these 60% elect to study Agronomy. Of this number, some 15% to 20% elect to specialize in soils. At the present time, few of the graduate students in soils remain to take the post-graduate soils courses, preferring to leave the University for work on Agrarian Reform projects. The Department of Soils has somewhat inadequate laboratory facilities, but these are being gradually improved with the assistance of external organizations. The situation will improve greatly when the proposed University City is built; but meanwhile, advanced soils students and graduates have laboratory facilities provided in a new Department of Soil Correlation which has recently been created by agreement between the Division of Experimentation of the Ministry of Agriculture and

SIPA and the Agrarian University.

At the present time there are only three soils post-graduate students studying in the University.

V. Need for Further Soil Studies

General Observations

There is no question that Peru is acutely aware of the importance of soil studies and the need for these to keep pace with the Agrarian Reform and land settlement programs. What apparently is not so widely realized, is the need for such studies to have a common scientific basis so that soil experiences in one sector can be safely transferred to other sectors.

There are four government organizations concurrently engaged in making soil maps (Instituto Nacional de Planificación; Dirección de Riego of the Ministry of Public Works; Instituto de Reforma Agraria y Colonización and Servicio de Investigación y Promoción Agraria (SIPA)) as well as university groups and some private organizations. In the past, soil maps have been made by the Misión Técnica de la Organización de los Estados Americanos; Oficina Técnica de Agricultura S.A.; International Cooperation Administration of the U.S.A.; International Development Service, Inc; Vidalon Engineering Service, S.A.; Servicio Cooperativo Interamericano de Fomento and FAO; in addition to many made by different branches of the Ministry of Agriculture and Ministry of Public Works and Development. Whereas these early maps undoubtedly have been of great value in resolving local problems, their national value has never been exploited to the full because no uniform basis for preparing them was ever established. This limitation is understandable in the case of maps made ten or fifteen years ago but that it should be allowed to continue at the present time, when criteria for mapping and classifying soils are fairly well established, is certainly questionable.

This comes about as a direct result of the fact that Peru has never developed a centralizing policy in regard to soil studies. Soil studies have been regarded as accessory investigations to specific projects, and only in the University of "La Molina" has the unity of soil science been to some extent preserved. While the university tried to teach the essential unity and inter-relationships of soil problems, various government, private and even international organizations, applied only that part of the science that would give immediate answers to their problems. This is not of great moment if there is some central soils organization following the various projects, tabulating the findings, compiling a classified index of soils and their properties, and investigating further investigation of unresolved problems; but in situations where no central classification and coordination bureau has evolved, then much of the money spent on soil surveys, and on soil investigations generally, is partially wasted. This would appear to apply to the situation in Peru.

The situation is not entirely unrecognized in Peru. Already the University of "La Molina", the Division of Experimentation of SIPA and the Ministry of Agriculture, and the University of North Carolina, have combined to create a joint Department of Soil Correlation, complete with offices, draughting equipment and soil laboratories. The University of North Carolina has also provided a consultant in soil fertility to assist in soil correlation studies. This Department still lacks the appointment of an official Peruvian soil correlator.

The need for giving strong support to this soil correlation centre will increase enormously if the National Inventory of Natural Resources is successfully launched and if the proposed Special Fund projects concerned with land development become a reality. In this respect, it is interesting to note that the specifications for soil mapping in the National Resources Survey call for the "pedological classification and estimate of soil profile maturity within the classification" and "soil association name, if considered desirable". At present Peru has no trained soil correlator and no international expert in this particular field is working in the country, nor has the appointment of such a person yet been officially proposed.

Another aspect of soil science, long neglected in Peru, concerns the investigation of soil erosion. It has been estimated that about 6,400 square miles of soil covering are depleted by erosion annually, to the point where the land passes out of production. Certainly, Peru possesses some of the most spectacular erosional landforms in the world, and the process is an active and continuing one. A first step in remedying this deficiency was taken with FAO/UNSF help in 1961, by the inauguration of Soil Conservation Courses in the Faculty of Agricultural Engineering in the University of "La Molina". The next logical step is the initiation of some soil conservation research and demonstrations to show what scientific conservation measures can do to maintain and improve land productivity.

Peru has embarked on an enlightened program of land reform, relying heavily on soil investigations and applied soil technology; the strength of a chain lies in its weakest link, and the two weak links in the case of Peru are soil classification and soil conservation.

Specific Observations

Soil Identification, Genesis, Classification and Correlation: There is no adequate soil map of the whole of Peru showing the soils properly classified. The Mapa Agrológico del Perú (13), published in 1960, as a first approximation, shows only the broadest soil relationships and no real genetic classification of the soils was attempted. A soil map with a stronger genetic basis was that exhibited (but unpublished) by Eng. Zavaleta at the First Latin American Soil Science Congress in Mendoza, in 1962 (14). This map also lacks sufficient analysis of the soil-forming factors operating to produce different soils (which may appear morphologically similar) in the different environmental regions. During their field investigations, the Mission verified that the Ecological Map of Peru, prepared by Joseph A. Tosi, Jr., in 1960 (1) could be used as a valuable guide in rapid soil reconnaissance studies.

There appears to be considerable confusion amongst Peruvian soil surveyors concerning the classification of the soils of the Altiplano and adjacent Andean mountains; and also the soils of the humid eastern slopes and the foothill regions precisely in the regions where land settlements are proposed. The latter soils are repeatedly referred to as "Latosols", which they certainly are not, whereas widely occurring Red-Yellow Podzolic Soils (12) are scarcely ever mentioned. There is also some confusion in desert regions, between Regosols and desert Lithosols and between Gray and Red Desert Soils and Sierozems.

Peru is unquestionably in need of assistance in this field of soil classification. If Peru is to take advantage of accumulated soil experience from

Brazil, Argentina, Chile and other Latin American countries where the soils are more accurately classified, an attempt must be made to classify the Peruvian soils correctly. Adequate understanding of modern principles of soil classification are, of course, a prerequisite for setting up a soil correlation centre.

Availability of Basic Information for Soil Studies: Peru is fortunate in having a vigorous military geographic institute which has produced 96 map sheets of a scale of 1:200,000 covering much of the coast and the southern part of the country. In addition, 20 sheets of a National Topographic Map at a scale of 1:100,000 have been published. There are also some areas mapped at a scale of 1:50,000 and a number of miscellaneous maps of various scales covering particular regions. Aerial photography covers about 50% of the whole country at the present time (see Fig. 2) and there is expected to be almost complete coverage by the end of 1964. Most photographs are on a scale of 1:50,000 and the quality is very good. The main areas not yet covered by aerial photographs are in the Amazon basin, from Iquitos to the Colombian frontier and along the Brazilian frontier. Ground control stations have been established from the coast to about 150 to 250 km inland, and the work of establishing new ground control stations is proceeding rapidly with assistance from the Cartographic Cooperation agreement between Peru and the U.S.A. Under the Geodetic Astro-Control Program of the Instituto Geográfico Militar, astronomic stations have been established in the Amazon lowlands.

Training of Personnel: In this matter Peru is somewhat deficient. The annual output of trained soil scientists, to the graduate level, is scarcely enough to guarantee replacements for existing personnel, and certainly far from adequate to supply all the soil surveyors and soil investigation personnel who will be needed as counterparts if the major resources survey and various Special Fund projects become a fact. Moreover, much of the new soil survey work will have to be done under jungle conditions which are liable to be fairly rigorous: an adequate supply of replacements will be available.

The Special Fund project proposal sponsored by the Division of Experimentation of SIPA and the Ministry of Agriculture, includes amongst other things, a proposal to enlarge and extend university training courses in soil science. This is a step in the right direction but might become effective too slowly to remedy the shortage of trained soil personnel which will appear on the inauguration of the National Resources Survey.

Financial Limitations: Peru is probably not so severely restricted by financial limitations as in some other countries. The agricultural budget is relatively small but the effective amount of money available for agricultural investigations is usually supplemented through international bilateral programs. However, in the future, the country may be faced with the need for considerable increase in counterpart expenses for UNSF and other international projects.

VI. Recommendations

1. Expansion and Re-orientation of Studies

The Mission commends the present orientation of soil studies, and recommends continuing expansion. It also urges that all possible support should be given to increasing the out-turn of soil science graduates from the universities.

2. Initiation of New Studies and Integrated Programs

The Mission agrees in principle with the proposed Natural Resources Survey elaborated by the National Planning Institute, but cautions that the soil survey work will lose considerable value unless care is taken to ensure that the soils are properly classified according to modern concepts of soil genesis.

The latter comment also applies to the project proposals currently being prepared for submission to the Special Fund of the United Nations. Most of these projects concern areas with tropical soils that tend to resemble one another morphologically. This resemblance often conceals highly significant genetic differences which become increasingly important as agricultural development is intensified.

3. Technical Assistance

At present there are four FAO/EPTA experts working in Peru, and the Peruvian Government has indicated that there are several other fields of technical aid in which it would like assistance under the EPTA Program. Many of the Peruvian Governmental authorities actively engaged in land development and agricultural work, and also the Agrarian University of "La Molina", have indicated their desire for an EPTA soils expert. The Mission wishes to emphasize very strongly that Peru has very real need of the services of a competent soil scientist to serve as a soil correlator and to train a Peruvian counterpart in soil classification and correlation.

The local situation is particularly favourable for making a start with this type of work. A suitable building with offices, draughting rooms and laboratories has been erected in the vicinity of the Agrarian University of "La Molina" and the cooperation of the University soils staff and the soils staff of the Department of Experimentation of SIPA and the Ministry of Agriculture is assured. From this nucleus, a centralized soil recording and information service could be developed.

The duties of an EPTA expert in soil correlation would be expected to include:-

- i. Identification of all soils currently employed in soil fertility trials.
- ii. Inauguration of a central filing system for recording all significant characteristics of identified Peruvian soils according to their position in a logical and natural system of classification.
- iii. From existing data, and from exploratory surveys, to draw up a provisional map of Peruvian soils showing their genetic relationships.
- iv. To act as an assessor to planned agencies, agricultural reform organizations, irrigation agencies, etc., on soil problems.
- v. To assist the National Resources Inventory by advising on soil classification and correlation.
- vi. To train a Peruvian counterpart in soil correlation.

The presence of an EPTA soil correlator and his Peruvian counterpart would be of the greatest value to soil surveyors engaged in land development and irrigation project surveys throughout the country, and of especial value to the Natural Resources Soil Survey teams if this project comes into being.

The Mission considers that soil erosion control problems have been too long neglected in Peru and that any project designed to initiate soil conservation research and application of soil erosion control techniques to an experimental watershed area, should be given high priority. The Mission therefore recommends that careful consideration should be given to any suggestions for increased activity in this field.

The Mission also agreed in principle with the project proposals for further pre-colonization soil and land use surveys in the Amazon foothill regions, provided information in greater detail than that provided by the Natural Resources Survey, should this latter commence in the near future.

The Mission further explored the possibility of the creation of a central Institute for Soil Survey and Research, but considers that the inevitable re-deployment of trained soils personnel might cause a period of temporary disorganization in current soil investigations which would be most undesirable during the present vigorous effort to solve the social and political problems of the rural population. The Mission considers that the best approach towards a future Soil Institute, to be created when the Agrarian Reform program reaches a less intense phase, is through strengthening the Department of Soil Co-ordination already created jointly by the Ministry of Agriculture, S.I.P.A., the University of "La Molina" and the University of North Carolina.

The Mission believes that, of the above recommendations, highest priority be given to the appointment of a soil correlation and classification expert to be appointed as soon as feasible under the EPTA program.

4. Co-ordination of Soil Studies with other activities

The Mission recommends that the soil classification and soil correlation expert be located, together with his Peruvian counterpart, in the newly-constructed Department of Soil Co-ordination at "La Molina" University, co-ordinating his work with both the Soils Department of the University and with the Department of Experimentation of SIPA and the Ministry of Agriculture.

It is also vital that close liaison be kept with the soil survey teams operating under control of the National Planning Institute, and with the survey activities of the Dirección de Riego of the Ministry of Public Works, with the soil survey activities of the Instituto de Reforma Agraria y Colonización and with soil survey activities of other universities.

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List of Figures

Fig. 1. Areas where soil survey work has been carried out.

Fig. 2. Areas covered by aerial photography (1963).

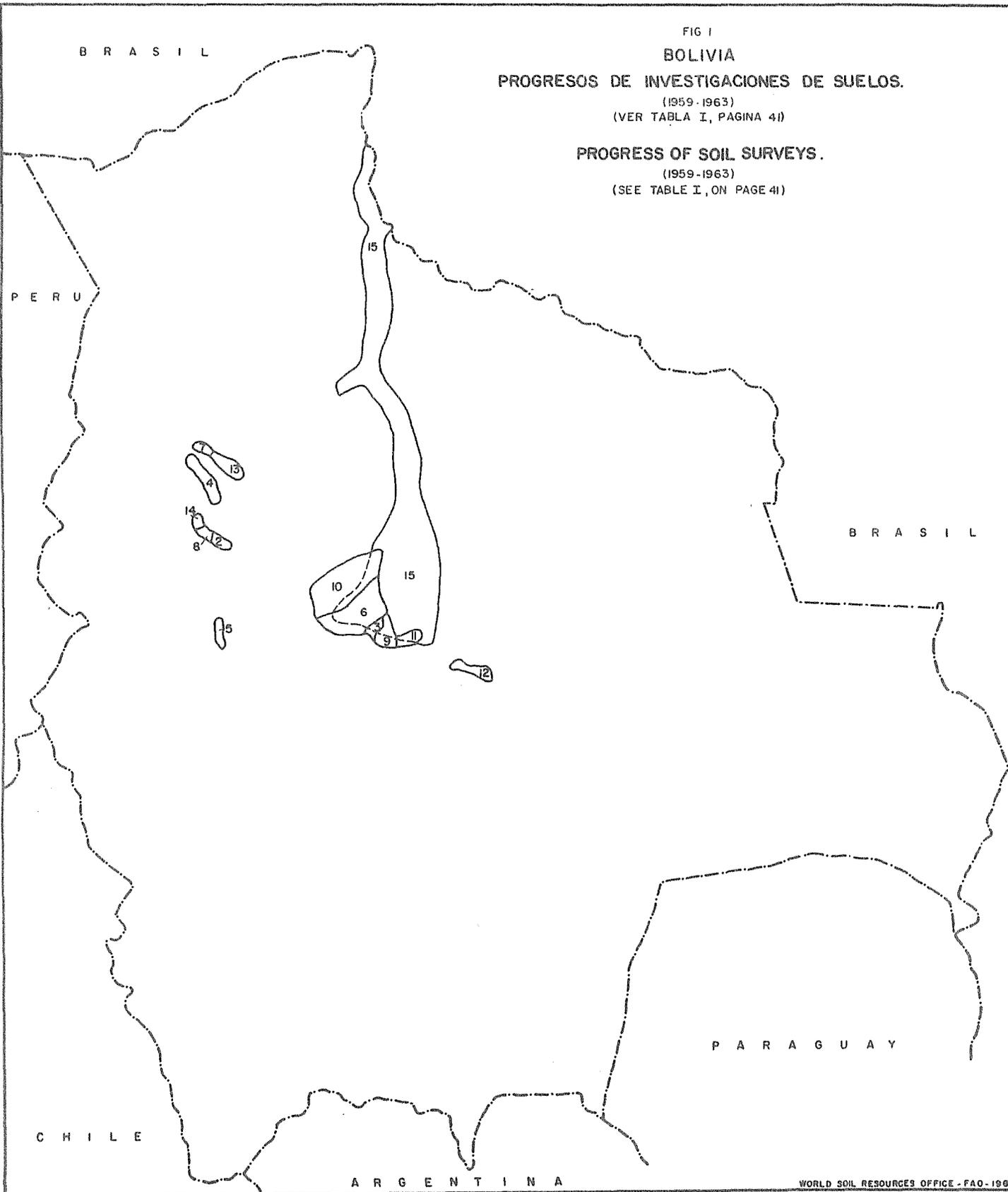


FIG.2
BOLIVIA
AREA CUBIERTA CON FOTOGRAFIA AEREA
(DICIEMBRE, 1963)
AIR PHOTO COVERAGE
(DECEMBER, 1963)

