AN INVESTIGATION INTO THE USE OF AN OPTIMAL GROUPING PROCEDURE IN LAND USE CAPABILITY ANALYSIS, PICHINCHA PROVINCE, ECUADOR

By

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SCOPE AND CONTENTS: The study concerns the development of a methodology which will allow the rating of soil or land units in view of their sustained economic capacity. Some literature is surveyed to show that no known scheme justifies stastistically the number of classes used; many schemes avoid the use of empirical crop yield data altogether. The factor analysis of farm activities and crop yield data will provide a set of scores, incorporating the important variables only, which may be grouped by the statistical method which is the core of the work. The Andean portion of the Province of Pichihcha, Ecuador, was the area studied. A number of farm types were discovered, differentiated by levels of investment and subsequently by type of activity. The strong crop yield/environmental correlations needed to create an improved land use capability scheme were found not to exist, but some important observations were made upon the profitability of the crop holdings and the fertility status of the soils. A number of land types with regional tendencies were found.

LAND CAPABILITY
IN
PICHINCHA PROVINCE,
ECUADOR

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TABLE OF CONTENTS

LIST OF FIGURES
(GRAPHS AND MAPS)

FIGURE

FIGURE

LIST OF PLATES

LIST OF TABLES

TABLE

LIST OF APPENDICES

INTRODUCTION

Theoretical Considerations

This work is concerned with land use capability, a concept used to rate soils or identifiable land units as to the intensity of use to which the units are suitable, the costs of conservation, or on a number of other measures depending upon the purpose of the scheme and the locale for which it is devised.

Applicable literature is surveyed in part to demonstrate a diversity of approaches; a number of schemes fail to embody an empirical basis on which reliable predictions can be made, while the more rigorous use the observed performance of the soil/environment/crop system to devise a rating scale. The survey is also utilized as a basis on which to set out a series of objectives and criteria on which the suitability of a land use capability scheme may be assessed.

Since no scheme to our knowledge has justified statistically the existence of any given number of classes, or the existence of any set of classes at all, we proceeded to submit data concerning types of farm activities and observed crop performance under a number of variables to a principal components analysis, (factor analysis). The tables of correlation were surveyed to verify the existence or otherwise of the correlations assumed 'a priori' to exist in land use capability rating. The factor scores, which are the subjects; standings on a new set of 'condensed' variables, were to be submitted to an optimal (hierarchical) grouping analysis if strong factor identities emerged.

The variables and associated items of interest in farming practices are described. It became clear in the course of the work that a great range of soil qualities existed and that a link between soil quality and the type and intensity of land use appeared to persist. A number of soil samples were tested for total cation exchange and observations are made upon the relationship of this measure to the type of land use, and some measures of income from the soil.

We acknowledge Weaver's[1] assertion that agricultural geography has been either too grossly descriptive of large areas, or restricted to intense, possibly irrelevant, coverage of very small areas. "In short the situation has been such as almost of necessity to induce superficiality with

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[1]John C. Weaver, "A Design for Research in the Geography of Agriculture", Professional Geographer, (November, 1958), 2-3.

respect to small topics and areas." Weaver believes that "rigorously established taxonomic identification"[2] is a first step toward valid interpretive efforts. This work is, then, an attempt to avoid the pitfalls to which Weaver alludes, and to accomplish in some measure taxonomic identification of the phenomena important in land use capability.

The effectiveness of any regional planning is related to the validity of the method used to discover regional types and their spatial dimensions. An optimal grouping procedure was utilized to discover the existence of a number of regional entities, using as a basis of selection four variables for land use capability derived from data supplied by the existing Ecuadorian scheme. It is thought that there is a possibility of discovering 'land types' in the study area - that is regional entities which exhibit a high degree of homogeneity among the variable profiles of the subjects comprising each set.

Introduction to Ecuador, and Highland Pichincha Province

The fieldwork was undertaken in the Province of Pichincha, Ecuador. This work represents a part of the probing being carried out in the pre-programming phase of "plan

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[2] *Ibid.*, 4.

Pichincha', a study in which there exists both a desire to improve regional investigation techniques, and a concern with the 'typing' of land in terms of its economic production characteristics.

Ecuador is a small country straddling the Andes on the equator. It is one of the countries suffering from an expanding population and a decreasing productivity in its older agricultural areas. There are substantial quantities of unsettled land to the east of the Andes, but opening of these areas may present problems similar to those experienced elsewhere; for example, upon the destruction of tropical forest.[3] As a result, settlement is being advanced very slowly under the auspices of the Ecuadorian Forestry Service, due to the caution exercised to avoid adverse environmental consequences and the time necessary to complete technical studies.

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[3]For depletion of organic matter see E. C. Mohr, The Soils of Equatorial Regions With Special Reference to the Netherlands East Indies, trans. R. L. Pendleton (Ann Arbor: Edwards, 1944), 476. For deficiencies of trace elements see Ibid., 478.

We have assumed, therefore, that for the foreseeable future the larger part, or an essential part, of any improvement in economic production will come from increasing output per hectare, possibly through the concentration of investment resources on the best land already in use, with an equitable distribution of the resulting increase in income. Other researchers have made similar assumptions[5] and it is important to identify those parts of the research area most able to accept increased inputs.

Population statistics for the years 1962 and 1970 reveal Ecuador to be following a pattern typical to countries in South America. The overall population increase is alarming, with urban increases greater than rural. The percentage of persons in primary pursuits[6] is constant, 57% of the economically active population, and some of the urban increase is going into service industries in which productivity increases are hard to achieve. In 1962 there were 17 persons per square kilometre and 88 per square kilometre of

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[5] R. G. Johnson and R. C. Buse, "A Study of Farm Size and Economic Performance in Old Santa Rosa, Rio Grande do Sul", (Madison, Wisconsin: Land Tenure Centre, University of Wisconsin, 1967), 2. Reporting on Cochabamba, Bolivia.

[6] Primary pursuits are nearly synonymous with agriculture.

cultivable land. In 1970 the respective figures were 22 and 118. The percentage increase is greater against the agriculturally useable land, demonstrating either a deterioration of agricultural lands or a downward revision in the inventory.

The per capita consumption of calories dropped between 1961 and 1963 (1850 per day to 1830); only Haiti is lower in the Americas.[7] Ecuador consumes per capita the lowest quantity of proteins (44 gms. per day) and only Bolivia is lower in fat consumption.

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[7] Datos Basicos de Poblacion en America Latina, (Washington: Department of Social Affairs; Panamerican Union, Organization of American States, 1970), 43-45.

CHAPTER I

A SURVEY OF SOME LAND USE CAPABILITY SCHEMES

PART I

The Soil Map and its Derivatives

The soil map is the usual starting point for land use capability rating. Where soil maps exist, the convenience of this data is taken to be an important consideration. The environmental variables which constitute soil formation determinants are reflected in the soil description. These variables are likely to have some bearing upon the agricultural possibilities of the soil, the costs and profits involved in using the land for a given pursuit, and the long term stability of the soil and crop relationship. "The purpose of soil survey interpretation is to provide people with the best possible information about every acre of soil in a form that is directly usable to them. Such interpretations are intended to furnish a better basis for making choices among alternatives in the use and management of soils."[1]

But the conventional soil map is usually based on the morphogenetic characteristics of soils. While soil formation determinants can influence agricultural practices,

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[1]Andrew R. Aandahl, "Soil Survey Interpretation - Theory and Purpose", Soil Science Society of America, Proceedings, (1958), 152.

there need not be a direct relationship, and the derivation of classes on pedologic principles, especially if a rigid statistical taxonomy is employed, may have few implications for agriculture.[2] While there may be no danger in using a soil map alone, the method is indirect, and therefore objectionable to the writer. It may be common sense only to state that agricultural potential should be related to an environment and not merely to a soil.[3]

We shall propose a theoretically more elegant approach which does not assume that land capability is necessarily a proxy response to the environmental soil formation variables.

In addition, the soil map may be a reflection of conditions which have ceased to exist. Since soil as an entity responds to natural external stimuli there may exist some cases where the soil is no longer able to perform in the expected manner once an agricultural activity pattern is introduced or changed.[4] The removal of tree cover, wind-

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[2]W. R. Oschwald, "Quantitative Aspects of Soil Survey Interpretation in Appraisal of Soil Productivity", Soil Surveys and Land Use Planning, ed. by Bartali et al., (Madison, Wisconsin: SSSA, 1966), 153.

[3]R. P. Moss, "Soils, Slopes and Land Use in a Part of Southwestern Nigeria: Some Implications for the Planning of Agricultural Development in Inter-Tropical Africa", Institute of British Geographers, Trans. and Papers, (1963), 144.

[4]Aandahl, "Soil Survey Interpretation", 154.

breaks or the lowering of the water table, for instance, may cause changes in land performance which might not be deduced from the soil map. On the other hand, a soil which may appear useless in the virgin state may give high returns under specific and possibly complex management practices. Such possibilities are evident only from soil management research and cannot be adequately presented on a soil map or a very simple derivative of that map.[5]

The quality of soil maps, especially in under-developed countries may be suspect. Attractive maps may have been produced from scanty fieldwork, faulty sampling procedures, and ill-equipped laboratories employing persons with preconceived notions about the results. Good maps are not rare, but poor ones are common; unfortunately there is no easy way to tell the finished products apart.

Soil maps are employed in a variety of ways. Each soil series, or other taxonomic unit, may be labelled with a set of qualities, an approach followed by both the United States and Canada. However, since this method, described later as the USDA Eight-Fold System, takes into account a number of variables, it will be of value first to note sim-

[5]B. A. Krantz, "Soil Survey Interpretation - Interpretation of Soil Characteristics Important in Soil Management", SSSA, Proceedings, (1958), 155.

pler cartographic derivatives of the soil map.

Single Factor or Simple Derivatives of the Soil Map

An example of an interpretive system on a simple level is the reduction of the soil map according to one variable. The resulting map is said to be derivative. Pons[6] presents a map of a part of the Netherlands on which the availability of moisture in the soil is the mapped variable. The availability of groundwater is mapped for its potential contribution to the soils in each of three classes. Another is a soil suitability map on which the sole criterion is the agricultural suitability of the soil in terms of water availability. Suggestions for cropping are based on this variable alone.

Maps derived from soil maps could be devised to show other single factors such as excess salinity, depth of rooting zone or total depth of soil, or the discontinuity of indurated horizons.[7]

Other simple interpretive maps may be oriented to individual crops. Pijls[8] has pointed out that the Nether-

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[6]L. J. Pons et al., "An Example of the General Soil Map: 1:2000000 of the Netherlands (1956) with Some Derived Maps", ICSS, V (1956), 509-511.

[7]The New Zealand Soil Bureau has published 44 single factor maps.

[8]F. W. Pijls, "Applications of Soils Survey in the Netherlands" and "Horticulture", ICSS, IV (1956), 631-632, 633-638.

lands, being under population pressure, needs to increase yields. The mapping classification is meant to show the suitability of the soil for the crops already grown on the farms, or conversely, the rearrangement necessary to allocate crops to soils to which they are best suited. The approach has been on a subject basis: horticulture, agriculture, forestry, land improvement and drainage, and town and country planning.

In the case of horticulture[9] a horticulture suitability map was commissioned because of the infringement of urban uses on this intensive pursuit around cities. Soils suitable for horticulture were specified, located on the map and keyed as being either excellent for the purpose, or suitable with restrictions. The desirable soils were further keyed in various groups according to their suitability for the individual pursuits (vegetables, bulbs, trees, _et al._) comprising the category horticulture. The legend for bulb growing contained six classes. It is not known what statistical method was used to reveal these classes.

The New Zealand Soil Bureau has attempted to avoid a solely genetic approach to the mapping of soils.[10] Gibbs

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[9] _Ibid._, 633-638.

[10] H. S. Gibbs and M. L. Leamy, "Soil Survey Interpretation in New Zealand", _ICSS_, IV (1968) 235-241.

points out that genetic features have different agricultural implications depending on the type of soil in which they are found. Iron concretions on a floodplain have a different agricultural meaning, for instance, than a similar feature on a nearby upland. Nor is the mapping of single characteristics a usable approach. The correction of an adverse feature in the soil needs to be understood in terms of the soil processes which will be initiated by the correction. Dry soil, for example, may be changed into a saline one by irrigation.

The soil characteristics considered by Gibbs and Leamy to be of major importance in New Zealand are:

1) slope
2) temperature and moisture regime
3) colour, texture, consistency and structure
4) nutrient and colloid composition

Gibbs points out that present land use and the yields and difficulties of the present agricultural system are a good starting point in soil survey interpretation. Valid generalizations come from associating the land use map with the soil map. This process may lead to results of overwhelming complexity.[11] Sophisticated correlation methods are needed to identify the pertinent factors and

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[11]Moss, 165.

and to dispel illusory associations. The discovery of the existence of toxic or deficient levels of molybdenum occurred in this way in the North Island.

In New Zealand the cartographic portrayal of soil limitations is based on a simple qualitative approach to avoid drastic revisions of the map brought about by the arrival of new data or knowledge.[12] The method is admitted to be too subjective but precision is expected to come from further research without the need for a complete revision of the original data base. The approach is unsophisticated apparently because the country is relatively prosperous and because an over-all soil capability system would have to exist on a national level. A conflict among the levels of government might result. This possibility is avoided by the vagueness of the approach leaving the governments to grope for a compromise.[13]

A Resume of More Complex Approaches

<u>The United States Department of Agriculture Eight-Fold System</u>: This scheme "is one of several interpretive soil groupings made for agricultural purposes. It deals with

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[12]Three qualitative levels of limitation severity are used: mild, moderate, and severe.

[13]This is the official view, as portrayed by Gibbs.

problems involved in the long-time proper use and management of soils and the production of useful plants."[14]

Assessment, accomplished by a panel of soil scientists and agricultural researchers, is based on the following assumptions:

1) Permanent soil characteristics only are taken into account, eg. slope, soil texture, permeability. Transient features, such as stumps, are ignored.
2) The farmer is expected to use his resources intelligently, and behaviour over the rated area is taken to be constant, assuming a moderately high level of management.
3) Grouping is not meant to lay down the most profitable use of the land.
4) Grouping is not a productivity rating, although it is obvious that the sustained economic yield will decrease from the highest class downwards; the class is not a valid data level at which to make generalizations.
5) Adverse features such as stones, salts, or waterlogging are not taken to be permanent if they can be removed. Costs of improvement are ignored. (See #6.)
6) Soils improved as in #5 may have important continuing limitations which are taken into account. While improvement costs are ignored, not all wet soils, for instance, will be useful upon draining; some may be useful for only a short time.
7) Land already improved is assessed on the basis of the criteria mentioned in #6.
8) Major improvement projects will change the grouping. Smaller projects which will not likely have a permanent influence may be ignored.

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[14] A. A. Klingebiel, "Soil Survey Interpretation - Capability Groupings", SSSA, Proceedings (1958), 161-162. This account is condensed and the numbering does not follow the original.

9) The grouping should keep pace with and be responsive to developments in soil science, mapping, and agronomy. This assumption related to the precision of the system.
10) The plant/soil relationship is the main criterion. The problems of labour availability, distance to market, etc., are left to the planner.
11) Assumptions are made that the upper groups (I to IV) may be harvested with machinery common to an average farm, but some of the soils in these groups may need draining to be so worked, or the farmer may need specialized machinery.

Problems in cropping are rated by their magnitude and farmers are encouraged not to crop soils that will suffer from intensive use. The objectives of the system may then be seen to be:

1) Intelligent conservation of the land.
2) An indication to the farmer or to the prospective farmer as to the type of activities suited to a tract of land, and consequently an indication as to the potential income from that land.
3) (a) A guide to the planner as to the locations suitable for different agricultural land use systems.
   (b) Conversely, an indication as to the location of non-agricultural pursuits in the event that the land is under pressure for food production.

Individual soils as seen on the soil map are grouped into "capability units" within a framework of eight general classes. The classes are divided into subclasses representativeof four kinds of conservation problems. Classes are determined by the degree of limitations affecting "kind of use risks" of soil damage. Subclasses are based on the dominant kind of limitation (eg, slope, excess water, root zone depth, etc.). The unit is the lowest level of grouping.

Class: There are eight classes, the greatest diversity of permissible uses being found in Class I. Class I soils have few limitations in use. They are deep, nearly level, permeable, and well aerated. Climatic limitations such as lack of rainfall are minimal. Classes I to IV are suitable, with increasing limitations, for cultivation. More rigid management practices are specified as the quality of the land decreases. Classes V to VII are suited to grazing, forestry or wildlife and perhaps to some very extensive and controlled forms of cultivation. Class VIII soils are recommended for recreational, wildlife and unproductive purposes.

Subclass: There are no subclasses in Class I or VIII. Four subclasses exist in each of the other classes according to the dominant limitation:

(e) runoff and erosional problems
(w) excessive wetness
(s) root zone or tillage limitations
(c) climatic limitation

Unit: Units are detailed and specific groupings of soils that are similar in plant growth factors and response to management.

Soils are grouped into units by the following criteria:

1) kinds and amounts of crops that can be grown successfully. Management practices are specified.
2) the response of the soil to management.
3) type and intensity of remedial measures to halt decay of mismanaged soils.

The grouping of soils into units and into the higher categories is accomplished by the consultation of a number of specialists in such fields as agronomy, soil science and agricultural engineering. Experimental crop data and farm records are used where available, but the manner in which this data is integrated is not known.

The Canadian Version of the Eight-Fold Scheme: As mentioned previously, this scheme has been widely adopted. The Canadian Land Inventory relies upon a near duplicate, with one class, Class VIII, having been removed. Whereas the costs of improvement are ignored in the American system,[15] the Canadian specifies that where improvement is feasible, but costly (and unlikely) the soil should not be upgraded, but remain in the lower class.

The subclasses are more numerous in the Canadian example, and include the following:

(c) climate
(d) structure and permeability
(e) erosion

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[15] See assumption (5) above.

(f) nutrient deficiencies
(i) overflow
(m) soil moisture deficiencies
(n) salinity
(p) stoniness
(r) lack of depth of soil
(s) adverse inherent soil characteristics
(t) topography, slope or pattern
(w) excess water other than due to overflow

A series of these letters may form a suffix when appropriate.

A set of guidelines is provided for placing soils in classes; this procedure is similar to the USDA system. However no guidelines are laid for subclasses d, e, and w. A combination of subclass indices may be associated with class numbers where appropriate. The unit as the third level of classification does not exist.

Ecuador: The National Office of Tax Evaluation and Cadastral Surveys (ONAC) in Ecuador uses an eight class system with major modifications. A number of variables are given 'a priori' weighting, and variables may be weighted negatively.

Detailed instructions are given for the point rating within each range. For instance, under "Texture of the Arable Horizon", coarse sandy soils receive four points, fine sandy soils five points, and very fine sandy soils ten. Some variables possess negative weighting for poor conditions, no numerical influence for average conditions, and positive rating for good conditions.

TABLE OF LAND CLASSIFICATION, ECUADOR

		MAXIMUM POINTS
I.	**AGRONOMIC CONDITIONS**	
	1. texture of arable horizon	10
	2. effective depth of profile	15
	3. textural rating of profile	15
	4. drainage	10
	5. level of fertility	6
	6. pH	4
II.	**TOPOGRAPHIC CONDITIONS**	
	1. relief and erosion	10
III.	**CLIMATOLOGICAL CONDITIONS**	
	1. distribution of rain and temperature	10
		RANGE OF POINTS
	2. solar radiation	-1 to -2
	3. winds	-1 to -5
	4. frosts	-1 to -5
	Subtotal of I, II, and III	80
IV.	**CONDITIONS AFFECTING EXPLOITATION**	
	1. labor	-1 to -2
	2. health	-1 to -5
	3. availability and use of water	-1 to +18
	4. internal access	-5 to +2
	5. discontinuities	-1 to -5
	6. geometric shape of property	-1 to -3
	Total of I, II, III, and IV	100

The final point score places a land unit in one of eight classes. These land units need have no correspondence to units on a map constructed to show soil bodies, but some correspondence is inevitable due to the inclusion of points reflecting soil qualities.

FINAL POINT SCALING
IN THE ECUADORIAN LAND USE CAPABILITY SCHEME

CLASS	QUALITY DESCRIPTION	POINTS
I	Excellent	68 to 100
II	Very good	56 to 67
III	Good	47 to 55
IV	Average	38 to 46
V	Mediocre or marginal*	29 to 37
VI	Poor	20 to 28
VII	Very poor	9 to 19
VIII	Unproductive	1 to 8

*The translation of 'regulare' is problematical.

The range of points within each class decreases as the class number increases. The range of points over which arable pursuits may be carried on is approximately sixty, while all productive pursuits cover eighty points.[16]

Ghana: Ghana also uses a derivative of the American scheme. The original assessment follows the USDA guidelines, but the sheets prepared for field workers have only three classes, which division is implicit in the American method.

Group A: more than 50% of soils in Classes I to III; sole class suitable for mechanized farming.
Group B: Classes IV to VI; hand tillage only.
Group C: Classes VII and VIII; to remain in forest or to be used for other non-agricultural purposes.

This approach has been found practical for large areas soon to be developed. We are not in possession of information as to how already settled areas are assessed for redevelopment in Ghana.

Peru: A substantial study in the Department of Puno, Peru, near Lake Titicaca, applied the eight-class scheme.[17] The

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[16] It is not known whether the use of the scheme is advisable in the tropical zones of the province; insufficient negative points for the limitation most severely affecting agriculture may not depress the final point rating sufficiently. The possibility of having all land compressed into a few classes should be considered.

[17] Programo de Inventario y Evaluacion de Los Recursos Naturales del Departamento de Puno, I (Lima: ONERN, CORPUNO, 1965).

classes followed these criteria:

Land Suitable for Intensive Cultivation and Other Uses

Class III:	Land eminently suited for intensive cultivation; suitable for indigenous cultivated crops and cultivated sic pasture; subtle limitations in soil qualities.
Class IV:	Land more or less suited to cultivation as in III, but more severe limitations on edaphic criteria.

Land for Permanent Vegetation

Class V:	Good land but of limited use for cultivation; best suited to intensive grazing on cultivated or improved pasture.
Class VI:	Land more or less suited to pasture, specifically improved pasture; limitations originate in very shallow soils, an excess of erosional material, poor drainage and high susceptibility to erosion.
Class VII:	Land typically suited only to extensive pasture (natural); limitations as in preceding class but extremely poor drainage.

Land Without Use

Class VIII:	Land not suited to any agricultural pursuit; limitations extend to excess salinity, extremely impeded drainage, extreme topography, very unfavourable climate.

Class associations may occur between Classes III and IV, V and VI, VI and VII, and VII and VIII, such that these associations become intermediate classes. There are no Class I and II soils in the study area, the Class III criteria appearing to encompass the qualities normally associated with Class I lands elsewhere. But note that the criteria for intensive cultivation specify indigenous crops only. There are but two subclasses. Subclass 'A' represents the more favorable climatic regime at the lower altitudes; subclass 'B' applies to a rather frigid regime.

Schemes Involving Quantitative Estimation

Portugal: Quantitative development of the USDA system has occurred in Portugal.[18] The framework is similar to the USDA classification although there are only five classes, lettered A to E. Three main limitations are acknowledged:

(e) risks of erosion
(h) wetness, drainage sic or overflow
(s) root zone limitations

An index has been derived which places any soil area into one of the lettered classes.

$$I = \frac{N \times E \times Re \times H \times P \times R \times S}{100^6}$$

[18] J. Carvalho Cardoso, "Soil Survey and Land Use Planning in Portugal", ICSS, IV (1968) 261-269.

where[19] (N) nature of the soil
(E) effective depth
(H) water in or on the soil
(Re) risks of erosion
(P) stoniness
(R) rock outcrops
(S) toxic salts

A soil may have any value from 10 to 100 in the following sequence:

Class A: I greater than 80
Class B: I equals 70 to 80
Class C: I equals 50 to 70
Class D: I equals 30 to 50
Class E: I less than 30

Land planning aims to achieve an "ecological" relationship between the soils and their environment (climate). Areas of similar agricultural potential are areas with similar soil ratings and climatic controls. Cardoso believes that, since the system is strictly based on landscape characteristics that change only slowly, the maps should have a long period of validity. The "Map of Ecological Stations" is used in conjunction with knowledge of the favourable conditions for Portugese crops. National needs of production can be met, and social factors may be taken into account in the planning phase.

This scheme is a step toward achieving a balance between land use and the production capacity of the land

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[19] The weighting or index range of these elements is not given.

base. We question whether all pertinent variables have been named and whether the index weighting treats the variables with equal importance.

The Soviet Union: A scheme has been created in the Soviet Union which relies upon the observed performance of crops on different soils.[20]

Soils are typed and the actual yields for each type recorded. As soil type is assumed to be a function of climate, climatic criteria are ignored. The analysis of crop yield against soil type indicates that variation from the predicted yield increases on the poorer soils. Soils may possess up to 100 points within ten classes, this number being employed to avoid the concentration of a sizable range of yields into a small number of classes.

Crop yield has been found to relate to soil quality in the form of an equation of a parabolic (p) form:

$$Y = 2pX^2 + a$$

where (Y) average yield
(X) class of soil appraisal
(a) quantity of seed per hectare

The law of diminishing returns affects yields in the higher classes. Variation in the yield increases as the soil becomes poorer.

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[20] N. L. Blagovidov, "Principles of Soil and Land Evaluation", ICSS, IV (1960) 357-363.

THE SOVIET UNION: LIST OF SOIL TYPES AND LAND APPRAISAL CLASSES

CLASS OF SOIL APPRAISAL AND LAND EVALUATION	CLASS POINTS	COMMENTS	AVERAGE RELATIVE CROP YIELD FOR PODZOLIC SOILS ONLY
X	91-100	High quality soils and lands	100 ± 10%
IX	81-90	As above	85 ± 14%
VIII	71-80	As above	69 ± 12%
VII	61-70	Medium, as to their quality, soils and lands	57 ± 12%
VI	51-60	As above	43 ± 14%
V	41-50	As above	35 ± 12%
IV	31-40	Low quality soils and lands	27 ± 15%
III	21-30	As above	20 ± 20%
II	11-20	As above	14 ± 25%
I	1-10	Practically unfit soils and lands	

This depends upon accurate typing of soils, and the adherence to modal types. There may be some areas in which there is no firm modal type, or an array of soils of such great variety that indexing could be accomplished only at low levels of confidence. Topographic dissection may lead to a very fragmented map displaying units which are individually too small to give an economic return in view of their peculiar requirements and the necessity of varying the agricultural practices greatly over short distances.

Holland: Another approach involving observed performances of soils is used in Holland. Vink[21] writing on the "Quantitative Aspects of Land Classification", does not believe that the American scheme has laid down its operational assumptions with precision, a belief with which we concur. There is a need for quantitative information to predict soil capability. This can be obtained only from an empirical process; the USDA, in his opinion, is guilty of approximation.

To correct this state of affairs a "Soil Suitability Classification" is offered. Crop yields are aver-

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[21] A. P. A. Vink, "Quantitative Aspects of Land Classification", ISCC, IV (1960), 371-377.

aged for different soil types and grouped to show the practical differences between production on various soil types. The following table shows these differences:

THE NETHERLANDS

SOIL TYPE	S_A SOIL SUITABILITY IN RELATIVE MONETARY UNITS
Humus podzol, sand, excessively drained	24
Deeply humose soil, loamy sand, somewhat excessively drained	153
Brown podzolic soil, loamy sand, excessively drained	276
Gray brown podzolic soil, sandy loam, excessively drained	387
Alluvial soil, sandy loam, well-drained	1036
Alluvial soil, loam, well-drained	1122

A "budgeting technique" is used to relate soil suitability on a farm-size basis to various factors such as percentage of farm in a certain crop, fertilizer input, yield of crop on the given soil type, farm overhead, and certain temporary economic parameters. The yield of the soil type is known beforehand for a number of crops and the process is meant to show the farmer what income he may expect under certain economic conditions with certain management practices. The process is vectorial and maximization of income is sought. The method is dependent upon the accuracy of the soil typing, the crop yield data, and the related statistical procedures.

A Binary Scheme: In concluding the treatment of individual approaches, mention should be made of the curious binary system of Desaunettes.[22] He sees the American system as universal but difficult in application because an intimate knowledge is needed concerning the operation of the subclass criteria. The importance of these criteria may change greatly over a short distance.

A simple system is devised involving only the usable depth of the soil[23] ('profondeur utilisable') and the water holding capacity in its widest sense ('capacite de retention unitaire'). These two notions are symbolized by two pairs of figures, said to define adequately the use capacities of the soil. Suffix letters may specify the types of amelioration needed, and the place of the suffix letter dictates the urgency of the improve-

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[22] J. R. Desaunettes, "Classification Binaire des Sols en Fonction de Leur Valeur", ICSS, IV (1960), 379-387. This scheme originated from observations in a heavily irrigated zone in Southern France.

[23] How this "usable depth" is established is not made clear.

ment.

Water retention is said to be a function of the texture, a function of the type of clay present, and of structure. The potential, (P), of the soil can be expressed as:

$$P = Cr \times h$$

where (Cr) water retention
(h) usable depth

The best soils will be those with a depth about 120 cm. and a field capacity (P) such that:

$$P \longrightarrow 960\ m^3/ha.$$

Soils are rated from one (low) to nine on the two variables. The higher the product index, the better the soil.

As Duchaufour mentions,[24] fertility has been reduced to physical factors, while organic matter, nutrient content and base exchange capacity have been ignored. Desaunettes' answer is that only potential, not actual, fertility has been described. Without suitable depth and structure no soil ever <u>can</u> be fertile and the insertion

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[24] *Ibid.*, 387.

of nutrients, if they are deficient, can be effected. Perhaps Desaunettes has isolated the first two (most important) elements of a capability function, but this has not been proven. Nor has Desaunettes offered any proof that the improvement of fertility in soils throughout the range he has proposed indicates any statistical quality usable for purposes associated with economic research.

PART II

Criteria for the Evaluation of Capability Schemes

We have described a number of schemes to display a diversity of approaches. Some approaches derive classes solely from a soil map, on the assumption that soil series or other units are sufficient evidence of agronomic conditions. Others use the soil map to locate areas of soil qualities similar to the qualities of areas which have been experimentally tested and from which a known response has been obtained under a certain set of conditions.[25] All the schemes which use a class representation of the results fail to justify statistically the selection of the number of classes used or the range of points within the classes. We do not know of any scheme which has tested variables for their relative importance or for the properties of their combination. "The geo-

[25] Aandahl, 1958, 153.

grapher, even as the chemist, must identify and describe structures of combination among his elements. The geographer ... is confronted with functional groups of elements which tend to unit behaviour ..."[26]

We believe, however, that a scheme may be devised to meet some important criteria. We shall first state the criteria, and then the hypotheses believed necessary to discover an improved scheme of land use capability.

Criteria

I <u>Universality and Suitability to Replication</u>: It would seem that the invention of a scheme which could rate units of land on a constant scale, regardless of their location, is desirable. Only the Dutch vectorial scheme approaches this state. The widespread acceptance of the USDA system is no recommendation, and may be in fact an acknowledgement of its non-rigorous nature. Our failure to trust the USDA method and methods embodying similar deficiencies when used in different applications arises from several considerations.

1) The system is based on 'a priori' reasoning

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[26]Weaver, 1958, 7.

to the extent that none of the subclass criteria are weighted. In addition, the interaction of the subclass criteria is not appreciated or even alluded to. Desaunettes[27] has responded to this weakness by devising a simple binary scheme, claiming that only a highly trained person could make the ultimate decision as to the proper crop, even with the knowledge imparted by any of the capability schemes devised up to the present. The criteria for entry into any class are apparently rigid, but in practice the method fails. Usually the failure results from the assumption that arable pursuits can be accomplished only on soil in Class IV land, or better. There is a tendency to assume, incorrectly, that any cultivated tract qualifies as an entry into an arable class. Conversely many economic pursuits may be found to be located on theoretically unsuited land.

2) The only apparent differences between Classes I and II are the requirement of fertilizer and the diligence of the operator. It may be assumed that both classes will be worked by the same machinery and that returns will vary with the time spent. The com-

[27]Desaunettes, 1960, 379.

parative marginal advantages in fertilizer use between Class I and Class II land may not be known, or the advantage may be greater on the Class II land if it incurs lower taxes or other costs. If the opertors perseverance may be called a cultural variable (and cultural variables are to be excluded, according to the assumptions), then the difference between the two classes is not great, perhaps nil in practical terms.

One wonders what difference would exist (following the Canadian terminology) between a Class IIIs[28] soil and a Class IV, or whether an intergrade is implied. An intergrade between Class IVs and V would be relatively meaningless, but such a situation has not yet been declared, to the writer's knowledge, to be impossible. While the USDA classification appears to allow the insertion of any soil in one class, difficulty lies in subjecting continuous interrelating data to an 'a priori' hierarchical system. The insertion into categories is accomplished without the resort to statistical testing of the data to discover the nature of the

[28]'S' is a suffix used to denote the prescence of a number of adverse features, which need not even be named.

continuity or the location of discontinuities. This fault will affect the possibility of universal application with close replication.

II <u>Statement of the Objectives of a Land Use Capability Scheme</u>: In the past a common error has been the failure to state clearly the objectives of interpretive soil groupings.[29] A second error has been the tendency to use an interpretive grouping for purposes for which it was not intended.[30] To these two, we may add a third: the tendency to import a scheme to an area to which it may not be suited. This error is usually compounded by the simultaneous commission of one or both of the others.

For instance, it is stated under assumption (4) described above, that the USDA scheme is not a productivity rating. Yet the adoption of the USDA scheme has led to exactly this process in some cases, much to the detriment of the results. Inventory is an expensive, lengthy process. For what other purpose would a research agency expect to use this data once it had been created? The land class data in the Puno study mention-

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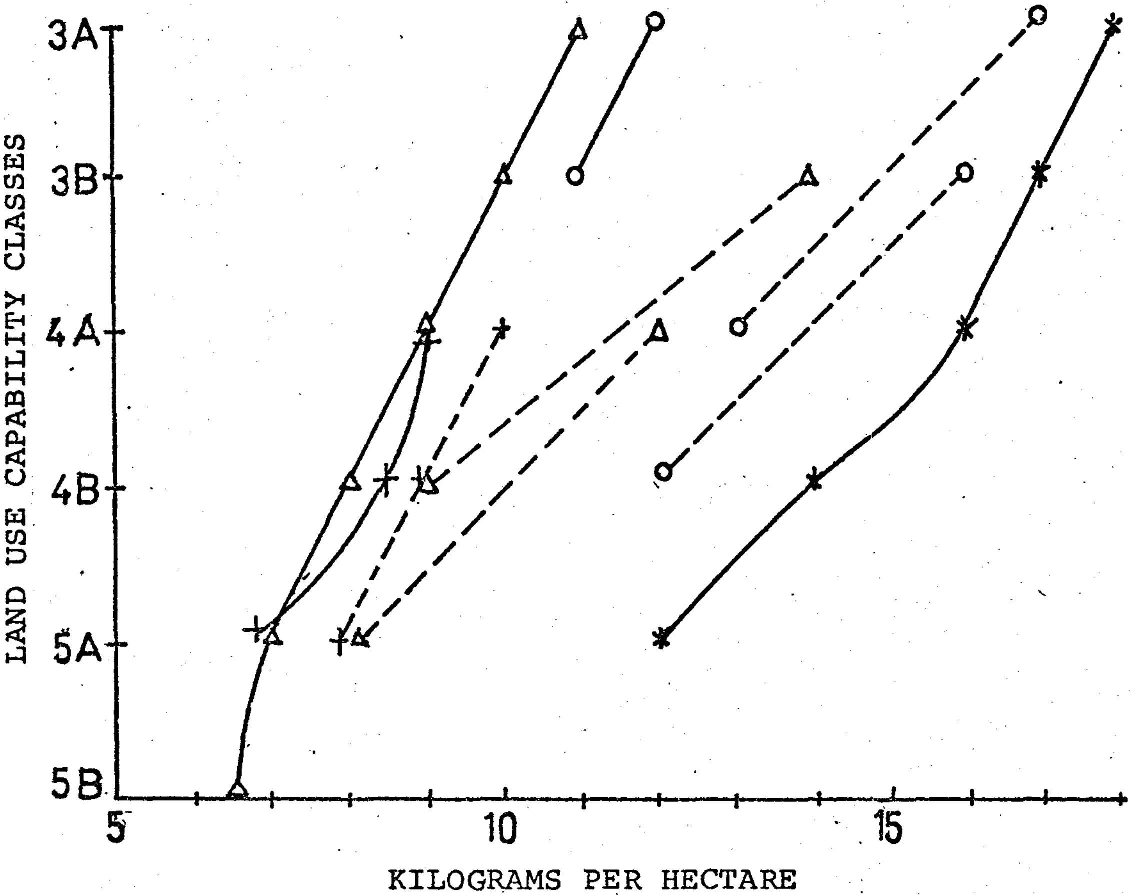
[29] Aandahl, 1958, 154.

[30] *Ibid.*, 154.

ed in Chapter I, Part I was subjected in that study to linear programming. As can be seen from the following graphs (figures 1, 2, and 3) the data assumes a non-linear shape when normally plotted. This type of curve may violate the provision that returns to scale be constant (if we consider land class as an input). (Perhaps, unknown to us, the class intervals were rescaled for the actual analysis.)

Furthermore the American application of this scheme disregards the class as a level at which generalization may be made; the Peruvian study failed to observe this caution. While the gross value of an eight year rotation increased steadily through the classes, the net value of the rotation reaches zero halfway through Class III, (figure 3). In other words, the whole set of activities which show a profit is confined to one half of one category. Would not the researchers have been better advised to discover the 'edaphic' location of farmers making money, or producing sufficiently for subsistence, and to discover the environmental foundation of their operation? To return again to a previous point, that of universality and replication, some other set of researchers may have placed this activity on Class II or Class IV land.

FIGURE 1



EXPECTED RETURNS IN KILOGRAMS PER HECTARE
FROM DRY AND IRRIGATED LANDS, VARIOUS LAND CLASSES,
DEPARTMENT OF PUNO, PERU

NON IRRIGATED ————

IRRIGATED --------

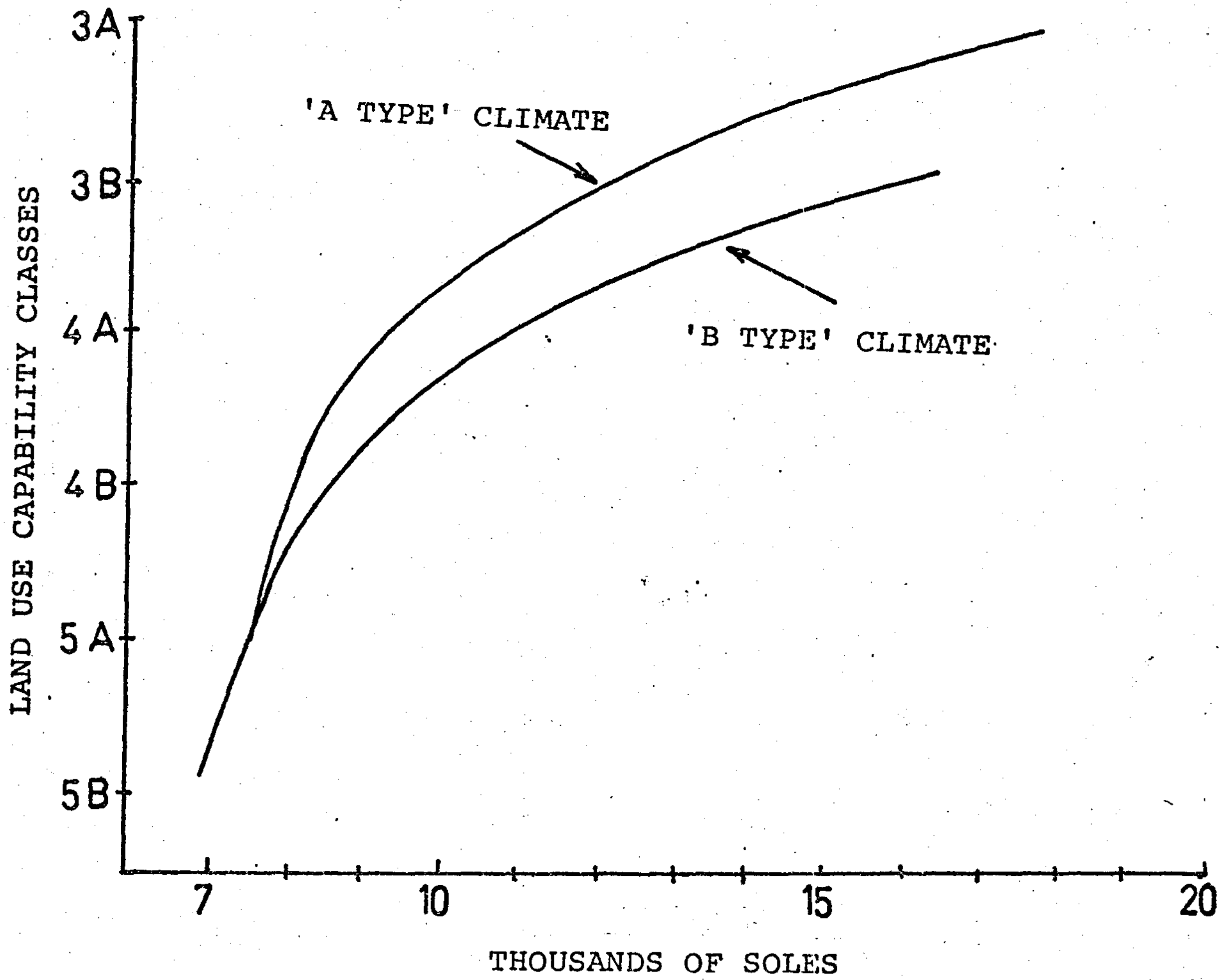
Δ OATS

o POTATOES

+ 'BITTER' POTATOES

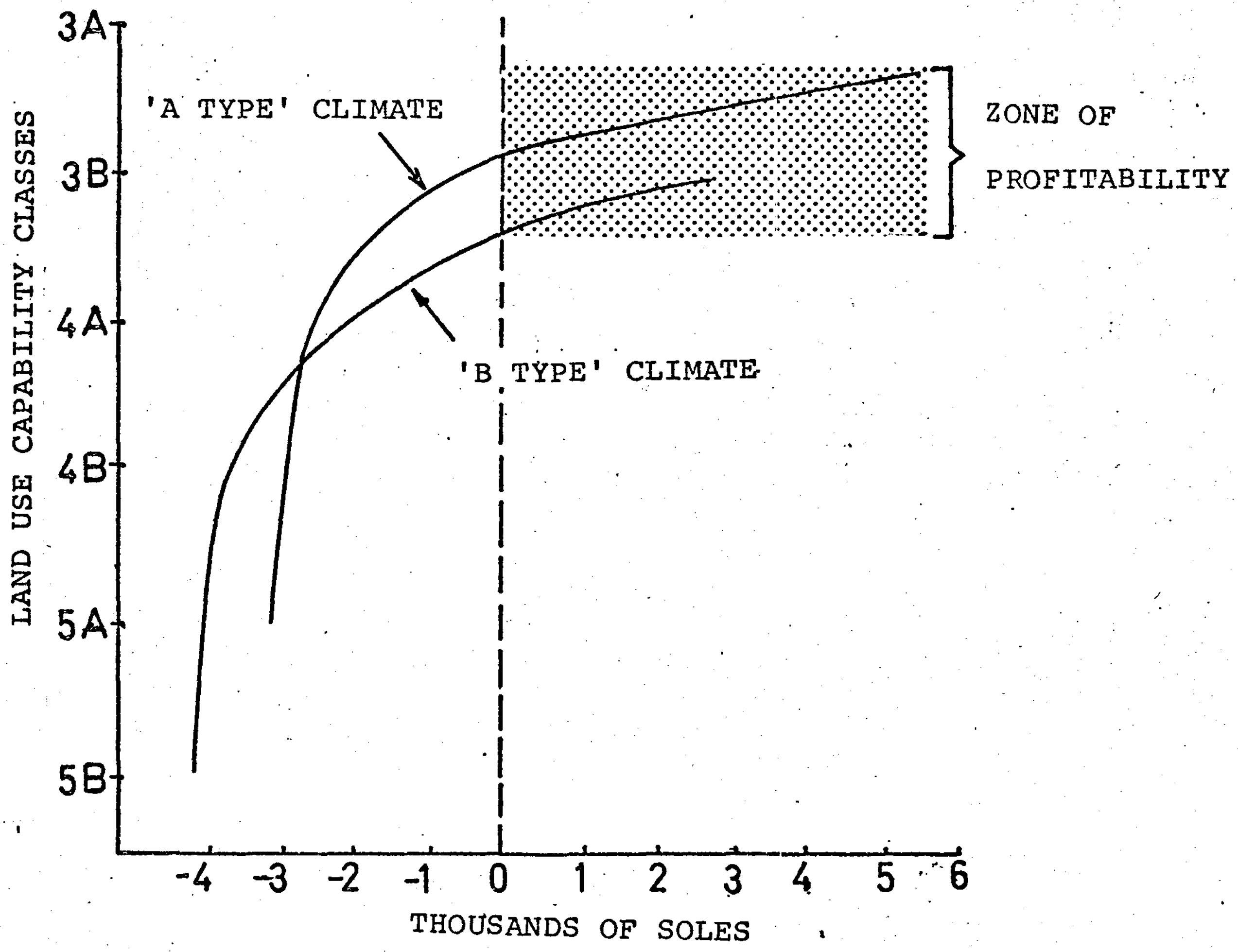
* ALFALFA

FIGURE 2



GROSS MONETARY VALUE OF AN EIGHT YEAR ROTATION,
VARIOUS CLASSES OF LAND
DEPARTMENT OF PUNO, PERU

FIGURE 3



NET MONETARY VALUE OF AN EIGHT YEAR ROTATION,

VARIOUS CLASSES OF LAND,

DEPARTMENT OF PUNO, PERU

THIS GRAPH SHOWS THE CONFINEMENT OF THE ECONOMIC PURSUITS TO A SMALL SEGMENT OF THE LAND CLASS INDEX SCALE

The USDA system, which is drawing most of our criticism was devised in a part of the world where annual cropping or some rotation weighted to food, feed grains, or pasture is in general vogue. This pattern may be the result of market demands or environmental aptitude. Part of the richness of North America lies in the reliability of crop returns. Government agencies have been regarded as information services;[31] the United States has never used the rigid central planning[32] that many "developing" countries have commenced and has typically used regions as economic census tracts. It is unfortunate in our view that a capability scheme adequate to the United States should be imported to areas needing a version of higher predictive value.

In tropical zones, for instance, some soils are poor in nutrients and/or organic matter and require a long fallow period. Year by year these soils may deteriorate from Class IV, for example, to Class VII. The cartographic and statistical representation of this condition can be problematical unless the soils are

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[31] Aandahl, 1958, 153.

[32] Hugh O. Nourse, Regional Economics (New York: McGraw, 1968), 131.

shown on the basis of their economic capacity per unit time of the rotation. This pattern involves an estimation of productivity not provided for in the USDA scheme, or a redefinition of the classes to encompass some economic consideration of practices over a period of time.

Some rotational schemes imposed by fluctuating soil fertility could realistically be characterized only as a spatial economic or ecological system, and not by the type of numbered scale we are reviewing. In these cases it becomes necessary to talk of "land systems"[33] which will exist in space and whose size and identity will be governed by the intensity of the activity being carried on, the physiography of the land base and some cost measure of conservation to preserve the return on human effort.

III Expected Problems in Planning Implementation: Weighting Criteria: These problems relate to the difficulty of formulating planning decisions based on soil units studied on an 'a priori' basis. The subclass criteria are not weighted in a simple categorical scheme. Do we

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[33] Oschwald, 1966. 154-155; Anthony I. Young, "Natural Resource Surveys for Land Development in the Tropics", Geography, 53 (1968), 233, 243.

know at what frequency, size and depth stones start to influence yield adversely? Is a wet stone-free soil better, or worse than a stoney dry soil? Sub-class "S" is designed to represent, in the Canadian adaptation of the USDA scheme, a complex of adverse features which need not be named and whose interaction remains undescribed.

If none of the subclass criteria are weighted, then prediction within given confidence limits, and comparison of results with those obtained in different soils in the same class, but not possessing precisely the same "mix" of characteristics, is impossible. Successful prediction would be an illusory result due to the fact that the values of the important functional variables were, by chance only, more similar than dissimilar among sample populations. Blagovidov's discovery,[34] that variation increases in the lower ranges of yield on poor land would tend to confirm this assertion.

If the probability of faulty prediction to other populations at known and accurately forecasted levels of input is high, then the chances for accurate prediction through factorially iteritive cycles would be impossible. Most programs used in income maximization

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[34] Blagovidov, 1960, 357-364.

planning employ some such method. This deficiency, except in the case of those models employing observed crop performance, mitigates against the use of agronomic research or pot experiments carried out in agricultural research stations. There will be no known coefficient by which the experimentally obtained yield figures may be altered to discover the best areas suited to a crop or to test for the degree of expected improvement gained by a change in practice under a given set of conditions.[35]

This problem may arise in areas in which an inventory has been carried out on 'a priori' assumptions with the eventual discovery that, after much money has been invested, the increase in income does not materialize.

Considerations on the Statistical Basis of Grouping: Before any plan concerning space can be effected, one must identify by quality and location the entities to be dealt with. We refer specifically to the identification of

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[35] For a review of this problem and proposed solutions see R. T. Odell, "Soil Survey Interpretation - Yield Prediction", SSSA, Proceedings (1958), 157-160. For erratic results in some unusual locales see John W. Brown and Tirso A. Wolfschoon, "Some Chemical and Physical Properties of Representative Soils of the Republic of Panama", ICSS, IV (1956), 215.

land use capability units - the number of classes and their identity, their homogeneity and contiguity over space.

There never has been any justification other than that of convenience for assuming that any capability scheme should contain any given number of classes. Obeng[36] has managed with three. The Dutch and Russian schemes reviewed could manage adequately with no interval scaling.

The imposition of arbitrary group membership and the possibility that agents may be under constraints to discover some land in any one class may impose a distortion on the curve of the production function.

The intra-class distribution may vary from place to place and if, for example, there is a high concentration of available locations in one class, as in the case of the Puno study, the class number will have little meaning, if any, since no intra-class variance is assumed in the computations.

Since a capability classification is, however, in fact a taxonomic system (only the objectives are

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[36] H. B. Obeng, 'Land Capability Classification of the Soils of Ghana Under Practices of Mechanized and Hand Cultivation for Crop and Livestock Production", ICSS, IV (1968), 215-223.

different from other branches of soil taxonomy), one might ask that it conform to modern taxonomic standards. To quote Goodall: "The predictive ability of a classification is the size of the intra-class variance as compared with the inter-class variance for any attribute."[37] No scheme of which we have knowledge has utilized this statistical test to discover the nature of such comparative variances. To elaborate this point, we may postulate as examples three views of any population:

1) As a particulate group exhibiting distributional peaks.
2) The objects are real individuals, but the classes are abstract.
3) As a continuous distribution.

The second viewpoint is taken in the USDA scheme. A similar approach is used in the <u>Seventh Approximation</u> and in view of the problems in soil taxonomy and the purpose to which it is put, it is probably eminently justified for soil classification. But it is possible, and likely, that the qualities and phenomena involved in soil fertility and management belong with either of the other two concepts of populations or with a combination of the views.

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[37] D. Goodall, "Classification, Probability and Utility", quoted in F. R. Gibbons, "Limitations to the Usefulness of Soil Classification", <u>ICSS</u>, IV (1968), 159-167.

In addition, the identification of land use capability classes will involve the treatment of a large number of variables. The statistical problems in discovering the identity of classes are considerable, since intra-class variance must be held to a minimum over all the variables. However, if such classes can be discovered and the number of such classes is small enough to be usable in agricultural planning, we feel that a considerably improved land use capability scheme will result.

PART III-

Creation of Hypotheses to Test for the Existence of Real or Optimal Classes of Land Use Capability

We have reviewed the deficiencies of the 'a priori' approach. In those empirically based schemes in which observed crop performance was utilized, no attempt was made to determine the number of real classes or the error associated with compressing the data into a given number of classes. Therefore we wish to discover:

1) the variables which most affect sustained income from the soil and the functional combination of these variables;
2) the number of real classes of land use capability, or the error associated with assuming the existence of a given number of such classes.

Any agricultural system which has existed long enough to be stable in its year to year patterns has become part of an ecological balance. "(The) land use pattern may be legitimately studied as a biogeographical reality in which man has created a distinct ecosystem by the planting of crops."[38] But in many countries fallow periods are being shortened[39] in response to population pressure. Industrialization does not always create income which is used or could be used for investment in agriculture or environmental stabilization. The pressure on the environment has led some writers to consider 'crises points' occurring at some time in the future, these points being either cataclysmic ecological disasters, or the time at which per capita income and nutrition start to decline drastically over the whole surface of the globe. Thus any introduced change must aim for a new 'stable' equilibrium.

An appreciation of the land as a system may help in charting a course toward stability between the people and the land. Young[40] has defined a land system

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[38]Moss, 1963, 159.

[39]C. J. Piggott, "The Maintenance of Fertility in Sierra Leone Soils", ICSS, IV (1956), 213.

[40]Young, "Natural Resource Surveys ...", 1968, 233.

as "an area with a recurring pattern of topography, soils and vegetation", For a part of Malaya, land classification[41] was derived by superimposing soil and landscape type maps.

But "it is disputed whether economics should, should not, or inevitably must be taken into consideration".[42] This question need only arise when there is confusion as to the objectives of the scheme; "... there has frequently been a lack of understanding between natural and social scientists. This has led to interpretations of a poorer quality than people have a right to expect."[43] In our study, we are concerned with the discovery of a methodology of economic value.

<u>Hypotheses</u>: To avoid 'a priori' assumptions and to discover a set of land use capability classes we therefore postulate the following:

1. By the appropriate statistical treatment of a number of crop yield and associated environmental and economic variables a number of natural land use capability groupings may be discovered.

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[41]Prof. Young may be referring to land capability or potential.

[42]<u>Ibid</u>., 242.

[43]Aandahl, 1958, 153.

2. In the alternative, if natural groups are absent, an optimum grouping may be derived such that the intra-group variance is lower than the inter-group variance.

By "appropriate statistical treatment" we refer to the following process:

1. The derivation of factor scores on a representative sample of subjects for which data is entered on variables known or assumed to have a bearing upon the net income from the land and upon the type of activity which the land will sustain. Data concerning the types of farm activity, the quality of the land on the farm, precipitation, crop yields, soil qualities, and a number of other variables to be enumerated will be utilized. Factor analysis will be used to destroy the statistical influence of unimportant variables, to reveal the combinatorial properties of the remaining variables, and to create a new set of subject readings (factor scores) which incorporate the relative weightings of the important variables.

2. The submission of the factor scores to an hierarchical grouping analysis to discover the existence, identity, number, and spatial characteristics of classes of land use capability. The grouping process provides information as to the existence of natural classes, or, in the alternative, the compromise attendant upon the assum-

tion that any given number of classes exists.

3. The mapping of the locations of the members of the various groups to discover the degree of spatial contiguity among members of the same group. Intra-group contiguity should have important implications in regional analysis and agricultural planning.

The methodology, then, is directed toward discovering a weighted combination of variables and a set of scores grouped by a form of statistical taxonomy. This method should dispose of the two major objections we have raised against the schemes reviewed in the literature survey:

a) The methods which rate soil units as they are found on pedological maps do not attempt to discover the relative or correlative importance of the variables considered, nor is the number of classes used based upon statistical considerations.

b) Methods using empirical data do not proceed to justify the number of classes of land use capability.

This procedure will be valid only if:

1. There are an acceptably large number of strong correlations among the variables.

2. The factor identities are clear and usable, and those concerned with income or yield account for a substantial portion of the variance in the correlation matrix, (i.e. are associated with one of the higher eigenvalues).

The grouping method is described in detail in Chapter V.

CHAPTER II

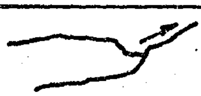
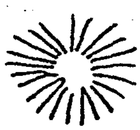
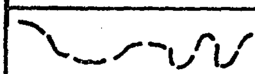
SOME DESCRIPTIVE NOTES ON HIGHLAND PICHINCHA PROVINCE

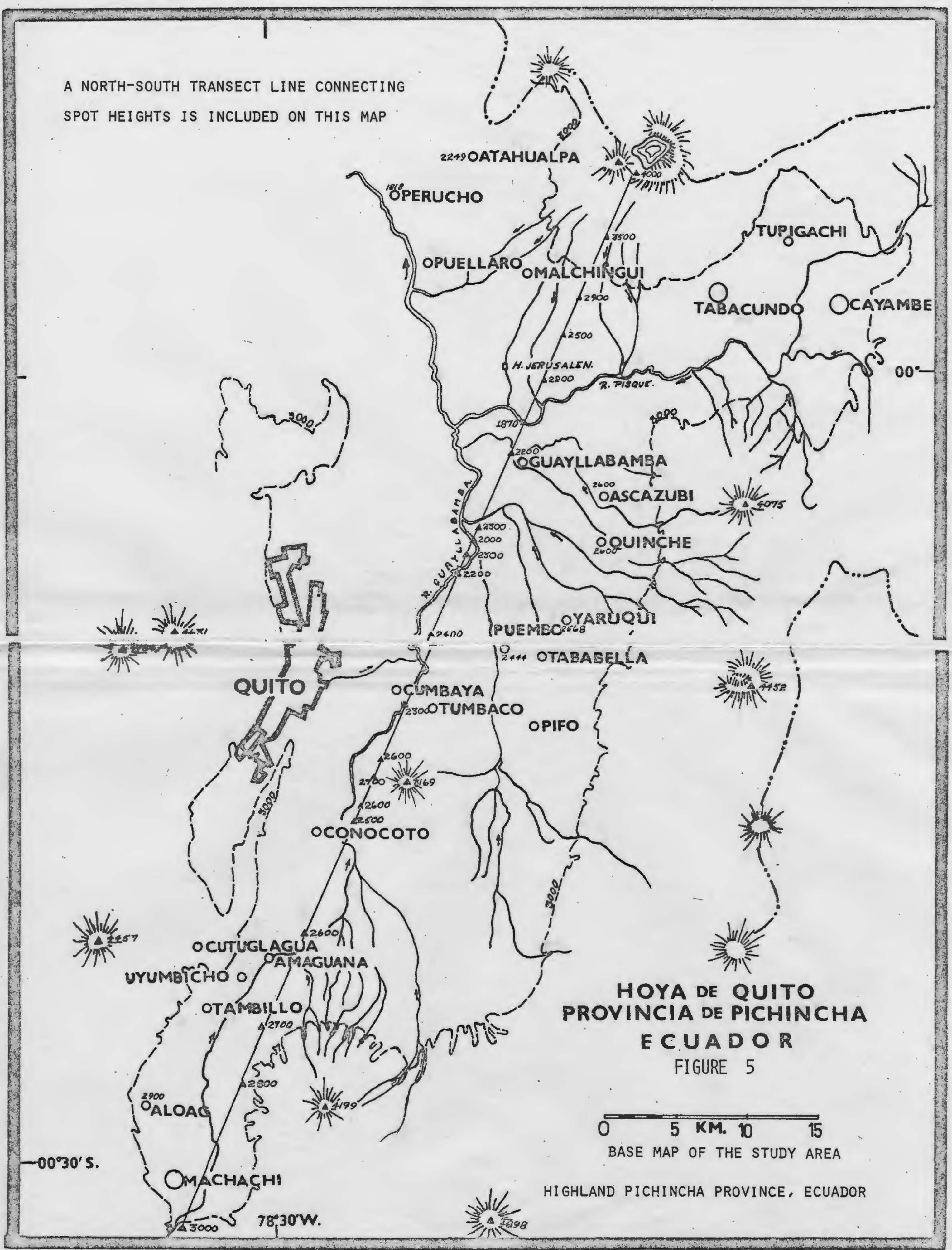
Description of the Area Studied

The sample covered the Andean portion of the province of Pichincha in north central Ecuador, as shown on the base map, figure 5. The national capital Quito is located on the western flank of a complex depression, the margins of which are indicated by the 3000 m. contour. It is surrounded by extinct volcanoes on the east, north, and west. To the south of Machachi the valley floor rises above the level of cultivation into a zone known as the Machachi Paramo. This rise is one of the 'ladder rungs' which divide the central valley, between the two north-south Andean ridges, into a series of depressions along the length of the country. There is a pass to the north, through which the Panamerican highway runs, between the volcanoes of Imbabura and Mojanda. To the northwest the Guayllabamba River has cut a deep gorge, one thousand metres in depth in some places, through easily eroded volcanic material. This river, its major tributary the Pisque, and the tributaries of both drain virtually all of Andean Pichincha.

FIGURE 4

THE SYMBOLS USED ON THE MAPS

	CAPITAL CITY OF THE COUNTRY, AND OF THE CANTON OF QUITO
○CAYAMBE	OTHER CANTON CAPITALS
OPIFO	PARISH CAPITALS; ONLY THOSE IN WHICH FIELD WORK WAS CARRIED OUT ARE MARKED
	MAJOR RIVERS. THE ARROWS ON RIVERS AND TRIBUTARIES INDICATE THE DIRECTION OF THE FLOW
	MAJOR TRIBUTARY RIVERS
	MAJOR MOUNTAIN PEAKS ("CERROS")
▲ 2300	SPOT HEIGHT IN METRES ABOVE SEA LEVEL
	3000 METRE CONTOUR
	PROVINCIAL BOUNDARY



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 5

BASE MAP OF THE STUDY AREA

HIGHLAND PICHINCHA PROVINCE, ECUADOR

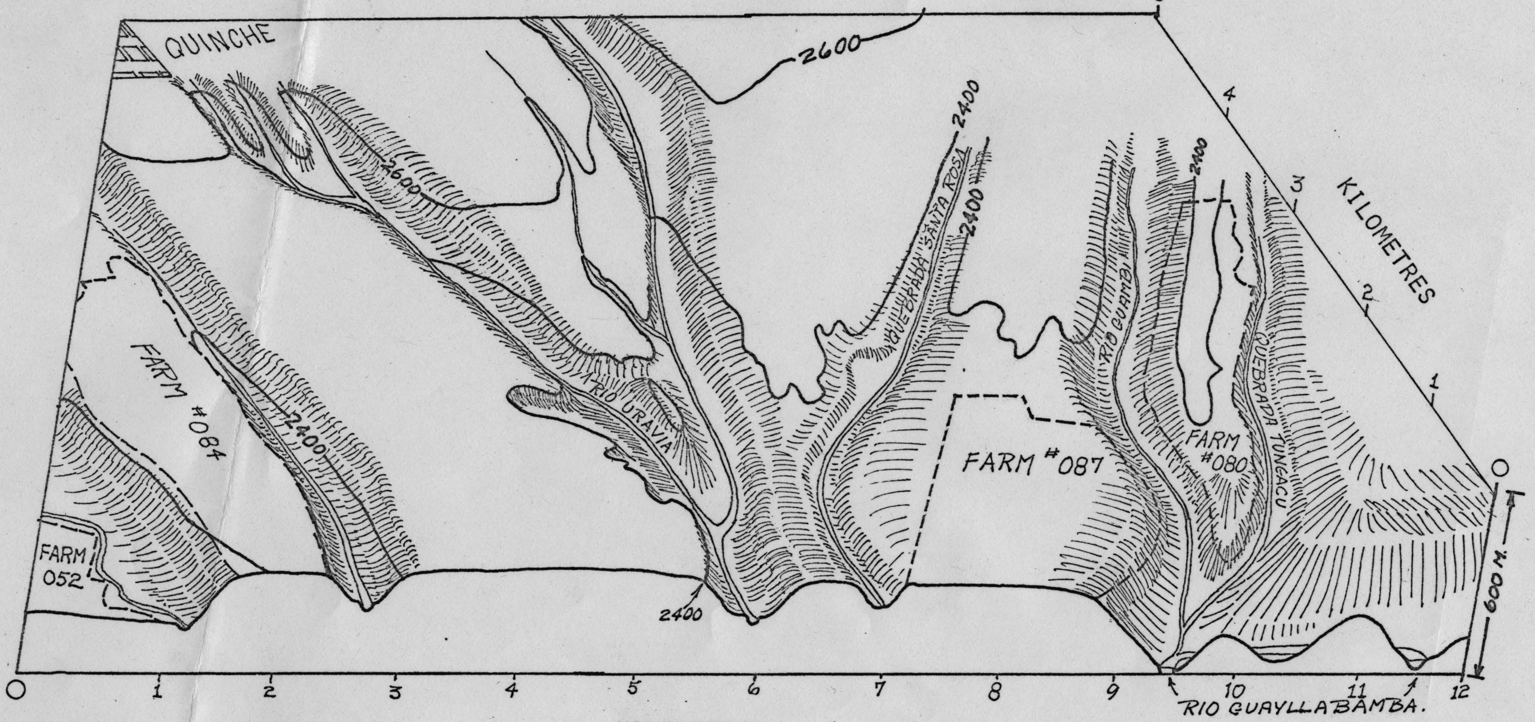
CON PERMISO DEL I.G.M. B.D. 1971.

Topography: The depression is concave in both directions, and elongated on the north-south axis, but in detail the relief is extremely variable. The area surrounding Cayambe in the northeast is flat, in places marshy, to gently rolling. The central part of the valley (Puembo, Pifo) exhibits flat finger-like interfleuves divided by deep quebradas in which flow the major tributaries shown on the map; many other subtributaries disect the landscape at intervals depending upon the magnitude of stream flow. (See Plate 2.) On the slopes of the extinct volcanoes the quebradas extend upwards, dividing the land into finger-like units. (See Plate 3.) This is demonstrated by the path of the 3000 m. contour to the southeast of Tambillo. The valley floor between Uyumbicho and Machachi is almost flat and not as dissected as the territory in the centre of the valley. The zone in the top centre of the map (Malchingui to Atahualpa) is extremely dissected as a result of stream activity, soil erosion by wind, massive earth slumps and tectonic movements. (See Plate 4.)

Parent Material and Soils: The detail relief results from the nature of the parent material. Except for ridge outcroppings at high altitudes (over 3400 m.) the area of the map is covered by a continuous blanket of

FIGURE 6

SCHEMATIZED REPRESENTATION OF THE TOPOGRAPHY EAST OF THE GUAYLLABAMBA RIVER BETWEEN GUAYLLABAMBA AND QUINCHE



THE 2400 AND 2600 METRE CONTOURS ARE PROVIDED

FOUR FARMS IN THE SAMPLE

PLATE 1

VIEW NORTHWEST FROM SLOPES ABOVE AMAGUANA. NOTE THE COMPLEX SLOPES, ERRATIC FIELD SHAPES AND THE WIDE RANGE OF SOIL QUALITIES. THE LARGE UNDIVIDED FIELD TO THE LEFT IN THE MIDDLE GROUND OF THE PHOTO SHOWS A WAVY SURFACE INDICATIVE OF THE DESTRUCTION OF TOP SOIL. THE SOILS ON THE RIGHT SIDE OF THE PICTURE ARE DEEP AND HAVE BEEN WELL CONSERVED.

PLATE 2

VIEW FROM HACIENDA YACUPAMBA WESTWARD TO QUITO, SHOWING THE VALLEY FLOOR, GULLY DISSECTION AND FIELD SHAPE. HAND TILLED WHEAT OR BARLEY FIELD OF HACIENDA CONIBURO ON FOREGROUND SLOPE. THE BLACK AREA IS "MATORRAL", A SCRUB OR THICKET VEGETATION.

PLATE 3

A VIEW OF NATURAL PASTURE AT HIGHER ALTITUDE (C. 3300 M.) SHOWING BASALTIC BLOCK IN UPPER LEFT. NOTE OLD FIELD PATTERNS AND EROSIONAL NETWORK STARTING TO PENETRATE THE SOIL ALONG THE CROWN OF THE CENTRAL RIDGE.

PLATE 4

VIEW WESTWARD FROM CRATER OF CERRO MOJANDA (C. 3700 M.). THIS IS A GLACIAL VALLEY COVERED WITH AN ABLATION MORAINE. ATAHUALPA AND SAN JOSE DE MINAS ARE LOCATED ON THE HEAVILY RELIEVED TERRAIN IN THE MIDDLE BACKGROUND. 'STYPA ICHU', A WILD NATIVE GRASS COVERS THE FOREGROUND OF THE PICTURE; THIS AREA IS USED FOR PASTURE.

volcanic debris. This debris is composed of dust ranging in particle size from talc-like to aggregates of pebble size. The stratigraphy is horizontal in the upper levels except where the air suspended load of recent eruptions has fallen in a blanket formation over old undulating surfaces. Sequential buried soils in dramatic dimensions and states of preservation abound. The strata vary in depth from a few millimetres to scores of metres in depth. The medium textured material is converted to excellent soil. The finer material becomes plastic when wetted and forms rich but heavy soils while coarser material tends to remain sandy and structureless. Except for the classic black Andean soils which exist at higher altitudes, it is not known what soils were present in prehistoric times, nor what natural vegetation was present. This interpretive problem exists because soil destruction in the areas cultivated the longest and most intensively (the central area of the valley) has proceeded at a greater rate than soil formation. These areas are coincidentally drier. Many farmed tracts are now operating essentially upon parent volcanic material. In the wetter areas soil formation has proceeded at a uniform rate of mineralogical decomposition such that agricultural practices are independent of the nature of the original material, or in the alternative, soil destruction has been minimal.

Miller and Coleman[44] have divided the soils in our research area into three categories: Black Paramo soils, Moist Sierran soils, and Dry Sierran soils. Soil temperature is considered to be a reliable zonal property on which to assess soils,[45] the soil and environmental temperature increasing respectively through the categories. In pedological terms the soils are youthful and in the natural virgin state possess high concentrations of exchangeable metal cations. In the agricultural context many soils have, however, been exhausted and do not display this feature.[46]

Soil management problems are many, and will be treated in detail in combination with other variables later in the work, and in a section on the total cation exchange. In general, however, the difficulties are as follows.

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[44] E. V. Miller and E. T. Coleman, "Colloidal Properties of Soils from Western Equatorial South America", SSSA, Proceedings (1952), 239-244.

[45] Ibid., 239.

[46] For detailed analyses see A. Kupper et al., Estudio Morfologico y Analitico de los Suelos de los Principales Areas Trigueras del Ecuador, n.d.; reprinted in Acosta Solis, I, 2 (1965).

PLATE 5

VIEW AT UPPER LIMIT OF CULTIVATION IN THE HUASIPUNGOS OF HACIENDA LA COMPANIA, NEAR CANGAHUA. THE FORMERLY BLACK ANDEAN SOILS ARE NOW GRAY IN COLOUR WITH THE REMOVAL OF ORGANIC MATTER AND THE EROSIONAL REMOVAL OF THE FINER FRACTIONS. FOREGROUND CONSISTS OF THE SAND SIZED FRACTION OF THE ORIGINAL SOIL.

PLATE 6

VIEW IN SAME LOCALE AS PLATE 5. AREA IS BLANKETED WITH VOLCANIC DUST, ON WHICH SOILS HAVE DEVELOPED. NOTE STEEP SLOPES, ONSET OF EROSION IN POCKETS, AND RETREAT OF CULTIVATION UP SLOPES. THIS RETREAT IS DUE TO UNECONOMICAL YIELDS ON QUEBRADA SLOPES AND THE USE OF MACHINERY.

Structural problems are most marked in finely textured shallow soils which have become mixed with an underlying layer of fine volcanic particulate matter. These soils possess an extreme plasticity approaching doughiness when wet. Most of the soils styled as 'Brunizems' in local studies fall in this category.[47] They are concrete hard when dry. Such soils absorb high levels of hand labour and degrade easily when dry. Root development is shallow and lacks vigour. Tillering of grain crops on these soils is slight and the plants are badly affected by even short droughts. In some places the land is unworkable for many months of the year.

At the opposite extreme are the sandy soils. These soils are exhausted of nutrients by constant cultivation and the erosional removal of the colloidal clay fraction. Reclamation will be very slow at the lower elevations due to high soil temperatures and extreme porosity. Reforestation can be proposed, but the

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[47] The soils known as 'Desert Brown' soils are thought, by the writer and a colleague involved in pedological research, to be degraded forms of 'Brunizem' soils. The 'Brunizems' are observed to be degraded forms of Black Andean soils and the nature of the intergrade is subtle and completely known. The taxonomy of the soils is most problematical.

eucalyptus evergreens which will tolerate the climate produce little litter and what does fall is removed by fuel hunters. Plate 7 shows a reforestation project south of Malchingui; the trees have been growing for fifteen years or so and have caused no noticeable soil improvement. Usually such trees are cut for timber before a substantial aggregation of them have an opportunity to affect the microclimate.

On a large scale the soils of the dry areas and wet areas are distinctive, as Miller and Coleman have aptly observed. Small scale trends are hard to define however; we must stress the phenomenal difference in soil quality over small distances - between farms, within one field, or in a distance of a few feet.

Climate: Climate is always said by the indigenous people to be the single greatest limitation on agricultural activity. Mean rainfall is extremely variable over the valley and the amount which will fall from year to year is unpredictable. The research area is affected overall by an extremely marked dry season occurring from July to September. In the drier section no rain falls for this period; in others there is enough for the sustenance of maturing grain crops.

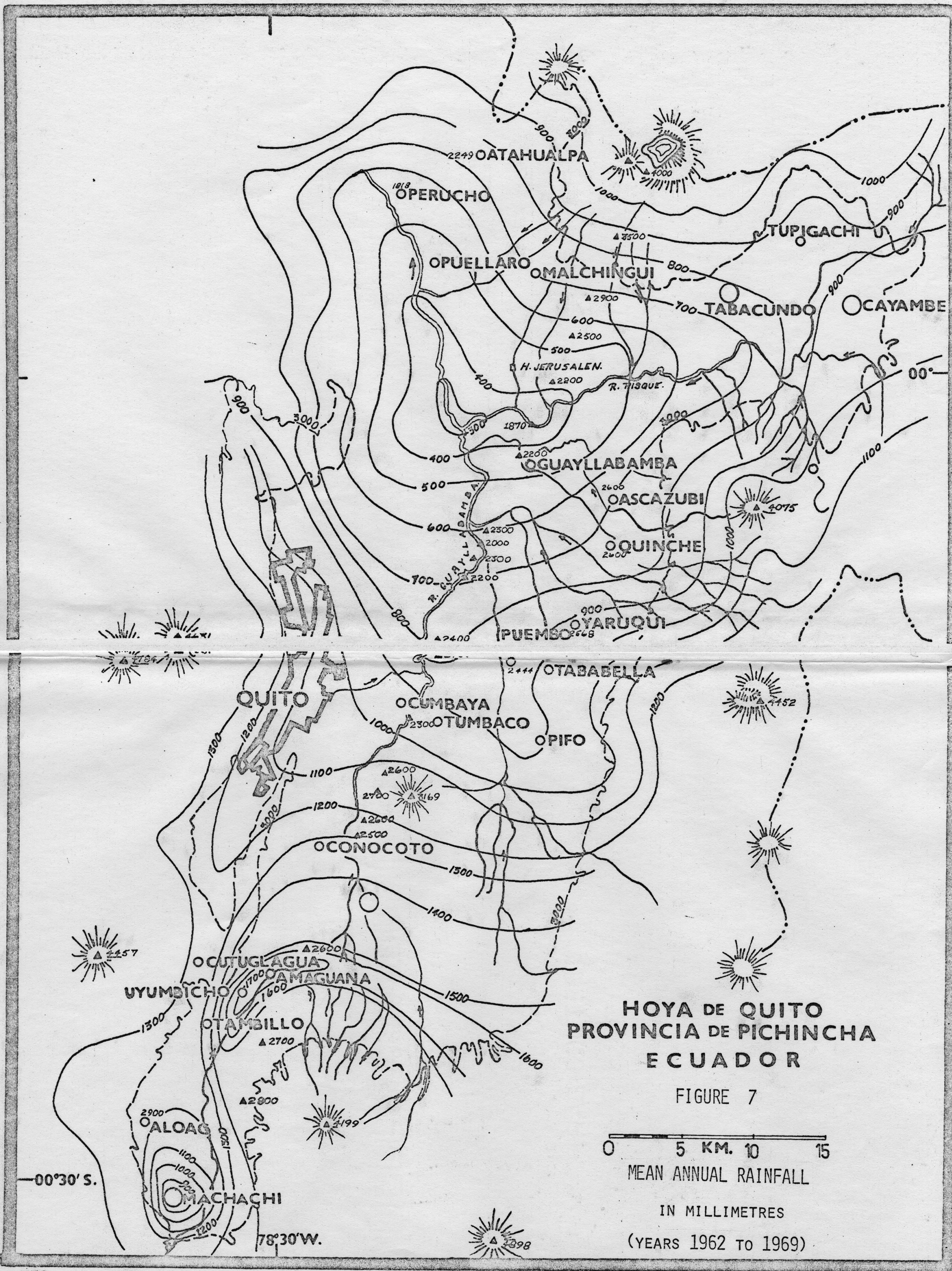
PLATE 7

SANDY LAND SOUTH OF MALCHINGUI. THE COARSE LIGHT SOILS RADIATE LARGE AMOUNTS OF HEAT. THE EUCALYPTUS TREES ARE ABOUT FIFTEEN YEARS OF AGE. THE AREA IS SUBJECT TO HIGH WIND VELOCITIES.

We have constructed six maps, (figures 7 through 12), concerning rainfall which demonstrate the variation over a short distance. The mean annual rainfall map (figure 10) shows a marked arid zone in the centre, with a desert-like appearance relieved somewhat by the irrigation practiced around Guayllabamba. Outside this node rainfall increased toward the valley flanks in all directions, both in amounts of water and the number of days per year of precipitation. It appears from these maps that a sizeable proportion of the moisture received in the province arrives via a mountain pass to the southeast of the map.

These maps show the means for the years 1962 to 1969 which are the only years for which data is available in adequate detail.

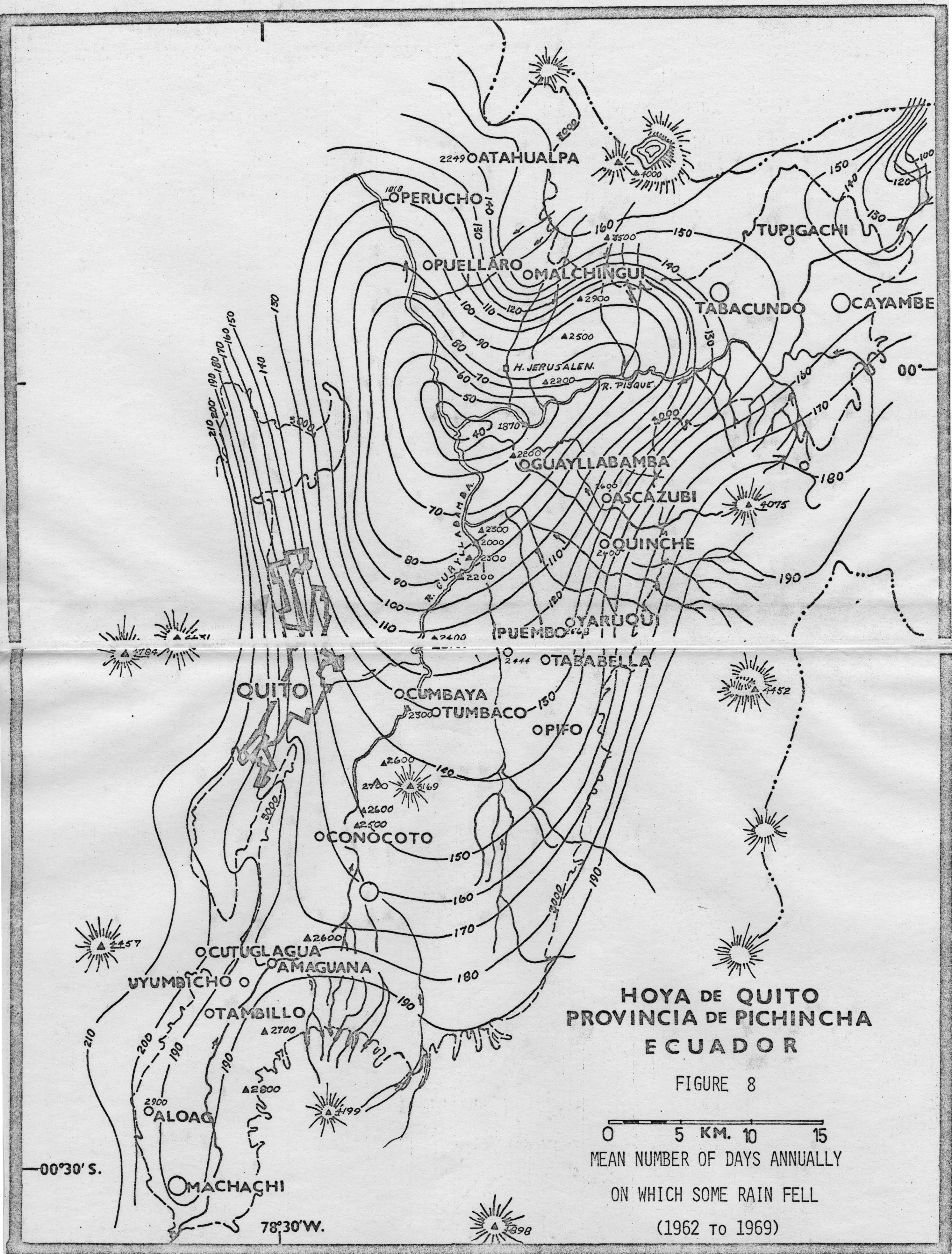
The central part of the country is subject to very dry years because of the oscillation of the Humboldt current, or so it is said. Whatever the reason, a drought reoccurs in three to six year cycles, the last being in 1965 to 1967. The rainfall tables demonstrate this fluctuation, which is not sudden, but undulating between 'peaks' and 'troughs'. Because of local phenomena, the whole valley may not feel the effects the same year, part receiving adequate rain when other sections are arid. Respondents in the field interviews,



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 7

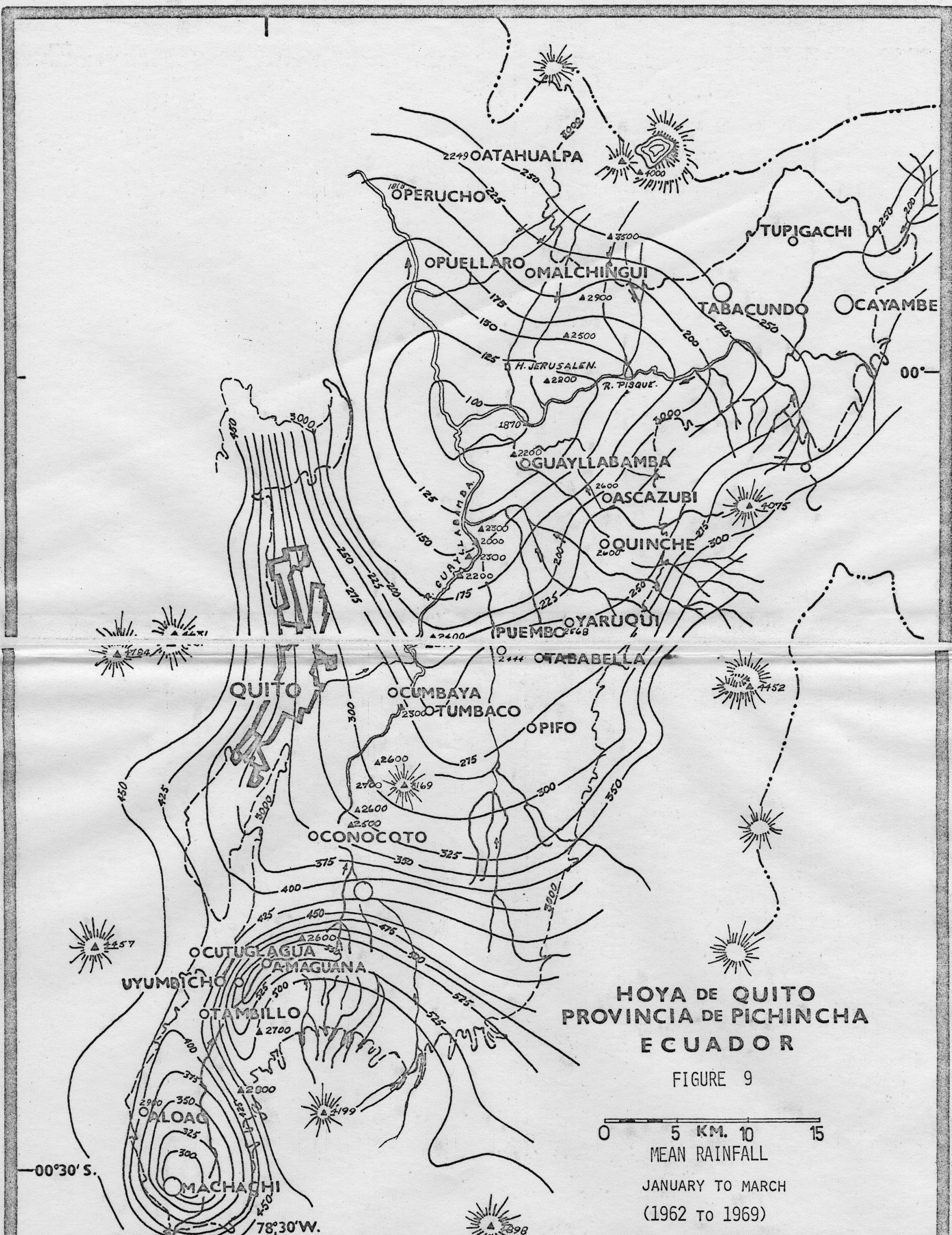
MEAN ANNUAL RAINFALL
IN MILLIMETRES
(YEARS 1962 TO 1969)



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

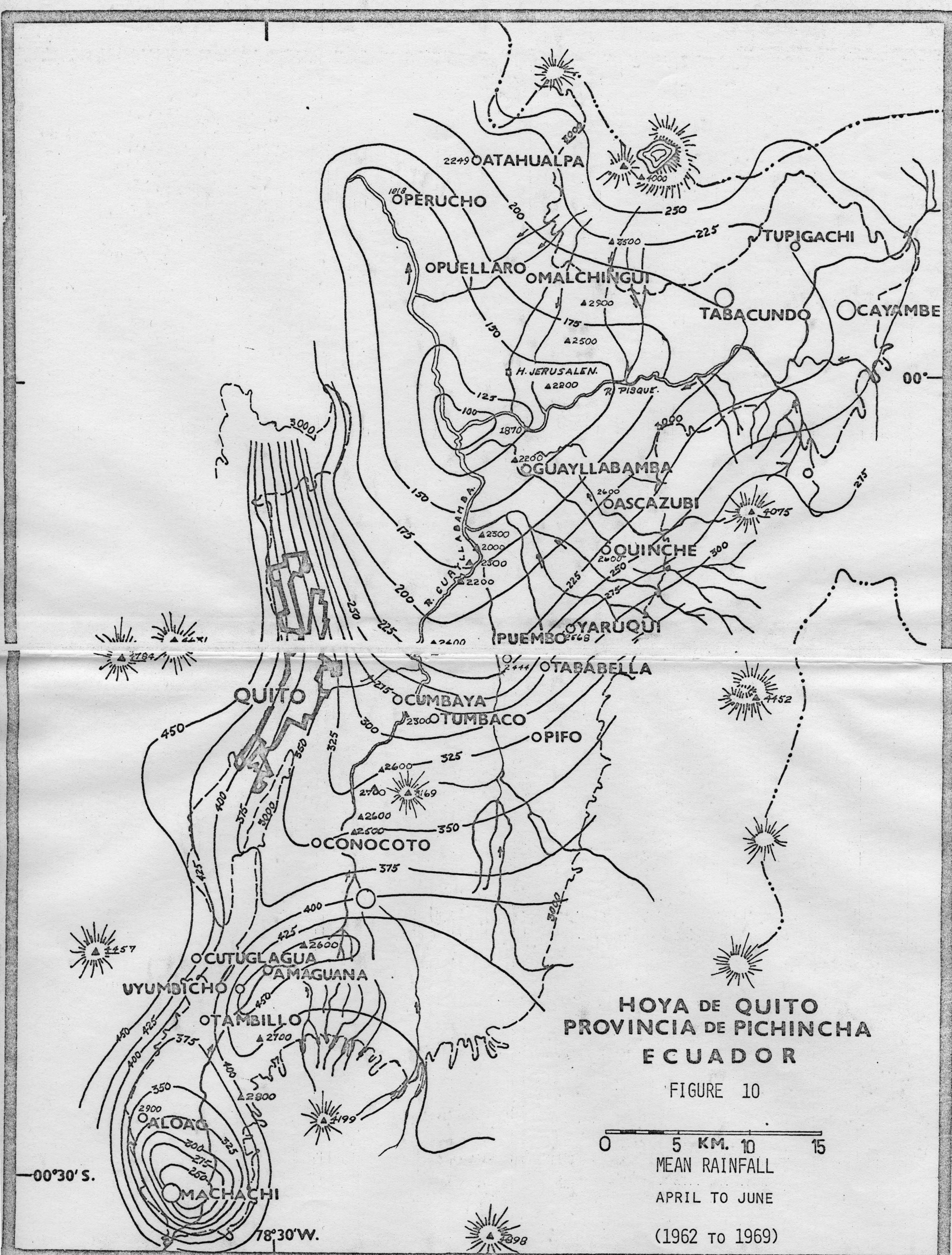
FIGURE 8

MEAN NUMBER OF DAYS ANNUALLY
ON WHICH SOME RAIN FELL
(1962 TO 1969)

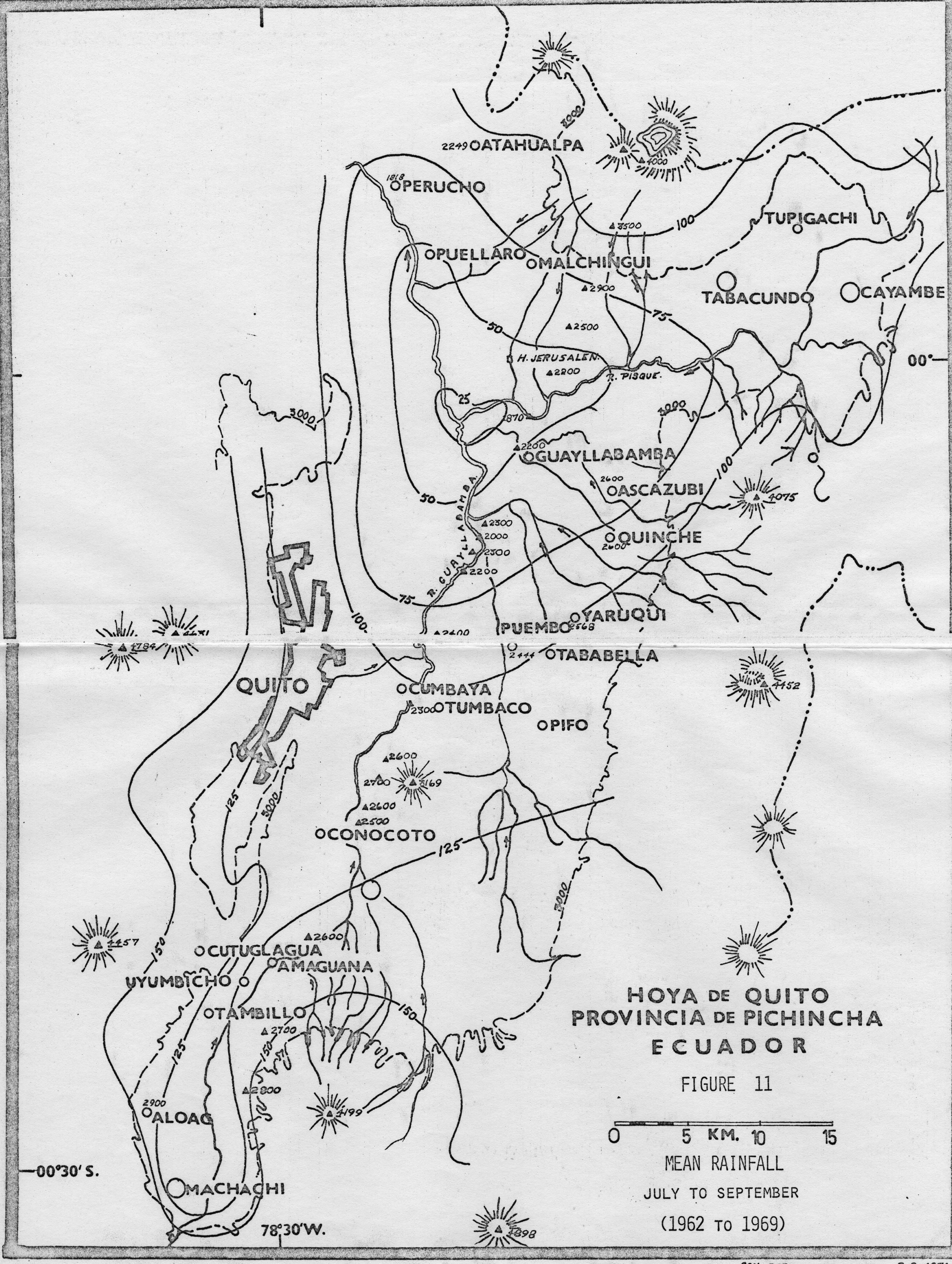


CON PERMISO DEL I.G.M. B.B. 1971.

F101 RAINFALL APRIL to JUNE, MEAN 1962-1969.

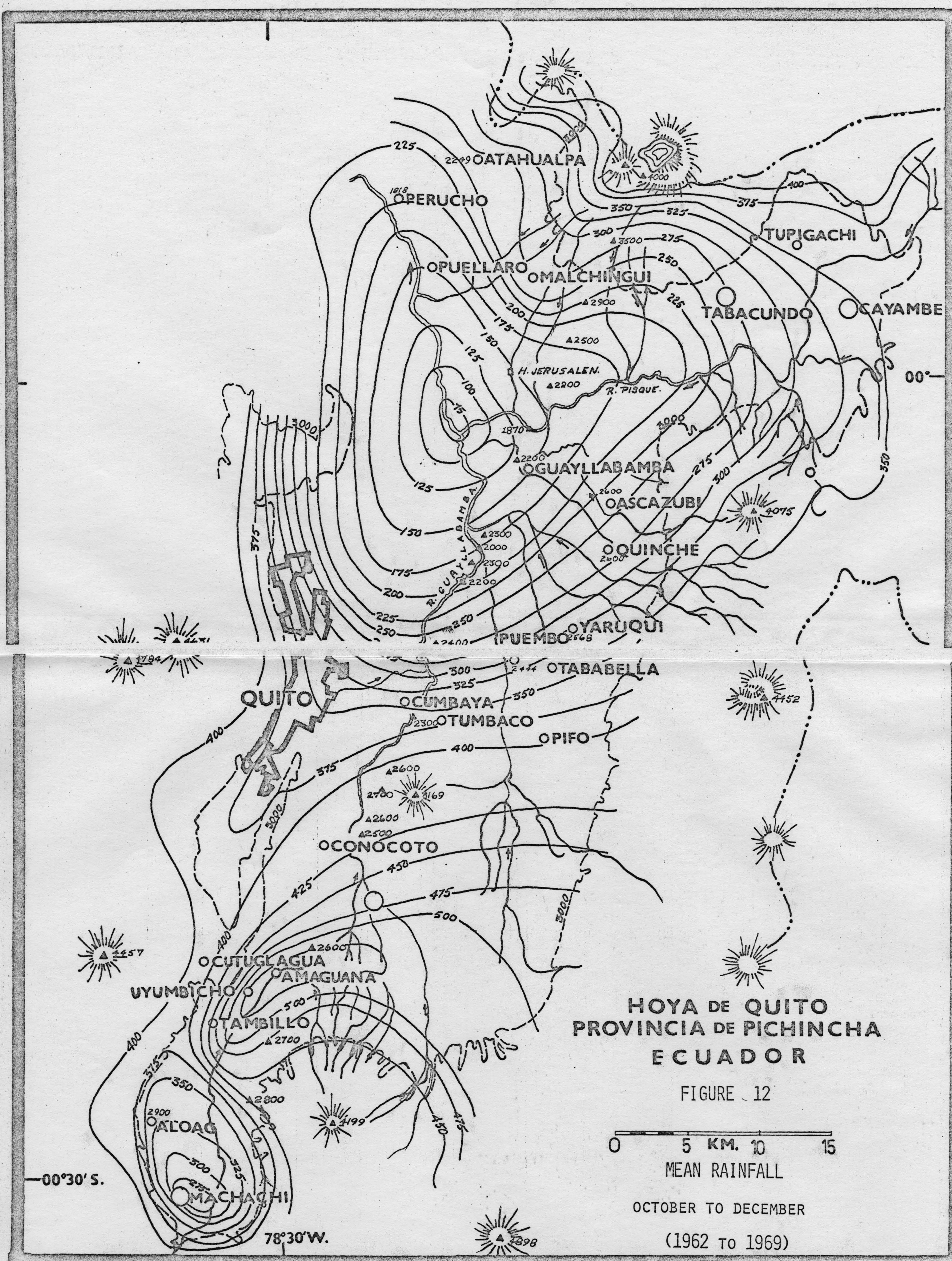


F102



CON PERMISO DEL I.G.M. B.D. 1971.

F121 MEAN RAINFALL, OCT-DEC, 1962-1969.



for example, gave diverse answers depending on their location in the valley when asked for an example of a 'bad year'.

It evolved that rainfall data was the only climatic information usable for the study.

Maps are presented for mean quarterly rainfall in addition to the mean annual rainfall and mean number of days on which some rain fell.[48] The closely spaced contours on these maps represent real distributions; it is not uncommon to find variations of 100% or more on single farms with corresponding corridors of land use running in the appropriate direction. One farm in the north of the province exhibits economic holdings of sugar cane, grain crops, artificial pasture, natural pasture and forest. The upper reaches are covered perpetually by frozen fog.

Evaporation measurements from the antiquated bowl apparatus are few, and vapor pressure readings are even less common. Wind velocities are available but the data was not trusted. Temperature figures are hardly meaningful to crops when taken in the shade above a soil which could be 40° C hotter; the annual range is, at any rate, very slight. Altitude has a great effect on temperature, and the upper limit of cultivation follows a sharp demar-

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[48]Referred to henceforth as 'days of rain'.

cation between favorable regimes and adverse ones. Above 3400 metres little can be grown; between 3100 and 3400 metres barley, legume and potato production is common. Below 3100 metres returns in all crops are not known to be further affected by air temperature, other determinants being more important.

CHAPTER III

A DESCRIPTION OF THE DATA

INTRODUCTION

Fieldwork for this study was undertaken between June and September 1970. A list was made of all the variables thought to have some bearing on land capability. This was an exercise only since one is rarely able to locate or to treat all pertinent data. It would have been interesting, for instance, to have reliable data on insolation, evaporation, wind velocities, and much, much more soil data. We have, however, tested many of the 'a priori' assumptions thought to be important in land capability.

The data was arranged in several sets. One set concerned farms as units - the percentage distribution of land types, the percentage of land in several types of crops, pasture, unusable land and investment in equipment and buildings.

Another set was composed of three hundred and fifty-six entries of crop performance entered for yield, fertilizer application, soil depth, slope, rainfall, and other variables. This set was subdivided into wheat, corn, and barley entries. A profusion of other crops were encountered, including sugar cane, potatoes, vegetables of many types and a large selection of beans.

But the occurrence of any one crop except for wheat, corn and barley was sporadic, and in many cases these other crops were grown for household use only. It was therefore not thought that any validity would be possible in attempting to deal with a small and widely spread sample of any of the other crops.

A further set of over fifty entries was based on the total cation exchange capacity of some representative soils. Results of these analyses with appropriate notes as to the type of land use and management problems are presented as Appendix I.

A fourth set was derived from the land class distribution of the parishes of the Andean portion of the Province; this set formed the basis of a fifth set which was used to estimate the zonality or regionality of 'land types' by the use of a grouping method.

Investigation Procedure

Week by week the field investigation proceeded in the following manner. Firstly, the National Office of Assessment and Cadastral Survey (ONAC) would be visited and over a period of days the available tax roll data for a number of farms to be subsequently investigated was entered on sheets. This information comprised the data concerning the activities and types of land occurring on the farm. The investigator possessed a set of maps on which the master cadastral farm maps were duplicated. These maps, combined with the farm name and the name of the owner facilitated locating the farm in the field, which is at times no mean feat in view of the scarcity and the quality of the roads.

The possession in advance of the cadastral and assessment data enabled the investigator to ask pertinent questions concerning the type of farm activities, the intensity of investment, and problems in management. In addition it was in a few cases evident that farm managers were at first loathe to describe their operation in detail until they learned that the investigator already possessed the tax roll information. The assurance that we were not present to modify this information for tax purposes usually paved the way for free discussion of the financial aspects of farm management. Only one operator refused flatly to discuss his farm, while three others are known to have misrepresented some aspects of their operation. On the other hand we came into possession of a quantity of information not divulged to the tax assessors or to other agencies involved in inventory, such as the National Wheat Commission (CNT).

The tax roll information is extremely detailed and contains data on the quantity of irrigation water used, the fields upon which it is placed, the number of trees, their age and species, the crops grown in the year of inventory, the fertilizer placed upon them and the yield, the number, type and age of animals, the specific names of pasture grasses and a complete list by type, age and value of farm machinery and farm buildings.

Once present on a farm we located the owner, or in his absence the manager or tenant. Only rarely did we fail to locate an informant. Questions were asked concerning the types, extent, and yield of crops being grown in 1970 and in other years which the informant could remember. Management problems, such as poor soils or adverse climatic conditions were discussed, and the respondent was usually keen to conduct the investigator around the farm pointing out items of interest. Soil samples were taken during these excursions when it was possible to obtain samples from fields of different qualities or of different uses through the history of the farm. Managers were asked as well about practices they had tried but discontinued.

The first hand information usually tallied well with that on the sheets we possessed in advance. A major divergence, however, appeared to be the failure of data concerning artificial fertilizers to turn up on the tax rolls. The yield figures in this data source were correct. We conclude that either fertilizer use has become more widespread in the last few years (most inventories were done from 1966 to 1968), or that, for some reason, the farm operators or tax assessors failed to enter this data. Since a tax roll yield entry was also an entry in the set of data on crops, in addition to the entry, or entries, for first hand information, some statistical faults may have developed because of this omission.

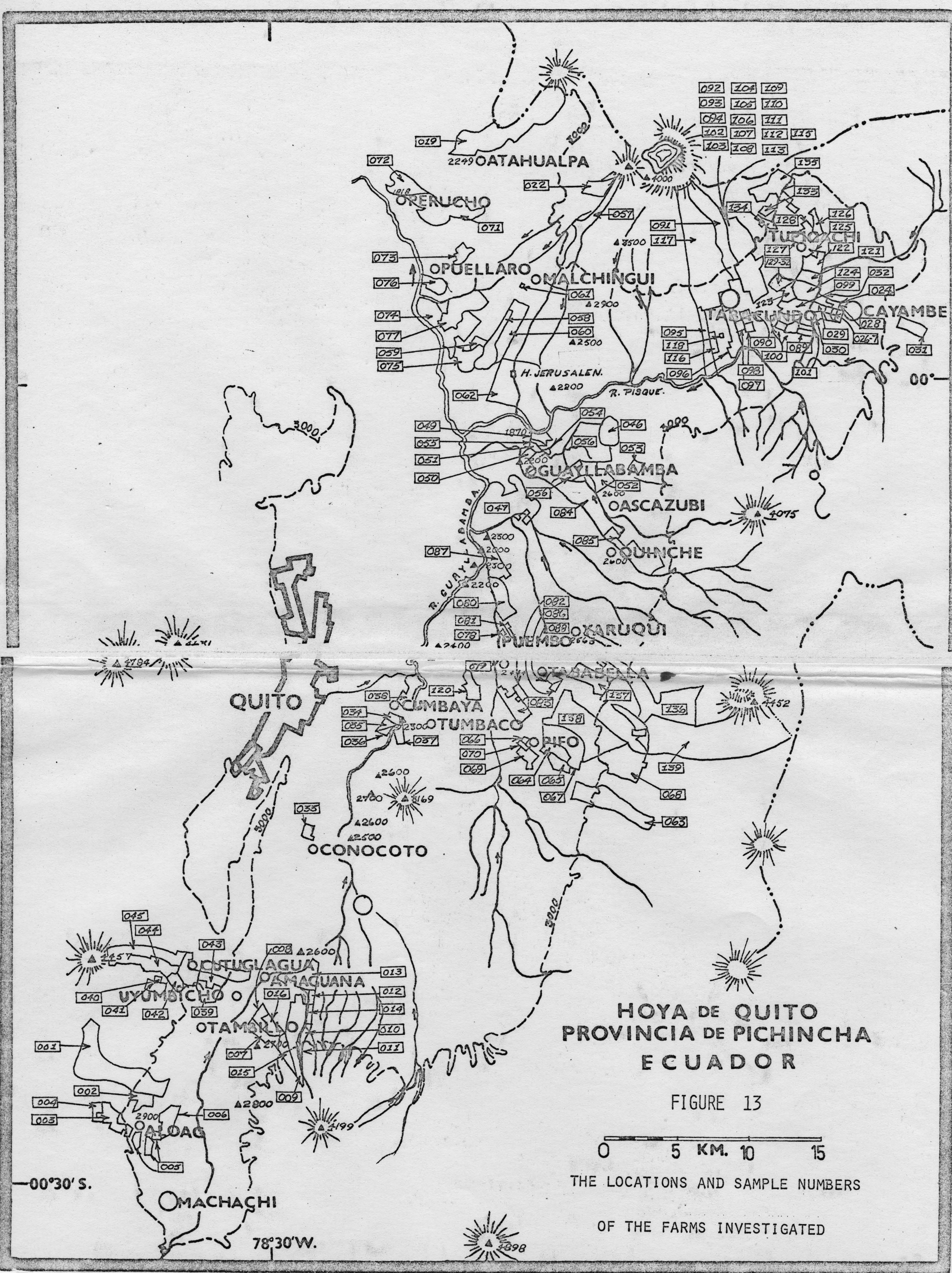
Approximately half the farms are represented by interviews. The remainder are unrepresented because of the following conditions:

1) Failure to locate a respondent on the farm at the time of the visit, or subsequently, if it was possible to return.
2) Failure to locate the farm due to a lack of roads, excessive consumption of time involved in looking for an isolated farm, inability of local informants to direct the investigator to the farm, or failure to find someone who knew even of the existence of the farm.
3) Knowledge that the farm, being part of a representative sample, had no economic use or

activity.

4) The disappearance of the cadastral unit by amalgamation or partition; in these cases we retained the data from an earlier year.

The farms in the sample may be located on the map (figure 13) which indicates the location, boundaries and sample numbers (001 to 139).



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 13

THE LOCATIONS AND SAMPLE NUMBERS

OF THE FARMS INVESTIGATED

DATA SET 1

The Activities, Land Use Capability and Investment on a Sample of 139 Farms

The farm was considered to be an important, slowly changing entity, which, it is assumed, will remain the managerial unit of agricultural activity for the foreseeable future. The farm is also the basis of tax assessment and as a data collection unit is difficult to avoid, since the tax rolls are usually fertile sources of agricultural information. In this study we have retained the farm as a data collection unit.

One hundred and thirty-nine management units were sampled. We call them farm management units because the cadastral farm is often not the management unit, some farms being subdivided on a long term arrangement with a number of tenants. These units amounted to 23841 hectares. It is difficult to assess the proportion of agricultural land in higher Pichincha we have investigated since the statistics provided by agencies extend to tropical and subtropical zones of the province not treated here. In addition, there is speculative planting in marginal zones, some of which is not considered officially to be agriculturally productive. It is probably safe to assume that the sample represents between five and ten per cent of the farm surface of the

Andean portion of the Province.

The sample was selected to represent varying levels of rainfall, types of farming practices, farm size, and general quality of the land base. 'Strings' of farms were used to obtain profiles of performance and land use across valleys or upon slopes.

The following data was available for these farms:

Variable 1

Farm Size: Farm size varied from small plots of one hectare (particulares) to an immense tract of 2824 hectares situated north of Atahualpa. The largest farm of which we have knowledge measures over 16000 hectares. The mean farm size was 200.84 hectares, the standard deviation being 483.91. The smaller plots have usually been split by land redistribution legislation from larger farms or have been purchased by their owners from savings. The distribution of sizes is interesting, the smaller examples tending to occur in clusters. The area immediately north-east of Quito is notable in this respect, as are the areas around Tabacundo and Atahualpa. The central irrigated portion of Guayllabamba is covered with small plots of fruit trees.

The larger farms (haciendas) are usually owned by absentee landlords who operate through a licenced manager, except in the case of dairy farm owners, who often reside on the farm.[1] At the extreme, one pair of elderly ladies in possession of a particularly dilapidated farm were resident in Paris. A few other owners lived in other Latin American countries but most were professional persons resident in Quito. Land is a desirable social and recreational asset and some of the younger professional people have purchased depressed farms with the intention of improving them. This trend is especially obvious around Puembo, a parish within commuting distance of Quito.

In detail, the farm size distribution is shown in table 1 .

Variables 2 to 9

Percent of Farm in Eight Classes of Land: These variables were the per cent of each farm in land of Classes VIII through I of the land classification scheme used by the National Office of Tax Evaluation and Cadastral Surveys (ONAC). This scheme, as described previously

[1]There are many Spanish words for farms or plots of land, (haciendas, particulares), the name usually indicating the form of tenure.

TABLE 1

TABLE OF DISTRIBUTION OF FARM SIZES
IN A SAMPLE OF 139
PICHINCHA PROVINCE

SIZE IN HECTARES*	NUMBER OF FARMS	% OF SAMPLE	ACCUMULATED %
20	36	25.9	25.9
40	21	15.1	41.0
60	22	15.8	56.8
80	4	2.9	59.7
100	3	2.1	61.9
140	7	5.0	66.9
180	6	4.4	71.2
220	9	6.5	77.7
260	6	4.4	82.0
300	4	2.9	84.9
Over 300	21	14.4	99.3
Total	139		99.28

* Example 1 to 20, 21 to 40, etc.

in Chapter I, evolved from the USDA eight-fold version. Within that discussion we criticized 'a priori' assumptions in the assignment of land use capability indices; the inclusion of these variables in this set of data is therefore intended as a partial test of these assumptions.

If we may assume that the agricultural land surface is a biogeographical reality, there should then be some correspondence between the type of land surface and the types and intensities of activities being pursued on that surface. As Garrison and Marble have postulated: "for every spatial location there is some jointly optimum intensity of land use, type of land use, and group of markets the selection of which by the agricultural entrepreneur leads to spatially ordered patterns of land use."[2]

Furthermore the ONAC data represents the work of eighty investigators over a four year period. We thought that some attempt should be made to integrate this bank of data into our study, if possible, to see whether the eight-fold distinctions as used in Ecuador have any mea-

[2] W. L. Garrison and D. F. Marble, "The Spatial Structure of Agricultural Activities", AAAG (June 1957), 137.

ning that could be expanded. Any new scheme which does not utilize this information would face a real practical disadvantage if it were accompanied by the recommendation that all this previous work be discarded. We suspect in fact that such a recommendation, however elegant the theory, would be rejected.

As to the accuracy of the data, the investigators, cartographers, and technical staff of the ONAC branch of the Ministry of Finance perform their duties in an objective and competent manner. While there are minor inconsistencies in the results, the data is regarded as highly reliable. We state this from personal knowledge.

The distribution of the means of per cent of the areas of the farms falling into Classes I to VIII[3] may be seen in table 2.

Note the heavy concentration in Classes II through IV, and the correspondingly high percentage of farms reporting some land in each of these classes. Smaller farms tend to be located on Class IV land or better. Table 3 is the result of a cross indexing analysis; this analysis computes the percentage of entries

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[3]Due to the weighting system invented for local conditions these classes should not be regarded as strictly comparable to the corresponding USDA class.

TABLE 2

DISTRIBUTION OF MEANS OF PER CENT OF LAND
IN EIGHT CLASSES OF CAPABILITY
(139 FARM UNITS)

CLASS	% MEAN	% FARMS POSSESSING SOME LAND IN CLASS
I	7.38	17.99
II	21.05	53.24
III	28.74	71.94
IV	12.33	53.96
V	9.24	48.20
VI	7.99	*
VII	8.17	*
VIII	4.23	*
Total	99.13	

*Not assessed

reporting within one category of one variable also reporting more than zero in any other given variable. The mean of the reported entries in the other variable is also supplied. It can be seen that the results in Class IV land are indefinite. However, while the percentage of farms reporting some Class III land remains between sixty and seventy per cent, the mean percentage of the area of the farm in Class III land declines as farm size increases. For Class II land, more farms per category report possessing some such land as farm size increases, but the mean declines from 80.92% to 30.36% of the farm as farm size increases.[4]

For illustration, plate 1 shows land in Classes IV, V, VI, and VII, generally decreasing in quality from the right to the left of the photograph; the majority of the flat area in plate 2 is Class III; plate 3 shows Class VII or VIII land; plate 5 exhibits flatter areas of Class IV and sloping land of Class V or VI; the area in plate 7 is Class VII.

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[4]It is this sort of trend which plays havoc with correlation techniques.

TABLE 3

CROSS INDEXING OF FARM SIZE BY LAND USE CAPABILITY CLASSES

FARM SIZE IN HA. (e.g. 1 - 20, 21 - 40, etc.)	NUMBER	% REPORTING SOME CLASS IV LAND	MEAN OF % OF CLASS IV LAND	% REPORTING SOME CLASS III LAND	MEAN OF % OF CLASS III LAND	% REPORTING SOME CLASS II LAND	MEAN OF % OF CLASS II LAND
20	36	11.11	27.50	63.89	72.74	36.11	80.92
40	21	57.14	34.50	66.67	45.93	47.62	63.80
60	22	45.45	33.90	68.18	39.29	63.64	30.36
80*	4	50.00	5.50	75.00	34.33	25.00	81.00

*The sample becomes small over 80 hectares.

Variable 10

Percentage of Farm Sown to Wheat: This and subsequent variables of the same type were included in an attempt to discover the zonal preferences of specific crops.[5] Fifty-four farms, or 38.85% of the sample reported growing some wheat. The distribution by percentage of the farm in wheat follows in table 4.

TABLE 4

PER CENT OF FARM SOWN IN WHEAT

% OF FARM*	NUMBER	% OF SAMPLE	ACCUMULATED %	MEAN SIZE OF FARM
10	11	20.37	20.37	412.18
20	17	31.48	51.85	68.24
30	13	24.07	75.93	156.31
40	6	11.11	87.04	55.67
50	2	3.70	90.74	N/A
(60 to 90 comprise a negligible sample)				N/A
90 to 100	3	5.56	96.30	N/A

*Example 1 to 10, 11 to 20, etc.

[5]It should be stressed that data entries are in the form of percentage of the farm area. Thus references to zonality are in fact references to zonal specialization. The constant and burdensome repetition of the phrase "as percentage of farm area" is henceforth often omitted after this caution.

The lack of specialization is apparent. The column for farm size is included to illustrate the typically erratic fluctuation of one variable against another.

Variable 11

Percentage of Farm Sown to Corn: The subjects reporting some corn production, (76), comprised 54.68% of the sample. Table 5 shows the distribution.

Again there is no marked specialization, and no clear relationship with farm size is noticed, this latter entry being given only as an indication as to the sort of variation experienced with this type of data.

Variable 12

Percentage of Farm Sown to Barley: Only thirty-three farms, or 23.74% of the sample, report barley production. Seventy-six per cent of those reporting planted less than thirty per cent of the farm in barley; a table is not offered for this crop.

Wheat, corn, and barley are staple food grains; much of the barley goes into ale. These crops occupied (means) 9.91%, 15.55%, and 5.15% of the sample area, for a total mean of 30.61%.

TABLE 5

PER CENT OF FARM SOWN IN CORN

% OF FARM*	NUMBER	% OF SAMPLE	ACCUMULATED %	MEAN SIZE OF FARM
10	29	38.16	38.16	409.24
20	20	26.32	64.47	81.25
30	5	6.58	71.05	61.40
40	5	6.58	77.63	122.00
50	0	--	--	--
60	4	5.26	82.89	29.50
70	0	--	--	--
80	1	1.32	84.21	41.00
90	2	2.63	86.84	12.50
100	10	13.16	100.00	10.00

*Example 1 to 10, 11 to 20, etc.

Other annual crops comprised a mean of 6.72% of the area of the sample; the mean total percentage in all annual crops was 37.33%. The types of crop encountered have been mentioned before, and it is clear that their extent in this sample is not great.

Variable 13

Total Percentage of Land in Annual Crops: One hundred and eighteen subjects, or 84.89% of the sample grew some form of an annual crop.

TABLE 6

PERCENTAGE OF FARM SOWN TO ALL ANNUAL CROPS

% OF FARM*	NUMBER	% OF SAMPLE	ACCUMULATED %	MEAN SIZE OF FARM
10	27	22.88	22.88	343.26
20	17	14.41	37.29	282.12
30	13	11.02	48.31	154.38
40	9	7.63	55.93	224.44
50	6	5.08	61.02	227.00
60	6	5.08	66.10	72.67
70	5	4.24	70.34	119.60
80	9	7.63	77.97	94.44
90	7	5.93	83.90	33.71
100	19	16.10	100.00	**

*Example 1 to 10, 11 to 20, etc.

**Not avaiLABLE

We have noted no specialization in the individual crops; the addition of all annual crops together indicates that while a sizeable number of farms have placed up to half their area in annual crops, the most noticeable concentration is below forty per cent of the area, indicating that mixed farm activity is very common.

Variable 14

Percentage of Land in Artificial Pasture: Artificial pasture is usually composed of alfalfa, a "rye gras",[6] blue grass ("pasto azul"), "holco", (or "olco"), a native grass susceptible to improvement, or a number of lesser varieties. Any combination of the above may be planted, and there is no distinct division between artificial and natural pasture. Sometimes "natural" grass varieties are irrigated and improved to the point that they may be considered artificial pasture. On the other hand, artificial pasture past its prime or gone wild (naturally seeding) may be assessed as natural pasture. A general rule is whether the farmer uses the artificial pasture as part of a rotation, removing it when depleted, or whether it is irrigated, artificially fertilized or otherwise treated differently from natural pasture. There were no figures available for the weight

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[6]"Rye gras" is Spanish idiomatic; it is not determined whether this grass is indigenous wild rye, im-

of cut feed removed. Two farms only placed fertilizer on pasture.[7]

Seventy-six farms, or 54.68% of the sample possessed some artificial pasture, and the distribution is shown in table 7. This table does not illustrate the strong concentration in the lower levels which was shown in each of the crop tables. There is an indication that farms with a high percentage of artificial pasture specialize in that type of pasture to the exclusion of the natural form. Reference to table 10 appearing later in the text will show that thirty-one farms possessing pasture use the artificial type only; natural pasture exclusively is kept by only thirteen farms.

Variable 15

Percent of Farm in Natural Pasture: Natural pasture usually occupies the upper slopes, but may be the sole type of cover on farms with few animals or a low intensity of operations. Varieties include a host of na-

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ported wild rye, or whether it bears a relationship to grain rye.

[7]The investigator was asked what would happen if this were done, and was asked other questions which showed the operators to be intelligent and concerned. Such information is not distributed in printed form and many persons were unaware of the existence of advisors who would supply it. A substantial improvement in extension services is necessary. Usually, those who avail themselves of this service are those who do not most need it.

TABLE 7

PER CENT OF FARM IN ARTIFICIAL PASTURE

% OF FARM*	NUMBER	% OF SAMPLE	ACCUMULATED %	% IN CATEGORY REPORTING SOME NATURAL PASTURE	% MEAN IN NATURAL PASTURE OF THOSE REPORTING
10	15	19.74	19.74	80.00	27.33
20	9	11.84	31.58	44.44	43.00
30	6	7.89	39.47	66.67	38.25
40	8	10.53	50.00	100.00	16.37
50	3	3.95	53.95	33.33	11.00
60	12	15.79	69.74	75.00	21.11
70	1	1.32	71.05	0	-
80	6	7.89	78.95	16.67	10.00
90	6	7.89	86.84	0	-
100	10	13.16	100.00	0	-

*Example 1 to 10, 11 to 20, etc.

TABLE 8

PER CENT OF FARM IN NATURAL PASTURE

% OF FARM**	NUMBER	% OF SAMPLE	ACCUMULATED %	% REPORTING ARTIFICIAL PASTURE	% MEAN OF ARTIFICIAL PASTURE
10	10	17.24	17.24	80.00	31.12
20	15	25.86	43.10	73.33	36.91
30	10	17.24	60.30	70.00	24.29
40	7	12.07	72.41	100.00	29.71
50	4	6.90	79.31	50.00	15.50
60	5	8.62	87.93	40.00	20.50
70	2*	3.45	91.38	*	*
80	1*	1.72	93.10	*	*
90	2*	3.45	96.45	*	*
100	2*	3.45	100.00	*	*

*Small sample.

**Example 1 to 10, 11 to 20, etc.

tive grasses or degraded naturally seeded artificial pasture. Often the dry cows are sent up to the natural pasture until they again produce milk. Plates 3 and 4 show such pasture. Plate 8 shows natural pasture on previously arable land.

Fifty-eight farms reported some natural pasture, or 41.73% of the sample. Table 8 will show the distribution in this sample and the correspondence with artificial pasture.

It is clear that few farms specialize in natural pasture.

Variable 16

Total Per Cent of Farm in Pasture: This variable arises from the addition of the previous two variables. Ninety-five subjects, or 68.35% of the sample possess some pasture. The distribution is interesting and may be seen in table 9.

This table shows no concentrations similar to those evident in the lower ranges of the tables concerning crops, but the upper ranges are notable, 32.11% of the sample reporting more than seventy per cent of the farm in some form of pasture.

PLATE 8

NATURAL PASTURE IN A EUCALYPTUS GROVE, URCU HACIENDA, MALCHINGUI. THIS SLOPING LAND WAS PREVIOUSLY PLANTED IN CROPS UNTIL THE SOIL WAS REDUCED TO TWENTY CENTIMETRES, YIELDING FIVE QUINTALS OF WHEAT PER HECTARE. THE BETTER PART OF THE HACIENDA IS NOW IN PYRETHRUM, BUT WIND VELOCITIES ARE SUCH THAT THE FLOWERS ARE BLOWN OFF.

TABLE 9

PERCENTAGE OF FARMS IN ALL TYPES OF PASTURE

% OF FARM*	NUMBER	% OF SAMPLE	ACCUMULATED %
10	7	7.37	7.37
20	10	10.53	17.89
30	9	9.47	27.37
40	5	5.26	32.63
50	10	10.53	43.16
60	10	10.53	53.68
70	4	4.21	57.89
80	16	16.84	74.74
90	10	10.53	85.26
100	14	14.74	100.00

*Example 1 to 10, 11 to 20, etc.

Variable 17

This is the percentage of land missed by the assessors; in fallow land, or land used for paddocks or buildings.

Variable 18

Percentage of Land Unusable for Any Economic Pursuit: This land is referred to as "chaparros" or "rastrojos" and is usually equated with Class VII and VIII. Land with no soil, excessively steep land, at elevations over 3600 metres, and stream gullies fall into this category. As can be seen from the map of sample farms (figure 16) many of the larger farms are located radially on mountain slopes. This custom, analagous to the elongated farms of Quebec, has meant that farm boundaries usually follow the bottom of quebradas. Each owner gets a share of a number of land types, but little conservation is practiced on the precipitous edges of the farms. Only two farms visited (Haciendas Mojanda and Picalqui in Tabacundo) had planted trees in the quebradas. The latter hacienda had been operated by American missionaries on a more or less model basis and had achieved significant micro-climatic benefits in comparison with its neighbors, partly as a result of the tree planting.

Seventy-one farms or 51.08% of the sample possessed some such land, a heavy concentration occurring at the lower percentages. Seventy-nine per cent of the farms possessed less than fifty per cent of their area in such land, 51.95% reporting less than thirty per cent. One-third (32.39%) of the farms reporting possessed less than ten per cent of the farm area as useless land.

Variable 19

Investment in Machinery: Machinery investment is extremely variable, with only 46.76% of the sample, or sixty-five subjects, possessing other than hand tools. One thousand sucres are equal, approximately, to American $200.00; the highest value of machinery found was 800,000 sucres. Forty-four of the subjects, or 67.69% of the sample reported less than 80000 sucres of machinery.

A mere handful of farms could be called highly mechanized; these are specializing in dairying, wheat, or barley. The types of machinery are similar to those on North American farms with a few exceptions. Several farms in the driest areas possess portable pumps which attach to the drive shaft of tractors. Water is pumped through light weight portable pipes to irrigation nozzles. A crew of two or three men keep moving this assembly day by day. This procedure is necessary on extremely porous sandy soils where conventional channel irrigation would be useless. One farm to the northwest of Quinche grows barley on pure sand using heavy applications of fertilizer and piped water. On our accounting the yields are not economic. This is in fact a form of hydroponic farming.

Loose, structureless, sandy soils may require special, more expensive tractors with four wheel drive and oversized tires since these sands are too loose to support conventional machinery. The heavier water-logged soils may require deep ploughing especially after several years of pasture. Powerful tractors and special ploughs are used. On some farms near Cayambe the Indian ridge and furrow patterns still function and are now being drained and levelled.

The value of farm machinery as entered into the data includes a correction for the age of the machinery, that is, the theoretical retail value at the time of assessment is listed. No breakdown was made by machinery type. All farms that possessed machinery possessed a tractor of one sort or another, and an assortment of plough attachments suited to local conditions.

Variable 20

Square Metres of Buildings: Again some farms possessed no structures; a substantial number had a house only while some exhibited very heavy investment in buildings. The greatest density of building occurred on two farms producing eggs and chickens. Otherwise, large floor spaces occurred on dairy farms where milking sheds, feed storage sheds and machinery storage areas accounted for most of the construction. The very intensively operated grain farms also possessed large amounts, some of recent metal construction requiring low upkeep.

The amount of building on a farm may be an inaccurate measure of any other economically important feature due to the fact that a very large portion of the roofed area may have been constructed in an era when labor and materials were cheaper and the farms more prosperous. Some farms could not afford to reconstruct all their buildings under present economic conditions and many buildings, especially at the higher altitudes, have been abandoned.[8] The oldest known structure in continuing use which figured in this study is over 200 years old.

The habit of constructing buildings of adobe and wattle, or rammed earth, consumes substantial quantities of soil. Each roofed area ten metres square removes soil from one hundred square metres of ground. This method of building is most common on the poorer farms which can least afford the loss; the larger farms have recently adopted modular trussed structures, or other more modern forms of construction.

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[8]The colour frontspiece includes a complex of such disused buildings.

Variable 21

Number of Animal Units on the Farm: We did not take advantage of any recognized formula for calculating this measure. It was thought that the extensive variety of blood lines, with the accompanying extreme variation in animal quality and size were confusing factors. A simple index only was used. The cow was used as one unit; two calves were assumed to equal one cow. Sheep were rarely encountered but were placed at 0.20 units each, as were hogs. Mature or growing bulls and heifers were assumed to equal one unit, as were horses. Mules were set at 0.70 units.

Variable 22

Number of Hectares of Pasture Supporting One Animal Unit: These entries were determined by dividing the total amount of pasture by the number of animal units on the farm. This is a very crude measure and it varies widely. The carrying capacity of pasture is extremely variable and it is difficult to estimate representative levels for several reasons:

1) Unirrigated pasture is susceptible to drought and failing pasture of low quality may force the sale of the whole herd.
2) There is a tendency to overgraze pasture. Conscientious farmers may report the same ca-

pacity per unit of area as a careless respondent with poorer pasture, if one happens to interview the former during a poor season.

3) Few respondents on the larger and better operations are up to full capacity and many operators have only a vague idea of the ultimate capacity of their pastures.

4) Most farms contain at least two grades of pasture, as tables 7 and 8 show. It is difficult to split the types by capacity and variation is extreme. The Ministry of Agriculture has recently started a well controlled test farm near Machachi and present estimates indicate an improvement in the order of one hundred per cent in pasture capacity and milk yield. It remains to be seen whether the marginal returns warrant the investment.

In addition to using the many grades of pasture, the animals are allowed to roam through the stubble of crops. Corn stubble provides a substantial quantity of food when badly needed in the dry period of the year, and varieties of corn used specifically for animal feed are commonly planted.

Table 10 demonstrates the difficulty with this data. The entries originate in farms possessing only one type of pasture, artificial or natural. While the figures may not represent the capacity of the pasture, they do demonstrate the extreme range at which pasture is actually being used. The data was entered as hectares necessary to support an animal unit because some researchers prefer not to divide the latter, and the hectare, being a divisible unit is usable in statistical budgeting techniques.

A few are far under capacity, but in general present levels of investment and technology would allow at best three animals per hectare. Usually paramo grasslands will support .33 animals per hectare per year. Note that although the means differ, a similar range is displayed by each column. It appears that the capacity of artificial pasture is twice that of natural under present intensities of management.

5) Many farms have converted to cattle raising because labour is not reliably available for other pursuits. The recent legal abolition of feudal

TABLE 10

A LIST OF THE DATA ENTRIES
FOR THE NUMBER OF HECTARES USED BY ONE ANIMAL UNIT
ON FARMS POSSESSING ONLY ONE TYPE OF PASTURE

ARTIFICIAL PASTURE		NATURAL PASTURE
.45	2.00	.78
.34	.54	.69
.56	.82	3.36
3.70	.76	.69
.66	.55	.36
1.07	.63	1.57
.91	.48	.36
1.00	.21	.90
.29	.44	6.47
.52	1.09	.51
.45	.78	1.16
.75	.34	2.27
.28	.62	3.00
.30	.42	
.13	.20	
	1.75	
Mean = 0.74		Mean = 1.70 (Excluding entry at 6.47 : 1.30)

> tenancy[9] has caused many labourers who were formerly bound to a hacienda, to work only enough to buy necessities. Labour may be unavailable at harvest time. In some places a three day work week has ensued (Tuesday to Thursday) because of the weekend festivities. Sometimes the work is of such low quality as to be useless. Consequently, some farms are now in pasture at a low intensity under the direction of a licenced manager and a few reliable resident workers. Such conditions do not give a good indication of pasture capacity.

Cattle operations in the Sierra may be regarded synonymously with dairy operations. Our original interview pattern included questions about meat production, but we soon found that such production in pounds per year equalled the weight of the herd divided by twelve, or the average age at which a typical cow ceases to give milk. This situation will

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[9]The most recent development in a series of laws is printed with the full text in: "Expedida Nueva Ley Que Favorece a Reforma Agraria", El Comercio (Quito: September 2, 1970), 1.

change as herds of better blood are built up and as markets assume a more sophisticated taste. In addition, beef of good quality originates in quantity from the western lowlands, and it is evident that meat sales in the Sierra are confined in part to surplus animals because of a failure to compete with this source. At present the local cattle, criollos, are crossed with Holstein which is not regarded as a meat animal of quality in other markets. There are a very few Swiss Browns.

Variable 23

Per Cent of Farm Irrigated: Irrigation water is captured on mountain slopes higher than the farming area to which it is directed and carried by ditches. Some channels are concrete - most trunk channels are of this type - and others are ditches dug in the ground. The water will travel several kilometres in these ditches without appreciable loss due to the rock-like character of the subsoil (cangahua). Until recently most of these works were cooperative and local in nature, but two canals of substantial size now exist operated by the government agency in charge of hydrological resources (INERHI). The Pisque canal runs along the southern side of the Pisque

River and another canal follows the eastern flank of the valley at about 3000 metres, passing close to Yaruqui, Quinche, and Ascazubi.

The trunk canals are tapped at intervals and a web of channels run to the farms where the farmer uses his manual labour to direct the water to the fields where it is needed. Timetables are assigned and each farmer breaches the local canal on the appointed day and allows the water to run according to the time he is allotted. The time is calculated by the farm size, the total yearly flow of water amounting on average to one litre per second per hectare. Because the water does not flow all the time[10] the fields sometime receive deluges of water which cannot all be assimilated. Plate 9 shows a barley field near Puembo receiving its weekly dousing. This field possesses less than thirty centimetres of top soil and the picture clearly shows much of this disappearing, along with the crop seedlings (barley). Most irrigated fields receive

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[10] Some farms tap springs on the property and are able to regulate the flow to requirements. The amount of water so used is unknown.

an equivalent yearly rainfall of 4000 millimetres, if the rate of irrigation is converted to rainfall. Very little of this water can be used, according to our observations; the empirical calculation of rainfall equivalents is problematical,[11] and the used amount of irrigation water may not be a quantity which can be identified even under experamentally controlled circumstances. We shall later describe some negative correlations associated for economic reasons with this type of irrigating practice.

Irrigation water is paid for in taxes at the rate of 1000 sucres per litre second per year; this cost was included in the crop costing studies described later.

Variable 24

Thousands of Sucres of Machinery per Hectare: This is self-explanatory, being derived from dividing the amount of investment in machinery by the size of the farm.

Variable 25

Square Metres of Buildings per Hectare: As in variable

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[11] C. W. Rose, Agricultural Physics (Oxford: Pergamon, 1966), 178, 179.

24, this figure comes from the division of the number of square metres of building by the size of the farm.

Variables 26 to 29

Rainfall by Quarters of the Year: Rainfall figures for years 1962 to 1970 were available month by month; the figures entered here are the means for each quarter for each farm entry. Where rainfall varied widely over the surface of one farm the values falling on the arable cropping part of the farm were entered. No correction was made in this set of data for the use of irrigation water.

While division of the year strictly into quarters may entail some approximation, we may consider that the sowing of grain crops usually occurs in the first quarter, growth in the second quarter, and harvesting in the third quarter, which is typically a marked dry season.

Variable 30

Mean Annual Rainfall: This is self-explanatory, the years averaged being 1962 to 1969.

Variable 31

Mean Number of Days per Year on Which Some Rain Fell: This figure is derived from figure 8 above which shows the mean days on which some rain fell, 1962 to 1969. As men-

PLATE 9

IRRIGATION OF BARLEY SEEDLINGS NEAR PUEMBO. BECAUSE IRRIGATION WATER ARRIVES IN WEEKLY ALLOTMENTS, THIS FIELD IS BEING ERODED, AND MOST OF THE WATER IS RUNNING INTO A RIVER.

tioned before, this is a very variable quantity across the surface of the research area.

DATA SET 2

The Yield of Three Crops for Various Years Under a Number of Conditions

Crop and Yield Data

This set of data, composed of three hundred and fifty-six entries, concerned the performance of wheat, corn, and barley crops from the farms in the sample under the local conditions of climate and varying conditions of fertilizer application, soil depth, and slope.

The variables in this set were as follows:

Variable 1

Land Use Capability Class: This is the class of land as determined by the tax office. This ranged from Class I to Class VI, the mean being more or less 3.00 depending on the crop. The standard deviation was 1.00 or less. This low standard deviation underlines our previous observation that one or a very few classes of land may contain the whole set of a certain activity.

For each of wheat, corn, and barley, the following set of information was entered. All of these quantities are on a hectare basis.

Variable 2

Quintals of Seed: Usually two quintals of wheat and barley seed are placed per hectare, and from .5 to 1 quintal of corn seed.

The use of improved or registered grades of seed purchased from the National Wheat Commission is not widespread. These varieties are used by farms already receiving good yields, although some farmers are replacing fertilizer inputs by the use of higher yielding seed. The greatest caution must be used with these substitute inputs. Full account must be taken of their anticipated effects. The conversion of soil matter to plant matter may be speeded up by the introduction of varieties which possess improved genetic capacity to accomplish this conversion. But these plants do not possess the ability to make more plant matter from the same amount of soil nutrient utilized by their ancestors. Just as matter may not be destroyed, it may also not be created. These varieties extract nutrients at a greater rate from the soil and should be placed only on very good soils or on soil which is enriched by other inputs.

Variable 3

Yield per Hectare: This variable has a great range from zero in all three crops to two hundred quintals for wheat and barley and two hundred and fifty quintals for corn. Farmers were asked what yields they achieved in recent years and such questions as: "What yield do you get when no fertilizer is applied?", "Do you have good fields and bad fields?", and so on. In this manner a number of entries could be made for each farm, changing the entries year by year and practice by practice in order to isolate some determinants.

Variable 4

Seed/Yield Ratio: Yields are expressed in local parlance as the seed to yield ratio, or vice versa as one wishes to state it. This measure was inserted because all the yield data originated in this form and it is possible that the sensitivity of this measure differs from that of the previous variable.

Variables 5, 6, and 7

Kilograms of N, P, and K Laid Down per Hectare: Application of fertilizer does not follow any recognizable pattern, no regional preferences being noted, nor any tendency to the restriction of fertilizer to use on poor soils or better ones. The very poorest of farmers cannot afford it; the more prosperous may ignore the need for its use. The 10-30-10 compound is ubiquitous and is thrown on the fields regardless of the needs of the soil. The effect is hard to determine - it may not noticeably increase yields but it appears that the omission of the material, especially on poorer soils, greatly increases the opportunity for crop failure. It is possible that some farmers omitted to inform the assessors that they used fertilizer. This may be intentional and we suspect that the declaration of fertilizer use was expected by the farmers to indicate to the assessors a higher degree of prosperity than the operators were willing to admit, the price of the item being high by local standards. Only a half dozen or so farms out of the sample of one hundred and thirty-nine used anything but a stock compound; 10-30-10, 10-40-10, or 10-20-10, in order of preference. Two farms used superphosphate, one used urea and one used raw sewage from the outfall of the sanitary system of the city of Quito. Only three farms used more than four quintals per hectare, one being the previously mentioned farm located on sand near Quinche[12] where eight quintals of 10-40-10 was applied to alfalfa in two quintal lots four times a year. This procedure did not produce an economic yield. Wheat and barley receive five quintals of 10-40-10 on this farm when sown. Only one farm used a non-stock fertilizer - a mixed farm also near Quinche, which applied four quintals of 18-46-0 per hectare to wheat.

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[12] Sample number 084.

The distribution of fertilizer intensities for wheat is shown in table 11 along with the mean yield for the category and the means of two income measures.

Wheat is the most heavily and regularly fertilized crop. Out of a sample of one hundred and thirty-eight entries for corn, only fourty-six subjects, or 33% show any application of fertilizer, and 76.09% of these applied less than one hundred kilograms per hectare. This is the equivalent of only two quintals of 10-30-10.

Usually the fertilizer is applied to wheat or barley and the following crop in rotation is left to feed on the residue. The assumption that a residue exists may be unfounded[13,14] as no effects have been noticed under experimental conditions. Phosphates may be fixed by iron and aluminum compounds[15] which are com-

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[13]Ing. Gonzalo Luzuriaga and Ing. Washington Bejarano, "Colaboracion con el Programa Latinoamericana de Unificacion de Metodos de Analysis de Suelos", (Quito: Inst. Nac. de Invest. Agro., 1965), 4.

[14]Informe Suelos, 1963, 14.

[15]Brown et al., 175.

TABLE 11

TOTAL KILOGRAM APPLICATION OF FERTILIZER TO WHEAT
IN A SAMPLE OF 120 TAKEN FOR THE YEARS 1966 TO 1970[1]

N+P+K[2] IN KG	NUMBER	% OF THOSE APPLYING FERTILIZER	ACCUMULATED %	MEAN YIELD QU/HA	NET RETURN IN SUCRES/ HECTARE	% RETURN ON INVESTMENT
48 to 83	5	6.25	6.25	18.00	204.89	25.87
84 to 118	26	32.50	38.75	23.56	696.70	41.66
119 to 153	18	22.50	61.25	33.35	1109.87	53.44
154 to 189	1	1.25	62.50	-	-	-
190 to 224	11	13.75	76.25	35.55	1684.44	62.43
225 to 259	10	12.50	88.75	31.32	*	33.56
260 to 295	-	-	-	-	-	-
296 to 330	4	3.33	92.08	55.50	3053.93	106.52

[1] 66.67% of the sample of 120 applied some fertilizer.

[2] Example 10-30-10 x 1 quintal = 50.

*Not available.

Continued...

TABLE 11 (CONTINUED)

N+P+K IN KG	NUMBER	% OF THOSE APPLYING FERTILIZER	ACCUMULATED %	MEAN YIELD QU/HA	NET RETURN IN SUCRES/ HECTARE	% RETURN ON INVESTMENT
331 to 366	4	3.33	95.41	36.00	1585.00	63.64
366 to 401	1	1.25	96.66	70.00	3770.00	95.93
Over 401 sample is small.						

mon,[16] or be immobilized by competing free hydrogen ions in the typically acid soils. In addition, phosphates may not create sustained yields[17] in the face of other deficiencies, especially if humic or organic substances are absent.[18] It was not common to find visible trace element deficiencies in crops studied, perhaps because these deficiencies were the least of the problems the plants faced. However, most of the fruit trees in the vicinity of Guayllabamba suffered from marked nitrogen deficiency, and plate 10 shows a young fruit tree near Puembo suffering from exaggerated symptoms of trace element deficiencies. The trees on the adjacent property were 2.5 metres high (vs. one metre) and flowering at the same age. Those trees received dosages of 10-30-10. We can speculate that the fertilizer contains trace elements (by design or accident), or that it mobilizes these elements in the soil.

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[16] Miller and Coleman, 241.

[17] Piggott, 215.

[18] E. Walter Russell, Soil Conditions and Plant Growth (9th ed., London: Longmans, 1961), 654.

PLATE 10

PHOTOGRAPH OF A YOUNG (1 M.) FRUIT TREE IN SHALLOW EXHAUSTED SOIL NEAR PUEMBO. THE SOIL IS DEFICIENT IN NITROGEN AND TRACE ELEMENTS, ESPECIALLY COPPER, WHICH DEFICIENCY CAUSES THE NOTCHING AND WARPING OF THE LEAVES. THE FARMER REQUESTED INFORMATION AS TO THE BENEFITS OF FERTILIZING TREES; SUCH INFORMATION, IF AVAILABLE, APPARENTLY DOES NOT REACH FARMERS.

All soils in the research area are poor in phosphorous[19] and all soils with less than 0.1 eq. mg. per one hundred grams of soil respond to phosphate application. Sodium levels may be naturally high.[20] Response to sodium occurred in soils with less than 0.1 eq. mg. per one hundred grams of soil, but the improvement in the soils in the upper ranges was erratic. Soils containing less than 0.4% N (total) give a yield response to nitrogen application with no confusion at increasing levels. Potassium application is needed if a reading less than 0.25 eq. mg. per one hundred grams of soil is found, but once this is raised to 0.45 some correlative effect enters and other elements are needed in combination. The best reaction to all elements is found in soils at neutral pH; there may be a level of acidity at which wheat production becomes marginal.[21] This economic effect may not be due to the acidity per se, the acidity being an indication only of soil exhaustion and the departure of exchangeable

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[19]Kupper et al., 7 and for much of what follows.

[20]Miller and Coleman, 241.

[21]Kupper et al., 17-18.

bases.

The foregoing has been offered not to recommend any specific type of application but to show that fertilizer use is erratic, and that the optimum types and dosages are not known for field application. The three agricultural research stations are located on the best land possessing desirable soil structure, depth, and fertility. The abstraction of meaningful relationships from this data will be difficult.

To conclude the description of artificial fertilizer application, we point out the existence of an aggravating occurrence - the propensity of the fertilizer to remain as undissolved pellets on the soil. Many farmers find that there may be too little rain to dissolve the fertilizer. A routine application to a small five hectare farm takes the wages a man makes in one month. The main research station claims that the domestic (cheaper) brands of fertilizer dissolve as readily as the foreign brands, but the conditions of use on farms are apparently not the same as research conditions.[22]

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[22] The research station is located in a region of adequate rainfall where differences in rates of dissolution may be minimal.

Several farmers interviewed treat the local brand with contempt and have reverted to a European product.

Variable 8

Growth Period of the Crop: This entry proved to be relatively worthless because of the impossibility of showing statistically an entry which did not grow at all. A good crop of wheat may take four or five months to grow, a poorer one six months, and a very good one seven months. While there seems to be some intuitive relationship between growth period and crop quality or the number of possible crops per year, in most cases only one crop is possible, and the period of growth is of little importance.

Variable 9

Soil Depth: The lower boundary of the soil is usually readily apparent, being a rock like surface of indurated material or the commencement of the volcanic parent material. In the former case the boundary is a limiting factor which will limit root penetration and impart undesirable hydraulic qualities to the soil, (limiting upward percolation and lowering the field capacity). Shallow soils are more common in the central drier part of the valley, and on the mild slopes at the valley edge.

It is apparent that these soils are degraded forms of earlier deeper soils, and that some of the soils on the valley flanks are degraded andosols showing a superficial resemblance to 'Brunizems'.

Soil under twenty centimetres in depth has little economic use;[23] respectable yields are obtained from soils between twenty centimetres and fourty centimetres in depth. Farmers indicate that yield increases with soil depth from ten centimetres to fourty centimetres with little change at greater depths than fourty centimetres. Degradation is a very rapid process, some soils having been destroyed in the last two decades only. Fossil fields are evident, for example, on aerial photographs of the parish of Malchingui and eastward across the Pisque plateau.[24] Land redistribution has given many peasants land but the lack of capital grants or loans to preserve yields and to conserve the land surface has caused the destruction of good land in a period of five

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[23]See plate 8 .

[24]The zone around Alausi and Chunchi in the south central part of the country has become denuded and unproductive in the last ten years.

to ten years.

Crops on shallow soils are the first to suffer during drought, and the variation inside fields may be substantial, the plants on the shallowest parts perishing first.

Some soils may benefit from deep ploughing. Constant hand cultivation has turned over only the upper twenty-five centimetres of some soils, under which layer still exists the remainder of the andosol as a black band laying upon cangahua.

Variable 10

Index of Structure: In view of the wide range of soil structure conditions, this five-point index was used to rate soil structure in terms of the magnitude of management problems attributable to structure. Soils with no restrictions received five points and those with severe limitations one point. The worst soils could be too hard, possess very chunky peds, or be extremely soft to the point of being unable to support machinery. While this procedure may seem objectionably simple, our opinion is that a crude measure should give some gross indication.

Variable 11

Months Soil Untillable: This variable indicates the number of months that the soil cannot be moved by hand cultivation methods because it is too dry and hard or too wet and heavy. The use of machinery is often not an alternative because hard dry soil may blow away as the tractor passes over; some tractor operators wear masks to avoid partially the discomfort of working in such conditions.

Variable 12

Altitude: Altitude is locally regarded as an important control on activities. In general, better yields are obtained on the higher fields, but these yields may be limited by criteria such as slope, increased wind velocities and rainfall intensities high enough to wash away seed. The sloping higher land was more recently put in crops, as the intensity of activities at the upper periphery of the valley has been developed in very recent times. These higher soils may possess higher natural levels of fertility than the longer cultivated soils at lower altitudes.

Variable 13

<u>Net Return in Sucres per Hectare</u>: This figure is the result of the following formula:

$$R = G-(Cs+(((N+P+K)x2.40)xF)+Pr+Cu+(Yx15)+180+(Wi+Wis)+Ad)$$

Where G = the yield x market price of crop

Cs = cost of seed[25]

(N+P+K)x2.40 = kilogram unit cost of fertilizer in sucres

F = kilograms of fertilizer applied

Pr = cost of preparing land

Cu = cost of weeding and tilling

Y = yield; fifteen sucres equal labour cost of cutting one quintal

180 = land taxes per hectare in sucres. (Based on the taxes applying to the mean land class)

Wi = cost of irrigation water (1000 sucres/litre second/year)

Wis = cost of breaching and closing dikes per year

Ad = fifty sucres bookkeeping and administration expense per hectare.

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[25]The cost of seed is calculated into every entry regardless of whether seed is purchased or held over from a previous crop; the held over seed penalizes the farmer by his failure to sell it.

In the realization that some small farmers do not pay themselves administration expenses, the cost of Wis and Ad was made optional. Many farmers may not pay some or all of these items, if for instance they hold over seed from the previous year. Some farms do not pay workers as much as allowed here; some pay more. We assume that with the removal of feudal tenure in 1970 a scarcity of labour will result at times of peak demand and, if anything, our costs are too low for accounting in the future. The liberation of labour will cause many operations to recognize their uneconomic status.

Variable 14

Percentage Return on Investment: This variable was computed by dividing the cost into the net return and multiplying by one hundred. In some planning applications this measure is regarded as a more sensitive indicator of income return than net monetary return.

Variables 15 to 29

These are rainfall variables and rainfall equivalent with the addition of irrigation water. The data was entered in quarters (eight variables) for the year of planting;[26] the rainfall and rainfall equivalent (two

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[26]The years of planting ranged from 1964 to 1970. The largest samples were from 1966, 1967 and 1970.

variables) for the year; the mean rainfall and mean rainfall equivalent over nine years (two variables); the number of days rain in the year of planting and the mean days of rain over nine years (two variables); and the annual amount of irrigation. All these items have been discussed previously and no elaboration is offered. The mean rates were included because it was postulated that there might be a higher correlation between yield and the mean, the mean being possibly responsible for some stable soil phenomenon which varies 'pari passu' over the whole sample independent of yearly variation of rainfall.

DATA SET 3

Percentage Distribution of Land Use Capability Classes By Parish

Data was available for the distribution of land classes by parish in the study area. The figures arise only from the farms which, to date, have been assessed in the various parishes and consequently may represent a biased sample in the sense that:

1) the sample was not in any way experimentally designed for our purposes or similar purposes and may possess any possible bias.
2) the sample may be small and non-representative.
3) the sample may derive to some extent from cases of assessment appeals and represent in some localities a systematic tendency to assess the best farms first, or the worst, depending upon the reason for the appeal.

On the other hand, coverage of some parishes is virtually total, and the parts of others not densely covered are known to be the parts of recognizably lower utility.

The eight classes of capability were reduced for our convenience[27] to four by the combination of Classes I and II, III and IV, and so on; the four divisions

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[27]Computer time consumption for the computation used increases substantially with the increase in the number of variables and 'throughput' time was a consideration.

as used here are implied in the original scheme and represent general categories of land use intensity as outlined in Chapter I. Classes I and II represent the land best suited to intensive arable cropping and the others represent diminishing potential.

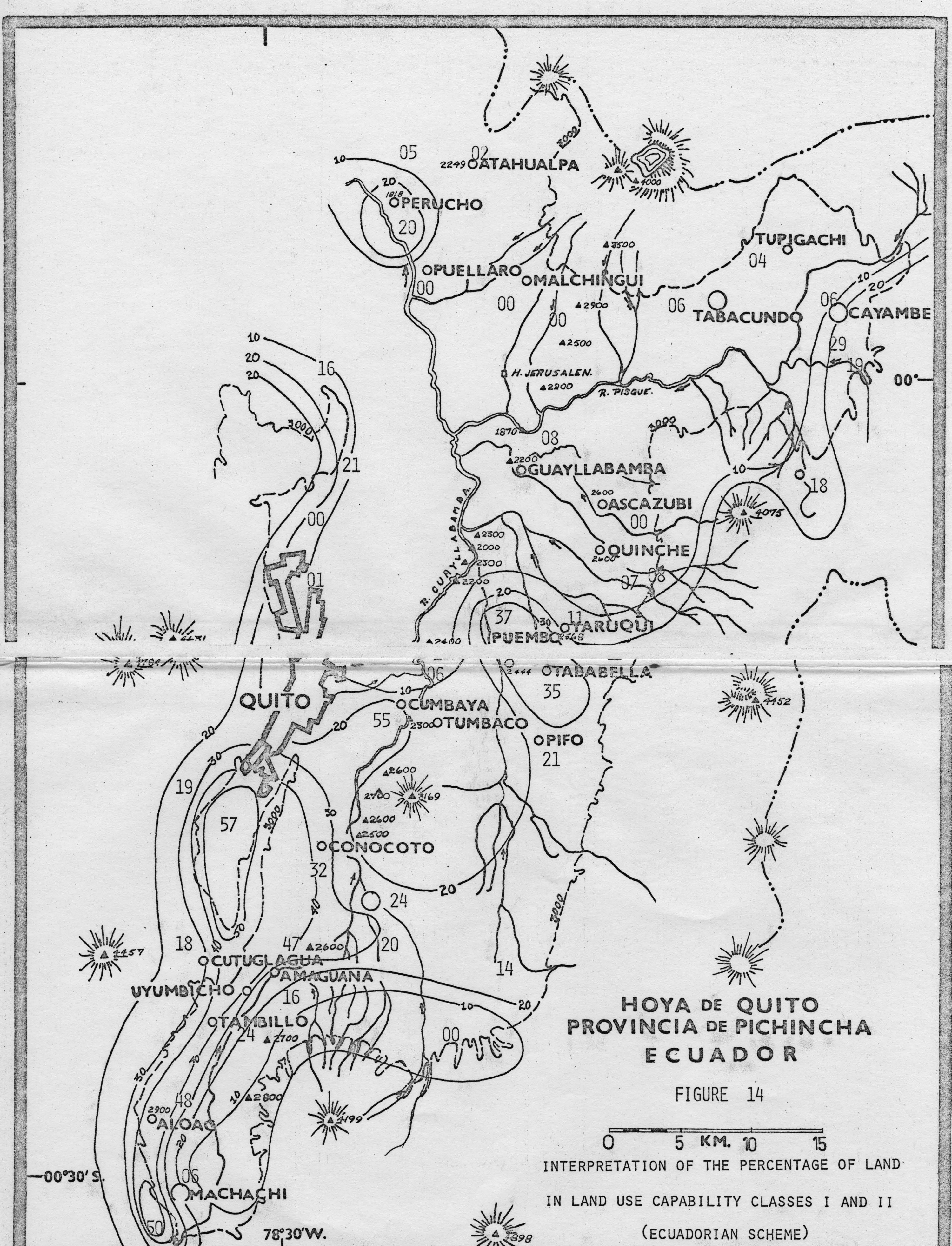
The percentages by parish for each of the four resulting classes are shown on four maps (figures 14 through 17) on which the large face numbers occur on isopleths drawn on the basis of the larger numbers. The four percentage readings for each parish add up to one hundred or nearly so, any error being due to rounding or to the occurrence of substantial amounts of land not appraised (i.e. under buildings and roadways).

This method is admittedly subjective inasmuch as the direction of many of the isopleths is determined by the writer's knowledge of the locale. By superimposition of a regular grid over the four maps and the addition of the four values as interpreted from the isopleths we shall gain an indication as to the adequacy of the maps. If the maps were each perfect, the sum at each grid point would be one hundred; any deviation represents an interpretive error in one or more of the maps.

These maps were constructed as a step toward discovering regional land types, and are necessary for

NOTES ON FIGURES 14 THROUGH 17

These figures show the assumed percentage of land in land use capability Classes I through VIII in two class intervals. These maps are interpretive only and some inconsistencies may be noted. For instance, there are some areas which should obviously exhibit 100% in figure 17 , but this possibility is ruled out by the interpretive method used. The fact that an isopleth may run through a large face number with a value other than that of the isopleth is of no importance since the large numbers pertain to parish names only. The size and shape of the parish and the location of the agricultural land as known to the writer have caused some lines to follow paths which may seem at first to be inconsistent with the printed spot values on the basis of which the lines were drawn.



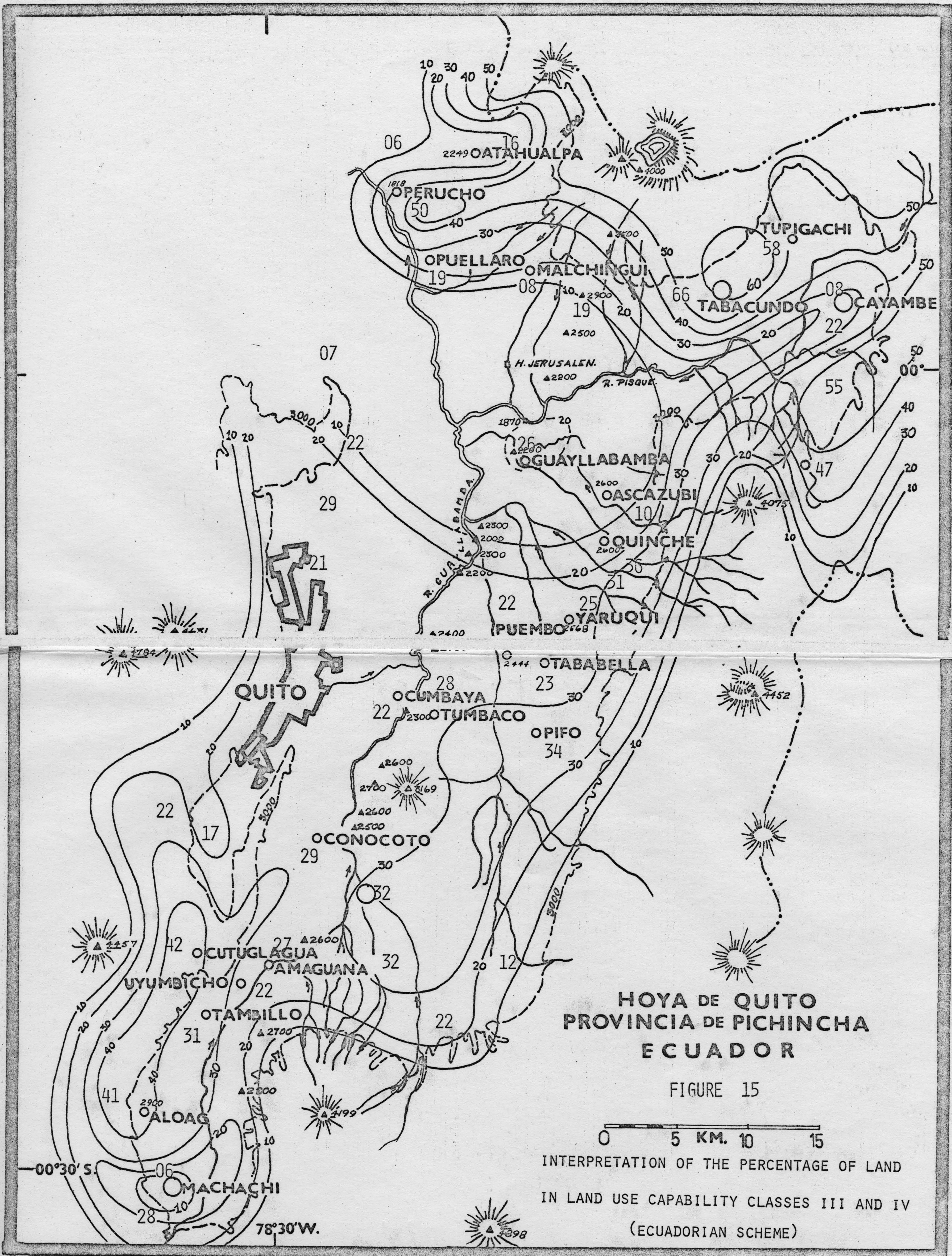
HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 14

INTERPRETATION OF THE PERCENTAGE OF LAND IN LAND USE CAPABILITY CLASSES I AND II (ECUADORIAN SCHEME)

CON PERMISO DEL I.G.M. B.B. 1971.

F151.

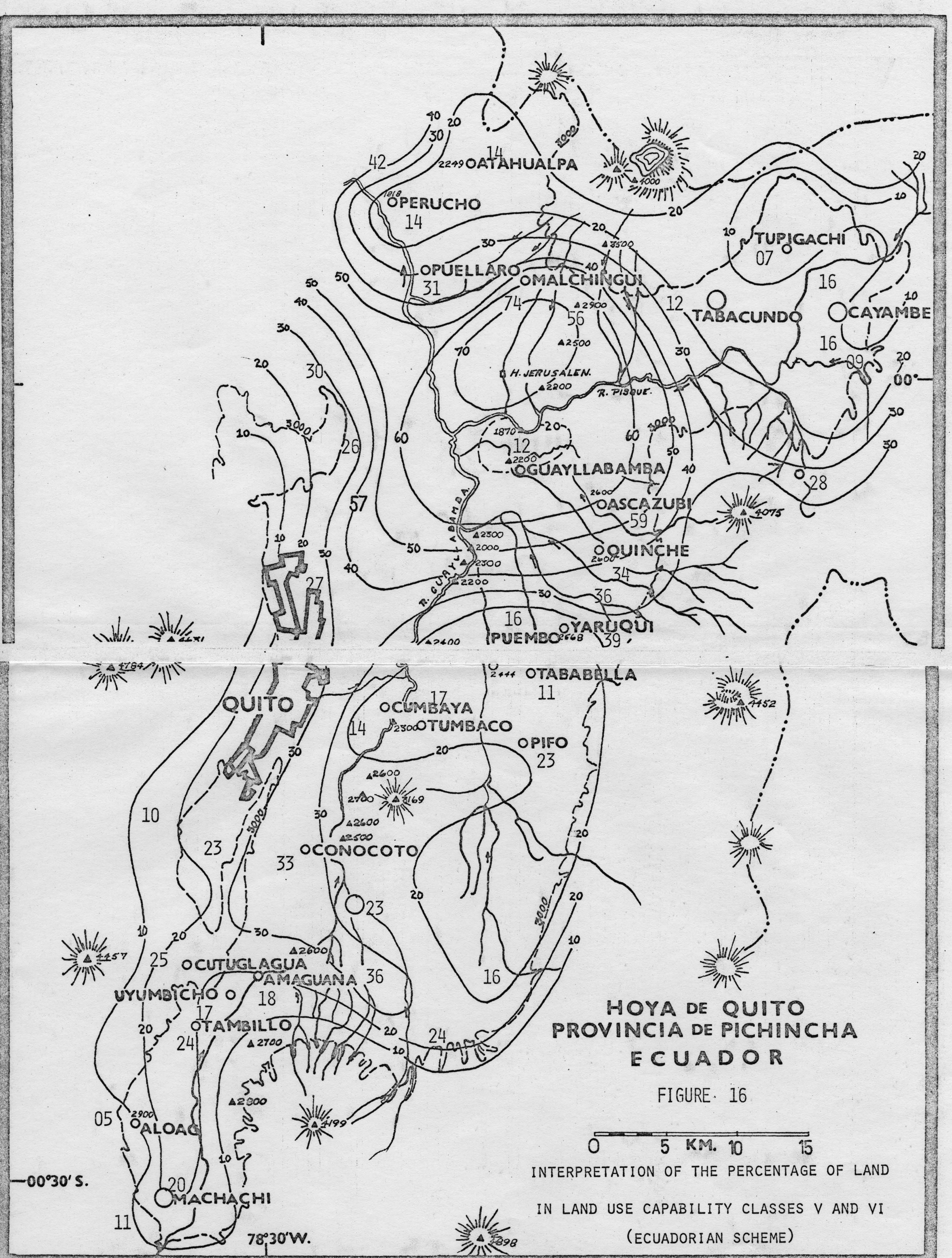


HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 15

INTERPRETATION OF THE PERCENTAGE OF LAND IN LAND USE CAPABILITY CLASSES III AND IV (ECUADORIAN SCHEME)

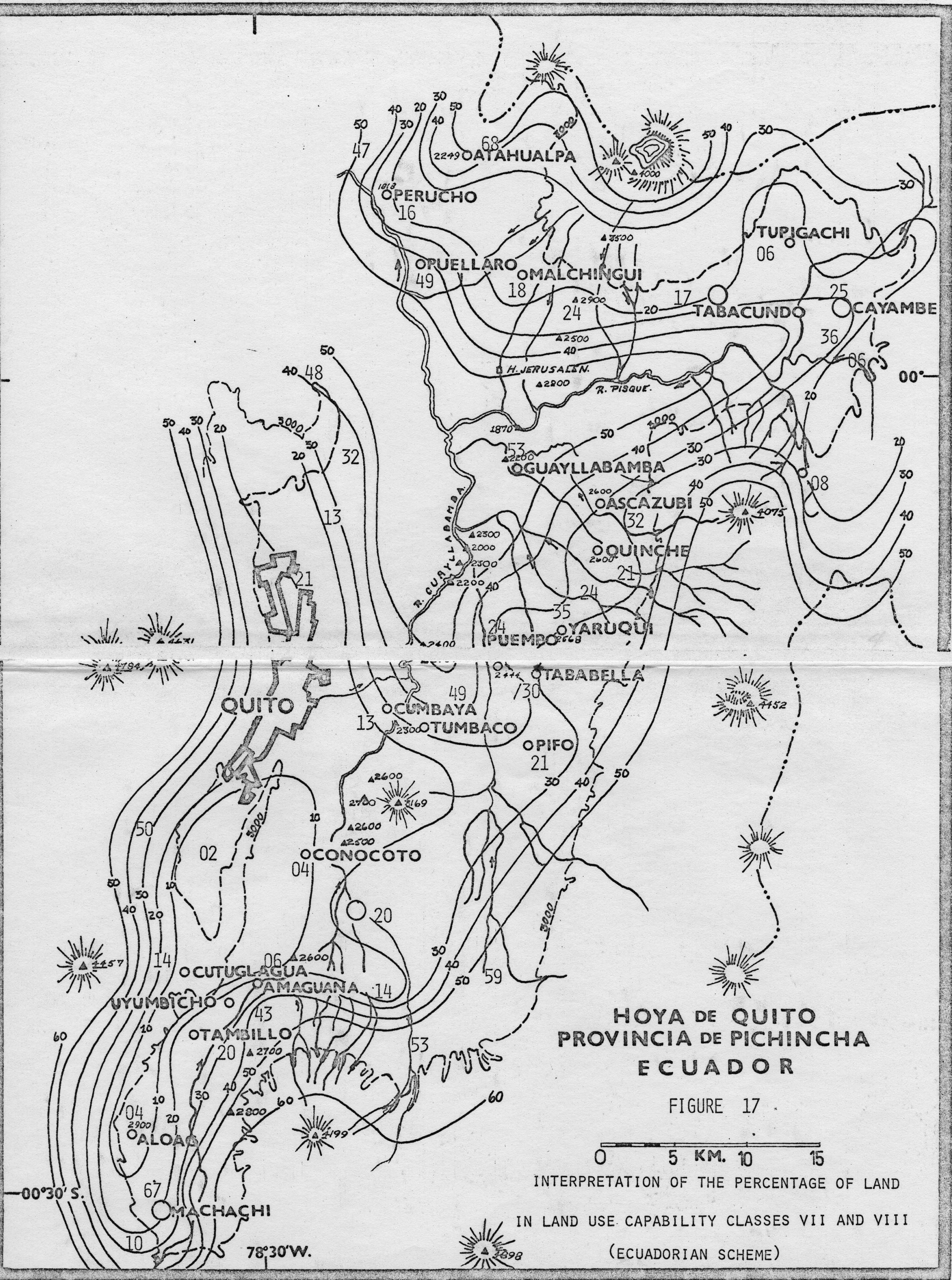
CON PERMISO DEL I.G.M. B.B. 1971



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 16

INTERPRETATION OF THE PERCENTAGE OF LAND IN LAND USE CAPABILITY CLASSES V AND VI (ECUADORIAN SCHEME)



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 17

INTERPRETATION OF THE PERCENTAGE OF LAND IN LAND USE CAPABILITY CLASSES VII AND VIII (ECUADORIAN SCHEME)

CON PERMISO DEL I.G.M. R.B. 1971

the creation of the grid, by means of which the spatially irregular arrangement of the parish readings may be avoided.

Assuming for convenience that each number representing a value for a parish is a point only,[28] and not representative of the size or shape of the parish, we make the following hypotheses:

1) The areas which are interstitial to assessment points do not exhibit distributions random to the neighboring assessment points.
2) There are regional types, if a regional type is assumed to be a unique distribution of percentages of land in each capability class (i.e. the members of the type possess a unique variable 'profile').
3) Regions as defined (3) may be consecutively numbered according to the location of the mode of the land use capability variables and regions with any given number tend to be adjacent to re-

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[28]This section and the last chapter concern a methodology only, albeit with illustrations. A much finer scale of sampling with more variables is desirable if practical application is to be considered.

gions with a number one higher or lower, or to regions with a number not inordinately higher or lower.

These hypotheses were tested by a hierarchical grouping analysis. The results follow in a subsequent chapter.

CHAPTER IV

THE STATISTICAL METHODS AND THE RESULTS OF THE STUDY

INTRODUCTION

Except for the ordering of raw data in each set as outlined previously, all the data treatment for this study was accomplished on an electronic computer. This was necessary due to the size of the sample and to the complexity of the desired calculations. Even with the advanced facilities available, however, some sets of calculations were found to be unfeasible. This problem was especially annoying in respect of the inability of library programs to handle some agricultural experimental data.[1]

It will be obvious that the treatment relies upon univariate procedures. Could the performance of farms and crops be better described by multivariate procedures? We refer to Kempthorne's[2] assertion that multivariate analysis in the standard form may, but need not, lead to scientific insight. Such analysis is usually

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[1]A Control Data Corporation 6400 machine with a usable memory of 120,000 was utilized for this study.

[2]Kempthorne, 521.

confined to the use of a few variables in which interest is high.[3] The multivariate methods are not as yet suitable for sifting problems of high dimensionality when one wishes to isolate important variables. There are, in addition, problems in testing multivariate distributions.[4] The major problem is in replication and prediction. In the absence of reliable tests of significance in the multivariate case we could not assume that a multivariate solution could be carried over to another sample. In any case, a system of confidence regions would have to encompass all components of the observation vector and the use of a number of treatments would lead to an unusable number of dimensions.[5] We are proceeding on the assumption that a univariate analysis of a large sample representative of a range of conditions should provide some usable correlations. The recombination of the variables found to be important may be most

---

[3]For an example of a multivariate treatment of only a few variables see Odell, 1958 in which only temperature, the sum of rainfall and soil nutrient status are considered.

[4]Kempthorne, 53.

[5]In fact, the number of treatments multiplied by the number of components in the observation vector.

desirable, but this is not attempted here.

PART 1

The Results of the Analysis of the Farm Activity Data

The data for farms was subjected to a principal componenets (factor) analysis to discover the correlation coefficients among variables and the existence of factors.

All readings of percentage were converted to the real common logarithm. In the case of the land capability class variables, the logarithms were added to create cumulative quantities from class to class. This was done in an attempt to avoid the difficulties of dealing with percentage readings in correlation. (False negative correlations may occur and the means and standard deviations in samples of large variance tend to a uniform quantity.)

The process of factor analysis has been used in several applications in geography.[6] It is not thought necessary to describe the process in detail here because of the now widespread use of the method and the sources

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[6] John H. Thompson *et al.*, "Toward a Geography of Economic Health: The Case of New York State", in John Freedman and William Alonso, eds., *Regional Development and Planning*, A Reader (Cambridge, Mass: M.I.T. Press, 1964), 187-208.

available. Using Veldman[7] as a concise source:

> the general goal of factor analysis is the reduction of a set of variables used to gather data from subjects to a smaller set of new, uncorrelated variables which are defined solely in terms of the original dimensions, and which retain the most 'important' information contained in the original data.

These factors may be used to describe subjects at a higher level of abstraction than the original variables.

To accomplish this a symmetric correlation matrix is created and subsequently deflated by the extraction of roots and vectors. This procedure results in "the construction of a new space which is maximally representative of the space defined by the original variables, but utilizes a minimum number of independent dimensions".[8] If the number of factors accounting for all the variance in the original matrix is less than the original number of variables, it is known that some of the original data was redundant. In application, it is rare to account for all the variance. The factors associated with the lower eigenvalues have little practical importance or relia-

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[7]Donald J. Veldman, Fortran Programming for the Behavioral Sciences (New York: Holt, Rinehart, 1967), 206.

[8]Ibid., 210.

bility, and the existence of statistically random occurrences in the data will mitigate against the accounting of all variance by a few factors. For our purposes, no eigenvalue below 1.00 was used and this limit resulted in the production of six factors accounting for upwards of seventy per cent of the variance.

Since the factors may be considered to be dimensional variables it is possible to rate the subjects by factor scoring. Each factor is identified by weightings of the original variables and may be 'typed' by the most heavily represented variables. Scoring the subjects may be accomplished by multiplying the original variable readings by each variable weighting in the factor, or by rescaling the original scores to z scores and multiplying. These scores are useful as raw data for other statistical treatments, and in geographical application they may be mapped in space. Since the weighting for each variable may be positive or negative and since each factor score for a subject is a product of these weightings, it is possible to obtain a score of zero if the bipolar influence across the variables is equal. This rarely occurs in practice, but some interpretive problems, to be resolved later, have arisen because of this bipolar phenomenon.

ROW 26 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO II

-.03177	.05064	.07741	.00422	-.03162	.07863	.10177	.14474	-.12178	-.12552
-.09410	-.07950	-.12116	.01156	.51855	-.09987	.48320	-.03600	.08639	.42840
.69601	.69463	.83258	.89833	.94372	.94345	.89971	.47687	-.30714	.03559
-.19228									

ROW 27 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO I

-.03037	.00276	-.00262	-.05555	-.04515	.08661	.06494	.06881	-.08326	-.10610
-.07057	-.05858	-.08791	.00446	.68629	.05292	.68947	-.10757	-.16184	.31195
.70286	.59803	.82263	.83488	.91759	.89971	.93559	.69293	-.39964	-.13533
-.35293									

ROW 28 PERCENTAGE OF FARM IN ALL ANNUAL CROPS

-.02474	-.08912	-.17897	-.04539	-.02773	.11556	-.02246	-.02660	.01459	.02560
.02569	.04148	.03254	-.02199	.87993	.52465	.90354	-.26180	-.54895	.01015
.54761	.29357	.55043	.45105	.59418	.47687	.69293	.98747	-.69197	-.50965
-.76683									

ROW 29 PERCENTAGE OF FARM IN ARTIFICIAL PASTURE

.06088	.01052	.06721	.03692	.14232	-.04455	-.07664	-.10340	-.04701	-.08640
-.05369	-.07701	-.07666	-.03908	-.52183	-.51302	-.57280	.26569	.23686	-.13947
-.49766	-.38556	-.48977	-.38215	-.43461	-.30714	-.39964	-.69197	-1.00000	.25790
.83747									

ROW 30 PERCENTAGE OF FARM IN NATURAL PASTURE

-.07939	.14265	.18014	.01235	.01418	-.06499	.14763	.16173	-.05998	-.03387
-.06298	-.05370	-.07003	.10556	-.27985	-.52779	-.42300	.10298	.37510	.15824
-.16837	.05107	-.06161	.05044	-.03761	.03559	-.13533	-.50965	.25790	1.00000
.74398									

ROW 31 PERCENTAGE OF FARM IN ALL TYPES OF PASTURE

-.00280	.08796	.14837	.03252	.10645	-.06757	.03050	.01996	-.06643	-.07892
-.07275	-.08363	-.09262	.03268	-.51918	-.65333	-.63540	.24200	.37598	-.00695
-.43941	-.23776	-.37357	-.23576	-.32184	-.19228	-.35293	-.76683	.83747	.74398
1.00000									

The Results of Factor Analysis of Farm Data

The correlation coefficients of this set of data exhibit curious features. The autocorrelation coefficient is typically high, but tends to a rather low level in variables possessing a high standard deviation and a large range. Assuming that a coefficient of correlation of 0.70 accounts for 0.5 of the variance of the dependent variable, any correlation above this will be considered strong. Between 0.50 and 0.70 mild correlation will be assumed to exist, and below 0.50 very mild or negligible correlation. The following section will demonstrate the absence of strong correlations.[9]

The correlation table for the farm data is printed as table 12 . Each variable possesses one 'row' and the correlation with each of the thirty other variables is in order, ten to a line. To find, for instance, the correlation between farm size and the number of animals on the farm, note that farm size is variable one, and the number of animals is variable four. Consult then the

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[9]Due to the rearrangement of the data for application to computer treatment, the variables in the set of farm data appear in a different order from that in which they were ennumerated.

TABLE 12

MATRIX OF CORRELATIONS AMONG 31 VARIABLES,

FARM ACTIVITY ANALYSIS, PICHINCHA PROVINCE

SIZE OF FARM

ROW 1

.40797	.25344	.36241	.26262	.12543	-.17058	-.05286	-.15338	-.02671	-.01721
.05051	.04862	.00098	.01702	-.05006	-.03927	-.00115	-.05341	.01886	-.01181
-.02165	-.06703	-.05629	-.02747	-.04648	-.03177	-.03037	-.02474	.06088	-.07939
-.00280									

ROW 2 GROSS VALUE MACHINERY

.25344	.77405	.51659	.21603	.00060	.11418	.67252	.09774	.10889	.10718
.07821	.09496	.10189	.12032	-.01995	-.12003	-.08173	-.06823	.09527	.06004
-.11010	-.09814	-.06834	.00087	-.00833	.05064	.00276	-.08912	.01052	.14265
.08796									

ROW 3 SQUARE METRES BUILDINGS

.36241	.51659	.71903	.38805	.05844	.15222	.25862	.36651	.08042	.04790
.07885	.03789	.06829	.03143	-.13156	-.20127	-.13639	-.07270	.15004	.00888
-.13806	-.14237	-.08187	.02595	.02022	.07741	-.00262	-.17897	.06721	.18014
.14837									

ROW 4 NUMBER OF ANIMAL UNITS

.26262	.21603	.38805	.43163	.09149	.08728	.02798	-.05282	.12258	.26132
.12523	.19600	.18698	.15868	-.04880	-.13305	-.03768	-.09815	.17458	.13002
.05527	.04200	.04070	.02583	-.00761	.00422	-.05555	-.04539	.03692	.01235
.03252									

ROW 5 NUMBER OF HECTARES PASTURE PER ANIMAL UNIT

.12543	.00060	.05844	.09149	.22926	-.05130	-.01233	-.11753	.13056	.14534
.08479	.06736	.11032	.17391	-.01265	-.04779	-.03745	-.05555	-.10629	-.09111
-.09603	-.10849	-.11067	-.08965	-.08091	-.03162	-.04515	-.02773	.14232	.01418
.10645									

CONTINUED ...

ROW 6 PER CENT OF FARM IRRIGATED

-.17058	.11418	.15222	.08728	-.05130	.40526	.24902	.31705	.02649	.21036
.03921	.21242	.15740	-.03028	.11874	-.01866	.14639	.01346	-.10717	.12941
.09382	.04506	.05977	.06183	.09536	.07863	.08661	.11556	-.04455	-.06499
-.06757									

ROW 7 MACHINERY INVESTMENT PER HECTARE

-.05286	.67252	.25862	.02798	-.01233	.24902	.74293	.47014	.02651	.07475
.02305	.07193	.06381	.05375	.01649	-.05529	-.01007	-.05237	.00774	.05482
-.01293	.03546	.06032	.11045	.10269	.10177	.06494	-.02246	-.07664	.14763
.03050									

ROW 8 SQUARE METRES OF BUILDINGS PER HECTARE

-.15338	.09774	.36651	-.05282	-.11753	.31705	.47014	.62323	.02646	.05453
.07018	.10313	.08734	.03844	-.01564	-.02817	-.00010	-.06364	.06226	.07422
.02371	.08211	.09528	.15803	.14795	.14474	.06881	-.02660	-.10340	.16173
.01996									

ROW 9 MEAN RAINFALL JANUARY - MARCH

-.02671	.10889	.08042	.12258	.13056	.02649	.02651	.02646	.94078	.75864
.81675	.76434	.90666	.76506	-.04441	.07242	-.02271	-.14292	-.00691	-.04520
-.05534	-.07564	-.10439	-.09971	-.08397	-.12178	-.08326	.01459	-.04701	-.05998
-.06643									

ROW 10 MEAN RAINFALL APRIL - JUNE

-.01721	.10718	.04790	.26132	.14534	.21036	.07475	.05453	.75864	.94097
.69740	.88067	.92270	.77473	-.05350	.13626	.01958	-.11572	.01706	.06860
.00180	.00616	-.06554	-.09098	-.08181	-.12552	-.10610	.02560	-.08640	-.03387
-.07892									

ROW 11 MEAN RAINFALL JULY - SEPTEMBER

.05051	.07821	.07885	.12523	.08479	.03921	.02305	.07018	.81675	.69740
.81631	.76150	.85098	.70845	-.00111	.07350	-.02231	-.15460	.01067	-.02663
-.02443	-.04468	-.06059	-.05669	-.03932	-.09410	-.07057	.02569	-.05369	-.06298
-.07275									

ROW 12 MEAN RAINFALL OCTOBER - DECEMBER

.04862	.09496	.03789	.19600	.06736	.21242	.07193	.10313	.76434	.88067
.76150	.95154	.93807	.79227	.00001	.09981	.02257	-.06133	.03937	-.01095
-.00911	.00011	-.04594	-.05285	-.03993	-.07950	-.05858	.04148	-.07701	-.05370
-.08363									

ROW 13 MEAN ANNUAL RAINFALL

.00098	.10189	.06829	.18698	.11032	.15740	.06381	.08734	.90666	.92270
.85098	.93807	.99003	.80782	-.03568	.12540	.00073	-.11707	.01101	-.00006
-.01933	-.02736	-.07647	-.08759	-.07343	-.12116	-.08791	.03254	-.07666	-.07003
-.09262									

ROW 14 MEAN NUMBER OF DAYS ANNUALLY ON WHICH SOME RAIN FELL

.01702	.12032	.03143	.15868	.17391	-.03028	.05375	.03844	.76506	.77473
.70845	.79227	.80782	.81723	-.01641	-.04183	-.02441	-.12751	.13442	-.00323
.01841	.06975	.01785	.03833	.04389	.01156	.00446	-.02199	-.03908	.10556
.03268									

ROW 15 PERCENTAGE OF FARM SOWN TO WHEAT

-.05006	-.01995	-.13156	-.04880	-.01265	.11874	.01649	-.01564	-.04441	-.05350
-.00111	.00001	-.03568	-.01641	.93382	.23615	.74253	-.20237	-.50190	.00231
.47501	.26686	.53249	.46547	.60223	.51855	.68629	.87993	-.52183	-.27985
-.51918									

ROW 16 PERCENTAGE OF FARM SOWN TO CORN

-.03927	-.12003	-.20127	-.13305	-.04779	-.01866	-.05529	-.02817	.07242	.13626
.07350	.09981	.12540	-.04183	.23615	.80946	.37095	-.04212	-.43038	-.08861
.10451	-.03563	-.01509	-.09174	-.03314	-.09987	.05292	.52465	-.51302	-.52779
-.65333									

ROW 17 PERCENTAGE OF FARM SOWN TO BARLEY

-.00115	-.08173	-.13639	-.03768	-.03745	.14639	-.01007	-.00010	-.02271	.01958
-.02231	.02257	.00073	-.02441	.74253	.37095	.91174	-.23909	-.45954	.02419
.50707	.28652	.54910	.46403	.58453	.48320	.68947	.90354	-.57280	-.42300
-.63540									

ROW 18 PERCENTAGE OF FARM IN FALLOW LAND, OR OTHERWISE NOT USED

-.05341	-.06823	-.07270	-.09815	-.05555	.01346	-.05237	-.06364	-.14292	-.11572
-.15460	-.06133	-.11707	-.12751	-.20237	-.04212	-.23909	.37461	-.02394	-.10895
-.20321	-.09178	-.17998	-.11368	-.16576	-.03600	-.10757	-.26180	.26569	.10298
.24200									

ROW 19 PERCENTAGE OF FARM OF NO ECONOMIC VALUE

.01886	.09527	.15004	.17458	-.10629	-.10717	.00774	.06226	-.00691	.01706
.01067	.03937	.01101	.13442	-.50190	-.43038	-.45954	-.02394	.67563	.37813
.09166	.31414	.09727	.17677	.03719	.08639	-.16184	-.54895	.23686	.37510
.37598									

ROW 20 PERCENTAGE OF FARM IN CLASS VIII LAND

-.01181	.06004	.00888	.13002	-.09111	.12941	.05482	.07422	-.04520	.06860
-.02663	-.01095	-.00006	-.00323	.00231	-.08861	.02419	-.10895	.37813	.71241
.65391	.68794	.51772	.51624	.40307	.42840	.31195	.01015	-.13947	.15824
-.00695									

ROW 21 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO VII

-.02165	-.11010	-.13806	.05527	-.09603	.09382	-.01293	.02371	-.05534	.00180
-.02443	-.00911	-.01933	.01841	.47501	.10451	.50707	-.20321	.09166	.65391
.91034	.87233	.85043	.77891	.76548	.69601	.70286	.54761	-.49766	-.16837
-.43941									

ROW 22 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO VI

-.06703	-.09814	-.14237	.04200	-.10849	.04506	.03546	.08211	-.07564	.00616
-.04468	.00011	-.02736	.06975	.26686	-.03563	.28652	-.09178	.31414	.68794
.87233	.93980	.88004	.84715	.74158	.69463	.59803	.29357	-.38556	.05107
-.23776									

ROW 23 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO V

-.05629	-.06834	-.08187	.04070	-.11067	.05977	.06032	.09528	-.10439	-.06554
-.06059	-.04594	-.07647	.01785	.53249	-.01509	.54910	-.17998	.09727	.51772
.85043	.88004	.97143	.95548	.90766	.83258	.82263	.55043	-.48977	-.06161
-.37357									

ROW 24 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO IV

-.02747	.00087	.02595	.02583	-.08965	.06183	.11045	.15803	-.09971	-.09098
-.05669	-.05285	-.08759	.03833	.46547	-.09174	.46403	-.11368	.17677	.51624
.77891	.84715	.95548	.97449	.94155	.89833	.83488	.45105	-.38215	.05044
-.23576									

ROW 25 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO III

-.04648	-.00833	.02022	-.00761	-.08091	.09536	.10269	.14795	-.08397	-.08181
-.03932	-.03993	-.07343	.04389	.60223	-.03314	.58453	-.16576	.03719	.40307
.76548	.74158	.90766	.94155	.97242	.94372	.91759	.59418	-.43461	-.03761
-.32184									

ROW 26 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO II

-.03177	.05064	.07741	.00422	-.03162	.07863	.10177	.14474	-.12178	-.12552
-.09410	-.07950	-.12116	.01156	.51855	-.09987	.48320	-.03600	.08639	.42840
.69601	.69463	.83258	.89833	.94372	.94345	.89971	.47687	-.30714	.03559
-.19228									

ROW 27 ACCUMULATED PERCENTAGE OF FARM IN CLASSES VIII TO I

-.03037	.00276	-.00262	-.05555	-.04515	.08661	.06494	.06881	-.08326	-.10610
-.07057	-.05858	-.08791	.00446	.68629	.05292	.68947	-.10757	-.16184	.31195
.70286	.59803	.82263	.83488	.91759	.89971	.93559	.69293	-.39964	-.13533
-.35293									

ROW 28 PERCENTAGE OF FARM IN ALL ANNUAL CROPS

-.02474	-.08912	-.17897	-.04539	-.02773	.11556	-.02246	-.02660	.01459	.02560
.02569	.04148	.03254	-.02199	.87993	.52465	.90354	-.26180	-.54895	.01015
.54761	.29357	.55043	.45105	.59418	.47687	.69293	.98747	-.69197	-.50965
-.76683									

ROW 29 PERCENTAGE OF FARM IN ARTIFICIAL PASTURE

.06088	.01052	.06721	.03692	.14232	-.04455	-.07664	-.10340	-.04701	-.08640
-.05369	-.07701	-.07666	-.03908	-.52183	-.51302	-.57280	.26569	.23686	-.13947
-.49766	-.38556	-.48977	-.38215	-.43461	-.30714	-.39964	-.69197	-1.00000	.25790
.83747									

ROW 30 PERCENTAGE OF FARM IN NATURAL PASTURE

-.07939	.14265	.18014	.01235	.01418	-.06499	.14763	.16173	-.05998	-.03387
-.06298	-.05370	-.07003	.10556	-.27985	-.52779	-.42300	.10298	.37510	.15824
-.16837	.05107	-.06161	.05044	-.03761	.03559	-.13533	-.50965	.25790	1.00000
.74398									

ROW 31 PERCENTAGE OF FARM IN ALL TYPES OF PASTURE

-.00280	.08796	.14837	.03252	.10645	-.06757	.03050	.01996	-.06643	-.07892
-.07275	-.08363	-.09262	.03268	-.51918	-.65333	-.63540	.24200	.37598	-.00695
-.43941	-.23776	-.37357	-.23576	-.32184	-.19228	-.35293	-.76683	.83747	.74398
1.00000									

fourth element in variable one, or the first in variable four. (The number is the same: 0.26262.)[10]

Since we are interested in land use capability we shall consult this table to see whether there are any strong correlations between the land use capability indices as used in Ecuador and the incidence of crops, rainfall, and investment indicators.

Farm Size: Farm size has no correlation of note with any other variable, and a low autocorrelation. This is possibly due to the high standard deviation.

Monetary Investment in Machinery: This variable indicates only mild correlation with two variables - the incidence of buildings (0.52) and the machinery per hectare (0.67). There is no correlation with the area of buildings per hectare.

Area of Buildings: There is a negligible correlation only with number of animal units on the farm, (0.39). This being the case we should expect some correlation with the amount of pasture, but this does not occur, (0.15).

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[10]The table is printed in its entirety as this description will touch only upon the highlights and readers may desire to consult the correlations in more detail.

Number of Animal Units: There are no correlations of note.

Number of Hectares per Animal Unit: This variable is notable for the complete absence of even low correlations. This problem may be due partly to a number of data blanks, since farms not possessing animals could be entered as zero in the preceding variable, but no projection could be entered for this item.

Per Cent of Farm Irrigated: This variable shows no correlation with any climatic or type of pursuit variable. It is related as follows to the building and machinery variables:

Gross value machinery	0.11
Machinery per hectare	0.25
Area of buildings	0.15
Area of buildings per hectare	0.32

The interpretation of very low values of 'r' is risky, but trends may be evident. It appears that as the percentage of the farm irrigated increases, the per hectare investment in buildings and machinery also increases.

Machinery per Hectare: There is a mild correlation (0.67) with the total value of machinery, and a very slim correspondence with the amount of building per hectare, (0.47).

It should be noted in this resume that no correlations with any land type or climatic variable have been found.

Amount of Building per Hectare: There are no correlations of note. This item is correlated to the total amount of building only to the extent of 0.37.

Rainfall Variables: The rainfall variables correlate very closely with each other. This indicates that the yearly pattern of rainfall by quarters of the year is constant throughout the area. The means are as follows:

First quarter rainfall	265.5 mm.
Second quarter rainfall	247.2 mm.
Third quarter rainfall	94.2 mm.
Fourth quarter rainfall	320.7 mm.
Total	927.7 mm.

There is no correlation between any of the rainfall variables and the land use capability indices or the types of land use.

Percentage of Farm in Wheat: This variable shows a high rate of autocorrelation (0.93), and a close association with barley growing (0.74). There is negligible association with the percentage of the farm in corn (0.23). Where wheat is present the percentage of natural pasture declines (-0.28), with artificial pasture declining in an even stronger fashion (-0.52). All types of pasture correlated at -0.52. There is a slight negligible correlation with the incidence of unusable land (-0.50), an association with Class VII land, (0.47), and a noticeable correlation with Class III and Class I land (0.60 and 0.69).

Percentage of Farm in Corn: This variable shows no significant tendencies, but we may note that it has a stronger negative correlation with pasture pursuits than does wheat, (-0.65). This tendency is understandable in view of the fact that corn is often fed to animals, and should, in fact, often be considered as pasture. Corn is not sensitive to any land use capability variable.

Percentage of Farm in Barley: Barley retains the curious predilection of wheat for farms with Class VII land, (0.51) and is best associated with farms possessing high levels of Class III (0.58) and Class I (0.69) land. Artificial pasture declines in the prescence of barley (-0.57), as do natural pasture and all types of pasture, (-0.42 and -0.64). The percentage of the farm in barley is poorly correlated to the corresponding variable for corn at 0.37.

Unused Land, Fallow Land and Land Under Buildings, or Land Missed in Inventory: This variable, included to ensure that the land use categories added to 100%, showed no correlations of strength.

Economically Unusable Land: The amount of such land on a farm decreases relatively in the prescence of crops, -0.50, -0.43, and -0.46, for wheat, corn, and barley respectively. It is positively correlated to pasture pursuits, although poorly, (0.24, 0.38, and 0.38 to artificial pasture, natural pasture and all types of pasture respectively). From this observation and others, there is an indication that artificial pasture occurs as a greater percentage of the farm on farms possessing, overall, a better quality of land according to the local capability index.

Land Use Capability Variables (ONAC Scheme): The variables exhibit a close association when autocorrelated, all except a per cent of land in Class VIII being above 0.90. With each land use capability variable a closer association is shown with variables representing class numbers near the class number being correlated, than with numbers at greater distances on the scale. For an illustration the percentage of the farm in Class VII land shows a decrease in 'r' to other land class variables:

CLASS	'r'	
VIII	0.65	
VII	0.91	(autocorrelation)
VI	0.87	
V	0.85	
IV	0.78	
III	0.77	
II	0.70	
I	0.70	

Similar information for Class IV is as follows:

CLASS	'r'	
VIII	0.52	
VII	0.78	
VI	0.85	
V	0.96	
IV	0.97	(autocorrelation)
III	0.94	
II	0.90	
I	0.83	

This tendency in the data would indicate that each class of land occurs with some frequency in association with neighboring classes on the scale and that within farms there is no marked tendency to wide fluctuations or discontinuities in land use capability as defined by the index in use in Ecuador. This phenomenon may be due only to the subjective interpretation of the assessors.

It is interesting that the incidence of artificial pasture is negatively correlated to all the land class variables. We have no suggestion as to why this occurs. The natural pasture variable shows no notable correlations with the land class variables, but the variable for all pasture types repeats the tendency of that for artificial pasture.

<u>Percentage of the Farm in All Types of Annual Crops</u>: This variable shows the following correlations:

% farm in wheat	0.89
% farm in corn	0.52
% farm in barley	0.90
% farm in artificial pasture	-0.69
% farm in natural pasture	-0.51
% farm in all types of pasture	-0.77
% farm unusable land	-0.55

From these figures we observe a weak tendency for farms to specialize in crops or in pasture. The production of corn, as expressed by the area of the farm in that pursuit, is problematical, the corn variable showing, as we have noted, none of the higher correlations exhibited by the other two crops. This is possibly due to a fact we have mentioned before - that corn should be, on occasion, considered as pasture. The indefinite correlations represent 'splitting the difference'.

If a negative correlation exists between the incidence of crops and pasture and crops and unusable land, we might expect in the prescence of some specialization that the pasture pursuits are being carried out on farms with a higher percentage of unusable land. This is so to a small extent - all types of pasture being positively correlated to the amount of unusable land at 0.38. These observations are independent of farm size, there being no correlation between this variable and the incidence of unusable land and land in the poorer classes.

Variables Concerning Percentage of Farm in Pasture: The incidence of artificial pasture is correlated to all types of pasture at 0.84. The corresponding reading for natural pasture is 0.74. Natural and artificial pasture correlate poorly together at 0.26, and there is a greater tendency for land in crops to diminish in the prescence of artificial pasture (-0.69) than in the prescence of natural pasture (-0.51). Farms with increasing percentages of artificial pasture show decreasing percentages of crops to a greater degree than farms with more natural pasture:

	ARTIFICIAL PASTURE	NATURAL PASTURE	ALL TYPES PASTURE
	'r'	'r'	'r'
Wheat	-0.52	-0.28	-0.52
Corn	-0.51	-0.53	-0.65
Barley	-0.57	-0.42	-0.64
All crops	-0.69	-0.51	-0.51

It appears that crops co-exist, except for corn, relatively better with natural pasture than with artificial pasture, and we may infer that farms with artificial pasture tend to specialize more in that pursuit. Alternatively, or in addition, both cropping and natural pasture tend to co-exist. Since these observations are independent of farm size we would expect that the relative specialization in artificial pasture would entail a higher number of animals per hectare on such farms. This is a relative measure only, involving negligible correlations, which, however, may have some comparative value. We note that the number of hectares supporting one animal unit is correlated with the percentage of the farm in natural pasture at 0.01. The corresponding correlation for artificial pasture is 0.14, indicating some increase in intensity on farms possessing higher percentages of artificial pasture.

Concluding Observations on the Correlations; The correlations are disappointing in regard to our failure to discern, by univariate analysis, any specialization of activities in terms of the land use capability index.

The level of specialization in the pursuits studied is low, but there does appear to be a demarcation between farms possessing pasture and farms with crops. This specialization was more marked in the case of farms with artificial pasture. Arable crops and natural pasture appear to co-exist more frequently than do crops and artificial pasture. Wheat and barley planting decrease in the prescence of artificial pasture at a greater rate than in the prescence of natural pasture. The decrease in corn planting was constant for both types of pasture, and the incidence of corn as a percentage of farm area showed an indefinite response to almost all variables.

The climatic variables indicated no zonality in the activities studied. Since the variation in rainfall is so great, and since the sample was carefully selected to cross all levels of rainfall, it was hoped that some zonality would become evident. In the prospective absence of correlations in the rainfall variables we included a variable for the percentage of the farm irrigated but no relationships became evident in the use of this item. It is especially noteworthy that the climatic variables correlate in no manner with the percentage of the farm irrigated.

The size of the farm is usually considered to have some importance, but the correlations in this variable were negligible.

It must be concluded that a univariate approach to this problem is inadequate, or that the addition of more variables is necessary. Perhaps the farm management unit is not a valid level at which to analyse the land surface or the activities on it. It is evident that some measures of income per hectare must be included in this set of data since the mere existence of an activity and the areal comparison of this activity with others gives little information as to the reason it is being carried on. It was hoped that the variables concerning investment in machinery and buildings, and the variable for percentage of the farm irrigated (which is a form of investment) would give better results by acting as proxy variables for income. Had this occurred these variables would be better correlated with the land class and climatic variables. We do not think that the expectation of a univariate response in these latter variables would be unreasonable.

Factor Identities in the Farm Activities

Factor 1

This factor (26% of variance) contains heavy positive weightings for the percentage of the farm in wheat, barley, and in all crops, and for all variables concerning the land use capability index for Class VII land through Class I. Artificial pasture and total pasture are negatively weighted. The weightings for all the variables are printed as Appendix II. It is clear that the high degree of covariance among the land use capability variables has caused this factor to be pre-eminent. Because of the accumulation of variable readings through the land class, low factor scores on this factor will indicate better land; negative factor scores will indicate a relatively good land base being used for artificial pasture. Such interpretations may, however, be only approximate; there are severe interpretive problems involved in the use of factors with such bipolar identities. This is an especially crucial problem here because of the different land uses appearing in the same factor. This factor cannot be adequately named.

Factor 2

The high intercorrelations among the rainfall variables lead to the heavy positive weightings in this factor

(16.7% of variance) which may be called 'rainfall'. Negative weightings are rare and of small magnitude in this factor and we are curious as to how negative factor scores, of which there are many, can occur in this factor.

Factor 3

This factor (12.2% of variance), which may be called 'type of activity' possesses the following weightings:

% of farm in wheat	0.405
% of farm in corn	0.770
% of farm in barley	0.565
% of farm unused land	-0.210
% of farm with no economic use	-0.459
% of farm in all crops	-0.70
% of farm in artificial pasture	-0.449
% of farm in natural pasture	-0.828
% of farm in all pasture types	-0.944

Negative factor scores on this factor represent pastoral activities and positive scores represent arable cropping.

Factor 4

This factor (6.5% of variance) represents 'investment' as indicated by the weightings associated with the gross value of machinery, the square metres of buildings, the respective readings of these two variables per hectare of the farm, and the percentage of the farm irrigated.

The last two factors (5 and 6) accounted for only a small proportion of the variance and were not deemed to be of practical significance. The six factors with eigenvalues over 1.00 accounted for 69.4% of the variance in the original data. This is quite an acceptable level.

The factor scores of the subjects on the first four factors were submitted to a statistical grouping procedure to investigate the possibility of regional distributions in types of farm activity and levels of investment. The results of this grouping are presented later in the work.

PART 2

The Results of the Analysis of Crop Yields

A. Wheat

The yield of wheat was calculated against costs for the period 1966 to 1970.[11] Over this period 63.69% of wheat plantings gave a monetary return, 29.94% were uneconomic and 6.37% were marginal. Marginal returns were considered to be those in which the operator was assessed costs for which he might not account, such as the 'flat rate' administration charge of fifty sucres per hectare and the labour cost of administering the arrival of irrigation water. These costs were then post-subtracted from the production expenses. This process gave a monetary return or 'the benefit of the doubt' to some entries because our cost formula was considered rather rigorous.[12]

Year by year accounts were made to discover the stability of returns over time. The results follow in table 13 . Since we are interested in planning a large area we did not take pains to ascertain whether the same

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[11] The formula has been given above.

[12] This is despite the fact that such an accounting should in future be used for locational selection.

TABLE 13

RETURNS FROM WHEAT PRODUCTION

VARIOUS YEARS

YEAR(S)	% ECONOMIC	% UNECONOMIC	% MARGINAL	% OF CROP IN 5 QUINTAL INCREMENTS PER HECTARE (e.g. 0 to 5, 6 to 10, etc.)										Mean Yield Qu/Ha
Experimental	97.14	0.00	2.86	0.00	2.86	5.71	11.43	0.00	0.00	5.71	0.00	5.71	68.57	48.94
1966-1970	63.69	29.94	6.37	17.20	8.28	5.10	26.75	12.10	8.28	1.27	10.19	2.55	8.28	24.03
1966	72.00	24.00	4.00	16.00	4.00	0.00	28.00	16.00	8.00	0.00	16.00	4.00	8.00	24.64
1967	74.42	16.28	9.30	9.30	6.98	6.98	34.88	23.26	4.65	0.00	9.30	0.00	4.65	21.30
1970	63.46	28.85	7.69	11.54	11.54	7.69	25.00	5.77	11.54	1.92	7.69	5.77	11.54	26.00

operator made money every year or whether he lost money on a recurring pattern. Such determinations are a study unto themselves which could not be accomplished here.

These returns are stable in distribution both as to percentage reporting a profit and the profiles of yield distribution per hectare. The mean return per hectare over this period was 606.29 sucres, the mean yield amounting to 22.78 quintals. Substantial percentage returns on investment are not available unless yields are targeted to more than twenty quintals per hectare on land able to utilize artificial fertilizers. The highest percentage return on investment discovered in practice was 198.67%, although plot experiments indicate that levels as high as 244% may be obtained depending on the type and intensity of fertilizer used. The point of marginal returns in fertilizer application intervenes more or less at the point to which yields are forced to sixty quintals per hectare. All entries on plot experiments in wheat were economic.

For all the years under study 120 entries were available for wheat production. Fifty-two of these originated from 1970 and were the result of first hand interviews.

We have noted elsewhere in the study that few entries for the earlier years as noted from the tax roles contained a notation as to artificial fertilizer application. We wondered whether this was a failure on the part of farmers to give this information to the tax inspectors or whether the application of fertilizer has in fact increased in the period of a few years. Table 13 might indicate that the use of fertilizer is now more frequent, since the yield has increased between ten and twenty per cent, but the percentage of economic holdings has decreased by approximately ten per cent. The incidence of marginal holdings has increased. It appears that the cost of the fertilizer, now used more, is greater than the increase in the monetary value of the crop per hectare. Comparison of two years, 1967 and 1970, reveals that the mean yield has increased from 21.30 quintals per hectare to 26.00. The mean percentage return on investment has decreased from 34.06% in 1967 to 23.50 in 1970.

Wheat yield is moderately responsive to fertilizer application (0.55) but is not responsive to any environmental variable. The correlation between yield and net monetary return per hectare is 0.95, and between yield and percentage return on investment 0.88. The latter coefficient is lower, due presumably to the non-linear relationship between input cost and yield at the higher levels of yield. The net return in sucres per hectare correlates at 0.95 with the percentage return on investment, indicating a near perfect linear relationship.

The failure of the yield of wheat, the net income per hectare, and the percentage return on investment to give firm correlations with the environmental variables leads us to disqualify the factor analysis of this set of data. A similar failure will be evident in the discussion of corn and barley.

B. Corn

Corn is a nutritional mainstay in the area - it is inexpensive, can be eaten by man or animal and is undemanding in its requirements for growth. Some lands have been planted exclusively in corn since colonial times.[13] It occurs with a mean rainfall of 910.95 millimetres but where irrigation is used this rate increases to 2125 millimetres. On the average, corn crops receive twenty-one fewer days rain[14] than wheat and eleven days fewer than barley; this deficit is more than made up by the irrigation.

The profitability of corn shows interesting characteristics. Many corn plantings are apparently uneconomic

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[13]"Since the Incas", as the writer was told by a number of informants, not necessarily in jest.

[14]That is, days on which rain falls.

as table 14 shows. This situation is not as grim as it appears due to the fact that:

a) large amounts of corn are destined for animals and the accounting should be made in costing husbandry,[15] and

b) there are many plots of corn tilled by people who do not pay for their own labour. It is notable that only 31.88% of the agricultural plot experiments on the best land are economic, and the economic results occur with the least input of fertilizer and with the heaviest. In addition, while the net money loss on the uneconomic experiments varies widely, from zero to -811.00 sucres per hectare, the percentage loss on investment is never over -60%, usually between -20% and -50%. Means may be misleading, but the following table (15) is useful for comparative purposes bearing in mind that many farm plots never receive fertilizer and that experimental station data is derived from well managed soils.

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[15]The fact that we found no correlation between the incidence of corn on farms and the incidence of pasture does not alter this proposition. In many cases the corn should have been listed as pasture.

TABLE 17

RETURNS FROM BARLEY PRODUCTION

VARIOUS YEARS

YEAR(S)	% ECONOMIC	% UNECONOMIC	% MARGINAL	% OF CROP IN 5 QUINTAL INCREMENTS PER HECTARE (e.g. 0 to 5, 6 to 10, etc.)										Mean Yield Qu/Ha
				5	10	15	20	25	30	35	40	45	Over 45	
Experimental	96.43	0.00	3.57	0.00	0.00	0.00	0.00	7.14	0.00	17.86	25.00	14.29	35.71	42.03
1966-1970	54.95	38.46	6.59	21.98	5.49	5.49	25.27	7.69	15.38	0.00	8.79	2.20	7.69	22.85
1966	65.22	26.09	8.70	13.04	0.00	4.35	43.48	17.39	21.74	0.00	0.00	0.00	0.00	23.57
1967	46.88	50.00	3.13	21.88	9.38	6.25	21.88	0.00	6.25	0.00	15.63	3.13	15.63	18.69
1970*	78.57	14.29	7.14	14.29	0.00	7.14	21.43	14.29	35.71	0.00	0.00	0.00	7.14	25.53

*Small sample

TABLE 15

MEANS IN CORN PRODUCTION

	NET PROFIT/HA.	MEAN FERTILIZER APPLICATION/HA(Kg)	RETURN ON INVESTMENT	MEAN YIELD QU./HA.
(1965-66) Experimental Farm	- 25.25	260.36	- 1.17	24.78
(1966) Actual Farms	268.59	25.60	8.83	25.60
(1967) Actual Farms	-616.63	10.25	-31.25	14.10
(1970) Actual Farms	383.22	56.70	10.60	31.80

The net loss per hectare on farms is roughly equal to the assumed price of labour inputs and many smallholders may not account for this item. The average farmer will apparently gain no marginal advantage by even moderate applications of fertilizer, and the heavy applications of fertilizer which gave increased income in the plot experiments represent a level of investment far out of reach of the average farmer. In monetary terms, the necessary investment is 2940 sucres per hectare or approximately AM $145.00.

It seems that farmers are receiving results economically at least as good as the experimental results, and experimental results are rarely directly transferable to field situations.[16] The production of corn appears to have a low elasticity of improvement unless the price is raised to affect the percentage return on investment.

The correlation matrix for corn shows few strong relationships. The capability class of the land shows little variation (mean 3.04; standard deviation 1.02) bearing out an observation earlier in this work that the whole production continuum may be compressed into an unusably small part of a numbered scale. The yield is not strongly related to any environmental variable, but we find a linear relationship between yield and net return per hectare (0.91) and yield and percentage return on investment (0.88). The linearity of this response indicates that no point has been reached in the function curve at which the income measures slope off despite an increase in yield. Such a phenomenon is usually found in crop studies and this observation leads us to the conclusion that either:

a) this set of data is unusual for its strictly linear response throughout the whole range, or

b) all corn production, including the experimental

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[16] Odell, 157.

attempts, have thus far been suboptimal.

The experimental data, when taken alone, indicates even stronger correlations (0.96) between yield and net monetary return, 0.96 between percentage return on investment and yield, and 0.99 between the two income measures.

The net return per hectare and the percentage return on investment exhibit inverse responses to irrigated land as may be seen in table 16 .

These readings may result from a sport in the manner in which the data was entered but we think not. It appears likely that:

a) corn yield increases with rainfall (0.44);

b) but the use of irrigation does not increase or decrease 'pari passu' with rainfall (0.25); there is, in addition, no correlation between days on which rain fell and the addition of irrigation water;

c) it therefore follows that irrigation is, in fact, being used on soil which is either:

1) unable by virtue of its inherently poor characteristics to utilize that input, or
2) attracts that input because of its known poor characteristics, or
3) is destroyed by the input (see plate 9).

The fourth alternative, and probably the most important, is that irrigation water is over-priced in relation

TABLE 16

RESPONSE OF INCOME FROM CORN TO IRRIGATION

	1st Quarter		2nd Quarter		3rd Quarter		4th Quarter		Year	
	A	B	A	B	A	B	A	B	A	B
Net Return In Sucres Per Hectare	0.07	-0.20	0.35	-0.15	0.27	-0.22	0.31	-0.14	0.39	-0.15
% Return On Investment	0.07	-0.15	0.40	-0.08	0.25	-0.17	0.33	-0.08	0.42	-0.09

A represents Rainfall Only

B represents Rainfall Plus Rainfall Equivalent Irrigation to any increase in yield received from its use. As an indication of this we note that yield increases with rainfall alone (0.44) to a greater extent than it does with rainfall augmented by irrigation (0.26). Fertilizer inputs increase as rainfall alone (0.41) to a greater extent than they do with rainfall and irrigation together (0.18). While the data for wheat production shows a similar trend, the coefficients never become negative. The higher retail price of wheat will tend to keep the 'r' value positive in that crop. We believe that wheat receives less irrigation water and is grown less frequently with irrigation. The higher sale price of wheat will disguise the over-pricing of irrigation water. We note that the mean application of irrigation water to wheat is 818 millimetres per year; to corn it is 1215 millimetres. (Barley receives a mean of 849 millimetres.)

We recommend that this matter be more thoroughly reviewed. It is generally assumed locally that more water is the answer to poor yields. This may not be true for corn production, at any rate in the locations in which corn is grown at the present under local economic conditions.

C. Barley

The observations for the previous two crops pertain generally to barley.

The mean yearly rainfall on barley plots was 1003 millimetres and the addition of irrigation water results in a figure of 1852 millimetres. Barley is but very slightly responsive to fertilizer application (0.45) and is non-responsive to any environmental variable. The returns for three years are shown in table 17 . Net return per hectare and return on investment vary with yield (0.92 and 0.83 respectively). The latter coefficient is less firm than that for corn and may betray some scattering at the upper levels of yield. This proposition is borne out by the discovery of a point of marginal returns in barley production when yield is stimulated by fertilizer application. This point occurs at yields in the order of fourty quintals per hectare. Furthermore there is a point of diminishing returns in the region of fourty-five quintals yield. These figures are estimates only since this trend is dependent upon the needs of the soil in fertilization and may occur at different points in different locales. The retail price of wheat may obscure this fact in that crop, the points of marginal and diminishing returns being at a level at which few operators will experience the effects.

TABLE 17

RETURNS FROM BARLEY PRODUCTION

VARIOUS YEARS

YEAR(S)	% ECONOMIC	% UNECONOMIC	% MARGINAL	% OF CROP IN 5 QUINTAL INCREMENTS PER HECTARE (e.g. 0 to 5, 6 to 10, etc.) 5	10	15	20	25	30	35	40	45	Over 45	Mean Yield Qu/Ha
Experimental	96.43	0.00	3.57	0.00	0.00	0.00	0.00	7.14	0.00	17.86	25.00	14.29	35.71	42.03
1966-1970	54.95	38.46	6.59	21.98	5.49	5.49	25.27	7.69	15.38	0.00	8.79	2.20	7.69	22.85
1966	65.22	26.09	8.70	13.04	0.00	4.35	43.48	17.39	21.74	0.00	0.00	0.00	0.00	23.57
1967	46.88	50.00	3.13	21.88	9.38	6.25	21.88	0.00	6.25	0.00	15.63	3.13	15.63	18.69
1970*	78.57	14.29	7.14	14.29	0.00	7.14	21.43	14.29	35.71	0.00	0.00	0.00	7.14	25.53

*Small sample

The curious negative response of income from corn to irrigation is carried over to barley. Although the divergence of the coefficients of correlation is greater, the reasons are expected to be the same, and we do not offer numerical elaboration.

Conclusions on Crop Yield Investigations

Our hypothesis provided for the evaluation of a set of variables by their intercorrelations such that this evaluation would lead to the discovery of, or the creation of, a set of capability groups. 'A priori' capability groupings have been based upon the assumption that 'obvious' environmental characteristics, such as rainfall, slope, and soil depth, dictate the capability of land for sustained production. A number of investigators have focussed upon a limited set of variables and using multivariate techniques[17] have obtained satisfactory results. But the use of multivariate techniques depends upon the accurate sifting of variables and the firm conviction that only the most important are being investigated. We are not aware of reliable tests of significance for multivariate prediction. We chose to include a large number of

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[17]Odell, 1958, is an example.

variables and to submit the data to a factor analysis trusting in the emergence of strong factor identities on the basis of which factor scores could be created. Unfortunately, we have found that univariate correlations do not exist to the degree expected, and that consequently we cannot regard the factor identities with confidence. No grouping was carried out on the factor scores from this set of data.

Factor analytic methods have been used previously in economic and agricultural studies and the results have gained some acceptance. One such study used data entered in a binary manner; the resulting correlations would have been in the point biserial form and the opportunities for high correlations using this form of data are much enhanced. We cannot now be optimistic concerning the creation of a land use capability scheme based upon empirical crop yield data and divorced from the soil map unless, for example, some method is found to integrate the data by a multivariate procedure which will allow the production of a series of scores which can be grouped statistically.

The list of variables did not include any measure of fertility. It is patently obvious that the level of soil nutrients available to plants is a most important consideration. The amount of fertilizer applied, which was included as a variable, need not indicate the avail-able level of nutrients since the material often does not dissolve. Few farmers, furthermore, use compounds suited to the unique needs of their soils. Fifty-one soil samples therefore were analysed for total cation exchange capacity (CEC). But since this sample is so much smaller than the number of crop yield entries and since many of the CEC readings came from pasture or disused land, the statistical integration of this information to this section is impossible.[18]

We may offer some suggestions with the benefit of hindsight as to why the correlations were so low, or absent. It became clear that the application of technology and investment inputs were erratic in the area studied. It is acknowledged that the markets of Quito are not firmly aligned to the wholesale or bulk handling of goods. There are few commercial storage or refrigeration facilities, for example. Whether the economy is in a transitional stage of technology or not is debatable, but we

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[18] The results of the laboratory analyses have been relegated to Appendix I.

have the impression that we are in possession of a set of data that reflects random input substitution and the application of technology and investment in an erratic manner. The erratic nature of these applications may come from the possibility that few producers possess or suffer from locational disadvantages or comparative disadvantages. The wealthier segments of society often hold land as a social anchor and few landlords live on their property and supervise its production.[19] There may be little motivation to produce at optimal rates under these circumstances and our data may suffer from a scattering effect consequent upon the suboptimal rates of production.

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[19]This problem is being alleviated by a recent law.

CHAPTER V

THE DESCRIPTION AND USE OF THE STATISTICAL GROUPING METHOD

INTRODUCTION

Several references have been made to the desirability of statistically proving the existence of groups. There is interest in the existence of land use capability groups themselves, and additionally in the existence of unique sets of groups - especially those which define a regional identity. This is so because the random occurrence of capability groups over an agricultural surface might imply a different mode of regional definition and planning treatment than does the existence of distinct contiguous sets.

To test for homogeneous sets an hierarchical grouping process[1] was adapted by the writer. This method originates in the behavioural sciences but the process is such that it may be used in other applications; we are not aware of a previous application in our field. "The purpose ... is to compare a series of score profiles (over a series of variables) and to progressively associate them into grou-

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[1]Adapted from Veldman, 308-317.

pings in such a way as to minimize an overall estimate of variation within clusters."[2] Since one group and N groups are limiting cases we wish to know the optimum grouping of the objects between 2 and N-1. As mentioned previously, the intra-group variance will be less than the inter-group variance.[3] Pairing every possible combination of subjects would lead to an insurmountable computational problem. A compromise approach begins by defining each original subject, (set of entries for a subject), as a group. At each step the number of groups is reduced by one. The criterion for this reduction is the sum of the squared differences, (error index), between corresponding scores in the profiles divided by the number of subjects in the potential group. As an object is removed from the remaining set of original subjects its qualities are removed from the matrix on which decisions are made. The removal of objects with a low potential error is accomplished first and the examination of the printed list of error indices which accompany the extractions will indicate:

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[2]Gibbons, 159-167; and J. J. Fortier and H. Solomon, "Clustering Procedures", in P. R. Krishnaiah, ed., Multivariate Analysis (New York: Academic, 1966), 493.

[3]Veldman, 308, and subsequently for much of the following.

a) the number of groups at which natural grouping may be assumed to exist

b) if the number of natural groups is inconveniently too large, the error associated with any desired level of grouping.

In the case of (a), the error index will be zero or some very low value. The magnitude of the compromise will be indicated by higher values of the index in the case of (b), unless, of course, there are found to be too few groups for the problem at hand.

Each variable has equal importance; when variability is not of the same magnitude for all variables, scores may be reduced to z score form. This procedure is required when variables of different types, such as age of the population, years of education, and income are being investigated. Alternatively, factor scores may be used and this option provides the added advantage of destroying the weighting of unimportant variables.

It should be noted that this method offers no basis of inference from one sample to another, the solution being unique to the one set under examination.

PART 1

The Grouping of the Scores Concerning Farm Activities

The factor scores from the one hundred and thirty-nine farms were submitted to this treatment. Factor scores represent the combination of important variables. Four factors were assessed. An individual factor score may be a positive or negative number, the sign reflecting the standing of the subject as a compromise between positively weighted and negatively weighted variables. (The variable weighting matrix appears as Appendix II.) As an illustration, farms with positive values in factor 1 possess relatively better land and more land in crops; negative values on this factor represent weighting toward either:

a) mixed activities on farms with relatively poor land, or

b) exclusively artificial pasture on farms with moderately good land, or very good land.

In the grouping analysis, the numerical value of the error index has little intrinsic importance. The increase in the error index as the number of groups is reduced is the criterion by which one decides upon the optimal number of groups. The farm scores revealed, in our opinion, an optimal level at six groups. The following list demonstrates the trend of the computations:

LIST OF ERROR INDICES
FARM ACTIVITY GROUPING

NUMBER OF GROUPS	ERROR INDEX	INCREASE IN ERROR INDEX FROM PREVIOUS LEVEL OF GROUPING
13	6.31	1.23
12	8.29	1.98
11	8.87	0.57
10	11.48	2.61*
9	13.23	1.75
8	13.55	0.32
7	15.03	1.48
6	17.16	2.13
5	25.36	8.20*
4	68.85	43.49*
3	80.49	11.64
2	86.23	5.73

*See text for explanation of asterisk.

The asterisks denote group levels with high increases in the error index. Should this increase be sufficient to deter the selection of that number of groups, it is then necessary to retreat one grouping level. The dashed line shows the level at which we believe optimal grouping to exist. The selection of five groups might be defended, but the reduction to four groups results in a very considerable compromise. The abrupt increase when the subjects are compressed into four groups shows that the data is divided relative to the assumption of four groups into mutually exclusive entities above that level.

Appendix III shows the factor scores associated into groups. It will be noticed that not all columns (variables) exhibit a low range. The important feature of the grouping is the fact that there is at least one column, in some groups more than one, which identifies the group by the small numerical range within the column and the absolute numerical value of the entries.

Figure 18 locates the members of each group by the group number, arbitrarily numbered from one to six according to the number in the group. Almost half the farm management units (58) may be called arable cropping units with low gross capitalization. A further thirty are weighted toward artificial pasture at a low level of gross capitalization. The investment per hectare varies in all groups as shown by the range evident in the fourth factor, which factor marks this feature. Twenty-eight farms (group 3) tend to balance land use between natural pasture and arable cropping, still at a low level of gross capitalization. Twelve farms (group 4) specialized in arable cropping or a mixture of cropping and artificial pasture at high in-

TABLE 18

GROUP SCORE VALUES AND GROUP IDENTITIES
FROM THE GROUPING OF FOUR FACTOR SCORES

GROUP NUMBER	NUMBER IN GROUP	VALUES ON FACTOR 1	VALUES ON FACTOR 2	VALUES ON FACTOR 3	VALUES ON FACTOR 4	GROUP IDENTITY (FARM TYPE)
1	58	Positive, moderate to high.*	Varies, usually moderately negative.	Positive, moderate.*	Varies.	Arable cropping with low capitalization on land of moderate or poor quality and medium or low rainfall.
2	30	Heavily negative.*	Varies.	Varies.	Varies, usually negative.	Pasture usually artificial with low capitalization on land of moderate to good quality.
3	28	Varies.	Varies.	Heavily negative.*	Varies.	Pasture usually natural with very low capitalization, combined with arable cropping.
4	12	Varies, usually positive.	Positive, very high.*	Positive, moderate.*	Varies.	Arable cropping, or mixed farming, with high gross capitalization but varying capitalization per unit of area.

NOTE 1: The column or columns which 'mark' the identity of the group are denoted by asterisks.

CONTINUED...

TABLE 18 (CONTINUED)

GROUP NUMBER	NUMBER IN GROUP	VALUES ON FACTOR 1	VALUES ON FACTOR 2	VALUES ON FACTOR 3	VALUES ON FACTOR 4	GROUP IDENTITY (FARM TYPE)
5	9	Very heavily negative.*	Positive, very high.*	Varies.	Varies.	Pasture, usually artificial, with high gross capitalization.
6	2	N/A	N/A	N/A	Positive, very high.*	Two farms involved in poultry production with very high investment.

NOTE 2: Groups 4 and 5 occur in areas of greater precipitation; factor 2, which denotes rainfall, otherwise shows considerable variance indicating that it is not an important consideration in the grouping procedure.

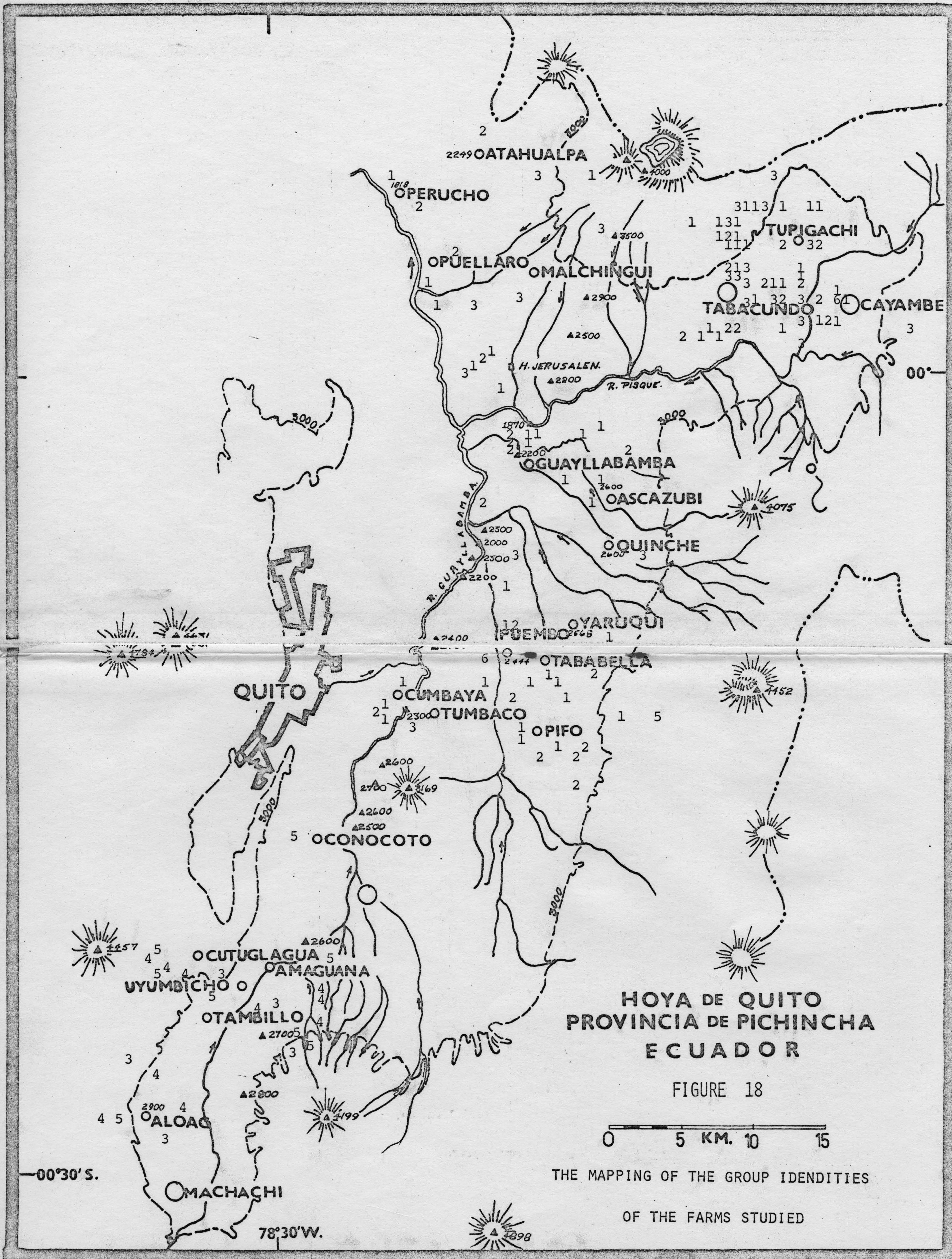

FIGURE 18

THE MAPPING OF THE GROUP IDENDITIES OF THE FARMS STUDIED

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vestment levels. Group 6 is an erratic group composed of two farms with a small area devoted to intensive production.

The map shows that the samples in the southern part of the province are members of group 3, 4, and 5 exclusively. The central part of the study area is identified by a preponderance of crop pursuits at low investment levels; where pasture occurs this type of land use is also lowly capitalized.

The northeastern part of the study area exhibits groups 1, 2, and 3 exclusively and is somewhat balanced to arable cropping, taking into account the fact that group 3 contains a combination of pastoral and cropping land uses.

This map shows that there exists some regionality in the type of land use as represented by the percentage of the area of the selected farms used for certain pursuits. High levels of capitalization are confined to the southern part of the study area, and the central part of the valley is notable for the substantial number of members in groups 1 and 2. Most entries in group 3 are clustered in a triangle composed of Tupigachi, Cayambe and Tabacundo.

This map alone is a slim base upon which to draw conclusions of great practical importance, but we believe that similar testing of a larger sample could reveal important regional differences in types of land use. In addition, it might be, for example, preferable to consider farms from the beginning in size categories. Since we are concerned with a methodology, however, we shall leave these speculations on sampling problems and turn to another set of data which was submitted to the grouping procedure.

PART 2

The Grouping of Land Use Capability Indices

The land class data from the assessed farm land in each parish was submitted to the grouping process. A grid was constructed over the surface of each of the four contour maps constructed for the percentage of land in each set of two classes of land use capability. (See figures 14 to 17.) Since most of the grid intersections fall in spaces interstitial to the 'point of assessment'[4] we may discover a percentage error of estimate by adding the percentage readings from the four maps together. Figure 19 shows the results.

As mentioned previously, the isopleths are interpretive insofar as they represent the ability of the writer to draw lines between points of known values so that the

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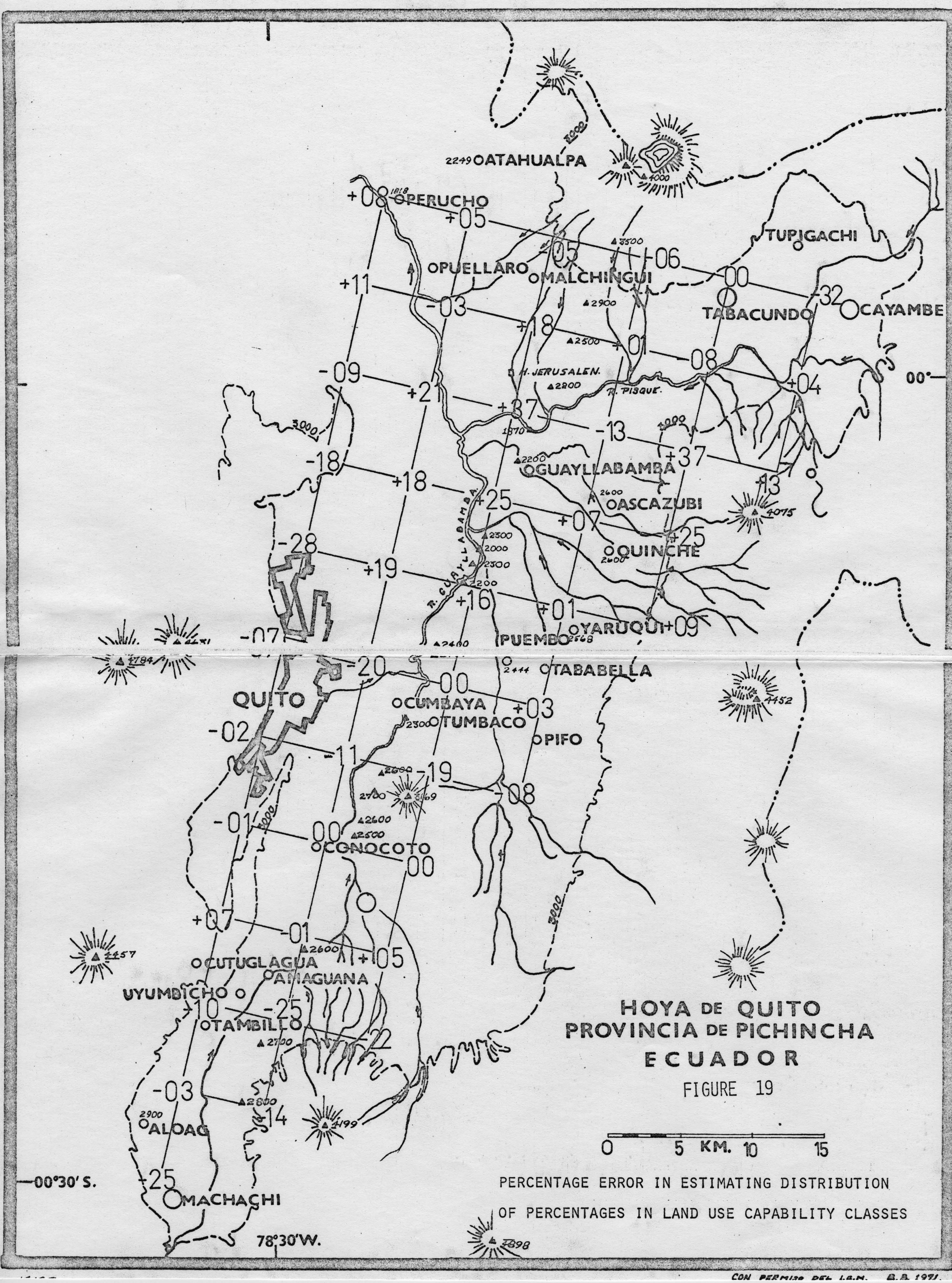
[4]The number representing the parish has been assumed to be a point for convenience only.

F191



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 19

PERCENTAGE ERROR IN ESTIMATING DISTRIBUTION OF PERCENTAGES IN LAND USE CAPABILITY CLASSES

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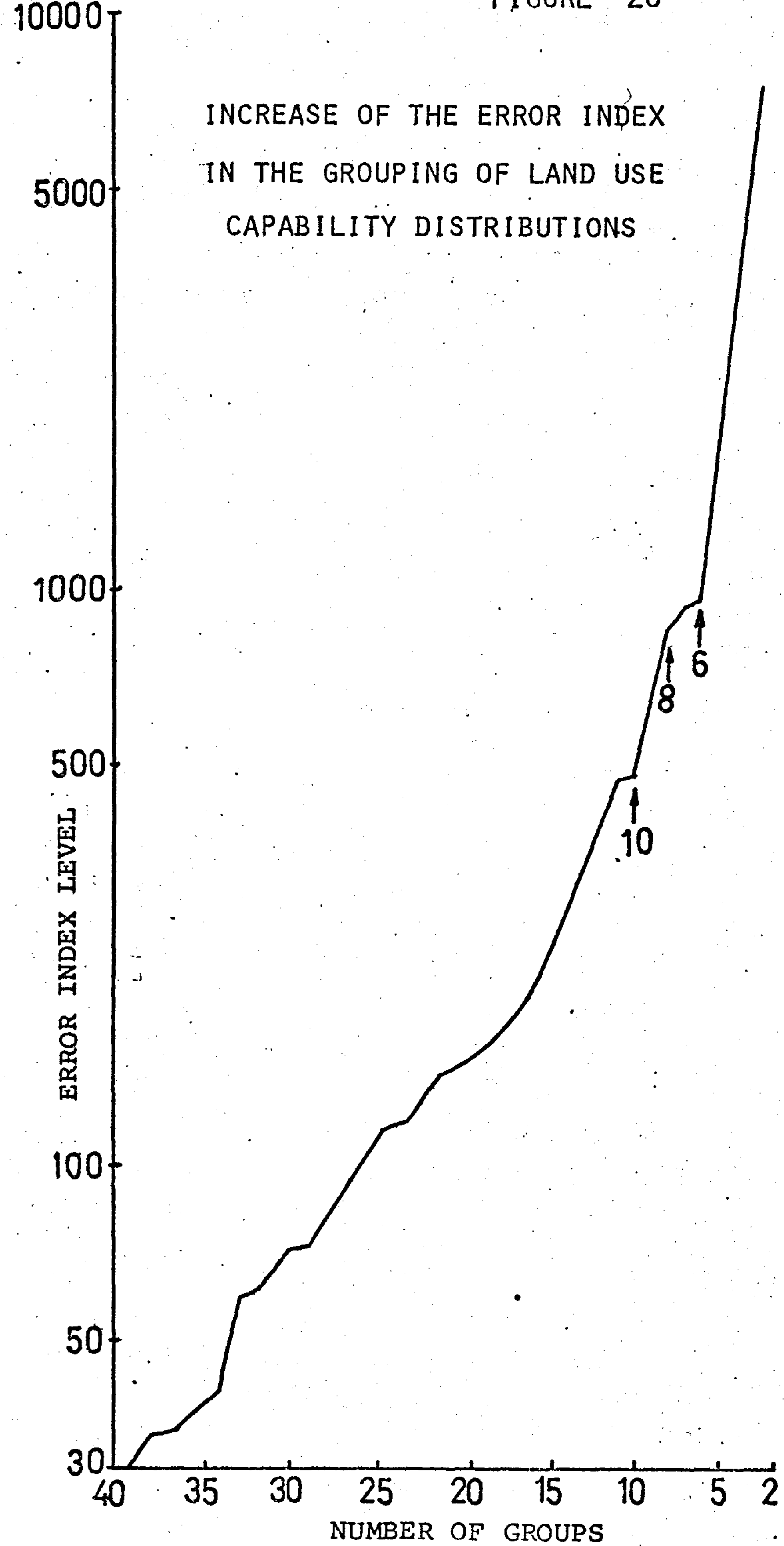
error between these points is minimized. Of course, the real sum at any point whatsoever on the map must be one hundred. Bearing this observation in mind we note that the highest errors of estimate occur in areas that have a large percentage of poor quality land and possess dissected terrain, or in areas where the ratio of assessed land to total land surface is known to be high. On the basis of this map we are inclined to accept the hypothesis that there is, given the subjective limitations of our method, a spatially continuous alteration of the percentage of land in any one category such that the increase or decrease of this percentage will be accompanied by an increase or decrease of the amounts in another category or categories, the total remaining at approximately one hundred per cent.

By taking the four land class percentage readings at each of the fourty-eight points and entering these as variables for fourty-eight subjects the hierarchical grouping was carried out. Figure 20 is a graph which shows the trend of the error increase as the subjects are compressed. Note the substantial increment at eleven groups, nine groups and eight groups. There is little loss of accuracy between eleven groups and ten groups, or between eight groups and seven. Depending upon requirements for detail, or in the alternative, for simplicity, the choice of eleven, nine, eight, or five groups could be made.

FIGURE 20


INCREASE OF THE ERROR INDEX
IN THE GROUPING OF LAND USE
CAPABILITY DISTRIBUTIONS
10000
5000
1000
500
100
50
30
ERROR INDEX LEVEL
6
8
10
40
35
30
25
20
15
10
5
2
NUMBER OF GROUPS

Since the program prints out group membership it is a small manual task to plot the location of members.[5] If members of the same class occur in association in space, there is a case for a unique regional identity. We chose to terminate at nine groups and for cartographic simplicity amalgamated these as follows: groups 1 and 2; 3 and 4; 5 and 6; 7, 8 and 9. The groups were numbered in decreasing 'quality', quality being determined by the location of the group centroid over the four category variables. The group number was then placed on the grid points of the subjects belonging to it and a new contour map drawn (figure 21).

Neighbouring areas tend to be closely related on the 'quality' number scale and two major concentricities will be noted: the very good area around Cutuglagua, and the very poor zone in the Guayllabamba basin. The discontinuity between Cayambe and Tabacundo is clearly shown, as is the boundary between category 5 and category 7 south of Tabacundo. The latter boundary follows contours on the rainfall map (750 millimetres per year), as does the incursion of poorer land toward Tumbaco (850 millimetres per year). We are inclined to accept the hypothesis that there

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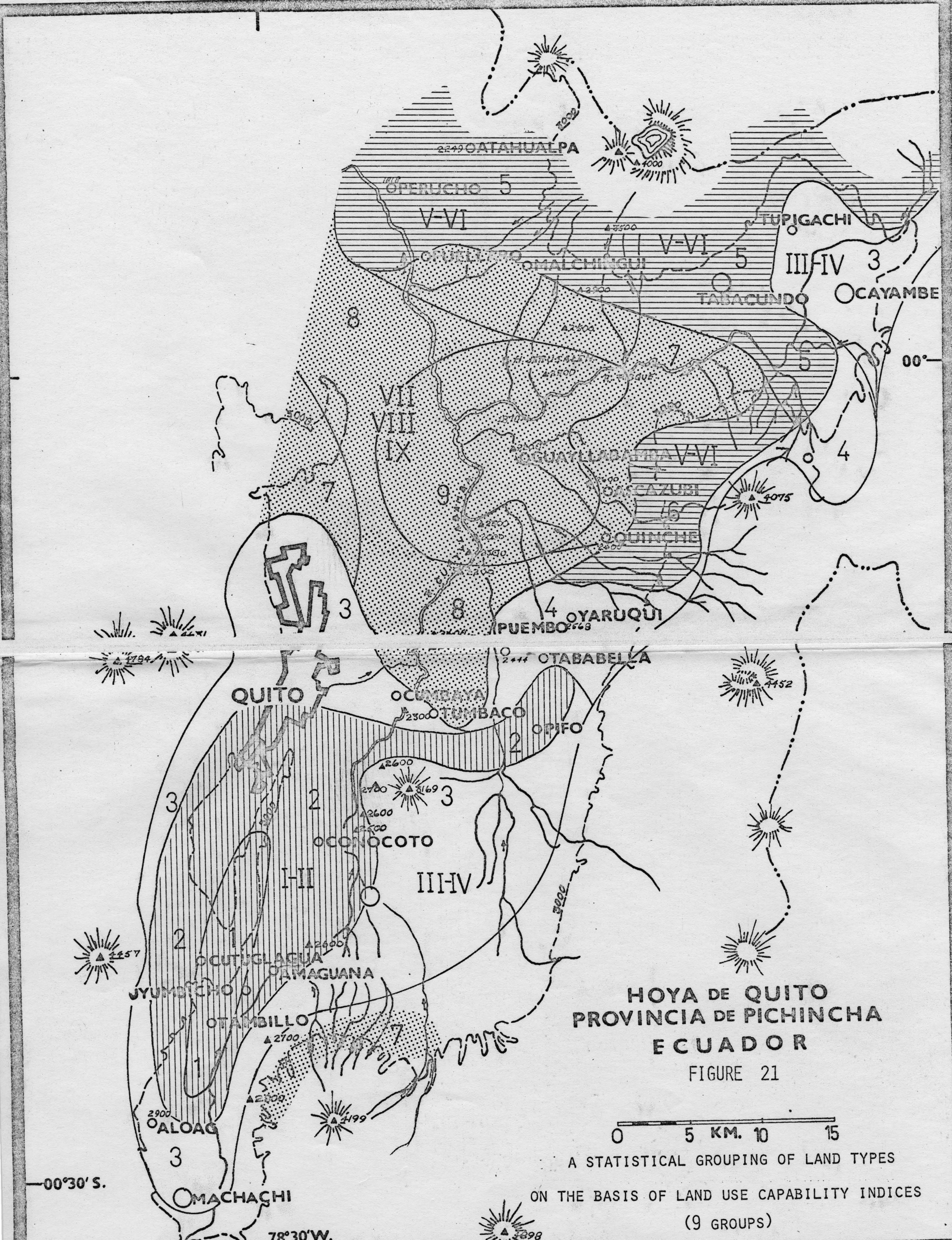
[5] See Appendix IV for subject and group identities. It is apparent that some subjects possess a sum over 100. We let this error stand, since we cannot estimate which map or combination of maps is in error. The character of the variable profile is the important consideration.

F211



HOYA DE QUITO
PROVINCIA DE PICHINCHA
ECUADOR

FIGURE 21

A STATISTICAL GROUPING OF LAND TYPES

ON THE BASIS OF LAND USE CAPABILITY INDICES

(9 GROUPS)

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is regionality of land type.

The time necessary to develop this program and the few illustrations we offer precluded a more detailed analysis of other facets of regionality in Pichincha Province. We propose that the method may be used to isolate regions by any desired criteria, and in particular it would be useful to consider the importance of isolating land types with the use of more variables. It may be postulated that areas with different combinations or percentages of land in the land use capability class scheme as used in Ecuador may have varying problems in economic development in terms of their susceptibility to investment inputs. Alternatively, with a fine scale of sampling, down to the farm level if necessary,[6] reliable regional boundaries may be drawn.

Destruction of the matrix to three groups and then to two produces figure 22. This was accomplished for interest only. At three groups the zone to the south of Quito remains intact and possesses an outlier near Pifo. On deflation to two groups however, this better land is

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[6]However, there are few electronic computers in existence which will handle more than two hundred subjects with this statistical method if all the options for data transposition are preserved.

F221

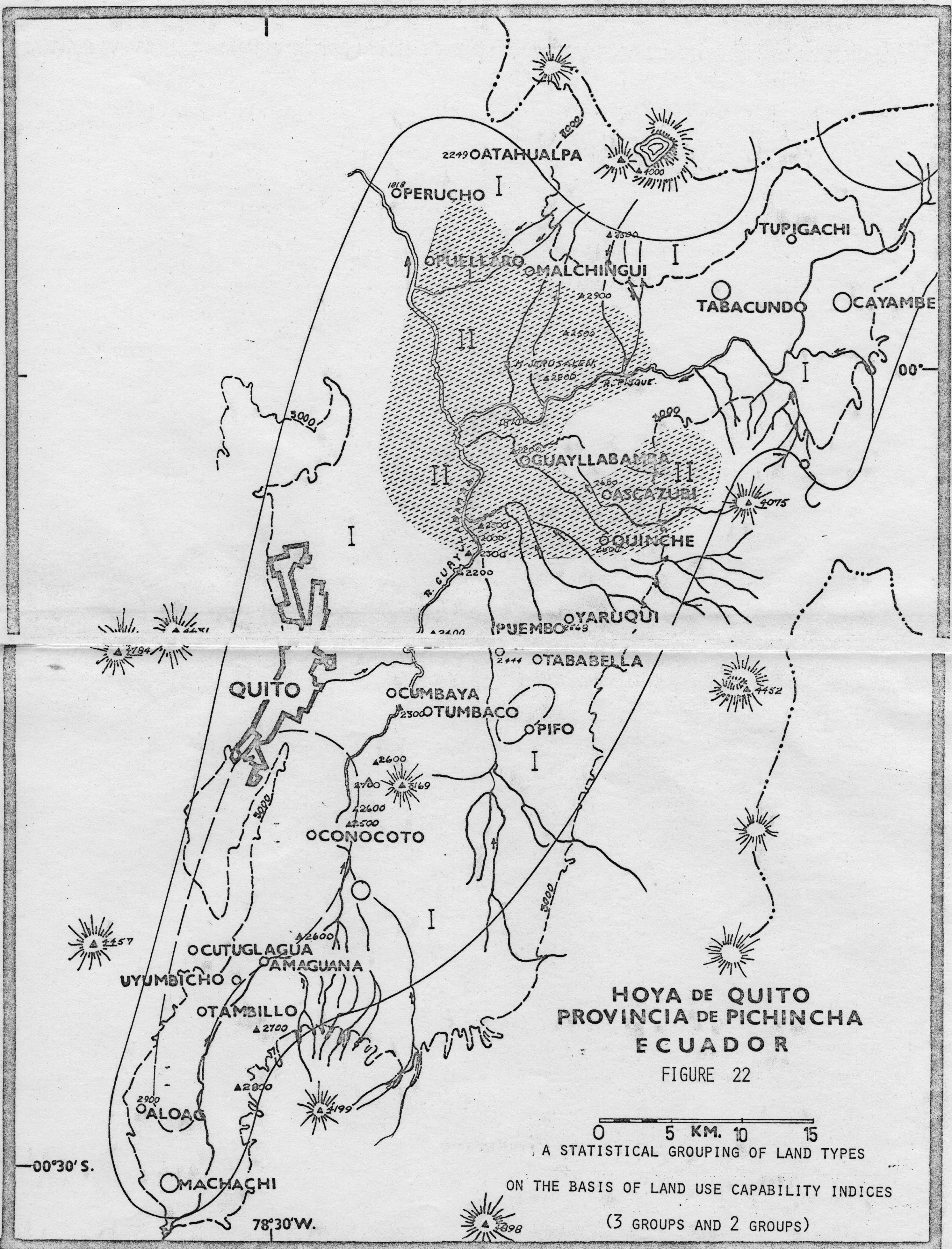

FIGURE 22

A STATISTICAL GROUPING OF LAND TYPES ON THE BASIS OF LAND USE CAPABILITY INDICES (3 GROUPS AND 2 GROUPS)

F222

CON PERMISO DEL I.G.M. B.B. 1971.

forced to join the rest of the province in contrast to the depression centred in the Guayllabamba basin. Note that the second category has appropriated several points to the north and to the east, but not to the west or south. This would result because the original centroid assessment was less exact than the program calculations.

Is there any correspondence between the identity of the 'land type' groups and the identities of the members of the 'farm type' groups appearing on the various 'land types'? Comparison of figures 18 and 21 reveals no fine correspondence; but the areas found to possess higher capitalization in the southern part of the area studied correspond with the best quality of land base. Groups 1 and 2 occur in areas of low precipitation, group 3 in zones of moderate rainfall, and groups 4 and 5 in zones of heavy precipitation. We noted the confinement of groups 4 and 5 to an area of high rainfall in association with the discussion of group identities. (See Table 18.) Arable cropping with low capitalization occurs on land in groups 4 through 9. There is no demarcation by farm identity in the northeastern part of the province (between Cayambe and Tabacundo). Perhaps the use of more than six groups of farm types is necessary to detect such a correspondence. On the other hand, we have noted elsewhere in this study that some operators seem to invest on poor land in defiance of what we might consider to be overwhelming adverse determinants. A widely varying set of input subtitutions has been noted in our study of crops.

Because of such conditions, the lack of adequate income measures for the farm units, and the scale of our sampling, we are not surprised to discover a lack of fine correspondence between farm types and land types. But the correspondence found here indicates that this methodology, if used in a very refined sample, may be capable of discovering real regional differences. The continuous haggling over the existence or non-existence of homogeneous regions and the statistical compromise, which was previously often not known, in appropriating slightly different areas to one region or to another may be relieved somewhat by use of this process.

If desired, the variables may be grouped instead of the subjects to determine which variables elicit similar responses from subjects. This option, not used here, would be useful to find the set of determinants which affect regional growth - always a thorny problem.

SUMMARY AND CONCLUSIONS OF THE STUDY

It was proposed that a scheme of land use capability could be devised through the grouping of a set of scores representing the condensation and appropropriate weighting of the variables thought to be important to the sustained capability of the land to produce at optimal rates. The present spatial pattern of agricultural activities as represented by farm data was investigated to see whether there is a regional specialization in types of pursuits and levels of investment. Additionally a large number of entries for crop yields under varying conditions were analysed. The regional nature of the land base as represented by the land use capability indices already in use in Ecuador was surveyed. Throughout the study we held to the supposition that the present pattern of activities and the intensity of these activities was the logical starting point for projections as to the future capability of the land.

It was found that farms tend, in general, to specialize in either crops or artificial pasture, natural pasture being found often in association with crops. By the use of an hierarchical grouping method it was found that a further division occurs between high and low levels of capitalization in each of these categories. The spatial representation of the farms by group identities on a map revealed that the higher levels of investment are confined exclusively to the southern part of highland Pichincha Province. It was found that the quality of the land base in this area is superior to the rest of the province in terms of the Ecuadorian (ONAC) scheme of land use capability, and it was only in this zone that any distinct statistical importance could be attached to the variables concerning precipitation.

The study of the crop data was disappointing in respect of the low correlations obtained in the factor analysis process used to generate the scores to be grouped. The variables for the amount and frequency of rainfall were found to have little importance in the analysis of both the farm activities and the crop yields. Multivariate procedures were not compatible with the methodology we proposed, and it became apparent that our study of crops was in need of a set of scores generated on multivariate considerations. Consequently, we had little confidence in the factor identities in the analysis of the crop data and did not proceed to a grouping of factor scores. The analysis of the crop data might have been compromised by the following problems:

1) The existence of faulty data resulting from the failure of tax assessors to ascertain accurately the levels

of investment and labour being put into crop production.

2) The fact that most land, however poor, is producing at sub-optimal rates due to a lack of operating or investment capital, economic motivation, or a shortage of labour. The data would then not be representative of all levels of production and income.

3) The apparently random application of investment. This may be partially due to the lack of locational disadvantages or the failure to recognize such disadvantages.

4) The random substitution of inputs, or the utilization of inputs whose economic effect is not known by or calculated for the farm operator, may have created some confusion. The use of standard fertilizer compounds and the use of irrigation water are examples.

5) The apparent failure of some farm operators to keep profit and loss accounts to discover the viability of their operations. Some operators, who may be keeping a farm for recreation or for social prestige may not be concerned about losing money; others may regard the loss over a period of a few years as a cost of land improvement. Still others, especially small holders, may in fact be making money, or a subsistence living, if they do not pay labour costs, but we could not account for this practice.

7) Much credit must be given to the National Office of Assessment and Cadastral Survey (ONAC) for the development of a weighted scheme for land use capability. This scheme was contrived for tax purposes but is now, for example, being used by the Wheat Commission to map lands suitable for wheat production. The class divisions are, however, too gross in scale to reflect differences in yield or income. This is one correlation (i.e. yield to land class) in which univariate procedures should be valid. We strongly recommend against any assumption that there are marginal production differences among any of the classes suitable for arable cropping in the ONAC scheme, and against the assumption, for the present, that there are any differences bearing upon production at all.[1]

It does appear that 'land types' exist as regional entities in the study area, if we suppose a land type to be a unique distribution of values across a variable profile describing the quality of the land base. The existing Ecuadorian indices were used to test for this regionality and a map was presented to show the location of these land types on a gross scale.

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[1]With the possible exception of Class I land which is rare and usually excellent.

A study of the total cation exchange capacity of some sample soils, presented as an appendix, revealed that there is one set of low readings and another set of moderately high readings. The higher readings are associated with the regular application of artificial fertilizer and the rotation of crops with pasture. The long term stability of agricultural production in the Andean portion of Pichincha Province will hinge upon the reclamation of exhausted soils and the preservation of the better ones. No one feature can be more important in this process than the return of organic matter to the soil under suitable conditions of moisture content and soil temperature. To accomplish this reclamation of the poorer soils it will be important to consider radical changes in the year by year land use of much of the province, especially the institution of adequate fallow and pasture rotational practices.[2]

In brief, then, the accomplishments of this study are as follows:

1) The adaptation of an hierarchical grouping procedure to the investigation of the types of farm activity, and to land type analysis. The use of this method is be-

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[2]Detailed recommendations appear as Appendix V.

lieved to be unique in regional investigations. Some 'farm types' which possess a regional identity were found; a number of land types, also with regional affiliations, were also discovered.

2) The discovery, albeit an understandable one, that factor analysis, which depends upon univariate assumptions, is inadaquate for the generation of scores concerning crop performance.

3) The compilation of a substantial body of data concerning the agricultural activities and the economic performance of three common crops in the Andean portion of the Province of Pichincha. This data includes a number of precipitation maps compiled for the first time from meteorological tables for the years 1962 to 1969.

4) The analysis of more than fifty soil samples to determine, on the basis of the total cation exchange capacity, the fertility status of the soils and the relationship of this measure to the type and intensity of land use, and to the income from the soil. Higher levels of artificial fertilization would appear to be indicated, and a radical change in rotational practices. This observation is general, since a number of well managed farms were encountered from which the long term potential of agriculture in Pichincha Province may be estimated. Detailed costing studies will be necessary.

5) The net income analysis of wheat, corn, and barley holdings over a period of years showed a rather high percentage

of uneconomic holdings.

6) The discovery that the land use capability scheme in use in Ecuador may lead to faulty economic projections. This problem exists because the whole range of yields, and the attendant range of costs, are compressed into a small segment of the land use capability index scale. The standard deviation is low- usually ammounting to the equivalent of one class.

APPENDIX I

THE TOTAL CATION EXCHANGE CAPACITY OF SOME SOILS AND OBSERVATIONS ON THE RELATIONSHIP BETWEEN THIS MEASURE AND INCOME FROM THE SOIL

This section will describe the results of tests to determine the cation exchange capacity of some sample soils. Sixty-seven samples were taken by the author in the course of visiting farms. Fifty-one of these samples were tested for total cation exchange capacity. Soil samples were taken for the following reasons:

a) It is possible, and became apparent that the farm environment, (e.g. slope, rainfall, present intensity of use and investment) bears little relationship to yields or income per plot of land and that some soil quality or set of soil qualities relating to fertility possessed a degree of importance.

b) It was desirable to know the range of some measure of soil fertility and the accompanying range of income to be expected from soils of various fertility levels.

c) It was desired to know the short term fluctuation of a measure of fertility through the crop-pasture rotation cycle, where this cycle exists.

In view of these criteria soil samples were selected to represent the entire range of crop yields and of pasture qualities, and to represent various points within the rotation cycle where more than one sample was taken from a single farm. In the latter case, care was taken to select samples in close proximity in space, representing the same soil series as far as this feature was recognizable in the field. Variables such as use of irrigation water, soil depth, texture, structure, slope, altitude, and distance downslope from an irrigation ditch were held constant when possible where multiple samples were taken.

The total cation exchange capacity (CEC) was determined according to the method of Peech.[1] This method involves the leaching of free cations, presumably those important to and available for plant nutrition, by ammonium acetate and the testing of a subsequent distillate of the leachate solution.[2] The soils tested were taken from the upper hotizon in a mixed sample to twenty centimetres depth. The cultivated horizon only was tested for the following reasons:

a) Many of the tested soils were shallow and such a sample was representative of the depth of soil available to plant roots, or the total depth of the soil.

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[1] Soil Survey Laboratory Methods and Procedures for Collecting Soil Samples, (Washington; USDA, Soil Conservation Service, 1967), 19.

[2] The results are in milligram equivalents per 100 grams of oven dried soil.

b) Because of aridity or other restricting conditions, a surface sample represents, even in some deeper soils, the part of the soil actually used by plants, or penetrable by plant roots.

c) We did not possess the means or time to carry out the excavations and analyses of deeper samples, nor could we propose a method of integrating numerous individual profile samples to the income received from the soil. A sample of over fifty would display subjects of various depths, numbers of horizons, textures, and so on. The integration of such a mass of material would be difficult, assuming in the first place that such detail is necessary for our purposes.

The CEC rating is assumed here to be a usable measure of fertility. One may, of course, receive high readings resulting from an elevated level of some element which has little bearing on plant nutrition. But the soils of the research area are not known to be rich in calcium or trace elements, and our study of the fluctuation of the CEC through some rotations indicates that this measure is sensitive to changes in the levels of nutrients extracted from the soil by plants.

Results of the Analyses and Observations

For soils under one of the three crops studied (wheat, corn, and barley), figures are available for gross income per hectare, net income per hectare and the percentage return on investment.[3] As mentioned throughout this work, we cannot describe any simple relationship between one measure and another, in this case, between the CEC and any income measure. It will become clear that some soils with a low reading are producing an income, and that there are some marginal or uneconomic pursuits on soils that show a moderately good rating. It has been found that soils giving a reading less than 12.00 meq. give a low economic yield, or that an economic loss ensues with the use of these soils. Any result over 20.00 represents a 'fertile' soil. Such soils appear to be high either in colloidal clays with easily detached cations, or in organic matter which also possessed easily detached cations.[4]

Results are presented here for the more interesting samples. The cation exchange capacity, the gross return in sucres per hectare, the net return, the percentage return on investment, and notations as to the present land use and

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[3]According to the formula given previously in the body of this study.

[4]Miller and Coleman, 241.

the history, where known, are presented. Entries for all items do not exist for all examples; due to the attempt to take a representative sample, some examples were obtained from unused land, or from land on which income estimation is difficult. Yearly income from milk sales only per hectare is known for some pasture entries, but since dairy operations could not be cost assessed, these figures are of informational value alone. We shall commence at the lowest readings.

The observations and data entries result only from first hand investigations and interviews by the writer.

The symbol 'S' in the table headings denotes the Ecuadorian unit of currency, valued approximately at twenty-five to the American dollar.

HACIENDA ATALPAMBA

(QUINCHE PARISH; FARM SAMPLE #084, NORTHWESTERN SECTION)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
QUI 221	2.88	Disused field, sparse covering weeds.	Coarse sandy, grey, no structure, depth 60-70 cm., 0° slope.	N/A	N/A	N/A
QUI 222	3.20	Pasture corn, first year after crop portion of rotation.	As above, but receives manure.	Average milk yield per wet cow per day from corn pasture is 5.5 litres. These are cruzado (hybrid) animals, and the figure is in a low range for this type of animal.		
QUI 223	3.68	One year barley after potrero, fertilized with 8 qu. 10-30-10 in 4 lots, 2 qu. each time.	As QUI 221, but fertilized, and periodically irrigated.	810	-1535	-70.60

Observations

The disused field possessed the lowest reading. It receives neither the manure nor the fertilizer which the other examples receive. The fertilizer application is the heaviest found in the study, and is applied in four doses due to its leaching through the porous sandy soil with the irrigation water. The quality of the barley and wheat grown is very good, the grain being well-formed and hard. The pasture corn pursuit is uneconomic if calculated for sale, (-60.10% on investment). This is a very interesting farm and it has received attention elsewhere in the study. In very poor years no production of any crop matter results.

HACIENDA TUCUSAGUHUA

(QUINCHE PARISH; FARM SAMPLE #085)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
QUI 161	11.50	Three years "national" alfalfa after a series of crops.	Shallow, 30 cm., medium brown, sandy loam, 0° slope, irrigated, very hard.	N/A: farm is understocked with native (criollos) cows which give 3 to 4 litres per day per wet animal.		
QUI 162	6.80	The "worst" part of a field of corn, part of a rotation.	Shallow, 30 cm., very hard, "kangahuoso", light brown, 10° slope.	1920	-210	-23.51
QUI 163	17.00	Barley, "Santa Catalina" corn planted previous year, no fertilization; this field has always been in crops.	Depth 50 cm., medium brown, friable, said by farmer to be his best field.	2160	680	45.95

Observations

The variability of soil quality within the farm is very great. The farmer complains of soils that are too hard to cultivate, and which dry out extremely quickly. No irrigation was used on the crops in 1970. Total crop loss is suffered in poor years, and year by year yields vary greatly. Some fields on this farm give economic returns and others do not.

URCUHACIENDA

(MALCHINGUI PARISH; FARM SAMPLE #057)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
MAL 011	13.44	Disused land (see below under observations); figures entered for wheat, fertilized with 4 qu. 10-30-10.	Depth 20 cm., slope 20°, light brown, hard structured "kangahuoso".	2200 0	250 -1550	12.82 ("average year") -100.00
				(Total crop loss in "poor years")		
MAL 012	6.80	Always in crops: wheat, barley, beans, fertilized 4 qu. 10-30-10.	Depth 30 cm., slope 8°, friable, medium brown, sandy loam.	4400	2250	104.65

Observations

The cultivated land has been recently converted to pyrethrum, which is being grown under the same rates of fertilization as previously were used for the mixed crops. The land in the first sample is now not utilized and is adjacent to that shown in plate 8 ; it is similar except for the existence of trees. The second sample shows a lower CEC reading but a substantial profit in wheat production. No irrigation is available and total crop loss is suffered when rainfall is deficient.

Another farm south of Malchingui (farm sample #060) showed a CEC of 8.40 in a field always planted in corn. Without irrigation or fertilizers, this flat field returned S 2400 gross income per hectare, S 1030 net, for a return on investment of 76.18%. A 'particulare', (private small holding) in Malchingui village, (sample #061), composed of sandy soil similar to that in plate 6 , gave a reading of 3.60 and no economic return - the owner being faced with starvation.

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[5]The land in plate 7 , of no apparent economic value, has been asigned to small holders who, in turn, have refused to accept it. They were squatting at the time of the writer's visit near the better part of the farm (sample #060), of which plate 7 is in fact a portion. By accepting title to the poor land, the squatters feared their fate would be sealed in the manner of the owner of the 'particulare' referred to above.

Hacienda Santa Teresita (Tabacundo Parish; Farm Sample #095; sample TBC 201): One sample of very hard, pale brown (tan) soil was taken from a level location on this poor farm. Soil depth was twenty-five centimetres. This land has perpetually been in crops which fail when rain is deficient. Year after year crops are planted without fertilizers, this sample, with a CEC of 6.24, being representative of the resultant exhausted soils. The economic performance of this land is interesting:

CROP RETURNS PER HECTARE
HACIENDA SANTA TERESITA, TABACUNDO, 1970

Crop (Year 1970)	Gross Return/Ha. In Sucres	Net Return	% Return On Investment
Corn	960	- 88	-21.95
Barley	960	-480	-70.97
Wheat	1870	560	42.75

The economic return for wheat is the result of the use of a registered grade of seed ("Napo"). It is not known whether this type of seed will be consistently able to give elevated returns from such poor soil. Soil that is as low in nutrients as this example must possess, without artificial fertilization, some reserve available to improved types of grain seed; we suspect that good returns, without substantial soil improvement by fertilization, rotation with pasture, and irrigation, will not be of long duration.

The Hacienda Picalqui, farm sample #116, some hundreds of metres to the east of the previous sample, showed the following readings:

HACIENDA PICALQUI

(TABACUNDO PARISH; FARM SAMPLE #116)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
TBC 981	10.00	One year corn after 4 years rye pasture, fertilized with 2 qu. 10-30-10; and 1 qu. of urea. Irrigation irregular.	Light brown, subangular blocky, sandy silt or clay, slope 3° to 5°.	1600	-610	-38.34
TBC 982	10.08	Six years alfalfa and rye pasture.	As above.	(No figures available for income from pasture.)		

Observations

The yield of corn may be uneconomic in the year of planting, but the subsequent crops of barley and wheat are not fertilized returning yields of twenty-five quintals and 22.2 quintals per hectare respectively. This farm gives the impression of having been well treated. At one time operated by American missionaries, it was subsequently divided. It appears that the level of soil fertility is being maintained and that there is, over the period of a rotation, a stable income from a variety of pursuits.

HACIENDA MOJANDA

(TABACUNDO PARISH; FARM SAMPLE #117

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT	
TBC 991	15.84	Nine years barley or wheat, one year fallow.	Medium tan, subangular blocky, medium firm structure, depth 50 cm., coarse, silty loam, slope 5° to 8°.	3300	1670	102.45	(W)
				3600	1930	115.57	(C)
				(Household use only)			
				3240	1050	47.95	(B)
				4050	1170	40.63	(B*)
TBC 992	12.92	Nine years barley or wheat, no fallow; poorer field than above example.	As above.	2540	910	55.82	(W)
				2592	402	18.32	(B)

(W) = Wheat
(C) = Corn
(B) = Barley

(B*) = Known response to barley on this farm when fertilizer application increased 50%.

Observations

These figures represent a heavily capitalized effort to produce grain crops at the high rates of yield suitable for sale through market channels. The farm is owned by a limited company. Arable lands are cropped for five years and fallowed one year. Natural permanent pasture is used in the upper reaches, five hundred hectares of the farm being cultivated in crops and one thousand hectares being in pasture. Barley is sown at three quintals per hectare, and fertilized with 4.80 quintals of 10-40-10 per hectare. The corn planted is sufficient only for use within the farm. Cultivation extends to 3200 metres. It is known that on the better parts of the farm, a fifty per cent increase in fertilizer application will give an increase in yield, but this practice results in a decrease in the percentage return on investment. The motivation of the operators may be directed to the repayment of certain capital at a certain percentage rate, rather than the production of a high gross income. This example also shows how a decrease of twenty per cent in the yield (as is the case with sample TBC 992 from a poorer field) decreases the percentage return on investment by at least half.

Investigations in the central part of the valley, in the parishes of Puembo and Tababella, revealed than an increase in the cation exchange capacity is associated with the use of the land for pasture, and with the accompanying deposition of manure.

HACIENDA PALERMO

(PUEMBO PARISH; FARM SAMPLE #080)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
PUE 151	9.28	Old alfalfa pasture (2 years plus) sparse; after crops in rotation.	Greyish brown loamy sand, depth 40 cm., crumb structure, slope 0°.	Milk receipts S 1820 per annum per hectare on this type of pasture; 10 litres per day per wet cow.		
PUE 152	6.28	Last year crops (wheat, corn, barley); after pasture; fertilized with 3 qu. per ha. various compounds.*	Very pale greyish brown coarse loamy sand, weak medium blocky structure.	2240 1650 2200 2700 3240	340.00 -350.00 - 99.00 19.50 504.50	- 0.51 (C-1) -30.67 (W-1) -18.67 (W-2) 0.73 (B-1) 18.44 (B-2)

(C-1) = Corn - 1970
(W-1) = Wheat - 1969
(W-2) = Wheat - 1965
(B-1) = Barley - 1969
(B-2) = Barley - 1965

*Yields are zero in the absence of fertilizer.

Observations

This farm has ceased the production of grain crops, partly because of the difficulty of obtaining reliable labour, and partly because of the unprofitability of the pursuits. Alfalfa pasture and the accompanying manuring appears to have increased soil fertility in this case. The alfalfa requires three months to grow to the first cutting, and fourty-five days to rejuvenate. These are long periods. The manager reports that, while alfalfa pasture used to endure for ten years or more, it now is depleted after two. Whether this is due to a change in livestock intensity or in other practices is not known; it is suspected by the indigenous people to be a reflection of soil exhaustion. Many contacts on various farms volunteered similar information.

A difference was found between the CEC of depleted alfalfa pasture and a cultivated field on sample farm #086: 9.28 meq. and 8.80 meq. respectively. On farm #081 a field fertilized with two quintals of 10-30-10 per hectare gave a reading of 12.80. This field was planted in barley which yielded a net loss of S 330 per hectare, and a percentage loss on investment of 28.43. An adjacent field of a similar type of soil (shallow, dark brown silty clay of high plasticity) gave a reading of 14.20 after four years in alfalfa, while a soil which had never been rotated with pasture gave a result of 10.30.

Hacienda San Jose (part now known as La Pradera; Puembo Parish; Farm Sample #082): A young professional man in Quito has taken over part of this depleted hacienda, previously owned by two elderly ladies who commuted annually between Paris and Quito. The new owner hopes to reclaim severely depleted soils by the use of irrigation, fertilizers, and pasture. To measure the results after two years of cultivating wheat and barley under irrigation, we took one sample of the 'old' and two samples of planted soil.

HACIENDA SAN JOSE

(PUEMBO PARISH; FARM SAMPLE #082)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
PUE 171	12.48	Two years barley, fertilized, irrigated.	Ten centimetres, sandy clay, light brown (tan), slope 0° to 5°.	2160	176.4	-8.61
PUE 172	12.58	One year barley, one year wheat, more heavily irrigated.	As above.	2200 (Results similar to above for barley.)	216.4	-6.92 (W)
PUE 173	11.60	Disused land.	Extremely dry, hard, "kangahuoso" material.		(Unusable)	

(W) = Wheat

Plate 9 includes the second and third sample, the second being in the foreground, the third on the unreclaimed middle background. The shallowness of this soil precludes the cutting of a network of irrigation channels, and the weekly arrival of irrigation water in quantity causes erosion. It is likely that the reclamation will be successful and the present loss on investment is not excessive if regarded as a cost of improvement.

We shall turn now to descriptions of some of the better soils investigated, and for comparison with the preceding example, look at a similar problem handled thirty years ago near Amaguana. (See plate 1 for the locale.)

HACIENDA RELICARIO Y SAN FRANCISCO

(AMAGUANA PARISH; FARM SAMPLE #016)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
AMA 811	21.68	Pasture, 5 years, kikuyu, after 2 years wheat; fertilized and irrigated.	Depth 50 cm., dark brown, fine sandy loam, slope 35°.	(Annual receipts from sale of milk, S 1622 per hectare; 6.5 litres per day per wet cow.)		
				For wheat, last planting:		
				4950	1785	56.40[1]
				7700	3910	103.17[2]
AMA 812	12.80	Disused land, see observations, not irrigated.	Depth 10-20 cm., slope 15°, hard, blocky, "kangahuoso" material.		No use.	

[1]With three quintals 10-30-10 per hectare.

[2]With 6.5 quintals 10-30-10 per hectare.

Observations

The second sample represents the land as it was thirty years ago. After the introduction of irrigation and pastoral pursuits the depth of the soil increased as the hardened relics of the old exhausted soil were made more manageable by the increase in the rate of favorable soil formation processes, especially by the introduction of organic material from animal waste. The implementation of a rotation weighted toward pasture has increased the output and the value of this land. The returns on this farm are typical of the area, which is regarded as a zone of prime quality.

A farm in Cutuglagua Parish (sample #0.44) gives a reading of 35.28 on old natural pasture. A wheat field on the same farm produced a gross income of S 3300, a net income of S 985, and a percentage return on investment of 42.55. The cation exchange capacity was 31.10 after three years of wheat with four quintals of 10-30-10 per hectare per year. The adjacent farm exhibited figures in the same range, and was keyed to a rigid rotation, whereas the former farm contained fields which would be kept in a crop until the yield declined. The operator of the former farm is discontinuing wheat production.[6]

[6]There were indications of severe nematode infestation on the roots of the wheat plants.

HACIENDA LA MERCED

(CUTUGLAGUA PARISH; FARM SAMPLE #045)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
CUT.361	31.36	Three years wheat after pasture, fertilized with 7 qu. 10-30-10.	Depth 60 cm., medium brown, sandy loam, friable, slope 15°.	6600	3985	152.39
CUT 362	30.82	"Matorral", or scrub thickets being cleared for cultivation, slope 7°, highly organic soil with matted roots, not previously cultivated, very friable, dark brown to black in colour, depth unknown.		This soil can be used for 3 years for grain crops without fertilization; it will then be similar to the soil above. However, 2 qu. of 10-30-10 will be applied in 1971.		
CUT 364	29.64	Three years heavily matted rye pasture, after 3 years wheat, irrigated.	Very dark brown sandy loam, blocky structured, damp, slope 15°.	Milk receipts per annum per hectare are S 1825 from this pasture; the cruzado cows yield up to 16 litres per day, with a mean of 10 litres per day.		

HACIENDA LA MERCED (CONTINUED)

FIELD SAMPLE NUMBER	CEC	LAND USE IN 1970	SOIL DESCRIPTION	GROSS INCOME (S/HA.)	NET INCOME (S/HA.)	PERCENTAGE RETURN ON INVESTMENT
CUT 364	19.84	Two years wheat, fertilized; not irrigated.	Medium to light brown, blocky structured coarse sandy loam, slope 35°.	2640	385	17.07

Observations

The high CEC readings on this farm may be due to the high rates of fertilization, without which the crops would fail. The year 1969 was very poor because of an excess of rain; since the grain turns soft, and in advanced cases, black, with excessive moisture, barley production has been discontinued. The steeper slopes over twenty degrees must be tilled by hand and yield between twenty per cent and fourty per cent less than the fields on milder slopes. This farm was among the best managed of those we investigated.

The latter two haciendas discussed occur in the zone of high capitalization and better quality land base as determined by the grouping analyses described in the body of the work. It is evident that the agricultural practices in this zone differ radically from those in other parts of the study area.

Conclusions

A large range is displayed in the total cation exchange readings. The highest readings occur in the south of the province, where local agricultural habits dictate a rotation balanced between pasture and arable cropping. A high level of fertility may be maintained, equal to that of the virgin soil, by the intelligent use of a rotation, and annual applications of fertilizer at levels above those in general vogue in the province as a whole. Very poor lands may be reclaimed if placed in a rotation heavily balanced to pasture with an adequate supply of water. Substantial applications of fertilizer to soil showing a pre-existing low level of fertility will not necessarily result in economic yields, unless perhaps irrigation water is obtained at no cost. The relative absence in the data of examples showing a reading for CEC between 12.00 and 20.00 may indicate that there are two categories of productivity, the lower set being profitable only under certain favorable conditions at certain times, and the higher being almost without exception profitable. The entries in the lower set represent examples which have never, or rarely, been placed in pasture.

There appears to be a small range of fluctuation in the CEC index through a rotation, the smallest fluctuations being found among soils which receive annual applications of fertilizer by means of which fertility is preserved through to the next pasturing. The fluctuations are larger in examples which are not fertilized between periods of pasture, and these examples show a lower total cation exchange.

The large number of low readings obtained and the proportion of respondents who indicated that crops will not grow without fertilizer suggest that the fertilizer solutes may be the sole nutrients available in a sizeable number of plantings. These solutes are thought to have been a considerable part of the total cation exchange capacity in a number of the analyses.

There is a weak correspondence only between the total cation exchange capacity and any measure of income from the soil, and the relative standings on the CEC index as they pertain to land use and rotational practices are thought to be the more important result of the soil analyses.

APPENDIX II

THE WEIGHTINGS OF THE VARIABLES IN THE FACTOR ANALYSIS OF FARM ACTIVITIES

THE VARIABLE NAMES MAY BE FOUND IN TABLE 12.

VARIABLE 1	-.03455	-.01568	.03756	-.20145	.01745	.57746
VARIABLE 2	-.03535	.04680	-.08602	.49027	.05021	.62484
VARIABLE 3	-.03228	.01308	-.16943	.34184	.02285	.69092
VARIABLE 4	.02697	.17337	-.01633	-.04715	-.13790	.51268
VARIABLE 5	-.05414	.13569	-.08210	-.14699	.16150	.14872
VARIABLE 6	.06377	.09864	.08562	.44596	.00253	-.05076
VARIABLE 7	.03871	.00898	-.05412	.77982	.02354	.20149
VARIABLE 8	.07929	.04430	-.07024	.68544	-.05545	-.06507
VARIABLE 9	-.06675	.90217	.03572	.00541	.04837	.05511
VARIABLE 10	-.05646	.90841	.09542	.09541	-.07765	.05308
VARIABLE 11	-.03428	.84506	.04596	.01022	.02526	.07141
VARIABLE 12	-.02495	.92593	.06692	.10425	-.01549	.03215
VARIABLE 13	-.05862	.98493	.08518	.08621	-.02046	.03968
VARIABLE 14	.07719	.86284	-.11814	-.02528	.02062	.06958
VARIABLE 15	.60764	-.01770	.40540	.02835	.53166	-.04909
VARIABLE 16	-.08828	.05963	.77042	.03661	.04104	-.16997
VARIABLE 17	.57396	-.00293	.56475	.01879	.39639	-.03515
VARIABLE 18	-.15838	-.12618	-.21031	-.01943	.01518	-.17378
VARIABLE 19	.06872	.04690	-.45884	-.03156	-.61872	.14409
VARIABLE 20	.49126	.00903	-.05402	.07059	-.59683	.04808
VARIABLE 21	.82591	.00303	.28594	-.03574	-.33400	-.03465
VARIABLE 22	.81327	.01399	.04534	.00376	-.49978	-.09766
VARIABLE 23	.94494	-.03798	.13532	.02842	-.17111	-.03186
VARIABLE 24	.95383	-.04311	-.02171	.08594	-.14240	.01858
VARIABLE 25	.96469	-.03084	.06039	.09471	.04845	.00776
VARIABLE 26	.92446	-.07834	-.06504	.09270	.04893	.04980
VARIABLE 27	.90510	-.05806	.13826	.05002	.23734	.00589
VARIABLE 28	.57143	.02075	.70024	.00796	.41522	-.05853
VARIABLE 29	-.37617	-.05154	-.44888	-.08004	-.04325	.03862
VARIABLE 30	.04389	.00028	-.82807	.16752	-.04618	-.04172
VARIABLE 31	-.26058	-.03716	-.94440	-.02891	-.00248	.01299

APPENDIX III

LISTING OF GROUPS OF FACTOR SCORES

FROM THE FACTOR ANALYSIS OF FARM ACTIVITIES

The listings in Appendices III and IV show the arrangement of data entries into sets by the hierarchical grouping program.

GROUP 1

FARM NUMBER	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
18	.9604	-.2288	.5274	-.5866
20	.9604	-.2288	.5275	-.5861
22	.6464	.3481	.6919	-1.6398
26	.9910	-.0121	.6868	.3705
28	.8595	-.0926	.6797	.9003
30	.4574	-.0636	.9262	.5702
32	.9129	.1946	.5751	.8903
34	.2752	.1701	.6595	-.0721
36	.2731	.1707	.6532	-.0713
38	.1832	-.2025	.7387	1.1864
46	.1965	-1.6649	.7655	-.2692
48	.8062	-1.4803	.5285	.1197
50	.8196	-1.4484	.5535	-.2221
52	.8205	-1.4812	.6119	-.2313
54	.8224	-1.4466	.5283	-.2058
56	.8075	-1.7500	.6363	-.1055
58	.8556	-1.1679	.4008	-.5547
60	.9460	-.7590	.2755	-1.0351
62	.8233	-1.6017	.5700	-.0492
64	.6931	-.0641	.8055	.8660
66	.9093	-.0540	.6230	.0009
68	.5556	.4200	.5549	-.5186
70	.5083	-.0638	.5327	.1798
72	.5266	-1.1822	.5123	-.4339
74	.5031	-1.5566	.5949	-.4065
76	.0084	-1.2299	.7975	-.2552
78	.6387	-.4268	.9839	.2206
80	.9883	-.6367	.7306	.0550
82	1.0041	-.1156	.6582	.0387
84	.6839	-.7443	1.0640	-.4675
86	.5522	.0623	.9613	1.3208
88	.9710	.1567	.7266	.3150
90	1.0474	-.3384	.6306	-.5607
91	-.0135	-.0853	.8478	-.2924
92	.2150	-.1471	.3472	-.6160
94	.5287	-.1994	.4928	-.6004
96	.4908	-.5547	.5747	.0224

100	.4614	-.0223	.6251	.3773
102	.5467	.3731	.5216	-.4953
104	.5267	-.0886	.4968	-.4937
106	.6786	-.1402	.6300	-.4836
108	.5191	-.0996	.4934	-.3417
112	.2202	-.1341	.3372	-.6472
114	.7938	-.1022	.4481	-.4174
115	.0992	-.4302	-.1078	1.5832
116	.4374	-1.0133	.8484	1.0238
117	.0590	-.0854	.6792	-.9285
118	.2938	-.8535	.8612	-.1119
120	.1214	.0720	.7264	-.1814
122	.7314	-.0536	.6147	.3804
124	.2994	-.0735	.8978	.0763
126	.7135	.1183	.6755	.3289
128	.9701	.1874	.5221	-.3344
130	.9650	.0583	.5213	-.3172
132	.8916	.0527	.5072	-.3098
134	.7830	.3514	.6310	-.4367
136	.6237	.5931	.6502	-.7145
138	.8778	.1659	.5458	-.3258

GROUP 2

19	-.6137	-.6994	-.8947	-.0997
23	-1.6014	-.3685	-.3727	-.3354
25	-1.4373	.1071	-1.5273	.2771
27	-.9240	-.1734	-.7345	.9357
29	-.6401	.0056	-.8886	-.0804
35	-1.7289	.1417	1.0617	.2463
47	-1.9604	-1.4987	-.3488	-.7026
49	-2.2111	-2.0820	1.2181	-.0338
51	-1.6032	-1.4359	-.7744	-.3848
53	-1.9792	-.9736	.1666	-.6332
55	-2.0482	-2.0228	.1461	-.4735
59	-1.6516	-1.4101	-1.2517	-.4243
63	-1.9005	.1049	-.4834	-.7514
65	-1.7534	-.1682	.8424	.7217
67	-1.0840	.0293	-.8079	-.1095
69	-.8412	-.1410	-.5365	-.1926
71	-1.5257	-1.2661	-.4980	-.7812
73	-1.0119	-1.2929	-.0582	-.2552
81	-.9429	-.0610	-1.0125	.9290
83	-.5926	-.2336	-.7034	.0431
95	-1.2891	-.9659	1.3444	-.3076
97	-.6250	-.4781	.3731	-.2971
98	-.6077	-.6185	.5103	-.2170
109	-.9683	-.3679	.6736	-.3114
110	-.5692	-.3327	.4542	-.5458
121	-1.3961	-.1316	1.1463	.2113
127	-.9892	.1433	-.5392	.5322
129	-1.9627	-.1276	1.0197	.6668
131	-1.8029	-.1302	.9281	.0157
137	-1.6644	.0550	.9565	-.1790

GROUP 3

1	.2879	1.4196	-2.0804	-.3338
5	-.1470	1.2756	-1.7595	-.7965
15	-.7465	1.4008	-1.5087	-.8266
17	.7363	-.0535	-2.7818	-.7187
21	.0822	.0234	-2.3256	-.4956
31	-.1481	.0431	-1.4442	.3516
37	1.1134	.1771	-.4973	.4548
43	1.3540	1.3314	-1.2767	-.5316
57	-.6558	-.3516	-1.4279	-.6716
61	-.0293	-.2222	-2.3134	-.4283
75	.4951	-1.7286	-1.5385	-.2186
77	-.3664	-1.6011	-1.6856	.7702
85	.1159	-.1467	-2.2652	-.6024
87	1.3575	-.8905	-1.9627	.5140
89	1.4470	.0349	-2.3008	2.2157
93	1.1043	-.2589	-.3479	-.7395
99	.1278	-.0094	-.3702	.0622
101	.0177	.0419	-.3597	-.6023
103	1.3332	.0441	-2.3932	-.7078
105	.6764	-.0474	-2.4624	-.6240
107	-.5789	-.0040	-1.8216	-.5026
111	-.0270	-.1865	-1.0101	-.9256
113	.9670	-.0410	-1.7097	-.2666
119	.7316	-.2907	.0713	.1305
123	.4016	.0869	-1.1379	-.3607
125	.3387	-.0302	-.9846	.6985
133	.7513	.3577	-1.6771	-.2257
135	.6610	.4035	-1.6102	.7280

GROUP 4

2	1.0278	1.3586	.6220	-.3037
4	1.0450	1.4216	.6432	-.7427
6	1.0360	1.0108	.5165	-.5630
7	-.4984	1.6499	.2230	.5246
8	.9043	2.4092	.7413	1.3918
10	-.1438	1.4413	.7979	.1066
12	-.1138	2.4525	.6740	.0803
14	.9834	1.6406	.3917	-.0832
16	1.0764	1.6160	.5312	-.0486
40	.3189	2.5850	.5504	-.1439
42	.3379	1.3567	.5950	-.2352
44	.8291	2.5751	.6098	-.1884

GROUP 5

3	-.9746	1.2827	-1.2380	1.6390
9	-1.1757	1.5812	-.5469	.2374
11	-1.6149	1.3314	-.8356	-.6674
13	-.8928	2.4780	-.7268	-.1423
33	-2.1090	1.3576	1.0949	.7163
39	-2.1945	1.2233	1.1749	-.3358
41	-1.3254	2.3906	.8754	.6488
45	-2.0469	2.4411	.9804	-.0754
139	-2.0895	1.5918	.4173	-.7005

GROUP 6

24	.6342	-.4983	1.1216	5.5140
79	-.3306	-.4521	-1.7406	6.0532

APPENDIX IV

LISTING OF GROUPS OF PERCENTAGE DISTRIBUTIONS OF SUBJECTS IN LAND TYPE ANALYSIS

GROUP 1

CATEGORY

1	2	3	4
52	21	23	03
52	30	22	03
46	31	24	09

GROUP 2

CATEGORY

1	2	3	4
30	26	22	20
30	33	23	11
22	24	28	13
30	28	33	08
38	27	29	08
32	30	11	30

GROUP 3

CATEGORY

1	2	3	4
18	22	20	22
11	26	21	23
13	26	21	23
18	20	20	16
05	24	31	20
12	28	24	17
18	31	24	27
19	32	36	18
07	15	16	30
19	32	20	21

GROUP 4

CATEGORY

1	2	3	4
18	22	28	40
16	25	25	35
18	29	27	35
12	28	33	40

GROUP 5

CATEGORY

1	2	3	4
01	49	19	26
00	39	30	26
00	42	25	27
04	62	12	22
06	48	18	32

GROUP 6

CATEGORY

1	2	3	4
03	31	68	35
08	31	50	36

GROUP 7

CATEGORY

1	2	3	4
10	08	25	48
09	15	08	43
10	18	00	58
06	28	17	49
00	11	08	53
00	12	23	52
00	20	22	50

GROUP 8

CATEGORY

1	2	3	4
07	08	47	51
00	10	40	47
01	23	43	42
07	23	35	51

GROUP 9

CATEGORY

1	2	3	4
00	10	74	34
00	10	61	30
00	08	61	38
00	05	61	55
00	08	58	52
00	15	70	52
02	06	64	53

APPENDIX V

RECOMMENDATIONS

These recommendations arise from knowledge gained about the research area and from the statistical treatment. They are not the sole reason, or necessarily the main reason for the work, but flow from it and represent the opinions of the writer alone.

1) Since no firm univariate correlations have been found to support the conventional 'a priori' land capability schemes, or to support the creation of a scheme according to our proposed methodology based upon observed crop performances, we recommend than an appropriate costing investigation be carried out to determine the incidence and location of economic pursuits. Such pursuits might be defined as those which give a monetary return, at a set rate if desired, in view of the expected cost of labour or the lack of this cost, once the Agrarian Reform Law of 1970 takes effect.

2) To facilitate the above it is of great importance to determine the impact of various inputs in real field situations. Farmers may be given fertilizer of different compositions and induced by this subsidy or others to record the results of varying input applications. Multi-

variate statistical procedures will apparently be necessary to evaluate the results.

3) The efficacy of irrigation should be investigated in view of the curious correlations obtained with some crops. These correlations may not be consequential, the application of irrigation being an indication of a randomly substituted input, assumed for instance to make up for soil deficiencies. However, this input may be overpriced, and the cost of irrigation works and the price of the water at the farm should be carefully evaluated.

4) Inducements should be made to introduce some period of pasture to each plot of land to avoid the type of degradation to the soil base which has occurred in the past. There will be substantial economic and logistical problems in this process but the alternative is much more unpleasant. The soil analyses indicate that substantial investment is being wasted on soils which are exhausted from constant cropping.

5) Land redistribution schemes should be accompanied by sufficient grants and agronomic advice to preserve the redistributed tracts in at least the status prevalent before redistribution. If these grants or subsidies were made part of the original costing of the redistribution the locational selection of these plans would be aided.

6) Consideration should be given to the creation of

land cooperatives as opposed to small tract redistribution. Title may be vested in individuals according to their share of the sum of the tract. This process would aid the institution of rotational schemes with the proper balance of fallow and pasture. Such fallow and pasture periods are impossible on farms under ten hectares due to the fluctuation of income per plot from year to year.

7) The existing land use capability scheme should be revised and a new set of classes constructed so that marginal production differences become apparent between classes. The present class divisions are too gross to reflect these differences. It is our opinion that much time is being uselessly consumed in such activities as the mapping of the locations of land units suitable for the production of a certain crop, the suitability being determined by the present land use capability class number. These class numbers, while they have been useful as raw data for part of our methodological study, have little practical economic importance.

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AAAG denotes the Annals of the Association of American Geographers.

ICSS denotes the papers of the International Congress of Soil Science.

SSSA denotes the Soil Science Society of America.

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NOTES ON THE BIBLIOGRAPHY

It will be apparent that not all references in the Bibliography have been keyed to any reference in the text. We follow the practice of enumerating all sources with which we have had contact in the course of this work. The high incidence of literature from the African environments is an indication that there exists a vacuum in the English language literature on agronomic and pedological disciplines in the Latin American milieu. Some of the references to foreign locales may not at first appear apt. However, many of the items pertaining to pedology reveal important methodological and environmental considerations. These considerations are especially important in terms of, for instance, the relationships between soil texture and organic matter content, and the influence of regular fallows.

All the literature references, regardless of the locale to which they pertain, contain some reference to the concepts of land use capability, land classification, or pedology as this latter discipline affects the former concepts. The reading was accomplished prior to the field work, and we feel that the literature references should be given in a complete form because many of our activities, field work methods, and ideas were influenced by contact with this material.