RELATIONSHIP BETWEEN AGRICULTURAL PRODUCTIVITY AND SLOPES

THE RELATIONSHIP BETWEEN THE SLOPE OF THE TERRAIN AND AGRICULTURAL PRODUCTIVITY IN COSTA RICA, CENTRAL AMERICA

by

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A Thesis

Submitted to the Faculty of Graduate Studies

in Partial Fulfilment of the Requirements

for the Degree

Master of Arts

McMaster University

September 1974

MASTER OF ARTS (1974)
(Geography)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: The Relationship Between the Slope of the Terrain and Agricultural Productivity in Costa Rica, Central America.

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NUMBER OF PAGES: ix, 178

SCOPE AND CONTENTS:

An average slope index and a number of agricultural productivity indices were determined for a sample of 100 districts in Costa Rica. To establish the relationship between these variables, correlation coefficients were calculated between the average slope index, on the one hand and, on the other, total gross agricultural income, total net agricultural income and also income and yields for individual crops. These relationships were calculated for the meseta central (the central, highly-populated area) and for areas outside of the meseta central and for the total sample taken from all of Costa Rica. Cases in which gross agricultural incomes were much lower than predicted by the study were investigated further to identify other factors which may have influenced the results.

ACKNOWLEDGEMENTS

I wish to express my sincere gratitude and a very special thanks to my supervisor, Dr. Harold A. Wood for his assistance, advice and encouragement in making this thesis a reality. I am also grateful for the help given by Dr. Lloyd Reeds and Dr. David L. Anderson in regards to certain parts of the work.

Special thanks are due to a number of individuals in Costa Rica, who assisted in the collection of data: Mario Barrantes (Director of the National Geographical Institute), Henrique Saborio (Director of the Regional Planning Department), Alvaro Saborio (former Sub-director of the National Planning Office), Fernando Solis Prado (Head Librarian at the Ministry of Agriculture) and Jorge Alvarro (Cartographer at the National Planning Office).

I am indebted to Mr. Herbert Siebert, Mr. Dale Cooper, Miss Cheryl Carr and Miss Merika Luubert for their assistance in data processing. A special thanks is due to Miss Raymonde Thibeault for typing the final manuscript.

A very special thanks go to my wife Vera, who prepared the final copies of the maps, figures and tables. Her devoted help and encouragement made the completion of this research possible.

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CHAPTER 1

INTRODUCTION

A. OBJECTIVE OF THE STUDY

The physical environment on the earth's surface varies from place to place as do man's activities in that environment. This study is concerned with the relationship between one factor of the physical environment, namely, the slope of the terrain and one phase of human economic activity, agriculture. The basic problem to be investigated in this study can be summed up as follows: What is the relationship between the slope of the terrain and agricultural productivity in the country of Costa Rica?

The configuration of the land surface,[1] "may be resolved into the fundamental elements of altitude above sea level or some other datum, degree and direction of slope, local relief, texture and pattern".[2] In this study only the element of slope will be investigated in detail.

It can be pointed out generally, that areas with steeper sloping terrain are difficult to manage agriculturally because of the inability

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[1]Surface configuration has been defined by W. Garrigus to mean relief, by his statement, "When unqualified, relief should always refer to the overall surface form". This is found in the following study: Garrigus, W. *Average Slope: A Morphometric Index Useful in Analyzing Areal Variations of Agricultural Productivity as Applied to the State of Ohio*. Ph.D. Thesis, Clark University, 1958, p. 5.

[2]Smith, G.H. "The Relative Relief of Ohio", *Geographical Review*. 1935, p. 272.

or the limitation of the use of machinery, the constant problems of soil erosion, the maintenance of roads and buildings and the difficulty of making climbs and traverses by individual farm labourers. Studies[3] indicate that cleared agricultural land with steeper slopes have denudation rates of soil erosion that are higher than land with gentle slopes. Other things being the same, these steeply sloping areas may have thinner soils, with coarser material in the soil layers, with the overall fertility of the soil being lower. As a result of some of these factors, farm incomes per unit of land may be expected to be lower on sloping terrain than on level terrain.

This study will attempt to derive adequate measures for the two variables involved, to determine the relationship between the two variables through quantitative analysis and to explain any apparent anomalies. The slope of the terrain will be defined in terms of an average slope index and the agricultural productivity will be expressed as the gross and net income per unit of land derived from the various agricultural activities of sample areas of Costa Rica. The hypothesis on which this study is based is that terrain slopes are negatively related to agricultural productivity or to be more specific: the higher the average slope index of a district the lower the gross and net income per unit area from the agricultural activities in the district.

There seems to be a tendency for a higher percentage of agricultural land to occupy steeper sloping land in tropical lands than in mid-latitude

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[3]Bennett, H.H. *Soil Conservation.* 1939, pp. 146-150.

lands.[4] For this reason, the study of the influence of sloping terrain on agricultural productivity is an important aspect of geographic research in tropical countries, such as, Costa Rica.

B. AREA OF STUDY

As indicated above the area of study is the country of Costa Rica, located in Central America between latitude 8° 00' and 11° 15' North and between longitude 82° 30' and 86° 00' West. The country's area is approximately 50,900 square kilometers and in 1969 the population was 1,696,476.[5] The country is divided into seven major political units called provinces, namely:

a. San Jose
b. Alajuela
c. Cartago
d. Heredia
e. Guanacaste
f. Puntarenas
g. Limon

These provinces are subdivided into cantons which are further divided into districts.[6]

The areal unit selected as a basis for this study is the district of which the total number is 335, since, for these areas, agricultural statistics are available from the Census Department. A topographic unit,

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[4] Some of the physical reasons for this phenomena may be the fact that steeper sloping land in the tropics may receive more rainfall and/or contain younger soils. This may be investigated further in H.A. Wood's book, *Northern Haiti*. 1963, pp. 35-64.

[5] *Directorio Comercial, Industrial y Turistico: Costa Rica*. 1971-1972, p. 15.

[6] A map showing all the districts of Costa Rica is located in the Appendix of this study (Map B).

such as a terrain unit, was not used since this would entail the collection of raw data for a relatively large area and the time limitation made this impractical.

Although the district is the smallest unit for which census data are available, the district size varies from 0.5 square kilometers to 2,896.8 square kilometers[7], which may cause some problems. Relatively small districts have the limitation of a small sample size of the individual crops reported in the district. Large size districts may have a variety of different physical environments while agricultural statistics may be reported from only a very small portion of the district, thus distorting the relationship in question.

The reasons for choosing the country of Costa Rica for this study are the following.

The government of Costa Rica is interested in developmental planning and has allocated people and money to carry out studies leading towards the formulation of a regional plan of the country. The Regional Planning Department of the Ministry of Planning has been investigating different regional planning approaches suggested by various organizations[8], in a preliminary analysis of the direction to be taken towards their goal. The author was working in connection with one of these regional planning

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[7]The smallest district is San Francisco in the canton of Goicoechea and the largest district is Talamanca in the canton of Limon. This information was obtained from unpublished material prepared by a fellow geographer, Herbert Siebert.

[8]The Pan-American Institute of Geography and History under the leadership of Dr. H. A. Wood and a number of researchers on loan from the Government of Germany have been involved in preparing regional planning guidelines for the National Planning Office of Costa Rica. The author was fortunate in working under Dr. H. A. Wood in this type of work.

approaches and this study includes part of the work done in this particular field.

Costa Rica is also a favourable area for study because of the availability of agricultural statistics and, with its democratic orientation, statistics can be obtained quite easily from the different Ministries and Institutes of the government. These advantages have in fact been recognized by many individual researchers and research organizations. As a result, a large number of studies have been executed in Costa Rica, and many institutions are actively pursuing research programmes in the country. Some of the major ones are as follows:

a. International Organizations:

1. "Instituto Interamericano de Ciencias Agricolas" (IICA) operates a large agricultural research institution in Turrialba. This is a busy research and teaching centre sponsored by the Organization of American States.

2. Alliance for Progress, U. S. Aid.

b. Costa Rican Organizations (Public):

1. The University of Costa Rica.

2. Government Ministries:

   i) "Ministerio de Agricultura y Ganaderia" (M.A.G.)

   ii) "Ministerio de Transportes"

   iii) "Instituto Geografico Nacional (I.G.N.)

   iv) "Instituto de Tierras y Colonizacion (I.T.C.O.)

3. The National Bank of Costa Rica.

c. Costa Rican Organizations (Private):

1. The Tropical Science Centre, a private research organization directed by J. A. Tosi and L. R. Holdridge, has done a number of studies for the government of Costa Rica.

Costa Rica is a country with a wide range of agricultural activities set in a varied physical setting. It has been said that, "Costa Rica has a range of altitude which makes it possible to grow nearly every known sub-tropical and tropical fruit".[9] Agricultural activities are found on a very wide range of terrain slopes, therefore, making the study a suitable setting.

Description of the Study Area

The author has divided Costa Rica into nine major regions based principally on elevation and relief (Appendix, Map A).

Region I is a large tropical coastal lowland stretching from Lake Nicaragua to the border of Panama. Almost all of the area is relatively level with the elevation below 500 meters. The population is concentrated in a number of larger centres (Limon, Quesada, Siquirres and Guapiles) and along the major railway and road routeways. In the extreme northwest close to Lake Nicaragua, subsistence agriculture is the dominant activity. In the area around the city of Quesada, patches of intensive agriculture are evident, with the growing of coffee, sugar cane and vegetables. From this city extensive areas of cattle raising extend to the north and northwest. Banana plantations are found on the rich, well-drained soils north

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[9] Lundberg, D.W. *Costa Rica.* 1968, p. 149.

of the city of Guapiles, in scattered areas north of Siquirres and around the town of Pandora in the "Valle de la Estrella" (south of the city of Puerto Limon). The other major crop grown in this area, cacao, is found along the railroad line north and east of the city of Siquirres and along the coast from Puerto Limon to the Panama border.

Region II is a mountainous area composed of relatively recent volcanic peaks stretching from the Nicaraguan border to the centre of the country. The terrain is dominated by relatively steep slopes ranging in elevation from 500 to over 3,000 meters. For the whole region, the population density is relatively low. The extreme higher elevations of this mountainous region are not used for agricultural purposes, however, the lower slopes (especially the southern slopes) are used extensively for cattle raising. Dairy cattle raising is the most important activity on the slopes north of Region III.

Region III is in the central part of the country and is a large elevated plateau called the "meseta central". The elevation varies from approximately 500 to 2,000 meters. The region has pockets of relatively level terrain around the cities of San Jose, Cartago and Turrialba with more sloping terrain along the northern and southern boundaries. Approximately 50% of the population of Costa Rica lives on the meseta central[10] in numerous towns and cities, the largest of which are San Jose, Cartago, Alajuela and Heredia. Intensive agricultural activity occupies most of the meseta central where a wide range of crops are grown, the most prominent being coffee and sugar cane. Also many types of vegetables are

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[10]Lundberg, *ibid.*, p. 34.

grown here to supply the inhabitants of the towns and cities.

Region IV is a mountainous belt called the "Ccrdillera de Talamanca", with steeply sloping terrain ranging from 500 to 3,000 meters in elevation. The population density of this region is generally very low except for isolated pockets south of Region III. Most of the region is in forest and therefore not used for agricultural purposes. However, the area immediately south of Region III does contain farms growing coffee and sugar cane as well as farms raising cattle.

Region V is a valley drained by a number of rivers coming off the "Cordillera de Talamanca". The elevation varies from approximately 300 to 1,000 meters with most of the area moderately dissected except for isolated pockets of level terrain around the cities of San Isidro, Buenos Aires and Potrero Grande. Most of the population is centred in and around the cities and towns, such as, San Isidro, Volcan, Buenos Aires, Potrero Grande and San Vito. The area around the city of San Isidro contains farms which grow a wide range of crops, such as, coffee, sugar cane, rice, tobacco and vegetables, as well as, raising cattle. The areas around Buenos Aires and Poterro Grande are mainly cattle raising areas while the area around San Vito specializes in the growing of coffee with some sugar cane.

Region VI, in the southern part of the country, consists mainly of a tropical coastal lowland with elevations below 500 meters, although, occasional hills reaching up to 700 meters do occur. The terrain is relatively level except for the steeper sloping hilly areas in the centre of the Osa Peninsula, along the coast west of Golfito and along the coast of the Burica Peninsula. Most of the population is concentrated in a number of smaller towns, such as, Golfito, Puerto Cortes and Villa Neily and along the Pan-American Highway. Intensive banana production is carried out around the town of Puerto Cortes and south of Villa Neily with most of the production being exported. Subsistence agriculture is located in isolated areas along the coastal lowlands of the Osa Peninsula and along sections of the Pan-American Highway.

Region VII is a relatively level coastal lowland with elevations below 500 meters. The population is evenly distributed on the lowland with the main concentration in the city of Quepos. The main agricultural activity is the growing of African Palm along with some cacao and papaya. The raising of cattle is also carried out throughout this region.

Region VIII includes a large part of the province of Guanacaste where there is a marked dry season in comparison to the rest of Costa Rica. Most of the area consists of relatively level lowlands below 500 meters in elevation. There are a number of isolated hilly areas with steeper sloping terrain, such as the area around the town of Esparta in the southern part of the region. There are a number of centres of population, such as, Puntarenas, Liberia, Santa Cruz, Nicoya, Canas and Esparta. The population throughout the whole region is relatively evenly distributed, except for the sparsely inhabited areas to the north of the mouth of the Tempisque River and around the Gulf of Papagayo. The main agricultural activity throughout the region is the raising of cattle, especially beef cattle. There are also isolated areas where rice, sugar cane and cotton are grown, such as, around the town of Filadelfia, Liberia and Canas.

Region IX consists of most of the Nicoya Peninsula. The terrain is generally a series of level river floodplains and steeper sloping river interfluves reaching 1,000 meters in elevation. The population is generally evenly distributed throughout the region. The main agricultural activity is cattle raising (beef), however, some coffee and sugar cane are grown in isolated pockets.

It is felt that Costa Rica is a suitable area for this research because of the variety of crops growing on the wide range of sloping terrain.

Although there are many geographical research studies that have been done in Costa Rica, only a few of them make brief reference to this relationship between sloping terrain and agricultural productivity. Thus, further research in this type of work may be of value in increasing the scope of knowledge of the geography of Costa Rica.

The study is divided into three major sections. The first part involves establishing an average slope index and then calculating it for a sample of 100 districts of Costa Rica. The procedure, as outlined in Chapter 3, involves detailed measurements and calculations from topographic maps. The second part establishes the agricultural productivity indices. This part, as outlined in Chapter 4, involves a detailed calculation of the gross and net income from agricultural production. The third and final part, which is found in Chapter 5, analyzes the relationship between the average slope index and the agricultural productivity indices for the 100 sample districts.

CHAPTER 2

REVIEW OF THE LITERATURE

INITIAL INTEREST IN THE RELATIONSHIP OF SLOPE TO AGRICULTURE

Before going into a review of the literature dealing with average slope a brief section will outline the author's reasons for undertaking this research. Since it involved some of the literature published in Costa Rica, this section has been included in Chapter 2.

The author's purpose in travelling to Costa Rica was to work on a regional planning approach for the country, as well as, to do research on specific areas using aerial photographs. The initial interest in investigating the relation between slope and agriculture in Costa Rica arose after he interviewed the land-use experts in Costa Rica and discovering that they held different opinions on the subject. The individuals involved are C. V. Plath of the "Instituto Interamericano de Ciencias Agricolas" and L. R. Holdridge and J. A. Tosi of the Tropical Science Centre.

Plath, a graduate in economics of Cornell University, devised a classification of potential land-use based on an estimation of economic return from the land.[1] Using this classification he has prepared a map

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[1] When the author interivewed Dr. C.V. Plath, the latter could not explain in definitive terms the criteria used in distinguishing between his different categories (intensive use, extensive use, very extensive use and forest use) although in his words "all the physical and socio-economic variables were considered". For this reason his classification of "Uso Potencial de la Tierra" is considered to be derived in a subjective manner.

of Costa Rica.[2]

Holdridge and Tosi in several studies commissioned by the government of Costa Rica, of which the most important is an investigation of the country's northern area, also evaluated the potential use of the land. In their approach to evaluation the bio-climatic criterion is the most important element.[3]

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[2]The students of Dr. Plath have refined his method by setting down in more detail the criteria used in the evaluation of economic returns from the land. Some of the criteria used in the evaluation of economic returns from the land included: soils, climate and general slope of the land. A number of large scale studies have been done in Costa Rica using the Plath system.

Aguirre, J.A. and Plath, C.V. *Mapa de Uso Potencial de la Tierra, Cuenca del Rio Canas, Nicoya, Provincia de Guanacaste, Costa Rica.* IICA, 1966.

Aguilar, L.A. *Estudio para el Desarrollo Agropecuario de la Cuenca del Rio Canas, Nicoya, Provincia de Guanacaste, Costa Rica.* IICA, 1966.

Uribe, G. *Regionalizacion y Programacion Agropecuaria para el Area Nicoya - Puerto Jesus, Provincia de Guanacaste, Costa Rica.* IICA, 1967.

Castro, J. *Planificacion del Uso de la Tierra, Peninsula de Nicoya, Costa Rica.* IICA, 1968.

Gonzalez, H. *Zonificacion Agropecuaria y Forestal en el Salvador: Guia para una Planificacion del Uso de la Tierra.* IICA, 1968.

Coto, J.A. *Diagnostico y Programacion para el Desarrollo Agricola de las Zonas Adyacentes a Puerto Limon, Costa Rica.* IICA, 1968.

Torres, J.E. *Estudio Agroeconomico y Regionalizacion en San Carlos, Alajuela, Costa Rica.* IICA, 1968.

[3]Centro Cientifico Tropical. *Investigacion Preliminar de la Zona Norte de las Provincias de Alajuela y Heredia.* 1968.

Holdridge and Tosi on the one hand and Plath and associates on the other, differ in their approach to the delimitation of areas which are considered to be homogeneous with respect to their potential land uses. Although both take general cognizance of the existence of different slope categories, they pay little attention to the influence of slope.

Plath and associates have evaluated areas of land according to the amount of return that can be derived from the land by a general estimation of the physical and economic factors prevalent, one of which is slope. Holdridge and Tosi estimate the potential use of the land by a more detailed approach classifying the physical factors involved. They delimit the land surface into terrain units and classify slopes into percentage categories. Due to this more quantitative approach, compared to Plath's more subjective approach, the author investigated the methodology of the Holdridge and Tosi studies in more detail.

In the early works of Tosi, slope categories were included as only one of many variables for the determination of land capability and potential land-use. In his study of the northeast part of Guanacaste[4] he divides the land into three physiographic regions. Slopes are differentiated into the following categories, namely:

a. 0 - 15%

b. 15 - 40%

c. 40% and more.

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[4]Tosi, Jr., J.A. *Capacidad de Uso de la Tierra Determinada por las Condiciones de Clima Fisiografia y Suelos en la parte Noreste de la Provincia de Guanacaste, Costa Rica.* ITCO, 1967.

Other factors such as soils and climate are also described generally for each of the three regions. However, in the study of the Indian Reserve of Salitre in "El Valle del General",[5] which Tosi divided into a plateau and a mountainous section, his division into soil regions only included such general descriptions of the slope, as, "high lands with little sloping land". In both of these studies slope is evidently considered to be of minor importance.

A very massive work by Tosi and Holdridge, which was the investigation of the north zone of Costa Rica, included a section on the delimiting of terrain units,[6] as one of the procedures leading to the eventual determination of the potential use of the land. Topographic maps at the scale of 1:50,000 and aerial photographs at the scale of approximately 1:60,000 were used as the basis for the terrain unit delimitation. The researchers state, "Each terrain unit, separately delineated by a fine line, was labelled by the following code (refer to Table 1):

1. The major soil category which covered the majority of the terrain unit was indicated by the corresponding letter; in cases of mixed soil groups or transitional soils between two soil categories, two letters were used with the first one being the dominant.

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[5] Tosi, Jr., J.A. *Un Estudio de Reconocimiento de los Recursos Naturales y Potenciales de las Tierras de la Reserva Indigena de Salitre, El Valle de la General, Costa Rica.* ITCO, 1967.

[6] Centro Cientifico Tropical, *op. cit.*, 1968, p. 36.

TABLE 1

CATEGORIES OF MAJOR SOILS, PERCENT SLOPES AND SURFACE CONFIGURATION FROM THE STUDY OF THE NORTHERN PART OF COSTA RICA BY THE TROPICAL SCIENCE CENTRE

SYMBOL	MAJOR SOIL CATEGORY
R	LATOSOLES
V	REGOSOLES AND ANDOSOLES (VOLCANIC)
A-1	ALUVIAL SOILS (GOOD TO IMPERFECT DRAINAGE)
A-0	ALUVIAL SOILS (IMPERFECT TO POOR DRAINAGE)
H-1	HYDROMORPHIC SOILS (INUNDATED SEASONALLY)
H-0	HYDROMORPHIC SOILS (INUNDATED ALL THE TIME)
L	LITOSOLES

SYMBOL	SLOPE (%)
0	0 %
1	0 - 15 %
2	15 - 30%
3	30 - 60%
4	60 + %

SYMBOL	SURFACE CONFIGURATION
A	FLAT TO GENTLY UNDULATING LAND
B	UNDULATING LAND TO MODERATELY BROKEN BY RAVINES
C	RAVINE FORMATION TO ROLLING COUNTRY WITH DISSECTION OF LAND
D	STRONG DISSECTION OF LAND TO RUGGED ROUGH LAND

2. The major terrestrial form category as expressed in percentage slope.

3. The local surface configuration from A to D, which expresses the proportion of the minor terrestrial forms ...".[7]

The details of their classification are shown in Table 1.[8]

The slope values as expressed in percentages were derived from field observations and through the calculation of slopes from measurements made on aerial photographs using the contour wedge. On top of this map of the terrain units were superimposed "life zones",[9] the bio-climatic variable. This information along with other information, such as, vegetation cover, transportation, population growth, etc., was then used in the final stages of the analysis which involved the formulation of recommendations for the potential use of the land.

It is evident, that in these major studies done in Costa Rica, slope has been treated in a general sense. The author will attempt to treat the slope of the terrain in a more precise manner than the Holdridge and Tosi study. Also, the concept of average slope was to be investigated so that different areas with a range of sloping terrain can be compared, which then can be used to determine the relationship between sloping terrain and agricultural productivity.

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[7]Centro Cientifico Tropical, *op. cit.*, p. 44.

[8]Centro Cientifico Tropical, *op cit.*, 1968: this chart was derived from map no. 3 showing Terrain Units.

[9]"Life Zones" refer to vegetation zones which are identified in a bio-climatic classification as proposed by L.R. Holdridge in *Life Zone Ecology*. Revised edition 1967.

EXPLANATION OF AVERAGE SLOPE

Geographers from a relatively early time have attempted to obtain objective measurements of the earth's surface configuration. There was a need for this type of research so that different areas could be objectively compared with each other. In accordance with this need, geographers have investigated a number of concepts, such as, average slope, relative relief, average elevation, etc. One of these, namely average slope will be used in this study to make a comparison of different areas of Costa Rica.

The use of the concept of average slope in geographic research, nevertheless, poses problems. One of the most important problems is expressed by Calef and Newcomb, "The real point is, however, that any area comprises a huge number of slopes of different angles combined in different proportions. The average of all of them reveals nothing about either the real slope angles or their relative proportion".[10] Although they express their point very strongly, it can be argued that the problem is essentially a problem of scale. To study individual fields with a specific slope is a different research topic than to study regions with a wide range of slopes. The measurement of average slopes makes it possible to change the complexity of areal relief into an index number, which is one way of making a comparison between different areas. Other alternatives have been investigated which also make these comparisons, such as, the concept of relative relief. However, the concept of average slope will

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[10]Calef, W. and Newcomb, R. "An Average Slope Map of Illinois", *Annals of the Association of American Geographers*. 1953, p. 312.

be used in this study since it has been preferred by most of the recent researchers.

SURVEY OF LITERATURE ON AVERAGE SLOPE DETERMINATION

Geomorphologists agree that ground surface slope is only one of many elements of form that comprise the total landform geometry but is important because it influences rates of runoff, soil creep, soil flowage and the ease of cross country movement of men and vehicles. Many papers have been written on the evolution of slope form under the action of geologic processes upon various structures. The work by G.H. Dury,[11] D. Brunsden,[12] A.F. Pitty,[13] and M.J. Selby[14] are only extensions of the work started by early geographers such as Davis, Penck, King and others who studied the formation of different slopes on different materials and the different variables involved in shaping the land. Work has also been done by Bunting[15] and others with regard to the effect of slope on soil and soil forming processes. Although these works deal with the variable of slope, they are only mentioned but will not be reviewed because the concern in

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[11]Dury, G.H. "Quantitative Measurement of Available Relief and of Depth of Dissection", *Geological Magazine*. 1951.

[12]Brunsden, D. *Slopes: Form and Process*. 1971.

[13]Pitty, A.F. *A Scheme for Hillslope Analysis II. Indices and Tests for Differences*. 1970.

[14]Selby, M.J. *Slopes and Slope Processes*. 1970.

[15]Bunting, B.T. *The Geography of Soil*. 1966, pp. 67-77.

this chapter is in the determination of an average slope index and not specifically in the explanation of why different slopes form in different materials.

Early geographic studies tended to describe the surface configuration of the terrain in generalized qualitative terms, such as, "gently-rolling" or "smooth". However, the use of such terms can result in differing interpretations by different individual geographers. Therefore, it was not long before researchers began to seek a more quantitative measurement of surface configuration.

German geographers were the earliest known researchers to calculate the average slopes of an area. One of the first methods was that of Koristka in 1858[16], who calculated the angle of slope between every set of two contour lines on a map. The use of this method is rather limited since it is applicable only in areas where the contour lines are almost parallel.

In 1873, Sonklar[17] presented a method which is suitable for use along the gradient between a ridge and a stream. It can be represented by the formula:

$$\text{Tan } S = \frac{e}{d}$$

S = angle of slope

e = average elevation of ridge

d = horizontal distance from the crest of the ridge to the valley bottom.

By averaging several of these measurements the average slope of an area

[16] Neunschwander, G. *Morphometrische Begriffe.* 1944, p. 3.

[17] Neunschwander, G., *op. cit.*, p. 12.

can be derived.

Unfortunately, both of these methods had faults due to uncertainty as to the number of computations to be made. Identical results would not normally be obtained by two workers using the same method in the same area.

During the years 1886-1890 several alternative methods of average slope determination were outlined, the most notable of which was by Finsterwalder.[18] His method was based on the following formula:

$$\text{Tan } S = \frac{I \cdot L}{A}$$

S = the average angle of the slope

I = contour interval

L = sum of the length of the contours

A = Area

Finsterwalder's method was favoured over preceding methods once the area to be measured had been selected because it was completely objective. Theoretically the method is perfectly sound; however, it is rather tedious and difficult to cope with in maps of great contour complexity.

The most important early work by Americans on the concept of average slope, was that of J. D. Justin, who in 1914, "defined the average slope of a drainage basin as the quotient of the relative relief of the basin divided by the square root of the area".[19] This definition is too general

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[18] Neunschwander, *op. cit.*, pp. 16-17.

[19] Hook, J.C. *The Relationship Between Roughness of Terrain and Phenomena Related to Agriculture in Northeastern United States*. Ph.D. Thesis, State University of Iowa, 1955, p. 17. The original paper by J.D. Justin is found in the following article: "Derivations of Run-Off from Rainfall Data", *American Society of Civil Engineers, Transactions*, 1914.

for any specialized work and as R.E. Horton mentions, Justin's measure of average slope is very crude even when applied to small drainage basins.[20]

John L. Rich continued the investigation of average slope determination by determining "the tangent of the angle of average inclination of the surface".[21] The method is of interest since it became a basis for later investigations by Wentworth, and is described as follows:

> "With a straight edge of paper and a sharp, hard pencil, begin at some point chosen at random in the area to be measured. Lay the paper edge perpendicular to the contours, and, by noting the contour intersections, count and add together the differences in elevation, both positive and negative, which one would encounter in traveling along the line of the paper edge. Continue thus to a point where the contours change direction. Without removing the paper, pivot on the pencil point and turn the paper until it is once more perpendicular to the contours. Proceed as before. Continue thus until the limits of the area to be measured are reached, always keeping the paper edge at right angles to the contour lines and counting and adding arithmetically all differences in elevation, whether positive or negative. Choose another point and repeat the process, continuing to add distances graphically along the paper edge, and to record the total "ups" and "downs" of the profiles. When the map has been sufficiently covered, scale off the total distance represented along the paper edge, find the sum of all the "ups" and "downs" and divide the latter by the distance. The result is the tangent of the angle of average inclination of the surface.[22]

Although the method of Rich is simpler and easier to use then the method of Finsterwalder it also had some drawbacks. He does not specifically indicate how many points to choose so that "the map has been sufficiently

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[20]Hook, J.C., *op. cit.*, 1955, p. 17.

[21]Hook, J.C., *ibid.* The original paper is as follows: Rich, J.L. "A Graphical Method of Determining the Average Inclination of a Land Surface from A Contour Map", *Illinois Academy of Science, Transactions.* 1961, pp. 195-199.

[22]Hook, J.C., *ibid.*

covered". Where the contour lines are very close together and where they change directions quite frequently the method becomes very tedious and is prone to measurement errors.

In the early 1930's, there appeared two important but similar works on the calculation of average slope, one by R.E. Horton[23] and the other by C.K. Wentworth. Wentworth's method, the more widely used of the two, "undertakes to develop and describe a perfectly general and random method for measuring mean slopes which can be applied to the most intricate of topographic maps and yield results of any desired accuracy up to the limit of correctness of the map".[24] Rich's method involved the counting of contour crossings of profile lines which were drawn at right angles to the contour lines, while Wentworth counted contour crossings of a regular grid of lines irrespective of the angles that the contour lines made with the grid lines.

Wentworth's method is outlined as follows:

> "(a) Select a typical area not unduly characterized by one way slopes, large valleys or unusual features.
>
> (b) Lay out an east-west, north-south grid of not less than three lines each way and of such size as to involve not less than 100 to 200 contour intersections, unless the area is very flat and such a size would involve diverse elements of the surface.
>
> (c) Count all crossings and tabulate, determining average numbers per mile. Tangency contacts which are not true crossings should be counted as one crossing each.

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[23] Horton, R.E. "Derivation of Run-Off from Rainfall Data - Discussion", *American Society of Civil Engineers, Transactions*. 1914, pp. 372-373.

[24] Wentworth, C.K. "A Simplified Method of Determining the Average Slope of Land Surfaces", *American Journal of Science*. 1930, pp. 184-185.

(d) Repeat with an oblique grid covering substantially the same area. For extreme accuracy use several other grids at different angles with the margins of the map.

(e) Average the results and divide the product of the contour crossings per mile and the contour interval in feet by the constant 3361 (5280 times the mean value of sin ø).[25] The result will be the average slope, i.e., the tangent of the average angle of declivity".[26]

In essence, the Wentworth method can be stated in the following formula:

$$Sm = \frac{I(N)}{3361}$$

Sm = measurement of average slope

I = the contour interval in feet

N = the contour crossings per mile

3361 = the constant

Actually, as Hook, a later researcher, justifiably argues, Wentworth introduces some bias to his method by stating in his opening step, "select a typical area not unduly characterized by one way slopes, large

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[25] The constant is used to take into account the fact that all contour lines will not intersect the grid lines at right angles. It can be determined that the mean value of all possible values of sin ø is .6366. Wentworth argues this fact by stating, "In order to obviate the need for measuring large numbers of values for the angle ø, it is desired to substitute an average value for the sin of ø. It may fairly be assumed that in the random placing of a small quadrilateral area on a map all values of ø are equally likely to obtain, and it is further assumed that the average of various values of the sin of the angle ø for a series of such areas ranged along a straight line of considerable length placed in a random fashion will approach the theoretical mean value of the random value of sin ø. The mean value of all possible values of sin ø can be determined by integrating the expression

$$y = \sin \phi$$

determining the value of the definite integral between the limits of 0 and $\pi/2$ radians and dividing by $\pi/2$. This gives the value $2/\pi$, which is equal to .6366+".

[26] Wentworth, C.K., *op. cit.*, 1930, pp. 194-195.

valleys or unusual features". Although not a serious operational limitation, the author agrees with the statement that, "such a limitation could influence an investigator to choose a particular area for study and formulate a specific problem that would fit these limitations, rather than to choose a method of calculating average slope that would fit the particular area and problem being studied".[27] However, Wentworth has had a profound effect on average slope research since other researchers have either modified his approach or combined his method with other methods.

C.H. Hamilton presented a paper in 1931 on the determination of an "index of topography" for the following purposes: "The social development of that area is limited by its topography more than by any other one factor. In making social studies of such mountainous areas or in planning institutional development in them, it is desirable to have an accurate method of measuring the influence of topography. The problem resolves itself into the construction of an index of topography which can be used in making correlations with various social and economic conditions".[28] The procedure used by Hamilton is in essence similar to Wentworth's method since he uses a grid system with the parallel lines being 2.5 miles apart (without the use of the oblique grid) and the calculation of the number of corssings of the grid by contour lines. However, the main difference from Wentworth's method is that he also takes into account the intersections of rivers with the grid lines, reasoning that, "it seems reasonable to assume that a stream constitutes a barrier to transportation or communication approximately equal to that of a five hundred foot

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[27] Hood, J.C., *op. cit.*, 1955, p. 19.

[28] Hamilton, C.H. "A Statistical Index of Topography", *Social Forces*. 1930-31, p. 204.

elevation".[29] The total count of these intersections is divided by 1/100 of the number of square miles in each county, therefore, obtaining comparable indices of topography. He concludes that the index of topography is of value to research because of the very high correlations which resulted from correlating the index with certain social factors, such as, percentage of negroes in the rural population or the number of members per rural church. The scale of the map that Hamilton used was relatively small (1:425,000) with a rather large contour interval (500 feet) compared with the topographic sheets used by previous investigators (scale of 1:62,500 and a contour interval of 20 feet).

Hamilton recognizes possible error in the calculation of his index of topography by stating, "the inclusion of streams on an equal basis with contour intervals (lines) in the computations was purely arbitrary".[30] Since Hamilton places such emphasis on the crossing of streams in his index, one may conclude that his index measures accessibility rather than average slope.

Local Relief

A brief section will be included on the research done on the use of "local relief" as a measure of surface configuration because it is mentioned by a number of researchers working with the average slope measure. Local relief is defined as, "the difference in elevation between the highest and the lowest points within a limited area".[31] The

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[29]Hamilton, *op. cit.*, 1930-35, p. 204.

[30]Hamilton, *op cit.*, 1930-31, p. 204.

[31]Smith, G.H. "The Relative Relief of Ohio", *Geographical Review*. 1935, p. 273.

use of local relief or relative relief involved the identification of the highest and lowest points in an area and subtracting the two; thus, the technique was very straightforward. The problem of using local relief as a measure of surface configuration is that, "the differences in techniques (in calculating local relief) are not concerned, therefore, with techniques of making measurements, but with determining the size of the 'given area' in which the measurements are to be made".[32]

The earliest work using local relief as a measure of surface configuration was by Partsch in 1911, who divided an area of Lower Silesia into five kilometer squares.[33] He then calculated the relative relief of these squares grouping them into a workable number of categories, namely, seven. The size of his squares and the categories of the relative relief figures were chosen on a subjective basis for ease of operation.

Another researcher, Gutersohn, proposed a method for the calculation of the size of the grid which would eliminate the choosing of grid patterns arbitrarily.[34] Gutersohn proposed a method of laying out different sized squares around a randomly selected central point. The relative relief was calculated in each square and the values were plotted in a curve as a function of the length of one side of the square. The curve produced a marked "knick", which Gutersohn claimed to indicate the dimension of the best possible size of square.

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[32]Hook, J.C., *op. cit.*, 1955, pp. 21-22.

[33]Smith, G.H., *op. cit.*, 1935, pp. 273-274.

[34]Neuenschwander, G., *op. cit.*, 1944, pp. 76-78.

In 1935, Guy-Harold Smith produced a relative relief map of Ohio to, "illustrate the value of the isopleth technique in the qualitative study of relief and of displaying graphically a regionalism in Ohio based on local differences in elevation".[35] His method involved the following:

> "The area was first divided into rectangular sections ... about 4.4 by 5.75 miles --- to enclose 25.3 square miles. For each of the five-minute rectangles the difference in elevation between the highest and lowest points was plotted in the proper area on the base map. This difference represents the maximum relief of each limited area."[36]

Smith concluded that, "the isopleth map of relative relief permits a measurement of the several areas and thus gives a quantitative statement of the irregularities of the terrain".[37] Further significant research using the relative relief concept has not been evident in recent years.

Recent Studies of Average Slope Determination

After analysing the study done by Smith, Raisz and Henry published an article in 1937 outlining an average slope map of Southern New England.[38] They concluded that the relative relief method was not satisfactory because of the lack of sensitivity to variation in land terrain of their area of study. For instance, a small isolated knob on a level plain would give a very high index number to the entire square in which it was situated. Similarly, a single deeply incised river valley on a level plateau may also give a square a high index number. The two researchers,

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[35] Smith, G.H., *op. cit.*, 1935, p. 275.

[36] Smith, G.H., *op. cit.*, 1935, p. 276.

[37] Smith, G.H., *ibid.*

[38] Henry, J. and Raisz, E. "An Average Slope Map of Southern New England", *Geographical Review*. 1937.

therefore, turned away from the relative relief calculation and reverted to a calculation of the average density of the contour lines.

Their method as described in their paper is as follows:

> "Finally we decided on an entirely unorthodox method, the result of which is the map shown in figure three. Each topographic sheet was subdivided, as in the previous method, into smaller regions so that within each subdivision the density of contour lines should be about the same. The size of the subdivisions is very different, depending on the evenness of the relief and their outlines may be quite irregular. It is not advisable to make the subdivisions too small, rarely smaller than a square mile. Occasional small knobs or small incized rivers can be disregarded. Usually there were in southern New England three to ten subdivisions to a topographic sheet. The subdivisions were outlined with coloured crayon. It is practical to lay out all the adjacent sheets too, to see the marginal relationships. Instead of taking the highest and lowest points in each subdivision, as in the previous methods, the subdivisions were classified into six categories according to the average density of the contour lines. A guide to the density of contour lines was prepared for average slopes of 50, 100, 200, 300, 400 and 500 feet to the mile."[39]

According to the writers, the resulting map that was drawn, "seems to agree well with the field observations. The major physiographic divisions of the land are easily recognized, and none of the major culturally important lowlands are missed".

One point of contention about the accuracy of their method seems to be the arbitrary drawing of lines around these subdivisions of uniform contour density. However, it is felt that the demarcating of these subdivisions can be as accurate as the researcher wants it to be depending on the scale and contour interval of the map used. For instance, subdivisions will normally be larger if made by using a map at a scale of 1:250,000 and a contour interval of 100 feet than using a map at the

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[39] Henry, J. and Raisz, E., *op. cit.*, 1937, pp. 470-471.

scale of 1:50,000 and a contour interval of 20 feet. It would seem logical to suppose that a weakness in the method used by Raisz and Henry would have been in the classification of the subdivisions. However, they state that, "although in this matter individual judgement seemed to play an important role, there was usually very little doubt in which of the six categories the region should be placed".[40]

One of the difficulties of devising a convenient technique for average slope determination has been and is the difficulty of obtaining the raw data. Some of the methods involved the counting of closely spaced contour lines over many inches on the map or the making of very careful slope measurements. Fortunately, Arthur Cozzens came up with a technique for the quick calculation of percent slope from contour lines by preparing an angle of slope scale. The principle of construction is simple as the writer contends: "the map distances between contours 200 feet apart vertically are calculated for the various angles of slope from one to fifty per cent, and lines of corresponding length are laid out ... For steeper slopes, five per cent gradations are employed, as finer distinctions are impractical, due to the decreasing accuracy of both map and scale at these higher angles. The slopes are recorded in per cent (number of feet rise per 100 feet horizontal) in preference to degrees or feet rise per mile to facilitate visualization ... For map scales other than those for which data are given above, the values for the slope

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[40] Henry, J. and Raisz, E., *op. cit.*, p. 471.

scales may be obtained as illustrated in a chart".[41] As he mentions in his conclusions, "among the advantages of the scale are speed of operation, compactness and ease of application under varied conditions. The measuring units are arranged vertically to obviate needless hand motions, and much time is saved by eliminating the necessity of changing from one device to another as in the contour matching method of Raisz and Henry which employs several small cards".[42]

A. N. Strahler set out to, "quantify the slope properties of a complex land surface taken in its entirety instead of measuring slope at one point on the surface or along a single profile line".[43] Strahler's method differs from previous methods by measuring the slope of lines on a topographic map which were selected by the random sampling of points. The method is outlined in the following section:

> "On a tracing paper overlay the amount of slope is first determined for a large number of points over the contour map and these quantities inscribed directly on the tracing paper. Slope determination is made with the set of a pair of dividers whose points are set to a fixed opening, equivalent to a specified horizontal ground distance (figure 1, distance ab). At a particular point P, where slope is to be determined, the divider points are set down on the map to lie on a line orthogonal to the contour passing through the point and with approximately equal distances falling upslope and downslope from the point

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[41] To obtain the values of the slope scales for any map, the following problem can be used as an example:

"To find the map distance between contours 200 feet apart vertically for a 5 per cent slope on a map at the scale of 1/24,000.

$$\frac{240{,}000 \text{ inches}}{24{,}000} = 10$$

$$\frac{10 \text{ inches}}{5} = 2 \text{ inches (answer)"}$$

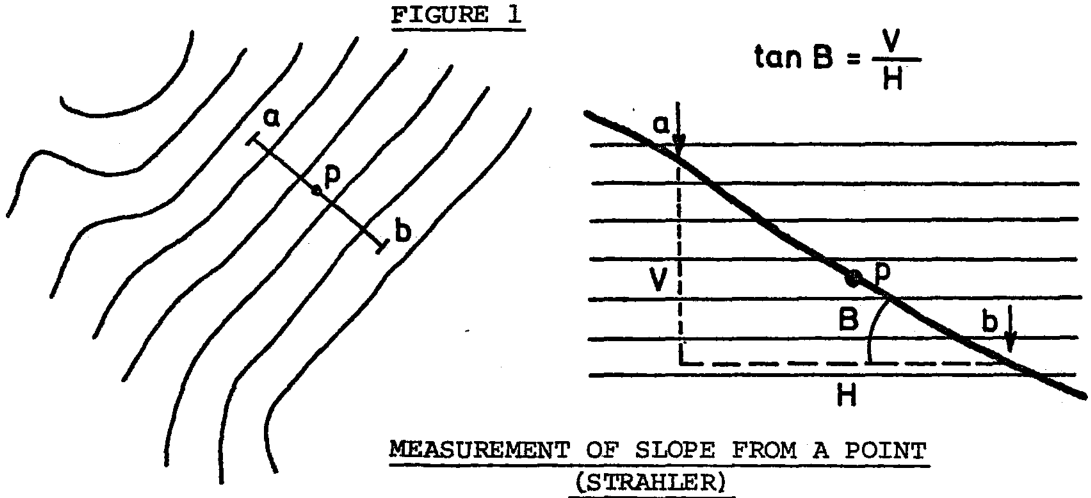
This information is in the study by Cozzens, A.B. "An Angle of Slope Scale", *Journal of Geomorphology*. 1940, pp. 52-53 and 56.

[42] Cozzens, A.B., *op. cit.*, 1940, p. 56.

[43] Strahler, A.N. "Quantitative Slope Analysis", *Bulletin of the Geological Society of America*. 1952, p. 573.

(figure 1). The drop in elevation is then estimated by counting the contour intervals intercepted and adding proportionate parts of incomplete intervals. Slope of the line is first calculated as the tangent of the angle of slope, angle B, where tan B equals V/H.

FIGURE 1



MEASUREMENT OF SLOPE FROM A POINT (STRAHLER)

If the map is to show sine of slope angle, tangent values are converted into sines from trigonometric tables and the sine values inscribed ... Thus the topographer places his rod stations (sample points) on ridge lines, drainage lines, and wherever the slope changes in steepness or azimuth. Similarly, by moving the dividers over the contours, one can easily see where contour parallelism exists and where contour spacing changes. Where slope changes, points are concentrated to limit the position of the new slope lines. As in topographic mapping, the number of points determined per unit area depends on the detail desired and is limited by the space on which numbers can be written legibly. On the Perth Amboy slope maps, about 300 points were used in contouring and on the Emporium, Pennsylvania map about 2,500."[44]

Strahler argues that previous maps depicting steepness of slope over an entire ground surface were done on a small scale and showed broad classes of slope values (example, Raisz and Henry (1937) used classes of average slopes ranging from 50 to 500 feet or more per mile). Strahler concludes that surface slope conditions must be mapped on a large scale with a continuous scale instead of by groupings of slope measurement.

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[44] Strahler, A.N., *op. cit.*, 1952, pp. 575-576,

During the 1950's a number of studies came out dealing with average slope and with the correlation between this parameter and agricultural production. One of the most important of these was the work by Calef and Newcomb. Their method of average slope determination was a combination of the methods used by Raisz and Henry (1937) and Wentworth (1930). The two researchers outline their methodology by stating, "average slopes were calculated for each delimited area by counting contour crossings along various intersecting lines and calculating average slope by means of the Wentworth equation".[45] The interesting idea presented in this work was the fact that these two researchers combined two previous methodologies to suit their study of Illinois. Whether their method has a greater degree of accuracy than other methods is difficult to assess, as the writers state, "just how much difference this makes for an average slope figure in comparison with the method used by Raisz and Henry is difficult to judge, because they do not explain exactly how they applied their contour density scales. It is probable that the differences are not very great and, as Raisz and Henry point out, differences in measurement techniques and in reliability of the contour map data do not significantly change the comparative relationships between areas".[46]

Calef and Newcomb argue quite strongly that statistical maps of average slope and relative relief have limited usefulness. They state, "the authors offer the value judgement that statistical maps of terrain are of extremely limited usefulness ... One of the greatest dangers in

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[45] Calef, W. and Newcomb, R., *op. cit.*, 1953, p. 306.

[46] Calef, W. and Newcomb, R., *ibid.*

the use of statistical maps of terrain lies in the tendency to read things into the maps and then assume that they can be read from the maps".[47]

The other two works done in the 1950's were doctoral theses, one by J.C. Hook (1955) and the other by W. Garrigus (1958), which will be outlined, not only because they are important in the development of a useful average slope index but also because they will be referred to specifically later in this study.

Hook states his main objective quite clearly in his thesis; "the problem involved in this work can be stated as: to what extent is the real differentiation in roughness in North-Eastern United States associated with the areal differentiation in phenomena related to agriculture?".[48] Hook's study was done on a large area, namely, the thirteen States of the eastern seaboard of the United States, using "a refinement of Hamilton's topographic index".[49] As the researcher points out, "the roughness index is based on the assumption that the density of contour lines in any given area is an indication of the degree of roughness of that area."[50] His method entailed the superimposition upon the topographic map of a grid of north-south and east-west lines. The intersections of the contour lines with the grid lines were then counted. The counting of streams advocated by Hamilton was not done by Hook. The grid was then rotated 45 degrees and the intersections were counted again.

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[47] Calef, W. and Newcomb., *op. cit.*, 1953, p. 315.

[48] Hook, J.C., *op. cit.*, 1955, p. 4.

[49] Hook, J.C., *op. cit.*, 1955, p. 26.

[50] Hook, J.C., *op. cit.*, 1955, pp. 26-27.

Basically, his method can be summed up in the following formula:

$$RI = \frac{\frac{n(m)}{4}}{a} \cdot 10$$

RI = the roughness index

n = the total number of intersections (all four directions)

m = the distance in miles between the grid lines

a = the land area of the county in square miles.

Hook makes an analysis of the relationship between intensity of land-use and the roughness index. He classifies intensity of land-use into three broad categories, namely, cropland, pasture and woodlots. He states the results of these relationships as follows: "there is a very slight tendency for total woodlots ... to increase as the roughness increases (r = +0.73) ... The percentage of harvested cropland decreases as the roughness increases (r = 0.51)".[51]

Hook also obtains the relationship between gross and net values of agricultural products sold per acre of farmland and the roughness index. The results are stated by Hook as follows: "the coefficient of correlation between the roughness index and the (gross) value of agricultural products sold per acre of farmland is -0.50, indicating that there is this inverse relationship between farm income and roughness ... The correlation between "net" value of the agricultural products sold per acre of farmland and the roughness index is -0.46".[52]

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[51]Hook, J.C., *op. cit.*, 1955, p. 56.

[52]Hook, J.C., *op. cit.*, 1955, p. 70 and p. 138.

Garrigus, on the other hand, made a study of a smaller area, namely, eighty-eight counties of the State of Ohio. The objective of the study is stated as follows, "if roughness of terrain were not a significant relief characteristic there would be little point in determining average slope values. However, roughness is often one of the most significant factors in agricultural productivity and it can be demonstrated that the areal variation of roughness in many regions is closely linked with the areal variations of agricultural productivity."[53]

The method employed is outlined in brief terms in the following paragraph:

> "United States Geological Survey topographic maps, scale 1:62,500, covering the State of Ohio were taken up one at a time in alphabetical order, and placed under a grid which was a modification of that used by Wentworth. Number of intersections between contour lines and traverse lines of the grid, and total length of traverse lines were recorded for each county on the map. After all this data had been recorded for all the maps, the total number of intersections, corrected to twenty foot contour intervals, and total traverse length for each county were tallied and the average slope computed. Totals for each map were also totalled and the average slope of the map computed to serve as a basis for constructing the average slope of Ohio".[54]

The results of the study by Garrigus are expressed in the following statement: "the scatter diagram which accompanies this chapter reveals a high negative correlation between average slope, or roughness of terrain, and agricultural productivity".[55] Although Garrigus did not

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[53]Garrigus, W. *Average Slope: A Morphometric Index Useful in Analyzing Areal Variations of Agricultural Productivity as Applied to the State of Ohio.* Ph.D. Thesis, Clark University, 1958, p. 26.

[54]Garrigus, W., *op. cit.*, 1958, p. 101.

[55]Garrigus, W., *op. cit.*, 1958, p. 126.

use the statistical measure of correlation coefficient, the author obtained the "r" value of the relationship between the (gross) value of crops harvested per acre of farmland per county and the average slope index ($r = -0.877$).

Both researchers used an average slope index formula that had already been devised by previous workers and modified the techniques to a minor degree. Both of these studies stressed the importance of the use of this average slope index rather than just the calculation of the index.

Although studies of the measurement of average slope seem not to have been undertaken in the 1960's, the influence of slope on aspects of agriculture continued to be of interest to geographers. Individual studies analyzed cattle distribution on steep slopes in southwestern Montana,[56] the influence of slope on the size and distribution of fields in Iowa[57] and the relation between landform parameters and soil properties in the State of Iowa.[58]

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[56] Mueggler, W.F. "Cattle Distribution on Steep Slopes", *Journal of Range Management*. 1965, pp. 255-257.

[57] Riecken, F.F. and Runge, E.C.A. "Influence of Slope on Size and Distribution of Fields in Iowa", *Soil Science*. 1967, pp. 529-534.

[58] Walker, P.H., Hall, G.F. and Protz, R. "Relation Between Landform Parameters and Soil Properties", *Soil Science*. 1968, pp. 101-104.

CHAPTER 3

CALCULATION OF THE AVERAGE SLOPE INDEX FOR SAMPLE DISTRICTS OF COSTA RICA

PREPARATION OF THE BASE MAP

The initial methodological decision that was confronted at the beginning of the study was the choice of the areal unit that was to be used in the analysis. As mentioned earlier in this study, the smallest unit for which census data is obtainable was selected, namely, the district.[1]

The cartographic delimitation of the provinces of Costa Rica had already been achieved by the National Geographical Institute (I.G.N.).[2] However, the boundaries of cantons and districts were not marked on any of the published I.G.N. publications except for those of the province of San Jose where the canton lines were marked on a map and their historical delimitation described by the director of I.G.N., Ing. Mario Barrantes Ferrero.[3] Accordingly, with the help of a cartographer Sr. Jorge Alvarro

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[1]The Census Department of Costa Rica (Direccion General de Estadistica y Censos) had used smaller units in the census taking of 1961. These units were later combined to give statistics for the district. The statistics for these smaller units could not be obtained and their boundaries were very arbitrarily set so they were not used as the units of analysis for this study.

[2]Instituto Geografico Nacional (I.G.N.) *Mapa Fisico-Politico.* Scale 1:50,000.

[3]Barrantes, M. *Evolution de la Division Territorial en la Provincia de San Jose.* 1968.

and a fellow geographer Herbert Siebert,[4] the author undertook the delimitation of the districts for all of Costa Rica, a task which was completed after four weeks of work. The research was a painstaking interpretation of roughly made district lines on marked topographic maps stored at the I.G.N. There were a total of 137 such maps at the scale of 1:50,000 which cover the country. Also, a limited number of roughly made district maps, that were available from the "Direccion General de Estadistica y Censos", were obtained to aid in the work.

The boundaries of the districts where the I.G.N. and the Census Department maps agreed were accepted. In most cases, where the Census Department maps were not available, the boundaries as marked on the I.G.N. maps were accepted. However, in some cases the boundaries had to be checked and rechecked according to the laws as passed by the Legislative Assembly.[5] Even with all these aids, there were a few instances where the boundaries could not be determined precisely. In these cases, lines were drawn, in what was believed to be the correct locations, by following major streams, major and minor roads or major drainage divides.

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[4]Senor Jorge Alvarro was and still is a senior cartographer in the "Oficina de Planificacion" or the Ministry of National Planning in Costa Rica. Herbert Siebert is a companion of the author who has studied the relation between population and levels of living in Costa Rica.

[5]The I.G.N. issues a booklet approximately every year listing the name of each district together with the different "barrios", villages, major streams, and crossroads contained in each district. All changes are referred to laws passed in the Legislative Assembly.

Ministerio de Gobernacion. *Division Territorial Administrativa de la Republica de Costa Rica.* 1963.

After completion of this primary task, the map of political units was reduced for working convenience to the scale of 1:250,000.[6] This map showing the complete political subdivisions of the country (seven provinces, 68 cantons and 335 districts), is not only the base map for this study but is also used as a base map by the Costa Rican National Planning Department (Map B in the Appendix).

Selection of Areas for Study

Maintaining the unity of the individual districts, Costa Rica was divided into two areas:

1. Meseta Central
2. The area outside the Meseta Central

As mentioned earlier in the study, the meseta central is generally a large elevated plateau in the central part of the country. This region stands out since the smallest political units, namely, districts, are relatively smaller in size in comparison to the rest of the country. A population density map of Costa Rica[7] indicates that the meseta central

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[6] The author was intensely involved in the reduction of these maps. A large sheet of semi-transparent paper was placed on top of each block of four topographic maps. The province, canton and district lines were drawn on the semi-transparent overlay by heavy dark lines in India ink and in such a way as to differentiate the canton and district lines. The large overlay sheets were then photographed and reduced by the photographic equipment at the I.G.N. These reductions were then carefully joined together in mosaic form and photographed again to be reduced to the scale of 1:250,000.

[7] AID Resources Inventory Center. *Costa Rica: Regional Analysis of Physical Resources, Central America and Panama.* 1965, p. map T16 and T17.

area has much higher population densities than the rest of the country. A map of land-use (Map C in the Appendix) reveals that this area has a relatively intensive agriculture where most of the crops grown are destined for export.[8] In travelling through this area it becomes apparent that almost all of the land has been cleared for some type of agricultural activity which is not the case in areas outside the meseta central. Since this region of the country seems to be somewhat different, it was decided to separate this region from the rest of the country and to determine whether the general hypothesis as postulated in this study differs in the meseta central as compared to the area outside the meseta central.

The term "meseta central" can be found in numerous studies of Costa Rica.[9] Most of them generally refer to an area that extends in a belt between the cities of Turrialba and San Ramon. In the "Atlas of Costa Rica"[10] a map of surface configuration labels the area as the "Valle

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[8] A land-use map is also found in the work by Ministerio de Obras Publicas. *Plan Vial: Proyecto de Caminos Vecinales*. 1962, pp. 87-88.

[9] Vargas, O. and Torres, J. *Estudio Preliminar de Suelos de la Region Occidental de la Meseta Central.* 1965

Lombardo, H. *Analysis de una Economica Agricola Dentro de la Meseta Central de Costa Rica.* 1965.

Dondoli, C. *Estudio Geoagronomico de la Region Oriental de la Meseta Central.* 1954.

Saenz, A. *Suelos Volcanicos Cafeteros de Costa Rica.* 1966.

[10] AID Resources Inventory Center, *op. cit.*, 1965, map T2.

Central" (central valley). According to this map the area is surrounded by mountains on all sides, while within the area, there are three sections of relatively level plains with the remainder consisting of hills. The National Geographical Institute (I.G.N.) has published a map of the central part of Costa Rica which includes a description of the limits of the meseta central.

Using the map of surface configuration and the I.G.N. map as a general guide, the 1:50,000 topographic maps of the area were examined in an attempt to identify the districts which may be included in the meseta central. The northern and southern boundaries were generally taken to be the drainage divides of the Cordillera Central and the Cordillera de Talamanca, respectively. A number of exceptions do occur due to the fact that some districts have irregular shapes and in some cases extend far into the mountainous areas. The remaining limits were drawn to correspond generally to the limits as described in the I.G.N. map. Of the 335 districts in Costa Rica, 169 were included within the meseta central (Map B in the Appendix).

SELECTION OF THE SAMPLE FOR THE STUDY

Of the 335 districts of Costa Rica, a sample of 100 districts was chosen for the study. This is a reasonably good sized sample since it constitutes almost exactly 30% of the total number of districts in the country. The criteria used as guidelines in the selection of this sample are described below.

In areal extent, as mentioned earlier, the districts in Costa Rica vary from 0.5 square kilometers to 2,896.8 square kilometers. Since the range in the size of districts is relatively high, it is argued that the selection of sample districts should generally reflect the range of district sizes in Costa Rica. Although the delimitation of districts and cantons in some cases has been done in a haphazard way due to political lobbying in the Legislative Assembly by regional and town pressure groups, on the whole the districts are of comparable economic importance; in other words, there tends to be a negative relation between district size and population density. The smaller size districts are concentrated in the central part of the country where the population density is relatively high. Districts to be included in the sample were selected to include a wide range of district sizes in all major sections of Costa Rica (see Map B in the Appendix).

Another criterion considered important was the existing agricultural land-use. Land-use information was derived from individual crop and cattle distribution maps provided by experts from the Ministry of Agriculture (M.A.G.) and other ministries of the government.[11] A compilation

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[11]In an important meeting in January 1969 at the Oficina de Planificacion in San Jose numerous experts were asked to contribute to a regionalization program directed by Dr. H. Wood. One of the topics dealt with agricultural potentials and the regionalization of agricultural land-use types. In the next few months maps were prepared by experts from the Ministerio de Agricultura y Ganaderia showing the distribution of each major agricultural commodity in Costa Rica. The following is a list of some of the experts and the commodities for which they reported: Abel Contreras (Cotton), Franklin Morera (tobacco), Alfonso Jimenez (banana), Gregorio Alfaro (corn), Miguel Grillo (swine), Adrian Arias (cacao), Alberto Vargas (rice), Carlos Ramirez (sugar cane) and Rodolfo Munoz (cattle). In addition to all the information derived from M.A.G., data were obtained from interviews with experts at agricultural extension offices in the following areas: Ciudad Cortes (Pacifico Sur), Heredia, Grecia, San Isidro del General, Golfito, Nicoya, Filadelfia, Cahuita, Canas, Guapiles, San Carlos and Limon.

of this information has been done by H. Nuhn, who has drawn a map showing the distribution and the general combinations of agricultural activities that are found in Costa Rica (Map C in the Appendix). Districts were selected from areas containing a wide range of different crop concentrations and combinations. This criterion is important since an analysis of individual agricultural activities, as they relate to the hypotheses in question, will be carried out. In this analysis the sample size of the different agricultural activities is critical and thus districts were selected that had a wide range of agricultural activities.

Actually, of the districts selected for the sample, a number had to be eliminated, as they were found not to comply with the area calculations indicated by the Census Department. In some cases the area of a district according to the Census Department was twice or three times the area as calculated by the author.[12] This aspect was important since production and area figures of individual agricultural activities for a district were used in the calculation of the agricultural productivity indices. If this data did not correspond to the districts involved than those districts were omitted from the sample and others were selected.

Taking these different criteria into consideration the sample was selected in a subjective but systematic manner. In this case, it is argued that a systematic subjective sample is just as good as or better that a random sample. It incorporated a wide range of different size

[12] The following is a list of a few selected districts showing some of the extreme cases of the differences between district sizes as calculated in this study and as given by the Census Department.

District	Sury Study (sq. kil.)	Census (Sq. kil.)
San Antonio	11.46	8.58
Rancho Redondo	11.79	36.90
Turrialba	102.17	184.19
Palmira	31.38	104.02
Germania	65.94	94.75

districts scattered throughout the country with a wide range of crop concentrations and combinations.

TERRAIN UNIT MAPPING

The 100 districts that were selected were divided into terrain units on the basis of visual inspection of the density of contour lines on the topographic maps. The procedure proposed by Raisz and Henry was followed, namely, "Each topographic sheet was subdivided, ... into smaller regions so that within each subdivision the density of contour lines should be about the same".[13]

Both topographic maps at the scale of 1:50,000 with a 20 meter contour interval and aerial photographs[14] were used in the precise delimitation of the terrain units. A sheet of transparent paper was placed on top of each topographic map which contained one or more of the districts

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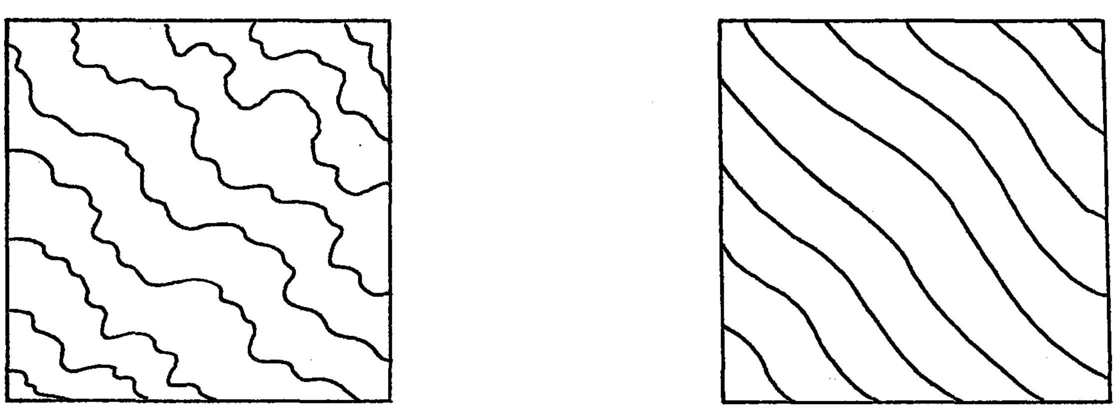
[13] Raisz, E. and Henry, J. "An Average Slope Map of Southern New England", *Geographical Review*. 1937, p. 469.

[14] Virtually all of Costa Rica is covered by vertical aerial photography at scales ranging from 1:15,000 to 1:60,000. This photography was taken for the Instituto Geografico Nacional to provide a base for its topographic mapping projects. Almost all of the photography was taken by the United States Air Force which often carried out this function for joint programs of national cartographic agencies and the Inter-American Geodetic Survey. More detailed information on the aerial photographic surveys done in Costa Rica is found in the work by Pan American Union. *Costa Rica - Annotated Index of Aerial Photographic Coverage and Mapping of Topography and Natural Resources*. 1965.

in the sample. District boundary lines were transferred to this sheet from the work sheets produced in the making of the initial district and canton map. Then using the topographic map as a guide, pencil lines were drawn where sharp breaks in contour density occurred. The size of terrain unit ranged from 0.01 square kilometers to 354.28 square kilometers. Finally, with the help of the aerial photographs, boundary additions, deletions and adjustments were carried out.

The aerial photograph analysis was significant not only in the detailed delimitation of some of the terrain units but also in determining whether an area ought to be classified as highly dissected or not. Evidence of such dissection may in some cases, of course, be given by the irregularity of the contour lines; as illustrated in Figure 2 . Figure 2 illustrates an extreme case of two squares of the same general slope but a different degree of dissection.

FIGURE 2



DEGREE OF DISSECTION IN AN AREA OF SIMILAR SLOPE

Although a subjective judgement was involved,these cases were designated as separate terrain units. This question was not pursued further since to do so would have introduced a separate research topic and much detailed study. Fortunately, the number of highly dissected areas in the 100 sample districts was extremely small.

Figure 3 portrays one of the topographic maps in the meseta central and the corresponding division into terrain units.[15] A "before and after" depiction of the terrain unit boundaries on the topographic map illustrates the result of the delimitation process used in this study. The section of the topographic map is included without any terrain unit lines so that a visual comparison could be made to the same area with the terrain unit lines. The terrain unit delimitation within the meseta central is evident on the topographic maps found in the appendix (Maps D to N).

An example of the aerial photograph used is found in Figure 4 (scale of 1:60,000).[16] Photographs of the scale 1:17,000[17], which were available only for the meseta central, were also used in the central part of the country to check and recheck the accuracy of the delimitation lines. However, the small scale photographs (scale 1:60,000) were used most often.

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[15]The topographic sheet of Naranjo was used because it illustrates a great variety of terrain units.

[16]These small scale aerial photographs were taken by the U.S.A.F. from 1954-1957 under a contract from the I.G.N.

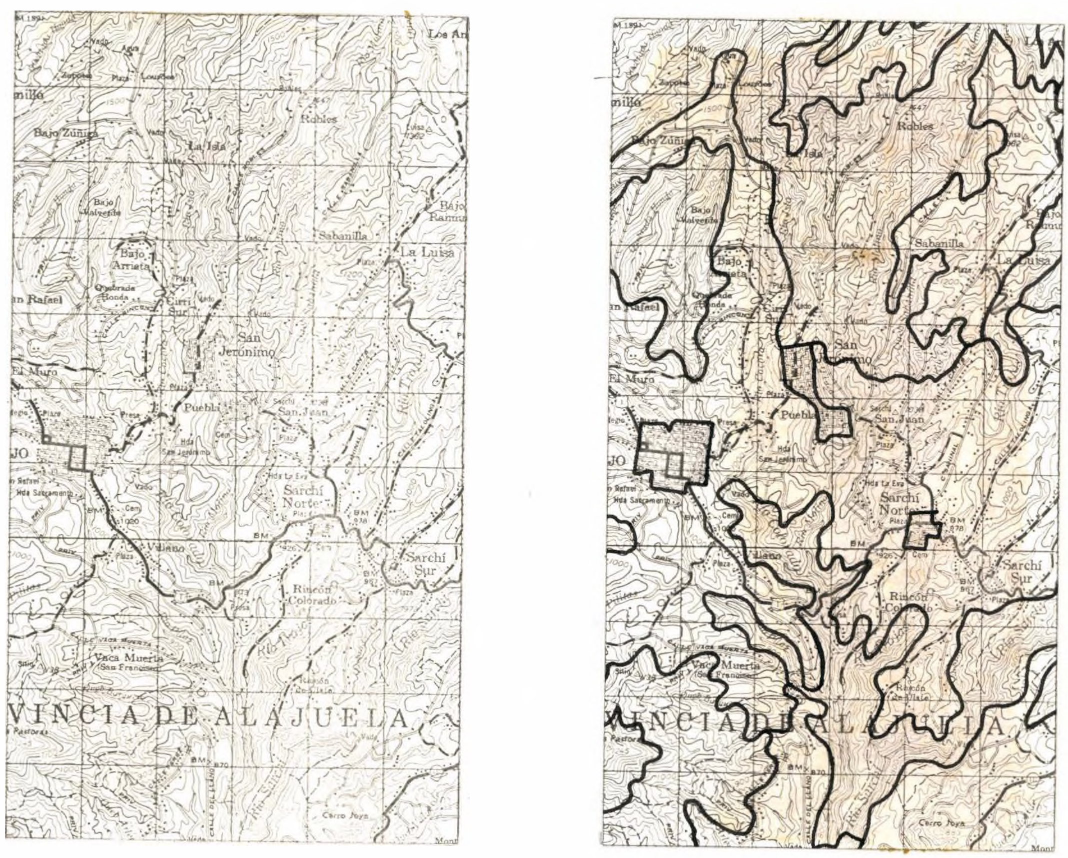
[17]These large scale aerial photographs were taken by the U.S.A.F. in 1961 under a contract from the I.G.N.

FIGURE 3

THE "BEFORE" AND "AFTER" PICTURE OF DELIMITING AREAS INTO TERRAIN UNITS

(Naranjo Topographic Sheet)

BEFORE AFTER



LEGEND

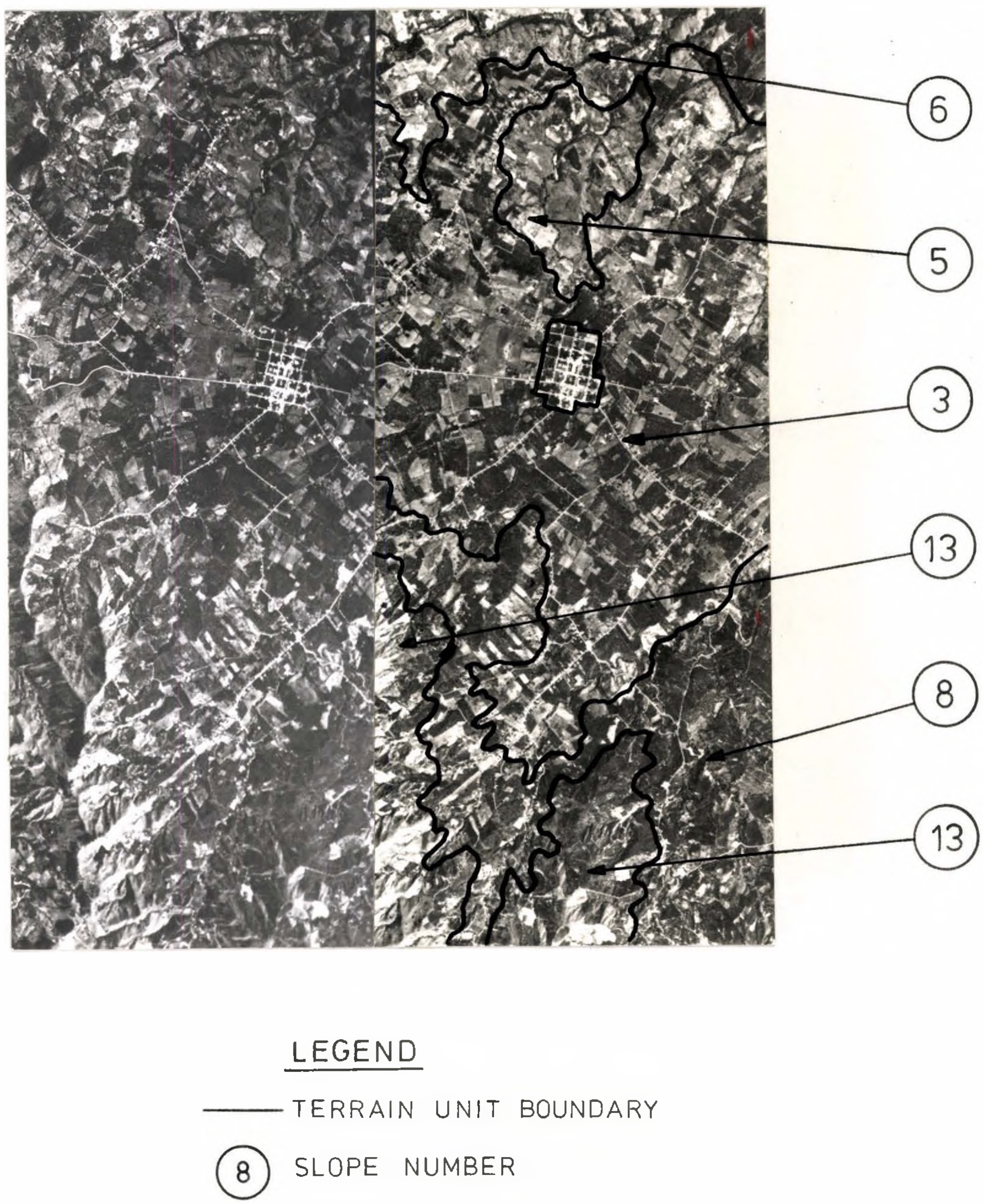
—— TERRAIN UNIT BOUNDARY

FIGURE 4

THE TERRAIN UNIT DELIMITATION ON AN AERIAL PHOTOGRAPH

(SCALE: 1:60,000)

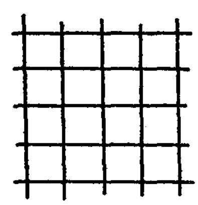
FROM AN AREA CLOSE TO NARANJO



DETERMINATION OF THE AVERAGE SLOPE INDEX

Each district in the study sample was thus divided into many parts each with different average slopes. The next step involved the careful measurement of the area of each of the terrain units in each of the districts. The method used in carrying out this process was the counting of squares, each representing 250 meters by 250 meters, with an overall accuracy of half a square (Figure 5). The measurement of the area was somewhat tedious where the terrain unit lines were very jagged or the areas were very narrow. The results were then converted to square kilometers and written on the terrain unit on the map as shown in Map D.

FIGURE 5



GRID OF 5 MM. SQUARES

The next step was the determination of the slope category for each of the terrain units in the district. The method used to calculate the slope category is outlined as follows:

a. On a transparency, a grid of 2 cm. squares was drawn. The size of the grid was 20 by 20 cm.[18]

b. The grid was scaled from 0 to 10 horizontally and vertically starting from the upper left hand corner of the grid.

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[18] This grid corresponds to the military grid (black lines) on the topographic map.

c. The grid was laid on the topographic map over the terrain unit to be measured so that the grid lines ran north-south and east-west.

d. Using a four digit number chosen at random from a chart,[19] the first two digits were used to identify one square (representing one square kilometer) and the second two numbers were used to pin-point exactly a dot within the one square kilometer chosen. The first digit gave the position on the north-south axis and the second on the east-west axis. Dots that fell outside the terrain unit were disregarded and the process was repeated. As mentioned earlier, a similar method was carried out by Strahler who selected points by random sampling and then used these points to make slope measurements.

e. Through the dots that fell on the terrain units to be used, lines were drawn perpendicular to the flow of contour lines along the longest slope.

f. Over a distance of two cm. (representing one kilometer) the number of contour lines crossed was counted. In taking the reading the one kilometer distance was taken to start from the selected point. In cases where the selected point or the end of the one kilometer distance were on top of a contour line, that contour line was counted. In the sample below (Figure 6), the number of lines that intersect the one kilometer distance is 6.

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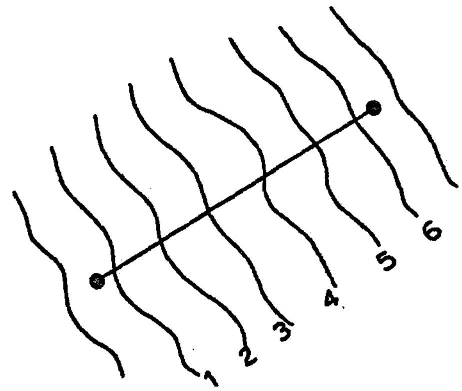
[19] Arkin, H. and Colton, R. *Tables for Statisticians*. 1963, pp. 158-161.

FIGURE 6



MEASUREMENT OF SLOPE ALONG A 1 KILOMETER DISTANCE

A large number of previous researchers used the technique of counting contour intersections per unit distance (Rich 1916; Wentworth, 1930; Hamilton, 1930; Strahler, 1956; Raisz and Henry, 1937; Calef and Newcomb, 1953). This technique was also used in this study.

If the terrain unit extended to two or more topographic sheets, a transparency was used for each sheet so that the entire terrain unit was covered. In cases where the terrain unit was relatively large in areal extent a larger number of sample readings were used to calculate the average. Great caution was taken in very small terrain units where straight downslope distances of one kilometer could not be taken. The sample readings were averaged to attain a number which was rounded off to the nearest whole number and taken to represent the slope category for the terrain unit.

The degree of dissection, as discussed in the previous section, was taken into consideration by arbitrarily increasing the slope category number by one. Whether the slope category number should have been increased by two or more is difficult to assess unless additional detailed research was undertaken. It is felt by the author, however, that the addition of one in this study is sufficient to allow for the steeper slopes on the sides of the larger valleys in terrain units which are considered "highly dissected".

The number of terrain units to be measured was enormous (Appendix, Maps D to N) and the number of measurements in each one had to be kept to a minimum because of the time element involved. Therefore, a small test was carried out to determine the number of one kilometer distance measurements to be made in each terrain unit. In the test, four terrain units with different slopes were randomly selected in the meseta central. For each of these terrain units a series of readings was taken, namely, 2, 3, 4, 5, 7 and 10. For each of the readings the average was calculated and recorded (Table 2).

Table 2 indicates, to one decimal place, the average number of contour lines that cross the grid line. It is assumed that the larger the sample of readings the higher the accuracy of the average slope number. If this assumption is true, the slope numbers should be 7.5, 2.3, 24.3, and 13.6 for cases A, B, C and D respectively. From the results obtained it can be observed that significant departures from these values only occur in the cases of 2, 3 or 4 readings. However, for five or more readings the values are fairly stable. From this simple test it was concluded that five readings are sufficient to obtain the necessary average.

The next step was the calculation of the percentage of the total area of each district which fell into each slope category; the results of this calculation are shown in the tables in the appendix (Chart A).

TABLE 2

RESULTS OF READINGS FROM FOUR DIFFERENT TERRAIN UNITS

TERRAIN UNIT FROM WHICH READING WAS TAKEN	AVERAGE NO. FOR 2 READINGS	AVERAGE NO. FOR 3 READINGS	AVERAGE NO. FOR 4 READINGS	AVERAGE NO. FOR 5 READINGS	AVERAGE NO. FOR 7 READINGS	AVERAGE NO. FOR 10 READINGS
NORTH OF BARBA (A)	7.0	9.0	7.5	8.4	7.6	7.5
NORTH-EAST OF SAN JOSE (B)	3.0	1.3	2.7	2.3	2.4	2.3
SOUTH-WEST OF ATENAS (C)	20.5	23.3	22.5	23.5	24.6	24.3
NORTH-EAST OF CARTAGO (D)	14.0	13.7	13.0	13.9	13.5	13.6

The final step involved the calculation of an average slope index figure for each of the districts. To arrive at this figure each slope category occurring in a district was multiplied by the figure representing its percentage of the total area. The resulting numbers were added, rounded off to one decimal place and the sum was taken to be the slope index number for the district.

In the calculations of the average slope index for each district a number of assumptions were made. The average slope index for each district incorporates the terrain slopes of the whole district. It is assumed that agricultural activities are found on all of the different terrain slopes within the district. Further discussion of this assumption will be made in Chapter 5.

It was also assumed that the average slope index calculated for each district was a realistic measure of the terrain slopes in the district. The process of averaging does introduce some implications. If a district has basically two types of terrain slopes, namely, very flat and very steep, the resulting average slope index will indicate a medium slope index. This average slope index would compare very closely to one in which a district has generally overall medium sloping terrain. Another implication of the average slope index as calculated in this study is that each slope category received the same weighting. Certainly different slope categories would have different degrees of importance on agriculture, generally speaking. For instance, it may be postulated that areas with slopes of about 30% may be 4 times as difficult to work in as areas with slopes of 10%. Further research on this aspect could be done to make the average slope index more meaningful.

Mathematically, the average slope index as calculated in this study, is given by the following formula:

The districts are partitioned into n terrain units labelled from 1 to n.

$$SI = \frac{100}{TA} \cdot \sum_{i=n}^{n} \frac{t_i a_i}{k_i}$$

SI = average slope index

TA = area of the district

a_i = area of the i^{th} terrain unit

k_i = number of 1 kilometer line segment samples in the i^{th} terrain unit

t_i = total number of contour lines crossed in the i^{th} terrain unit by all the k_i sample lines.

In the case of the 100 district sample, the lowest slope category number was 0 for completely flat land and the highest slope category number was 29. Theoretically, therefore, the lowest average slope index for a district would be 0 and the highest would be 2,900. However, in actuality the range for the 100 sample districts was from 127.9 to 2,286.7[20].

The average slope index used in this study is a combination of ideas from previous researchers in this type of work. It is thought to be an accurate and practical method for use in the Costa Rican case.

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[20]The average slope index of 127.9 is of the district of Guapiles in the canton of Pococi. The average slope index of 2286.7 is of the district of San Andres in the canton of Leon Cortes.

TABLE 3

RANDOM DISTRICT NUMBER	SURY METHOD	HOOK METHOD	GARRIGUS METHOD (%)
4	200.0	32.75	10.37
41	747.9	77.03	21.45
28	1439.6	115.15	38.34
65	1047.1	96.32	30.86
5	1773.1	118.07	36.72
39	1404.6	131.87	40.21
64	2005.2	161.49	48.50
7	200.0	26.12	6.98
8	252.1	57.59	18.25
33	717.1	87.52	27.19
61	942.3	93.36	28.51
43	1423.0	124.63	38.05
29	1017.0	103.10	30.94
38	641.1	64.67	18.47
31	826.6	71.89	22.48
22	2056.4	133.67	41.24
54	299.3	39.37	12.24
71	289.4	38.25	11.75
73	532.7	66.17	19.53
21	945.2	86.63	26.10

SLOPE INDEX READINGS OF SAMPLE 20 DISTRICTS USING THE HOOK, GARRIGUS AND SURY METHODS

Comparison with Other Average Slope Indices

The final stage of the average slope index determination analysis was to compare the index derived in this study with other average slope indices using a sample of districts from the meseta central. For this purpose the methods of Hook and Garrigus were used.

The sample of districts to be selected for this comparison was chosen from the meseta central by random sampling. Of the 80 districts in the meseta central each was given a number from one to 80. Of these, twenty districts were chosen using the first two digits in the random number chart.[21] The three average slope indices were then meticulously calculated and recorded. The Hook[22] and Garrigus[23] methods were used as mentioned in Chapter 2, with the grid lines spaced 2 cm. apart. The results were tabulated as shown in Table 3.

TABLE 4

RELATIONSHIPS	CORRELATION COEFFICIENT (r)
SURY WITH HOOK	.95400
SURY WITH GARRIGUS	.95407
HOOK WITH GARRIGUS	.99582

CORRELATION COEFFICIENTS BETWEEN DIFFERENT AVERAGE SLOPE INDICES

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[21] Arkin, H. and Colton, R., *op. cit.*, pp. 158-161.

[22] Hook, J.C. *The Relationship Between Roughness of Terrain and Phenomena Related to Agriculture in Northeastern United States.* Ph.D. Thesis, State University of Iowa, 1955.

[23] Garrigus, W. *Average Slope: A Morphometric Index Useful in Analyzing Areal Variations of Agricultural Productivity as Applied to the State of Ohio.* Ph.D. Thesis, Clark University, 1958, pp. 84-85 and 99.

The final analysis involved the determination of the correlation coefficient of the different indices compared to each other. The results are tabulated in Table 4.

The relationship between all the average slope indices is extremely good. However, the average slope indices of Hook and Garrigus are clearly more nearly identical to one another than to that derived in the present study. Nevertheless, it seems that the average slope index method used in this study is very similar to these other two methods of average slope index determination and that comparisons between the results obtained in all three methods are valid.

It is thought, however, that the technique of average slope determination described in this study is more practical and easier to interpret for the Costa Rican case, than the methods by Hook and Garrigus. Both the Hook and Garrigus methods involve the counting of contour intersections on a series of grid lines that cross the entire district. In some cases the lines were quite long because of the shape of the districts and therefore the contour intersection figure was relatively high.[24] For this reason it was difficult to keep track of the number, especially in areas where the contour density was high.

Another problem which arose after using both the Hook and Garrigus methods was in counting the cases in which the grid line was tangent to a contour line. These cases were quite numerous and were difficult to identify with precision; certainly counting errors probably developed.

[24]For district with random number 5, 1,352 and 1,478 contour intersections were counted for the North-South and East-West grid lines, respectively. For district number 22 the contour intersections for the North-South and East-West grid lines were 999 and 958, respectively.

Both the Hook and Garrigus methods used the county as the statistical unit. Most of these counties were rectangular in shape. However, the districts in Costa Rica are in most cases very irregularly-shaped Some difficulties were therefore experienced in counting the contour intersection on lines that were in some cases interrupted for a few inches before carrying on. For districts that were long and narrow differences were also noticed in the total number of intersections counted depending on how the grid was placed on the district.

CHAPTER 4

DETERMINATION OF AGRICULTURAL PRODUCTIVITY INDICES

In Chapter 1, the hypothesis was advanced that agricultural productivity on any given piece of land will be negatively related to the slope of the land. In Chapter 3, an index of average slope was devised and index values were calculated for a sample of 100 districts. In this chapter indices to measure agricultural productivity will be developed and index values calculated for the same districts. Then the two variables of agricultural productivity and terrain slopes will be correlated in an attempt to establish the degree of their interrelationship for the country of Costa Rica.

The Choice of Agricultural Productivity Indices

A number of researchers studying the relationship of terrain slopes to agricultural productivity have used intensity of landuse, gross farm income and net farm income as agricultural productivity indices.

In his study of the North-Eastern United States, Hook recognizes the fact that intensity of landuse is influenced by the roughness[1] of an area; he states: "if the roughness of an area is considered as a factor that limits the agricultural activity in that area then the limitations should be reflected in the intensity of the land-use ... For the purposes

[1]The concept of roughness as used by Hook is synonymous to the concept of average slope as used by researchers such as Wentworth, Raisz and Henry and Calef and Newcomb (refer to Chapter 2).

of this study, intensity of land-use can be classified into three broad categories. The most intensive type is cropping, second is pasture and third, woodlots".[2] The relationship between land-use intensity defined in this way, and to the average slope index in Costa Rica will be examined in Chapter 5 of this study.

One of the variables on which Hook placed great emphasis is farm income, namely, the "gross" and the "net" values of agricultural products sold per acre of farmland. Garrigus in his study of Ohio also felt it was desirable to use farm income as an agricultural productivity index.[3] W.Y. Yang, a United Nations agricultural researcher, states that, "the total gross farm output or the total farm income most adequately reflects the volume of the farm business as a producing unit".[4]

In considering the production of agricultural commodities from the land it may be useful to refer to the *amount* rather than the *value* of agricultural products. However, to convert metric tons of sugar cane, stems of bananas, kilograms of meat and number of oranges into a satisfactory volumetric index of overall agricultural productivity of an area is difficult. Because it is much easier to use the value of agricultural products in rating productivity, this study will use as indices the gross

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[2]Hook, J.C. *The Relationship Between Roughness of Terrain and Phenomena Related to Agriculture in Northeastern United States*. Ph.D. Thesis, State University of Iowa, 1955, p. 55.

[3]In Garrigus' study, the concept of "agricultural productivity is used ... in reference primarily to the value of agricultural products supplied per unit of area per unit of time". This is outlined in the study by Garrigus, W. *Average Slope: A Morphometric Index Useful in Analyzing Areal Variations of Agricultural Productivity as Applied to the State of Ohio*. Ph.D. Thesis, Clark University, 1958, p. 103.

[4]Yang, W.Y. *Methods of Farm Management Investigations*. 1958, p. 61.

and net values of agricultural products derived per district per manzana[5] in one year.

From an overview of the statistics available on a district basis it was discovered that the gross and net farm income could be calculated to a reasonable degree of accuracy for Costa Rica. The Census Department has available statistics on total production, total area in cultivation or pasture for each agricultural activity for each district. An average annual price for each commodity as well as the costs of production per manzana for each agricultural activity could be obtained from various sources in the country.

In the analysis of individual crops and cattle in Chapter 5, a further index will be used, namely, yields per manzana, since the calculations may be made with relative ease from the statistics of the Census Department.

In the present study, however, certain problems would arise if the agricultural productivity indices were based on the total value of farm products produced, since some aspects of agricultural production are completely or largely insensitive to the conditions of the land surface. In this category is the production of livestock using imported feeds, such as, large-scale poultry operations or urban cattle ranches.[6] Agricultural enterprises that were suspected to fall into this category in

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[5]"Manzana" is the most common unit of areal measurement used in agricultural statistics in Costa Rica. One manzana is equal to 0.699 hectares or 1.727 acres.

[6]In some parts of the U.S.A., such as Los Angeles, cattle are being raised within enclosed ranches in urban areas using imported feeds.

Costa Rica were not included in the calculations.

Calculation of the Agricultural Productivity Indices

The parameters chosen to show the agricultural productivity of the districts of Costa Rica in this study are the gross and net farm income. The gross farm income is defined as the total income derived from the sale of all agricultural products. The gross income was derived by multiplying the price per unit of each agricultural commodity by the total number of units produced in a district and adding the products. Net farm income is defined as the gross farm income minus the total costs of production. The net income for each district was derived by subtracting an amount equal to the total cost of production per manzana for all agricultural commodities from the gross farm income. The following sections will describe in detail the calculation of the gross and net farm income to be used as the indices of agricultural productivity.

DETERMINATION OF PRICES OF THE AGRICULTURAL COMMODITIES

The 1963 Agricultural Census of Costa Rica contains statistics showing, by district, the acreage and volume of production of 25 separate perennial and annual crops and also the numbers of livestock.[7] Table 5 lists the crops, the number of farms reporting, the total area in cultivation and the total crop production figures for Costa Rica. The first fourteen crops on the list are annuals; the remaining eleven are perennials.

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[7] Direccion General de Estadistica y Censos. *Censo Agropecuario 1963*. pp. 67-167.

TABLE 5

NUMBER OF FARMS REPORTING, AREA IN CULTIVATION AND TOTAL PRODUCTION OF DIFFERENT CROPS IN COSTA RICA

CROPS	NO. OF FARMS REPORTING FOR ALL OF COSTA RICA	AREA IN CULTIVATION IN (MANZANAS)	TOTAL PRODUCTION IN UNITS OF MEASURE[8]
1. Rice	18,787	72,223.4	868,136 quintales
2. Beans	26,910	62,677.4	1,084,340 cajuelas
3. Corn	31,001	75,898.6	158,215 fanegas
4. Potatoes	748	2,479.4	20,126 cargas
5. Tobacco	1,631	2,074.6	28,691 quintales
6. Yuca	4,773	3,277.6	136,845 quintales
7. Cotton	56	4,542.3	44,478 quintales
8. Camote	309	177.9	9,281 quintales
9. Peanuts	266	422.2	5,627 quintales
10. Ajonjoli	67	198.3	1,387 quintales

[8]Agricultural statistics in the Census are listed using local units of measurement for different agricultural commodities. The following list of these units gives their equivalents in internationally known units.

Quintal	= 100 pounds or 46 kilograms
Cajuela	= 28 pounds or 20 liters
Fanega	= 480 liters or 800 pounds (for corn)
	= 400 liters or 560 pounas (for coffee)
Carga	= 1,728 pounds
Racimo	= 50 pounds (one stem of bananas)
Ciento	= 100 units or pieces (e.g. oranges)
Tonelado (metric)	= 2,204 pounds or 1,000 kilograms.

This information is found in the study by:

Carvajal, M.J. and Ross, J.E. *Fact Sheets on Costa Rican Agriculture*. 1968, pp. 31-32.

TABLE 5 (cont'd.)

CROPS	NO. OF FARMS REPORTING FOR ALL OF COSTA RICA	AREA IN CULTIVATION IN (MANZANAS)	TOTAL PRODUCTION IN UNITS OF MEASURE
11. Garlic	200	84.7	2,434 quintales
12. Onions	379	303.3	37,808 quintales
13. Cabbage	388	310.6	35,109 quintales
14. Tomatoes	523	327.1	37,291 quintales
15. Plantain	6,653	10,424.1	3,830,903 racimos
16. Bananas	8,814	36,548.6	13,396,184 racimos
17. Pineapple	4,480	1,465.9	279,406 cientos
18. Oranges	21,139	909.4	2,224,972 cientos
19. Papaya	3,121	274.9	51,260 quintales
20. Coconut	4,812	2,579.3	192,389 cientos
21. Coffee	29,775	116,378.0	1,056,862 fanegas
22. Cacao	4,745	54,170.8	343,133 quintales
23. Cabuya	411	1,003.6	5,960 quintales
24. African Palm	24	7,231.0	922,062 quintales
25. Sugar Cane	16,356	13,911.4	1,178,025 tonelados

TABLE 6

NUMBER OF FARMS AND TOTAL NUMBER OF CATTLE, SUBDIVIDED INTO VARIOUS CATEGORIES BY AGE AND SEX, FOR ALL OF COSTA RICA

A. MALE	NO. OF FARMS	TOTAL NO. OF CATTLE
Calves (Terneros) - Less than 1 year	23,605	125,505
Bullocks (Toretes) - 1-2 years	9,326	47,410
Bulls (Toros) - 2+ years	10,535	20,510
Young Bulls or Oxen (Novillos) - 1-2 years	5,498	62,575
Young Bulls or Oxen (Novillos) - 2+ years	4,250	128,367
B. FEMALE		
Calves (Terneras) - Less than 1 year	21,180	117,779
Heifers (Vaquillas y Novillas) - 1-2 years	17,123	132,243
Cows (Vacas y Vaquillas) - 2+ years	33,645	385,720
	TOTAL	1,051,094

TOTAL NO. OF FARMS REPORTING IS 37,167.

All of these crops were included in the agricultural productivity indices because the land, which is our main concern, is directly involved as an element of production. Table 6 lists the numbers of cattle, subdivided into various categories by age and sex. In Costa Rica cattle graze on natural and/or seeded pastures all year round and the numbers per manzana should therefore be indicative of the carrying capacity of the land. For this reason, milk and meat production was also used in the calculation of the agricultural productivity indices.

The determination of the price of each of the commodities was complicated by the fact that the prices of certain commodities vary from season to season and from year to year depending on supply and demand. Prices of commodities may also vary from place to place in the country, if sold in local markets, and according to their quality. These and other factors made it very difficult for the writer to determine a standard price for a commodity. In this study use will be made of figures obtained from both public and private sources on the average prices of commodities for the whole year and for the whole country of Costa Rica.

The initial step was to collect the data available on the prices of crops for the year 1963, as given in unpublished tables compiled by the "Banco Central de Costa Rica", and listed below:

COMMODITY	FARM PRICE (in colones)[9]
1. Rice	55.54 per quintal
2. Beans	15.04 per cajuela
3. Corn	174.00 per fanega
4. Tobacco	201.85 per quintal
5. Cotton	171.70 per quintal
6. Bananas	15.07 per racimo
7. Coffee	214.68 per fanega
8. Cacao	132.76 per quintal
9. Sugar Cane	47.99 per metric ton
10. Beef (meat)	1.47 per kilogram
11. Milk	0.56 per bottle
12. Butter	4.52 per pound
13. Cheese	2.58 per pound

Reliable prices for a number of commodities were not available for the year 1963. In the case of 10 of these, however, statistics were available showing the value of production in colones and the total production in units of measure for each crop for all of Costa Rica for the year 1968. To derive the average price for a commodity the total value of production was divided by the total production figure. To reduce the price levels from these of 1968 to those of 1963, the "Indices of Prices" as published by the Census Department was used.[10] Indices of the retail prices for each commodity for the year 1968 were averaged for the twelve month period. The base for these indices was 1964 = 100.00. In this calculation the 1964 price level was assumed to approximate the 1963 price level. The percentage change in the retail price index of these commodi-

[9] The "colon" is the unit of currency of Costa Rica. The exchange rate in 1968 was 6.65 colones for one dollar (U.S.).

[10] Direccion General de Estadistica y Censos. *Indices de Precios Al Por Menor*. 1968, Nos. 181-186.

ties between 1964 and 1968 was calculated. It was also assumed that the percentage change in retail prices from 1964 to 1968 could be used as a surrogate for the percentage change in the farm prices over the same period. Therefore, the 1968 average farm price for each commodity was raised or lowered according to the percentage change that was calculated to give an approximation of the 1963 price level. The resulting figures are as follows:

COMMODITY	1968 PRICE (in colones)	1963 PRICE (in colones)
1. Potatoes	599.59 (carga)	627.66 (carga)
2. Yuca	7.28 (quintal)	7.33 (quintal)
3. Onions	42.80 (quintal)	45.56 (quintal)
4. Cabbage	14.99 (quintal)	14.50 (quintal)
5. Tomatoes	25.00 (quintal)	30.99 (quintal)
6. Pineapple	40.00 (cientos)	24.89 (cientos)
7. Oranges	5.00 (cientos)	5.36 (cientos)
8. Plantain	2.50 (racimo)	2.56 (racimo)
9. Peanuts	60.04 (quintal)	56.61 (quintal)
10. Coconuts	23.67 (cientos)	22.32 (cientos)

The retail prices of the two crops garlic and papaya were listed in the "Anuario Estadistico 1964".[11] To obtain the farm price the percentage difference between the farm price and the retail price was calculated for the four crops, onions, oranges, tomatoes and cabbage, for the year 1964. The results were relatively similar ranging from 30.85% to 35.73%. Using the average figure of 32.33% the farm price was obtained from the retail prices of garlic and papaya. This procedure gave values of 113.80 colones per quintal for garlic and 21.66 colones per quintal for papaya.

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[11] Direccion General de Estadistica y Censos. *Annuario Estadistico de Costa Rica, 1964*. p. 80.

Information on the price of ajonjoli (sesame) was not available for Costa Rica. However, the price of the crop in 1963 was known for the state of Jalisco in Mexico.[12] Ajonjoli is used for vegetable oil production and is usually sold on the international market. In any given year the international price would apply to both Costa Rica and Mexico. Therefore, assuming that the farm price in Mexico would roughly correspond to the farm price in Costa Rica a price of 47.93 colones per quintal was obtained.

Determination of the price of camote (sweet potato) was taken from Ospino[13] for the year 1967. He lists the price as varying from 10.00 to 20.00 colones per quintal since fluctuations in price occur during the year. The average figure of 15.00 colones was used. Since the price index for camote for the year 1967 was 99.99, based on a 1964 index of 100.00, it was assumed that the 1967 price, namely, 15.00 colones per quintal was also valid for 1963.

Statistics for the crop cabuya[14] were derived from Ospino for 1964. Ospino states that the fluctuation of price is from 100.00 to 115.00 colones. The average figure of 107.50 was assumed to be valid

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[12] The statistics are taken from unpublished material for the year 1963.

[13] Ospino, F. *Manual de Costos Basicos de Actividades Agropecuarias*. 1967, p. 33.

[14] "Cabuya" is the spanish word for a crop which is similar to sisal and from which a hard fibre is obtained.

for 1963.

The price of african palm was obtained from the Ministry of Agriculture from unpublished material for the year 1964. Figures of total production as well as total value were available, from which a figure of 97.52 colones per quintal was derived and assumed to be valid for 1963.

Gross Income Calculation

The other information necessary to permit the calculation of the gross farm income per district was the total production figure for each commodity for the year 1963. These figures were published by the Census Department by provinces and cantons but not by districts. However, the break-down at the district level was obtained from unpublished tabulation sheets at the Census Department.

The price figure for each crop and the total production figure for each crop per district were multiplied together to arrive at the gross income figure for each crop per district (Appendix Chart D).

For cattle, the gross income calculation was more complex. The unpublished Census Department tabulation sheets recorded the total number of cattle per district under three general headings:

a. Cattle raised for meat

b. Cattle raised for milk

c. Bullocks and oxen.

From unpublished data,[15] the proportion of cattle sold per year for each of the three categories above was estimated as follows:

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[15]The estimates used here were given to the author by Vernon Smith, who in 1968 was a Ph.D. candidate doing research on the cattle industry of Costa Rica. Although the information was received in 1968, it is assumed it would have been valid in 1963.

a. 1/7th of the number of cattle raised for meat were sold in one year.

b. 1/12th of the number of cattle raised for milk were sold in one year.

c. 1/15th of the bullocks and oxen were sold in one year.

From the same source, the average weight of one head of cattle for the three groups was also obtained,[16] namely:

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[16]The statistics for weight of cattle as presented in this section are the average weights as estimated by V. Smith. He based his estimates from unpublished material of the "Consejo Nacional de Produccion". Only a portion of the weight of the animal is sold as meat while the other parts of the animal are used for subproducts, such as, bone-meal, hides, etc. The figures for the percentage of an animal used for meat was not available for Costa Rica. There was some uncertainty as to whether the price 1.47 colones per pound, given by the National Bank of Costa Rica, was the meat price or the live weight price. To ensure that a large distortion in the gross income calculation would not occur by using the meat price as the live weight price, further investigation into the matter was carried out.

According to Smith the actual value that the rancher receives for his animal varies according to a number of factors: a) The quality of the animal, which, "depended a great deal on the bloodiness of the animal, the care it had received, the time it was sold with regard to the dry season and so on." b) "The choice of market channel(s) which each rancher makes either voluntarily or out of necessity". The farmer was usually paid a large part of the value of the animal after it was weighed alive.

For 1968, Smith estimated that the average value of one head of cattle that the rancher receives is as follows:

a. Cow - 750.00 colones
b. Beef cattle - 975.00 colones
c. Bull - 1,180 colones.

The value that the rancher would receive could be depreciated from 80 to 150 colones per head depending on the market channel used. Thus if the average of 115 colones was subtracted, the resulting figures would be 635, 860 and 1,065 colones per cow, beef cattle and bull, respectively. These figures were then scaled to 1964 levels by using an index which was based on 1964 = 100.0. By calculation the 1964 values for the three categories of animal were 502.92, 681.12 and 843.48 colones, respectively.

If the figures used in this study for the price per pound are multiplied by the animal weight to determine the value of one head of cattle, the results are as follows for the three divisions: 558.60, 598.29 and

a. The average weight of one head of cattle raised for meat was estimated at 407 kilograms.

b. The average weight of one head of cattle raised for milk was estimated at 380 kilograms.

c. The average weight of one bullock or ox was estimated at 510 kilograms.

Using these statistics the following formula was used in the calculation of the gross income from the sale of livestock per district:

$$GIL = \frac{1}{7} \cdot Tm\ (1.47(407)) + \frac{1}{12} \cdot Tmi\ (1.47(380)) + \frac{1}{15} \cdot Bu\ (1.47(510))$$

GIL = Gross income per district from livestock

Tm = Total number of cattle raised for meat in the district

Tmi = Total number of cattle raised for milk in the district

Bu = Total number of bullocks and oxen raised in the district

1.47 = The live weight price per pound.

Statistics on the volume of production of milk, butter and cheese were recorded by the Census Department by district on a one day basis for all of Costa Rica. The numbers were multiplied by 365 to arrive at a yearly figure and then multiplied by the price of each of the commodities.

749.70 colones, respectively. For cows the value in this study seems to be somewhat larger (approximately 9%), for beef cattle (12%) and bulls (11%) somewhat smaller. Since Smith's estimate and the values used in this study are quite similar, it was assumed that the price of 1.47 colones per pound, as given by the National Bank of Costa Rica, is the live weight price.

For each district the gross income figures for all of the commodities produced in the district were then summed to give the district's total gross income. This calculation was repeated for all sample districts and recorded on charts (Chart C in the Appendix).

CALCULATION OF THE COSTS OF PRODUCTION

The calculation of the costs of production for each of the commodities entailed a detailed analysis of data obtained from various sources.[17] The variation in costs of production from place to place in Costa Rica was also taken into account wherever possible. For some crops statistics on costs were available for different parts of the country from the Ministry of Agriculture, the Institute of Land and Colonization, the National Bank of Costa Rica and the Coffee Office for the year 1967. In these cases a percentage change between the 1964 and the 1967 production costs from Ospino's manual was used to scale the figures to 1964 levels. Because lack of information made it impossible to scale these figures to 1963 levels, it was assumed that the 1964 costs of production would not differ significantly from the costs of production for 1963. For other agricultural commodities production cost statistics were not available, and estimations had to be made using any information that was available.

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[17] Most of the statistics on costs of production were obtained from the works of Ospino, who has published a number of manuals on the costs of production for agricultural activities in Costa Rica. Furthermore, unpublished statistics were obtained from certain ministries and institutions of the government, such as, Ministry of Agriculture (M.A.G.), Institute of Land and Colonization (I.T.C.O.), National Bank of Costa Rica and the Coffee Office. Where no information was available from Costa Rica, statistics from other Latin American countries were used and were assumed to correspond to the costs of production in Costa Rica.

In these calculations the agricultural commodities were divided into three groups, namely, annual crops, perennial crops and cattle. For each group, the procedures for the calculation of the costs of production was distinctly different. Each will therefore be discussed separately.

ANNUAL CROPS

The costs of production for annual crops were obtained from published and unpublished material for either 1964 or 1967. Statistics for the year 1964 were accepted as being valid for 1963. However, statistics for the year 1967 were scaled to the 1964 level using the 1964 to 1967 percentage change for that crop as given in Ospino's manual. In cases where the calculation was different from this procedure a full description is included.

1. Rice

The most detailed information on the crop rice came from "Ministerio de Agricultura y Ganaderia" (M.A.G.)[18] for the year 1967, in which costs of production were listed for each of the major producing cantons. These 1967 costs of production had to be scaled to the 1964 level. According to Ospino, the average cost of production for rice rose by 11.7% between 1964 and 1967.[19] This figure was therefore used to scale down the 1967 M.A.G. data on costs of production for the different cantons of Costa Rica. The results are listed in Table 7 .

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[18]The agricultural statistics for the costs of production from the "Ministerio de Agricultura y Ganaderia" were taken from unpublished tabulations. The short form M.A.G. will be used in the rest of this section.

[19]Ospino, F., *op. cit.*, pp. 3-7 (1964 manual), pp. 6-9 (1967 manual).

TABLE 7

COST OF PRODUCTION OF RICE

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
San Jose Central	662.00
Escazu	662.00
Desamparados	662.00
Puriscal	443.27
Tarrazu	443.27
Aserri	443.27
Mora	443.27
Goicoechea	847.15
Santa Ana	662.00
Alajuelita	662.00
Coronado	847.15
Acosta	443.27
Tibas	847.15
Moravia	847.15
Montes de Oca	847.15
Turrubares	436.21
Dota	443.27
Curridabat	662.00
Perez Zeledon	534.29
Leon Cortes	443.27
Alajuela Central	926.54
Alajuela Central (Sarapiqui)	514.48
San Ramon	716.03
Grecia	926.54
Grecia (Upala)	574.53
Grecia (San Rafael de Guatuzo y Los Chiles)	577.40
San Mateo	436.21
Atenas	665.83
Naranjo	716.03
Palmares	716.03

TABLE 7 (cont'd.)

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
Poas	926.54
Orotina	436.21
San Carlos	459.07
Alfaro Ruiz	436.21
Valverde Vega	716.03
Cartago Central	662.00
Paraiso	662.00
La Union	662.00
Jimenez	443.27
Turrialba	309.05
Alvarado	662.00
Oreamuno	662.00
El Guarco	443.27
Heredia Central	847.15
Heredia Central (Sarapiqui)	514.48
Barba	847.15
Santo Domingo	847.15
Santa Barbara	847.15
San Rafael	847.15
San Isidro	847.15
Belen	847.15
Flores	847.15
San Pablo	847.15
Liberia	485.65
Nicoya	846.00
Santa Cruz	707.91
Bagaces	690.91
Carrillo	696.22
Canas	690.91
Abangares	1045.93
Tilaran	719.71
Nandayure	713.47
Puntarenas Central	776.74
Esparta	671.35
Buenos Aires	534.29
Montes de Oro	890.73
Osa	612.60
Aguirre	726.63
Golfito	524.51
Limon Central	503.72
Pococi	309.05
Siquirres	309.05

TABLE 8

COST OF PRODUCTION OF BEANS

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
San Jose Central	339.07
Escazu	339.07
Desamparados	339.07
Puriscal	217.14
Tarrazu	217.14
Aserri	271.03
Mora	271.03
Goicoechea	339.07
Santa Ana	339.07
Alajuelita	339.07
Coronado	767.20
Acosta	271.03
Tibas	339.07
Moravia	339.07
Montes de Oca	339.07
Turrubares	218.99
Dota	271.03
Curridabat	339.07
Perez Zeledon	184.16
Leon Cortes	271.03
Alajuela Central	427.86
Alajuela (Sarapiqui)	272.08
San Ramon	333.62
Grecia	445.19
Grecia (Upala)	305.82
Grecia (Los Chiles and Guatuzo)	464.27
San Mateo	218.99
Atenas	440.67
Naranjo	333.62
Palmares	445.19
Poas	395.35
Orotina	218.99
San Carlos	272.08
Alfaro Ruiz	333.62
Valverde Vega	333.62
Cartago Central	515.60
Paraiso	515.60
La Union	515.60
Jimenez	767.20
Turrialba	767.20
Alvarado	767.20

TABLE 8 (cont'd.)

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
Oreamuno	515.60
El Guarco	271.03
Heredia Central	411.18
Heredia (Sarapiqui)	272.08
Barba	411.18
Santo Domingo	411.18
Santa Barbara	411.18
San Rafael	411.18
San Isidro	411.18
Belen	411.18
Flores	411.18
San Pablo	411.18
Liberia Central	206.98
Nicoya	204.58
Santa Cruz	166.42
Bagaces	248.01
Carrillo	166.42
Canas	248.01
Abangares	319.76
Tilaran	246.85
Nandayure	204.58
Puntarenas Central	434.74
Esparta	434.74
Buenos Aires	288.94
Montes de Oro	339.08
Osa	304.43
Aguirre	212.58
Golfito	304.43
Limon Central	272.08
Pococi	272.08
Siquirres	272.08

TABLE 9

COST OF PRODUCTION OF CORN

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
San Jose Central	377.52
Escazu	377.52
Desamparados	393.94
Puriscal	272.82
Tarrazu	658.72
Aserri	658.72
Mora	272.82
Goicoechea	766.38
Santa Ana	377.52
Alajuelita	377.52
Coronado	843.35
Acosta	658.72
Tibas	766.38
Moravia	766.38
Montes de Oca	766.38
Turrubares	272.82
Dota	658.72
Curridabat	766.38
Perez Zeledon	522.68
Golfito	371.92
Limon Central	364.27
Pococi	364.37
Siquirres	364.27
Leon Cortes	658.72
Alajuela (central)	839.02
Alajuela (Sarapiqui)	284.58
San Ramon	378.56
Grecia	442.99
Grecia (Upala)	388.84
Grecia (Los Chiles, Guatuzo)	388.84
San Mateo	486.88
Atenas	442.99
Naranjo	619.08
Palmares	619.08
Poas	839.02
Orotina	486.88
San Carlos	294.48

TABLE 9 (cont'd.)

CANTON	COSTS OF PRODUCTION 1963 (colones per mza.)
San Carlos (La Fortuna)	305.20
Alfara Ruiz	269.62
Valverde Vega	619.08
Cartago Central	329.00
Paraiso	329.00
La Union	766.38
Jimenez	291.77
Turrialba	291.77
Alvarado	702.58
Oreamuno	843.35
El Guarco	393.94
Heredia Central	766.38
Heredia (Sarapiqui)	284.58
Barba	766.38
Santo Domingo	766.38
Santa Barbara	839.02
San Rafael	766.38
San Isidro	766.38
Belen	766.38
Flores	766.38
San Pablo	766.38
Liberia Central	332.27
Nicoya	299.98
Santa Cruz	574.24
Bagaces	375.14
Carrillo	346.82
Canas	443.03
Abangares	452.87
Tilaran	473.07
Nandayure	322.20
Puntarenas Central	344.27
Esparta	302.00
Buenos Aires	272.22
Montes de Oro	392.00
Osa	371.92
Aguirre	297.14

2. Beans

For beans, the procedures followed were the same as for rice. The 1967 price levels were scaled down by 7.6% to give the 1964 prices.[20] The resulting calculations are listed in Table 8 .

3. Corn

The procedure used for rice and beans was followed again for corn, using a scaling down factor of 10.5%.[21] Table 9 lists the costs of production calculated for corn.

4. Potatoes

Potatoes are grown mainly north of the city of Cartago on the slopes of the Irazu Volcano. Two crops are produced during the year, one in summer and one in winter. Using the Agricultural Census of 1963,[22] it was calculated that three quarters of the crop in the Province of Cartago was produced in summer and one quarter in winter. The costs of production for each of two seasons were listed in Ospino's work;[23] these values were then combined, with a 3:1 weighting, to give the figure of 2,743.75, which was then used as the cost of production per manzana for potatoes for all of Costa Rica.

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[20] Ospino, F., *op. cit.*, pp. 32-37 (1964 manual), pp. 52-57 (1967 manual).

[21] Ospino, F., *op. cit.*, pp. 39-42 (1964 manual), pp. 60-64 (1967 manual).

[22] Direccion General de Estadistica y Censos. *Censo Agropecuario 1963.* pp. 107-108.

[23] Ospino, F., *op. cit.*, pp. 43-44 (1964 manual), pp. 66-68 (1967 manual).

5. Tobacco

The data used for this crop were derived from two sources: Ospino and M.A.G. The M.A.G. figures for the Perez Zeledon region in the "Valle del General" and the Palmares zone, west of the city of Alajuela, were for the year 1967. Ospino also gave cost figures for the Palmares zone[24] which were averaged with those of M.A.G. The resulting production costs are:

Palmares zone = 2,863.64 colones per manzana

Perez Zeledon Zone = 3,061.26 colones per manzana

It should be noted here that in this case where only two costs of production were listed for the crop for all of Costa Rica, the district map (Appendix, Map B) was consulted to determine which cost figure should apply in each particular district. Although this was done subjectively, the author's general knowledge of the country's physiography, climate, infrastructure and economic conditions were used in this interpolation. This procedure was followed for the other crops that fell into this category.

6. Yuca

Costs of production per manzana for yuca were available for the year 1967 from two sources: Ospino and the National Bank of Costa Rica.[25] To scale the figures to the 1964 level, it was assumed that the changes in production costs would not differ significantly from those of three other crops grown for the local food supply, namely, corn, beans and rice.

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[24] Ospino, F., *op. cit.*, pp. 52-53 (1964 manual), p. 89 (1967 manual).

[25] The statistics reported by the National Bank of Costa Rica were obtained from unpublished material stored in M.A.G.

For these three, the average percentage change in production costs between the years 1964 and 1967 in Alajuela was 9.6%. Accordingly, the 1963 production costs for yuca were assumed to be as follows:

San Carlos zone = 1,528.97 colones per manzana

Alajuela zone = 1,872.19 colones per manzana

7. Garlic

Statistics on production costs for this crop were not available from any of the sources for Costa Rica. However, cost figures from Mexico and Guatemala were obtained.[26] Assuming that these costs of production would approximate the Costa Rican figure, the Mexican and the Guatemalan figures were averaged and converted to colones per manzana.[27] The result was 2,555.96 colones per manzana.

8. Onions, Cabbage and Ajonjoli (Sesame)

These crops are discussed together here because the cost of production figures were obtained from the same sources for the year 1964, namely, Ospino[28] and M.A.G. The figures are as follows:

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[26] Statistics for costs of production for a list of crops for the year 1963 from Mexico and Guatemala were obtained from H. A. Wood of McMaster University, who conducted research on agricultural productivity in these countries.

[27] The rates of exchange that were used are as follows:

1.00	quetzal (Guatemala)	= 1 dollar (U.S.)
12.50	pesos (Mexico)	= 1 dollar (U.S.)
6.65	colones (Costa Rica)	= 1 dollar (U.S.)

[28] Ospino, F., *op. cit.*, onions, pp. 24-31 (1964 manual), pp. 41-47 (1067 manual); cabbage, p. 50 (1964 manual), p. 85 (1967 manual); ajonjoli, p. 1 (1964 manual), p. 3 (1967 manual).

Onions:

Cartago	=	5,986.40 colones per manzana
Santa Ana	=	7,303.00 colones per manzana
Alajuela	=	5,804.00 colones per manzana

Cabbage:

Cartago	=	1,358.00 colones per manzana

Ajonjoli (sesame)

Pacific zone	=	619.00 colones per manzana

9. Tomatoes

Two sources were used to find the production costs for tomatoes, namely, Ospino[29] and I.T.C.O. The I.T.C.O. figures were recorded in colones per hectare and therefore had to be changed to colones per manzana.[30] The resulting figures are as follows:

Paraiso	=	4,901.00 colones per manzana
Alajuela	=	7,232.60 colones per manzana
Grecia	=	5,298.00 colones per manzana
Heredia	=	5,626.00 colones per manzana
San Carlos	=	4,460.13 colones per manzana

10. Cotton

This crop is grown mainly in a limited area in the Province of Guanacaste. Both M.A.G. and Ospino give costs of production for this crop. The M.A.G. data for the year 1967 was listed under three size of

[29] Ospino, F., *op. cit.*, pp. 54-61 (1964 manual), pp. 90-96 (1967 manual).

[30] Statistics for tomatoes were obtained from unpublished tabulations from the "Instituto de Tierras y Colonizacion", (I.T.C.O.).

farm categories, namely, 0-50 manzanas, 51-145 manzanas and 146 and more manzanas. Using the Agricultural Census of 1963[31], the percentage of the number of farms in the Province of Guanacaste for each of the three groups was as follows:

0 - 50 -	70.6%
51 - 145 -	19.6%
146 and more -	9.8%
	100.0%

The cost of production figures for the three sizes of farms were multiplied by the corresponding percentage, then summed and divided by 100.0 to arrive at an average cost of production figure. The figure was scaled to 1964 levels using the percentage difference as 19.9% obtained from Ospino's figures.[32] The resulting figure was averaged with the Ospino figure for 1964 to give a final cost figure of 1,385.50 colones per manzana.

11. Camote (sweet potato)

For the crop camote, data for costs of production were obtained from two sources,namely, Ospino and the National Bank of Costa Rica. Both sources recorded data for the Alajuela zone for the year 1967. The two figures were averaged and then scaled downwards by 9.6% using the same procedure as outlined for the crop yuca.[33] The result is a cost figure of 1,684.86 colones per manzana.

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[31]Direccion General de Estadistica y Censos, *Censo Agropecuario 1963.* p. 113.

[32]Ospino, F., *op. cit.*, p. 2 (1964 manual), p. 4 (1967 manual).

[33]Ospino, F., *op. cit.*, p. 32 (1967 manual).

12. Peanuts

Statistics for this crop were derived from Ospino's manual for the year 1967 and for the area of Alajuela.[34] As was done for other crops, the 1967 values were scaled down, in this case by 9.6%. The resulting figure for the costs of production was 947.64 colones per manzana.

PERENNIAL CROPS

For each of the perennial crops, the vegetative cycle as it relates to the length of the period before production and the number of years of production was investigated. The establishment costs during the pre-production period for each crop were averaged with the costs of production during the years of production during the normal lifetime of the plants. Each crop was investigated individually to arrive at the average yearly costs of production per manzana. Although this weighting factor is rather small in most cases, the procedure followed does make it possible to take into account certain expenditures, which are usually paid on a regular basis, to replace plants that have died or are too old to produce a high yield. In cases where statistics were not available, it was assumed that the costs of production as derived from other Latin American countries would be at the same level as that of Costa Rica.

1. Cacao

The costs of production for this crop were obtained from the work done by Ospino for the year 1964. Cacao has a 30 year vegetative cycle and bears very little fruit during the first five years.[35] Ospino

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[34] Ospino, F., *op. cit.*, p. 65 (1967 manual).

[35] The information on the vegetative cycle of cacao was obtained from unpublished material from the country of Colombia.

records the establishment costs and the costs of production per hectare per year.[36] Both of these figures were changed to colones per manzana.[37] The cost of production figure for one year was calculated by averaging the costs over a 30 year period taking into account the five year establishment costs. The resulting figure for the average cost of production for one year for Costa Rica was calculated to be 643.42 colones per manzana.

2. Cabuya

Statistics for this crop were obtained from two sources, namely, I.T.C.O. and Ospino. Cabuya has a twenty year vegetative cycle with production commencing in the third year.[38] Ospino has recorded the establishment costs for the two areas of Cartago and San Isidro del General.[39] The establishment costs for the San Carlos region were derived from unpublished tabulation sheets from I.T.C.O. for the year 1967. The percentage change (6%) in Ospino's figures between 1964 and 1967 was used to scale the I.T.C.O. statistics to the 1964 level. The costs of production for cabuya, once production had started, were only available for the San Carlos region. Since this was the only figure available, it

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[36] Ospino, F., *op. cit.*, pp. 11-12 (1964 manual).

[37] The conversion of hectares to manzanas was based on the following relationship:

1 hectare = 1.431 manzanas

This information is found in the following study: Carvajal, M.J. and Ross, J.E. *Fact Sheets on Costa Rican Agriculture.* 1968, p. 31.

[38] The information on the vegetative cycle of cabuya was obtained from unpublished material from the country of Colombia.

[39] Ospino, F., *op.cit.*, p. 10 (1964 manual).

was assumed that these costs would approximate those encountered elsewhere in Costa Rica. The establishment costs and the costs of production were averaged over a 20 year period to arrive at the following costs of production for one year:

Cartago region	706.90 colones per manzana
San Isidro del General region	696.27 colones per manzana
San Carlos region	664.18 colones per manzana

3. Pineapple

Statistics for pineapple were obtained from three sources; I.T.C.O. Ospino and the National Bank of Costa Rica. The statistics from I.T.C.O. and the National Bank were for the year 1967 and were converted from colones per hectare to colones per manzana.[40] Since Ospino's costs of production were the same for both 1964 and 1967[41], the I.T.C.O. and National Bank figures for 1967 were assumed to be valid also for 1964. Pineapple plants usually last four years in Costa Rica, with the first fruit production coming in the second year.[42] The establishment costs for the first year together with the costs of production for the other three years were averaged to arrive at the following average yearly costs of production:

[40]The information from I.T.C.O. and the National Bank was obtained from unpublished tabulation sheets which had to be copied out by hand since they were not permitted to be removed from the files.

[41]Ospino, F., *op. cit.*, p. 48 (1964 manual), pp. 75-77 (1967 manual).

[42]Ospino, F., *op. cit.*, p. 48 (1964 manual).

San Carlos region	1,250.89 colones per manzana
Grecia region	1,899.05 colones per manzana
Turrialba region	1,644.69 colones per manzana
Alajuela region	1,782.31 colones per manzana

4. Sugar Cane

The costs of production per manzana for sugar cane were derived entirely from Ospino's 1964 manual. In Costa Rica, sugar cane usually has an eight year cycle, the number of harvests depending on the altitude. For the areas of Alajuela and Cervantes, approximately five harvests are made during the eight year cycle, while in the Turrialba area (with a lower altitude and a higher temperature) usually six harvests are made.[43] The first year establishment costs were included with the costs of production for the seven remaining years of the cycle to give the following average yearly figures:[44]

Alajuela region	589.50 colones per manzana
Cervantes region	556.44 colones per manzana
Turrialba region	553.63 colones per manzana

5. Oranges

The costs of production per manzana were derived from Ospino's 1964 and 1967 manuals. Orange trees are able to produce fruit for a relatively long time, but, maximum production usually lasts only 30 years.[45] Fruit

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[43] Ospino, F., *op. cit.*, p. 38 (1967 manual).

[44] Ospino, F., *op. cit.*, pp. 19-23 (1964 manual).

[45] Chandler, W.H. and De la Loma, J.L. *Frutales de Hoja Perenne*. 1962, p. 215.

production usually does not begin until the third year. The establishment costs, as outlined by Ospino, were used for the initial three years.[46] The establishment costs and the costs of production for the 30 years in production were averaged to arrive at an average yearly figure of 866.26 colones per manzana for Costa Rica.

6. Papaya

The crop cycle for papaya[47] is usually four years with production starting in the second year.[48] Since the costs of production for papaya were not available for Costa Rica, statistics from Guatemala were used.[49] Two costs of production figures were averaged together and then combined with the establishment cost figure to give estimated annual costs over the four year cycle. The average yearly cost of production for papaya was determined to be 890.35 colones per manzana.

7. Coconuts

Coconuts usually have a vegetative cycle of twenty-five years. Full production does not occur until the sixth year. As in the case of papaya, reliable statistics for costs of production were not available for Costa Rica and therefore statistics from Guatemala were used. The costs of production for the first six years, which is the establishment period,

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[46] Ospino, F., *op. cit.*, p. 38 (1964 manual).

[47] Papaya is a large melon-shaped fruit growing on trees which may attain the height of up to 7.5 meters. This information is found in the book by Chandler, W.H. and De la Loma, J.L., *op. cit.*, p. 366.

[48] Ochse, F., Soule, J., Dijkman, E. and Wehlburg, S. *Tropical and Subtropical Agriculture*. 1961, p. 87.

[49] The Guatemala statistics were obtained from unpublished material. The conversion of quezals to colones is based on the following relationship:

1 quezal = 1 dollar (U.S.) = 6.65 colones.

increased from year to year. For years 6 to 25 the costs of production are fairly stable. Over the 25 year cycle, the average yearly cost of production for coconuts was calculated to be 812.20 colones per manzana.

8. African Palm

African palm has a normal vegetative cycle of thirty years with full production beginning in the fifth year. The establishment figures for the first five years were obtained from M.A.G. but the costs of production during the years of fruit production, were not available. Again, as with the case of papaya and coconuts the costs of production were taken from another Latin American country, namely, Colombia. As a result of the calculations, a figure of 441.38 colones per manzana was accepted as the average annual cost of production for African palm.[50]

9. Bananas

The costs of production for bananas were obtained from two sources, The National Bank of Costa Rica and Ospino. Banana trees usually produce fruit after 12 months from planting time. Both the establishment cost and the costs of production were included in one figure. The Ospino figures[51] and the National Bank figures were recorded for the Atlantic zone[52] and were averaged together to arrive at one cost of production figure. The average yearly cost of production for the Atlantic zone is 1,856.01 colones per manzana.

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[50]The conversion scale used was as follows:

16.00 Colombian pesos = 1 dollar (U.S.) = 6.65 colones

[51]Ospino, F., *op. cit.*, pp. 8-9 (1964 manual).

[52]The United Fruit Co. who control most of the production on the Pacific coast would not release figures on costs of production.

10. Plantain

The Ospino manual[53], unpublished material from I.T.C.O. and tabulation sheets from the National Bank of Costa Rica provided statistics for the costs of production of plantain. As for bananas, the establishment costs were combined with the costs of production per manzana for the Atlantic zone of Costa Rica. The three figures were averaged together to arrive at an average yearly cost of production figure of 471.32 colones per manzana.

11. Coffee

Information on the costs of production for coffee was obtained from two sources, Ospino's manual[54] and a study by M.A.G. and the Coffee Office.[55] Coffee in Costa Rica usually has a 40 year cycle with full production starting after the fifth year. The establishment costs were averaged with the costs of production for the 40 year cycle, for different areas in the country. The resulting figures are as follows:

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[53] Ospino, F., *op. cit.*, p. 78 (1967 manual).

[54] Ospino, F., *op. cit.*, pp. 13-18 (1964 manual).

[55] According to Carvajal, M.J. and Ross, J.E. *Public Institutions Affecting Agricultural Development in Costa Rica.* 1968, pp. 2-5, the "Oficina del Cafe" is a semi-autonomous institution created on June 21, 1948. The main objectives of this institution are to promote a sound relationship between all sectors of coffee production in coordination with government institutions and to encourage the development of coffee in its agricultural and social aspects.

Turrialba region	1,866.70 colones per manzana
San Isidro del General region	1,351.75 colones per manzana
San Carlos region[56]	904.19 colones per manzana
Tarrazu, Puriscal region	1,205.00 colones per manzana
Central part of the meseta central	1,783.81 colones per manzana

Cattle

The costs of production for cattle were derived from a study by V.A. Smith who investigated the cattle industry in Guanacaste.[57] Smith recorded the fixed costs per head of cattle according to the ranch size (Table 10).[58]

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[56]The costs of production for the San Carlos region are somewhat lower than the costs for the other areas of Costa Rica. These costs were derived from a co-operative study done by M.A.G. and the Coffee Office.

In comparing the San Carlos area with the other areas of coffee production in Costa Rica the average size of farm is found to be significantly smaller in the former (p. 20). The labour costs per manzana for San Carlos are approximately one-half of those for the meseta central (237.66 to 427.00 colones, respectively). Also the cost of materials is significantly lower for the San Carlos region. The cost of materials per manzana, of which fertilizer is the largest component, for San Carlos is 202.50 colones, while for the meseta central the figure is 709.00 colones (pp. 27-31 and 47-51). The pages in brackets refer to the following study: Ministerio de Agricultura y Ganaderia and Oficina del Cafe, *Estudio de Costos de Produccion de Cafe*. 1968.

[57]Smith, V.A. *Beef Cattle Production and Marketing in Guanacaste, Costa Rica*. Ph.D. Thesis, University of Florida, 1970.

[58]According to the figures as presented by Smith, the larger the ranch operation the higher the costs of production per head of cattle, especially for such items as, annual operating costs (labour, medicine, etc.) and pasture maintenance. This is found in the study by, Smith, V.A., *op. cit.*, p. 214.

TABLE 10

COSTS PER HEAD OF CATTLE ACCORDING TO FARM SIZE

	FARM SIZE (HEAD OF CATTLE)	COST PER HEAD (1 HEAD PER MANZANA)
A	BELOW 20	89.00 COLONES PER HEAD
B	20 – 100	93.90 COLONES PER HEAD
C	100 – 500	112.60 COLONES PER HEAD
D	500 AND ABOVE	125.90 COLONES PER HEAD

Statistics on farm size were obtained from the 1963 Agricultural Census on a cantonal basis.[59] For each canton, in which were located one or more of the 100 districts in the sample, the percentage of farms falling in each of the four categories, A, B, C, and D in Chart 10 was calculated. Each of these percentages was then multiplied by the cost per head that applied. The resulting four values were added together and divided by 100. This figure gave the average cost of production per head of cattle for the canton and was assumed to be valid for each district in the canton (Table 11).

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[59] Direccion General de Estadistica y Censos, *Censo-Agropecuario 1963.* 1965, pp. 215-216.

TABLE 11

AVERAGE COST OF PRODUCTION PER HEAD IN DIFFERENT

CANTONS OF COSTA RICA

Cantons	Average Cost of Production Per Head of Cattle (in colones)	Cantons	Average Cost of Production Per Head of Cattle (in colones)
Central (San Jose)	89.64	Central (Cartago)	90.16
Escazu	89.39	Paraiso	91.28
Desamparados	88.36	La Union	90.35
Puriscal	89.87	Alvarado	89.59
Aserri	89.63	Oreamuno	94.27
Mora	90.21	El Guarco	90.02
Goicoechea	92.64	Central (Heredia)	92.52
Santa Ana	89.54	Barba	90.88
Alajuelita	89.25	Santo Domingo	89.29
Tibas	89.00	Santa Barbara	90.02
Montes de Oca	90.76	San Rafael	89.87
Dota	90.69	San Isidro	89.44
Curridabat	89.83	Belen	90.75
Perez Zeledon	89.68	Flores	89.34
Leon Cortez	89.25	San Pablo	89.29
Central (Alajuela)	89.17	Santa Cruz	92.30
		Nandayure	92.16
San Ramon	90.44	Esparta	91.39
Grecia	91.40	Buenos Aires	90.16
Atenas	91.63	Aguirre	91.26
Naranjo	89.87	Central (Limon)	90.21
Palmares	89.58		
Poas	89.43	Pococi	90.21
San Carlos	92.52		
Vega	90.49		

The costs of production for milk were obtained from unpublished material for the year 1964.[60] The cost per bottle varied from 0.32 colones to 0.45 colones. The average of these two figures, 0.39 colones per bottle, was taken as the cost of production figure for milk.

It has been determined that six bottles of milk are needed to produce one pound of cheese.[61] The cheese figure in pounds was converted to the number of bottles of milk and the cost of production figure taken as 0.39 colones per bottle as calculated previously.

The cost of production for butter was estimated by agricultural extension personnel as 70% of the price of one pound of butter, or 3.17 colones per pound of butter.

The costs of production for all the agricultural commodities were tabulated on sheets which were then used for the calculation of total costs of production for each district. The costs of production for the crops were multiplied by the figures for the area in cultivation for each crop. For cattle, the average cost of production per district per head was multiplied by the total number of cattle sold in the district. The costs of production for milk, butter and cheese were derived by multiplying the cost per bottle or pound by the total production in each district.

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[60] Ospino, F., *op. cit.*, 1964, p. 70.

[61] Wilkowske, H.H. *Developing A Cheese Industry in Costa Rica.* 1958, p. 19.

Net Income Index Calculation

As previously indicated to obtain the net income figures the total costs of production for each district were subtracted from the total gross income figure for each district. For each district, the net income figure was then divided by the total land area (in manzanas) in crops or in pasture to give the net income index.

CHAPTER 5

THE DETERMINATION OF THE RELATIONSHIPS BETWEEN THE AVERAGE SLOPE INDEX AND THE AGRICULTURAL PRODUCTIVITY INDICES

In the analysis of the relationships between the average slope index and the agricultural productivity indices four steps are involved. In the first place, the relationship between three broad land-use categories and the slope index will be examined by the use of a triangle diagram. Secondly, by the calculation of correlation coefficients the statistical relationship between the average slope index and the productivity indices will be examined. Thirdly, a study will be made of individual crops and their relationship to the hypothesis in question. Fourthly, the principal anomalies will be examined in an attempt to explain why the hypothesized relationship is only partially true.

TRIANGLE DIAGRAM ANALYSIS

As mentioned earlier in this study, agricultural productivity can be reflected in the intensity of land-use.[1] In terms of intensity, land-use can be classified into three main categories, namely, cropland, pasture and forest land. We may therefore hypothesize as follows: it would be expected that the percentage of land in cropland for the districts would decrease as the average slope index increases and that the

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[1]Hook, J.C. *The Relationship Between Roughness of Terrain and Phenomena Related to Agriculture in Northeastern United States*. Ph.D. Thesis, State University of Iowa, 1955, p. 55.

percentage of land in forest and in pasture would increase as the average slope index increases. A triangular diagram will be used to analyze this hypothesis since with this method the relationship between these three land-use categories can be shown with relative ease.

The triangle diagram method is a simple device in which a dot placed within the triangle represents three variables which are components of a single whole. The distribution of the dots within the triangle can reveal interesting patterns which may be picked out from visual inspection. The triangle diagram is constructed in such a way as to indicate in percentages the three major categories of land-use for each district. The percentage of land in each of the three major land-use types is indicated by the position of the dot on one of the altitudes of the triangle (Figure 7).

The Census Department of Costa Rica classifies land-use into twelve categories, as shown in the following list:[2]

1. Annual crops (e.g., corn, beans, etc.)
2. Pasture lands in which the grass is cut for fodder
3. Commercial crops (flowers, nurseries, etc.)
4. Land in fallow
5. Other classes of arable land (e.g., crops that were destroyed or not harvested)
6. Permanent crops (e.g., coffee, cacao, etc.)
7. Natural pastures with low grass (e.g., grass varieties such as jenjibrillo, zacate amargo, etc.)
8. Natural pastures with high grass (e.g., grass varieties such as para, guinea, jaragua, etc.)

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[2] The data used for the land-use types per district were derived from unpublished tabulations from the "Direccion General de Estadistica y Censos".

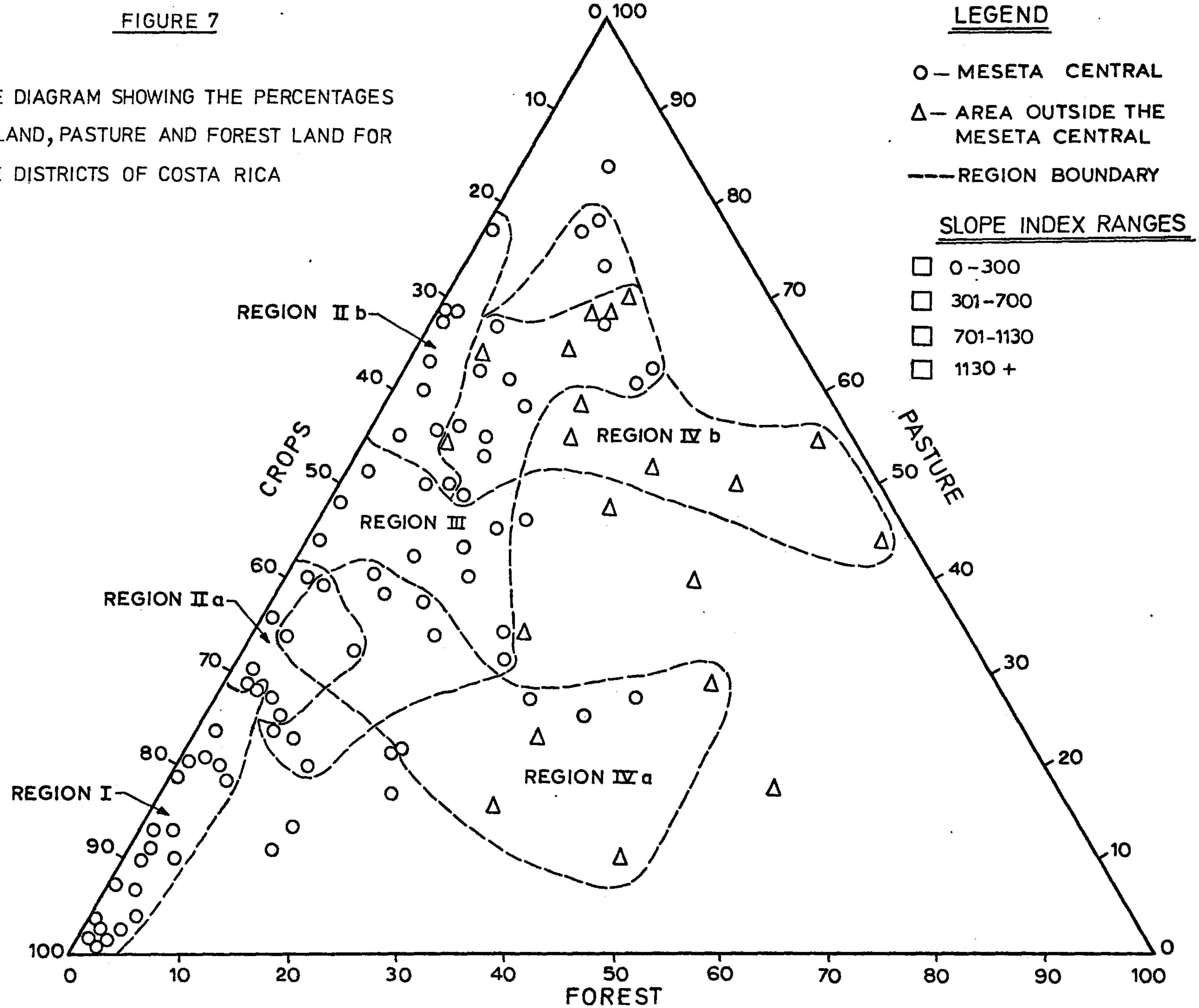
9. Woods with pastures
10. Woods without pastures
11. "Charrales" (scrubland and brushwood areas)
12. Other class of land (buildings, roads, etc.)

The following were selected as cropland: 1, 3, 4, 5, and 6; the following as pasture: 2, 7, 8 and 9; and the following as forest; 10 and 11. The total area in manzanas of each of the land-use groups was summed for each district and tabulated in a chart. The total area of all the categories, with the exception of "12", was calculated for each of the districts. The percentages of the total area used for cropland, pasture and forest were calculated, recorded and checked so that all three values summed to 100% for each of the sample districts. Using these values (Appendix, Chart B) a dot was placed on the triangle diagram in the correct location for each district. Each dot was labelled by its district number.

By the use of symbols and a colour designation, the dots, which represent the districts, were classified according to two criteria. The first, as shown by the symbols O and Δ, grouped the districts according to location, within the meseta central or outside the meseta central, for reasons detailed in Chapter 3. The second grouping, as shown by the colours red, blue, green and yellow indicate in four quartiles the average slope index. The average slope indices of the 100 sample districts were ranked from lowest to highest. The first 25 were placed in the first division (0 - 300), the second 25 in the second division (301 - 700), the next 25 in the third division (701 - 1130) and the last 25 were placed in the fourth division (1131 +). It was felt that four

FIGURE 7

TRIANGLE DIAGRAM SHOWING THE PERCENTAGES OF CROPLAND, PASTURE AND FOREST LAND FOR SAMPLE DISTRICTS OF COSTA RICA



divisions were sufficient to indicate the existence of any distinct pattern without creating problems of excessive complexity.

The immediate visual impression obtained from the triangle diagram (Figure 7) is that there is a concentration of dots in the lower left-hand corner of the triangle stretching out into a band along the left side. This observation generally indicates that there is a tendency for districts to have higher percentages of cropland and pasture than forest land.

To analyse the results in more detail, dots were grouped into a number of regions by visual inspection according to the colours of the dots. Each region was drawn so as to include a cluster of at least three dots of the same colour, irrespective of the shape of the dots. If other clusters or dots of the same colour were relatively close then these were included in that region. Only extreme anomolies of each colour were not included in the different regions. By following this procedure 4 main regions were delimited and two of these were further subdivided. Although this delimitation of regions was done in a subjective manner, it was felt that the procedure does indicate the existence of a clustering of dots according to the average slope index factor.

The red dots (Region I) indicating districts with average slope indices between 0 and 300, tend to cluster in the area where there is a relatively high percentage of cropland (ranging from 70 to 98%), a relatively low percentage of pasture (ranging from 0.5 to 29%) and a very low percentage of forest land (ranging from 0 to 5%). The blue dots with average slope indices between 301 and 700 tend to be located in two regions: Region II (a) and Region II (b). Region II (a) shows a high percentage of cropland (55 to 70%), a relatively low percentage of pasture (25 to 45%) and a very low percentage of forest (0 to 9%). Region II (b) indicates a relatively low percentage of cropland (22 to 42%), a high percentage of pasture (50 to 78%) and a very low percentage of forest (0 to 6%). Most of the green dots (Region III), indicating districts with average slope indices ranging between 701 and 1130, are located to the right of Regions II (a) and II (b) where the proportion of the land used for crops ranges from 14 to 70%, pasture from 18 to 70% and forest from 2 to 25%. Districts with average slope indices of 1131+ (yellow dots), tend to form two clusters, Region IV (a) and Region IV (b). Region IV (a) has a cropland percentage range of 26 to 63% with pasture between 10 to 40%. On the other hand, in Region IV (b) the cropland range is from 3 to 38% and the pasture varies between 44 to 78%. Both of these regions have a higher percentage range of forest land (ranging from 3 to 55%) than Regions I, II or III.

The districts from the area outside the meseta central tend to have a lower percentage of cropland than the districts in the meseta central. The mean percentage of cropland for the districts in the meseta central is 54.92% while for the area outside the meseta central the figure is 25.50%. The districts within the meseta centra, tend to have lower percentages of forest land than the districts from the area outside the meseta central. The mean percentage of forest land of all the districts in the meseta central is 8.67% while for the area outside the meseta central it is 28.70%. The difference between the two areas for pasture is not very great. The mean percentage of pasture for the meseta central is 36.41% while for the area outside the meseta central the percentage is 46.15%.

The differentiation between the meseta central and other areas of Costa Rica has been explained in general terms in Chapter 3. To summarize, the meseta central has historically been the area of highest population density in the country. The people of this region are engaged in agricultural activities, not only supplying the needs of the major cities located in the area but also growing export crops such as coffee and sugar cane. Physical factors such as rich volcanic soils, moderate rainfall and temperature and an altitude of approximately 1,000 meters above the sea level favour the growing of high-value crops, such as coffee and sugar cane. The pressures of population and the growing market for agricultural products were responsible for the increased clearing of forest for cropland and pasture. For these reasons, the meseta central generally is used for agriculture and is relatively free of its original forest cover.

On the other hand, cattle raising seems to be the most extensive agricultural activity in the area outside the meseta central and large areas have been cleared for pasture, especially in recent years. There are also isolated areas of intensive agricultural production (refer to the map of agricultural land-use, Map C), which are mainly occupied by large company farms (e.g., United Fruit Co.), which have usually developed their own transportation and marketing networks. In the area outside the meseta central, a large portion of the land is still in the pioneering stage of development and thus forested areas are slowly being cleared year by year. Therefore, statistics that have been gathered by the Census Department would indicate larger areas in forest on individual farms in the area outside the meseta central in comparison to the farms within the meseta central.

The triangle diagram analysis seems to support the hypothesis that as the cropland decreases the average slope indices increase. The mean percentages of the land in the three use categories for the different average slope category ranges are shown in Table 12. From an inspection of this Table it is evident that the mean percentage of cropland decreases as the average slope category range increases (Regions I to IV).

The expected relationship that as the percentage of land in forest increases the average slope index increases also holds true, using the evidence in Table 12. The mean percentage values of forest land increase as the average slope category range increases.

The hypothesis that the percentage of land in pasture increases as the average slope index increases is difficult to assess. On the triangle diagram, there seems to be a scatter of dots with a wide range of percentages of pasture for all the different slope categories, except for possibly the most level land. From Table 12 the mean percentages of pasture, for the average slope category ranges of Regions II, III and IV, are quite similar. Therefore, it may generally be concluded that the pasture and slope are not closely related as hypothesized.

The cultivation of crops on level land is generally considered to be easier than on steeper slopes provided that the physical factors, such as, soils and climate, suit the growing of crops. Steeper terrain is expected to be left in forest because of the problems of soil erosion. This general pattern seems to hold true for Costa Rica. On the other

TABLE 12

REGIONS ON THE TRIANGLE DIAGRAM	THE MEAN PERCENTAGE FOR CROPLAND	THE MEAN PERCENTAGE FOR PASTURE	THE MEAN PERCENTAGE FOR FORESTLAND
REGION I (SLOPE CATEGORY 0-300)	85.92%	12.13%	1.95%
REGION IIa (SLOPE CATEGORY 301-700)	64.57%	31.28%	4.15%
REGION IIb	34.11%	62.55%	3.34%
REGION II combined	47.45%	48.87%	3.68%
REGION III (SLOPE CATEGORY 701-1130)	40.30%	46.83%	12.87%
REGION IVa (SLOPE CATEGORY 1131+)	47.80%	27.56%	24.64%
REGION IVb	20.47%	60.68%	18.85%
REGION IV combined	32.46%	46.14%	21.40%

MEAN PERCENTAGES OF CROPLAND, PASTURE AND FOREST LAND FOR THE DIFFERENT REGIONS OF THE TRIANGLE DIAGRAM hand, pasture occupied both level and steep areas which may be attributed to a number of reasons some of which are, accessibility, soil fertility and climate.

There are, however, a number of individual cases on the triangle diagram that show high average slope indices and high percentages of cropland, particularly in Region IV (a). It is noteworthy that most of these districts are located in the meseta central. In this case it appears that economic and/or population pressures have influenced the intensity of land-use.

In summary, the triangle diagram analysis does point out some general relationships between the intensity of land-use and the average slope index. It has been shown that the percent of the land used most intensively, for crop production, does have a tendency to vary inversely with the average slope indices. Furthermore, it also seems that the percentage of land in forest increases as the average slope indices increase. On the other hand, there seems to be no definite relationship between the percentages of land used for pasture and the average slope indices.

CORRELATION COEFFICIENT ANALYSIS

There are various statistical measures that can be applied to series of raw data; these include, correlation, central tendency, dispersion and regression analysis. In this study, a statistical measure to show the relationship between two variables was needed.

Generally speaking, the correlation coefficient is a measure of the degree of association between two sets of variables. The correlation coefficient (r) varies from $\pm$ 1.00, when the two sets of variables are perfectly related, to 0.00, when there is no relationship between the two sets of variables at all.[3] The correlation analysis was used since it suited the type of analysis conducted in this study.

Correlation coefficients were calculated for the following:

a. The relationships between the gross and net income indices and the average slope indices of the districts for all of Costa Rica, the meseta central and the area outside the meseta central.

b. The relationships between the gross income, the net income and the yield indices and the average slope indices, for individual crops and cattle, for all of Costa Rica and the meseta central.

What constitutes a "close" relationship is difficult to put in definitive terms. The "r" value obtained varies according to the sample size and this may give varying significance levels. All of the results in the study were significant except in cases that were indicated.

An assumption is made that the relationships investigated are linear. This study will not examine the data using curvilinear techniques, however, speculation will be made as to the possible value of applying such techniques. All calculations of correlation coefficients were performed by the 3600 IBM computer using the Statistical Package for the Social Sciences (SPSS)[4].

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[3]Gregory, S. *Statistical Methods and the Geographer*. 1963, p. 170.

[4]The correlation coefficient program was stored in the computer (SPSS - version 2.3, March 15, 1972 from Vogelback Computing Centre, Northwestern University).

Results of the Correlation Coefficient Analysis

The results for the 100 district sample for all of Costa Rica and for the areas within and outside the meseta central are recorded in Table 13.

TABLE 13

	THE RELATIONSHIP BETWEEN THE GROSS INCOME INDEX AND THE AVERAGE SLOPE INDEX (r)	THE RELATIONSHIP BETWEEN THE NET INCOME INDEX AND THE AVERAGE SLOPE INDEX (r)
MESETA CENTRAL	—.59147	—.41114
AREA OUTSIDE THE MESETA CENTRAL	—.01865	—.09628
ALL OF COSTA RICA	—.52400	—.32096

CORRELATION COEFFICIENTS OF THE RELATIONSHIPS BETWEEN THE GROSS AND NET INCOME INDICES AND THE AVERAGE SLOPE INDEX FOR THREE PARTS OF COSTA RICA

All the correlation coefficients have the negative sign postulated in the hypothesis. However, the "r" results do not indicate very strong relationships.

The relationships for the meseta central indicate a stronger association between the gross income relationship than the net income relationship. One reason for this result is that costs of production on level land may be higher than on sloping land. If this assumption is accepted as being correct, then certainly the "r" value will be smaller in the net income relationship. In actuality, this is an expected result because of the following reasons:

a. If conditions are favourable, high value export crops may be grown on large plantations or farms which are usually on level areas. The owners of these large farms may invest more money per unit of land in their operation than farmers that own small holdings on sloping terrain.

b. Because of the intensive and sustained production from these more level areas, soil exhaustion may be more evident and therefore more fertilizer may be necessary.

It is noteworthy that the results for all of Costa Rica are relatively similar to the meseta central, since most of the 100 districts in the sample are located on the meseta central.

On the other hand, the results for the area outside the meseta central seem to indicate a stronger association between the net income relationship than the gross income relationship. This may be explained by the fact that the farm prices of agricultural commodities in areas outside the meseta central may be lower in actuality than the figures presented in this study. If this is the case, the income derived from the sloping terrain in the area outside the meseta central is higher than the actual case. Thus, this distortion may be a reason for the weaker relationship.

In the calculation of the average slope index an assumption was made that agricultural activities were located on all the slope categories in the district. It may be suggested that the "r" values of the relationships of the area outside the meseta central are weak because this assumption does not hold true to the same degree as in the meseta central. As mentioned earlier, the districts in the meseta central have significantly higher percentages of land that are used for agricultural purposes than the areas outside the meseta central. Thus it may be expected that the average slope index, for the districts outside the meseta central, is not a realistic measure since the agricultural activities are only found in possibly the flatter areas. This may account for the difference of the results between the meseta central and the areas outside the meseta central. Other possible reasons for the difference in the results will be indicated later in this study.

Study of Individual Crops

A further analysis was carried out to find the relationships of the two variables in question as they relate to individual crops.

The yields per manzana for each crop were calculated from the data obtained from the Census Department. The total area under cultivation for each crop and the total production was given for each district. For crops that had statistics for areas under cultivation not in age of production and in age of production, only the latter figure was used in this calculation. To find the yields index for each crop per district, the area in cultivation was divided into the total production. In the case of cattle the yield per manzana is indicated by the number of cattle per manzana in pasture. These figures were also obtained from the Census as mentioned in Chapter 4. The net income index figure for each of the agricultural commodities was taken from the calculations as outlined in Chapter 4.

It was hypothesized that, for each crop, as the average slope index increases the yield and net income indices will decrease. This hypothesis will be tested by comparing the correlation coefficients for the various agricultural commodities. Table 14 gives the correlation coefficients for the sample taken from the whole country and for the meseta central.

For the agricultural commodities for all of Costa Rica there is a range of negative and positive correlation coefficients. Although for the yields and the net income columns together negative relationships predominate (29 negative to 15 positive), the correlation coefficients are generally very low.

For the meseta central the range of "r" values is generally similar to the all of Costa Rica figures. Most of the crops usually retain the same sign, positive or negative, in comparison to the all of Costa Rica figures, although exceptions do occur.

From the results of this analysis, it may be stated that there is only a slight tendency, for most crops, toward the expected negative relationship. However, for some crops there is virtually no relationship between production and slope and for other crops the relationships tends to be the reverse of what was expected. If the effect of sloping terrain on the net income of different crops varies widely, then it may be expected that the combination of crops within each district taken as a whole has a bearing on the net income index relationship for that district, as discussed earlier.

TABLE 14

CORRELATION COEFFICIENTS (r) OF THE RELATIONSHIP BETWEEN THE YIELDS AND NET INCOME INDICES AND THE AVERAGE SLOPE INDEX

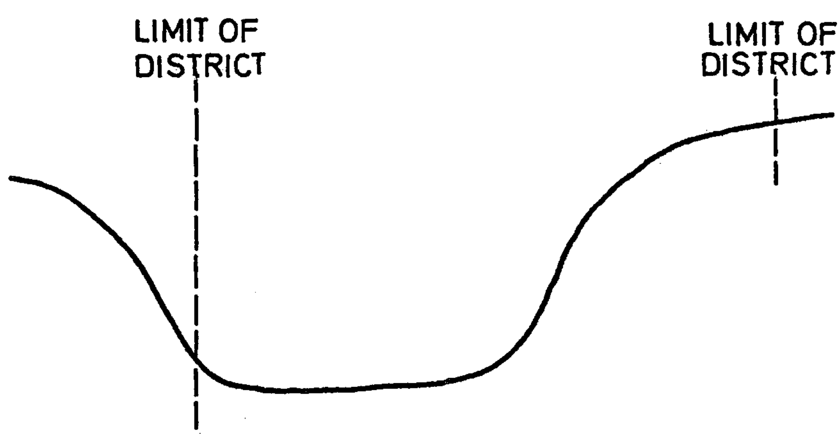
		COSTA RICA		MESETA CENTRAL	
		Yields Index	Net Income Index	Yields Index	Net Income Index
1.	Rice	-.22342	+.08414	-.10458	+.22340
2.	Beans	-.16094	-.15228	-.14281	-.16848
3.	Corn	-.21771	-.13060	-.26298	-.17104
* 4.	Potatoes	+.03207	+.03168	+.19188	+.19188
* 5.	Tobacco	-.32980	-.30826	-.31879	-.31381
6.	Yuca	-.15458	-.27915	-.21413	-.21425
* 7.	Camote	-.66089	-.66097	-.64488	-.64500
* 8.	Peanuts	+.07097	+.06984	-.15847	-.15975
* 9.	Garlic	+.20351	+.20343	+.25168	+.25159
*10.	Onions	+.03340	+.08732	+.03340	+.08732
11.	Cabbage	+.14924	+.09537	+.35658	+.29765
12.	Tomatoes	-.19398	-.08034	-.15322	-.01235
13.	Plantain	-.00964	-.00964	+.07374	+.07375
14.	Bananas	-.03949	-.05373	+.03005	-.01136
15.	Pineapple	-.07022	-.03827	-.10162	-.05011
16.	Oranges	+.10081	+.10017	+.06415	+.06300
17.	Papaya	-.18106	-.18107	+.10203	+.11413
*18.	Coconuts	-.05881	-.05453	+.75141	+.75141
19.	Coffee	-.33896	-.31922	-.35927	-.37883
20.	Sugar Cane	+.12121	+.12465	+.21548	+.21785
21.	Cattle	-.31368	-.24920	-.34514	-.27827

*Sample size is small.

The Range of Slopes on Which Some Crops Are Grown

One of the difficulties in working with an average slope index for a political unit such as a district is that the actual slopes are averaged together in the area. A certain crop may be located only in a specific range of slopes in the district where it is grown. To give a simple example let us consider an hypothetical district that has a general cross-section as shown in Figure 8 . The district has two physiographic regions: (1) a flat alluvial valley and (2) a steeply-sloping mountainous area on the side of the valley. The average slope index for this district (using the same method as presented in this study) may be about 1400, which indicates a medium average slope.

FIGURE 8



CROSS-SECTION OF A HYPOTHETICAL DISTRICT

The crop to be studied may only occupy the flat valley bottom. In this case the yields and net income indices may be exceptionally high. Therefore, it would be unrealistic to expect a close correlation between the average slope index and the yields and net income indices. Ideally, the average slope index should be calculated only for the areas where the crop is actually grown.

Thus the question arose as to whether certain crops are only found within a limited range of slopes in Costa Rica and whether it is therefore incorrect to assume that all slopes are used in the district. To answer this question measurements were taken in the field of the actual slopes used for different crops. Basically, the method involved the measuring and recording of specific slopes and noting the crops being grown at a selective random sample of points within the meseta central of Costa Rica.

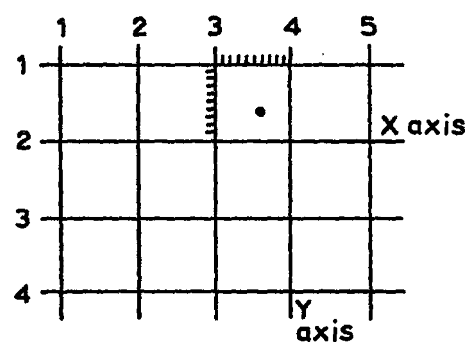
The study area of the sample was limited to the meseta central. Time was limited and the work was done in the middle of the rainy season, therefore, only those points on or close to passible roads could be considered. Since the density and conditions of the roads in the meseta central are better than any other parts of Costa Rica, the sample was limited to this area.

A selective random sample was used since for logistic reasons the points had to be accessible along a modest number of traverses. Twenty traverses were selected crossing the meseta central in several directions. Before going into the field, the points of the selective random sample were located on the topographic maps at the scale of 1:50,000 using the following procedure:

> Each topographic map was divided into six separate sections on each of which a ten by ten grid of squares was superimposed. The first two numbers of a random number table were then used to identify a specific square while the second two numbers

indicated in the square a specific location which was marked by a dot (Figure 9). In both cases, the first random number indicated was the "x axis" reading and the second number related to the "y axis". For each section, 30 random points were marked by dots on the topographic maps. Those random points were selected for field checking that were on or very close to the traverse lines.

FIGURE 9

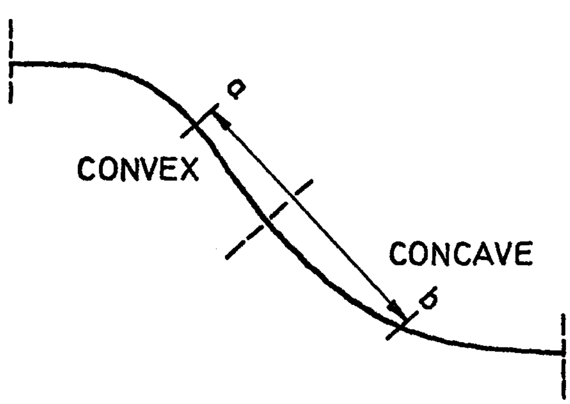


GRID USED IN SELECTING RANDOM POINTS

For a majority of slopes in the field, a cross-section would indicate usually two parts, a convex and a concave section as shown by Figure 10. Further, the slope profile becomes enormously complex if one includes microrelief features such as, minor rock outcroppings, cases of soil slip and the like. If, in taking the field measurements in the meseta central, the crop or pasture included both the convex and concave sections of the slope, the largest section of the slope was measured (Figure 10 , line ab) and all microrelief features were ignored.

Measurements were carried out for six days from 8 a.m. to 5 p.m. using a rented jeep. Most of the sample points were, of course, not actually on the roads and had to be reached by hiking across the fields. At each sample point, readings were made of the longest slope for the agricultural activity engaged in on that slope. Within a radius of approximately 50 meters, other slope readings were also made and notes taken of other agricultural activities carried out. As many readings as possible were made of different agricultural activities at and around the sample point to increase the sample size for each of the land-use categories. In total 150 sample points were utilized and a total of 296 readings were made which averages about two readings per point. Table 15 lists the 20 traverses, the sample points in each traverse and the number of readings in each traverse.

FIGURE 10



THEORETICAL CROSS-SECTION OF A SLOPE SEGMENT

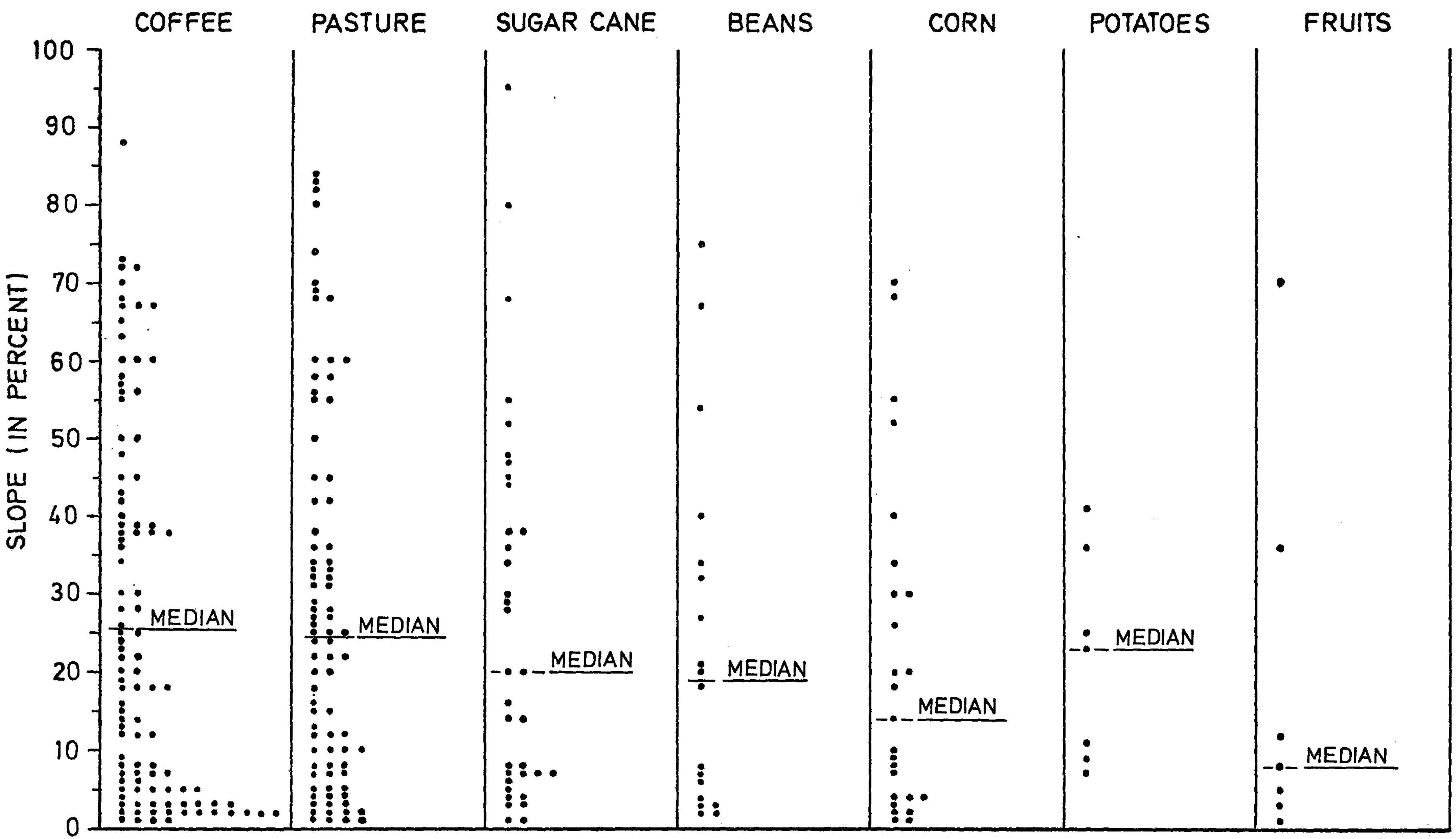
At the points studied in this survey, 14 different crops plus one type of pasture were recorded. For 8 crops the number of readings was five or less and they were therefore ignored in subsequent analysis. For

TABLE 15

LIST OF THE NUMBER OF SAMPLE POINTS AND THE NUMBER OF READINGS ALONG TWENTY TRAVERSES

	TRAVERSE	NUMBER OF SAMPLE POINTS	NUMBER OF READINGS
1.	Animas to Llano Limon	9	16
2.	Turrucares to San Ramon	16	34
3.	Escazu to Villa Colon	8	17
4.	Ojo de Agua to Heredia	5	8
5.	San Jose to Cartago	5	12
6.	Curridabat to Asseri	9	12
7.	Cartago to Tobosi	6	14
8.	Cartago to Paraiso	2	5
9.	Paraiso to Turrialba	12	24
10.	Paraiso to Juan Vinas (Cachi)	14	25
11.	Cartago to Volcan Irazu	9	25
12.	Turrialba to Volcan Turrialba	6	11
13.	San Jose to San Isidro	5	6
14.	Heredia to Cerro Redondo	4	5
15.	Heredia to San Jose de la Montana	3	3
16.	Barba to Volcan Poas	10	16
17.	Fraijanes to Naranjo	10	22
18.	Naranjo to Zarcero	5	13
19.	Naranjo to San Ramon	6	14
20.	End (San Ramon to Alejuela) Highway	6	16

FIGURE 11



GRAPH SHOWING THE SCATTER OF RANDOM POINTS WITH REGARD TO PERCENT SLOPE
FOR DIFFERENT CROPS IN THE MESETA CENTRAL

the remaining six crops and the pasture the scatter of readings was plotted on a graph. The mean was calculated and indicated on the diagram (Figure 11).

As expected, in the light of the results obtained from the triangle diagram analysis, the mean percent slope was the highest for the pasture. The means for coffee and sugar cane were, however, somewhat similar while for beans, corn, potatoes and fruits (oranges) the means were somewhat lower. The deviation about the mean seems to be relatively high for coffee, pasture, sugar cane, beans, corn and fruits. For potatoes the deviation seems to be less. This may possibly be due to the fact that most of the potatoes for the whole country are grown in a limited area north of Cartago (on the slopes of Irazu Volcano). However, the other crops and pastures were found throughout the meseta central. Therefore, it was concluded that for most of the agricultural activities that were observed in the field, namely, coffee, pasture, sugar cane, beans, corn and fruits, tended to be located on a wide range of slopes within the meseta central.

Interpretation of the Results of the Correlation Analysis of Five Individual Agricultural Activities

Five individual agricultural land-uses were chosen, namely, coffee, pasture, sugar cane, beans and corn in order to interpret the relationship between sloping land and agricultural productivity in more detail. Correlation coefficients were obtained for the relationship between the yields, gross and net income indices and the average slope index. The results of the correlation are recorded in Table 16.

TABLE 16

	ALL OF COSTA RICA			MESETA CENTRAL		
	YIELDS INDEX TO AVERAGE SLOPE INDEX (r)	NET INCOME INDEX TO AVERAGE SLOPE INDEX	GROSS INCOME INDEX TO AVERAGE SLOPE INDEX	YIELDS INDEX TO AVERAGE SLOPE INDEX (r)	NET INCOME INDEX TO AVERAGE SLOPE INDEX	GROSS INCOME INDEX TO AVERAGE SLOPE INDEX
BEANS	-.24120	-.21854	-.24469	-.26846	-.31014	-.26738
CORN	-.21771	-.13060	-.21666	-.26477	-.16895	-.26386
COFFEE	-.33896	-.31922	-.33919	-.36061	-.38101	-.36107
SUGAR CANE	+.12121	+.12465	+.09084	+.21548	+.21785	+.21561
PASTURE	-.31368	-.24920	-.27610	-.34514	-.27827	-.30743

CORRELATION COEFFICIENTS OF THREE RELATIONSHIPS FOR 5 INDIVIDUAL AGRICULTURAL ACTIVITIES FOR TWO PARTS OF COSTA RICA

From an initial observation of the results, the relationships, whether positive or negative, seem to be relatively weak as mentioned previously. Generally speaking, the correlation coefficients for the meseta central tend to indicate a stronger relationship than for all of Costa Rica. A possible explanation of this result has already been outlined earlier in the study. Except for a few values, the relationship between the net income index and the average slope index is in most cases weaker than for the yields and gross income index. This result has also been explained earlier. Generally speaking, the "r" values for the agricultural productivity indices, namely, the yields and gross income relationship are relatively similar.

The positive relationships for sugar cane are contrary to the general hypothesis as postulated in this study. Mechanization of the operation for the crop sugar cane is evident in Costa Rica, especially on level terrain. However, on relatively steeper terrain manual labour is dominant. The higher production per manzana of sugar cane on sloping terrain may possibly be due to the care taken, because of manual labour, of the crop in the maintenance and the harvest. Where machines are used, lower productivity per manzana may be due to the disregard of this careful maintenance and/or the disregard of selection cutting of the crop. For the other crops the use of manual labour seems to be just as important on relatively steeper slopes as on gentle slopes. Therefore, using this line of arguement, it may be expected that the relationships are positive for sugar cane.

INVESTIGATION OF THE ANOMALIES IN THE SCATTERGRAM

Anomalies in the relationships between the gross income index and the average slope index for all of Costa Rica were investigated. It was expected that by this procedure additional reasons why the relationships were rather weak could be identified.

Two types of factors may influence the "r" values of the relationships, namely, factors internal or external to the system of analysis. Of the internal factors, the following were considered to be of possible significance:

a. One factor is that there is an inaccuracy in the assumption that agricultural activities are distributed throughout a district. For various reasons, both physical and human, any given district may be used only in part for agricultural purposes. If only the better land is being used, the agricultural productivity indices will give an exaggerated impression of the potential production of the entire district.

b. Since the slope index is an average figure, it may not be representative of the actual slopes in the district. This would be the case in a district in which, say, half of the land was flat and the other half steeply sloping.

The external factors which are considered to be significant are as follows:

a. The choice of the farmer to raise cattle rather than grow crops.

b. The fertility of the soil and the use of fertilizers.

c. The climate, particularly the severity of the dry season.

The importance of each of these factors was investigated by the use of the following rather simple procedure. The line of best fit[5] was drawn

[5] One of the assumptions made concerning this relationship was that it was linear. After a visual inspection of the scattergram, it seems that for low average slope index values, the gross income index values tend to be consistently rather high. This observation may indicate that the true relationship is slightly curvilinear. Due to the time limitation, curvilinear techniques were not applied to the data in this study. Nevertheless, the linear line of best fit can be accepted as a very close approximation to the best curve that could be fitted.

on the scattergram showing the relationship between the gross income index and the average slope index for all of Costa Rica (Figure 12.). Also drawn were the lines of 1 and 1-1/2 standard errors of estimate on either side of the line of best fit. For operational purposes, the anomalies were defined as the points located outside the lines designating 1-1/2 standard errors of estimate. The seven points located above the upper line were considered to be positive anomalies and the seven points below the lower line were considered to be negative.[6]

For comparison with the fourteen anomalies, a control group of fourteen points was randomly selected from within the area of less than 1 standard error of estimate. Each of the points within this area was given a number and using the random numbers chart,[7] fourteen points were selected. Each point in the anomaly groups and in the control group was labelled by its district number.

The scattergram was then divided into a number of bands each representing a limited range in the slope index. The sample points within these bands were then compared. Anomalies with above average gross income are designated Group A, the control group is designated Group B and anomalies with below average gross income are designated Group C.

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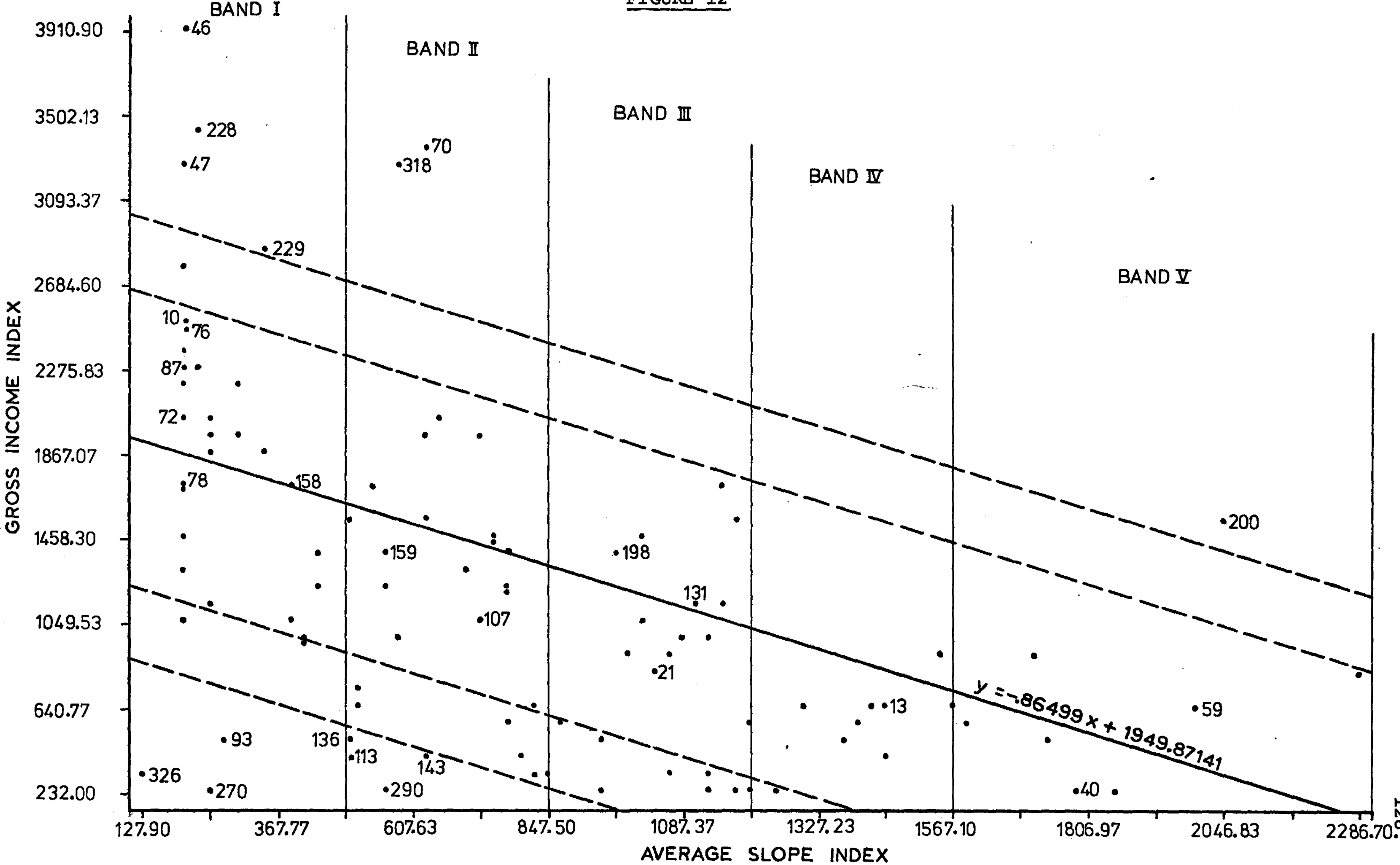
[6]To keep the number of anomalies to a reasonable size the 1-1/2 standard error of estimate lines were used since it was evident that to use 1 or 2 standard errors of estimate would have given respectively too large or too small a number of points.

[7]Arkin, H. and Colton, R. *Tables for Statisticians*. 1965, p. 159.

FIGURE 12



SCATTERGRAM SHOWING THE RELATIONSHIP BETWEEN THE GROSS INCOME INDEX AND THE AVERAGE SLOPE INDEX FOR ALL OF COSTA RICA

Influence of the Factors Internal to the System of Analysis

As indicated above, one of the internal factors thought likely to affect the relationship being examined was the inaccuracy of the assumption that all parts of a district are used for agricultural purposes. Areas where this assumption is invalid, and where anomalies might therefore be expected to occur are mainly outside the meseta central. In these areas of low population pressure it is reasonable to suppose that agriculture would be located on the more level land, and the income derived from that land would be higher than would be expected for the district, taking into account its overall slope index. In other words, this factor should produce positive income anomalies. In actuality, however, the income seems to be lower than expected in almost all districts outside the meseta central (districts 326, 93, 270, 136 and 290). Therefore, this factor must be of relatively minor importance in explaining the anomalies.

The other internal factor, namely, the degree of representativity of the slope index, if significant, would produce a clustering together of districts that contain large areas both of very flat and of very steep terrain. From an examination of the topographic maps and Chart A in the Appendix, districts 40, 318, 21, 143, and 13 were seen to fall into this category. These districts, however, were scattered throughout the scattergram and only two are considered to be anomalies, indicating that this factor is of relatively minor importance in this analysis. The fact that four of these districts have lower incomes than expected is probably due to climatic considerations as all four lie in the drier southern section of the meseta central.

Influence of Factors External to the System of Analysis

Of the external factors that may influence the relationships between terrain slope and agricultural income, the first to be investigated will be the crop-pasture ratio. From the discussion of land-use intensity earlier in the study, it has been established that cropland generally yields higher incomes per manzana than pasture. It may then be expected that for any given slope category in districts with relatively high gross income indices a significantly higher percentage of the agricultural land will be devoted to crops than would be the case in districts with relatively low gross income indices.

For district groups A, B, and C for Bands I and II, the average percentage of the area of the districts in the crop-pasture combination is as follows:

	BAND I			BAND II	
	Cropland	Pasture		Cropland	Pasture
Group A (high income)	95.3%	4.0%	Group A	68.5%	18.0%
Group B (control)	81.2%	13.6%	Group B	47.5%	37.0%
Group C (low income)	21.0%	56.0%	Group C	31.0%	48.0%

For Band III in Group B (no points fall into Groups A and C) the results are: cropland 45.0%, pasture 37.0%. For Band V the results are as follows:

	Cropland	Pasture
Group A	34.0%	27.0%
Group B	35.0%	58.0%

It seems that in all cases, except Band V, the expected relationship holds true. Generally speaking, as the average income values increase for each band the percentage of agricultural land used for crops also increases. It may be concluded, therefore, that a decision as to whether to plant crops or raise cattle may strongly influence the gross income index, regardless of slope.

The second external factor that will be investigated is soil fertility. It is expected that districts with higher fertility soils will show up on the scattergram as having relatively high gross income values. To investigate this relationship, each of the districts being examined was assigned a number which will generally indicate the fertility of the soil in that district using the following procedure: The "Atlas of Costa Rica"[8] has a map which classifies the soils according to whether they are of high, medium or low fertility. A district located completely within a high fertility soil region was assigned a number of 3.0. A district within a low fertility soil region was assigned the number 1.0. Numbers between 1.0 and 3.0 were assigned to districts with a combination of high, medium or low soil fertility types or which lay entirely within a medium soil fertility region.

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[8] AID Resources Inventory Centre. *Costa Rica: Regional Analysis of Physical Resources, Central America and Panama.* 1965, p. T9.

The results, for the different bands on the scattergram, indicate the average soil fertility number for the districts within each group.

BAND I

Group A - 3.0

Group B - 2.8

Group C - 1.2

BAND II

Group A - 2.6

Group B - 3.0

Group C - 1.2

BAND III

Group B - 2.8

BAND V

Group A - 2.0

Group B - 1.0

These results seem to indicate that the expected effect does in fact occur. Regardless of slope, districts with generally high soil fertility have high gross income and conversely, districts with generally low soil fertility have low gross income.

A further amplification of this aspect of soil fertility is the factor of the application of fertilizer. It may be expected that, regardless of slope, districts where a relatively high percentage of the agricultural land is fertilized will have gross incomes which are also relatively high. Accordingly, calculations were made, for each district, of the fertilized area as a percent of the total area used for crops. These percentages were averaged for each of the three groups on the scattergram with the following results:

BAND I			BAND II		
Group A	-	79.3%	Group A	-	39.6%
Group B	-	68.2%	Group B	-	59.9%
Group C	-	10.4%	Group C	-	15.7%

BAND III			BAND V		
Group B	-	54.2%	Group A	-	51.1%
			Group B	-	17.6%

As with soil fertility, the expected relationship seems to hold true. The major exception may be Group A in Band II, where in one district of recently cleared rich alluvial soils along the coast, very low percentages of land are fertilized probably because the land is sufficiently fertile for the crops that are being grown there.

Climate is the third factor that may influence the relationship. It may be expected that in districts, which experience a severe dry season,[9] the gross income values will be relatively low. Districts that fall within this category are: 270, 290, 113, 59, 40 and 143, and all but one are located in the area with low gross incomes on the scattergram, while 3 of the six have incomes as low as to be considered "anomalies". Therefore, it may be concluded that the existence of a long dry season will tend to influence negatively the gross income values.

In summary, this analysis of anomalies suggested that factors internal to the analysis seem to have little influence on the relationship between slopes and incomes. On the other hand, all the external factors seem to have a rather significant influence on the relationship.

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[9] AID Resources Inventory Center, *op. cit.*, 1965, pp. T7-T8.

CHAPTER 6

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of this study has been to investigate the relationship between the slope of the terrain and the agricultural productivity in Costa Rica. The slope of the terrain was represented by an average slope index and the agricultural productivity by gross and net income indices.

The calculation of an average slope index using topographic maps has been investigated by a number of researchers over the years. Most of the early research was concerned with the determination of an accurate and easy to use method of measurement of the roughness of the terrain. It has been only recently that researchers have utilized the average slope index to analyze agricultural phenomena.

The area of study in this work was the country of Costa Rica in Central America where a wide range of tropical and subtropical agricultural activities is carried on. The research has utilized data on a district basis, since this political unit is the smallest unit for which statistics are available from the 1963 Agricultural Census of Costa Rica.

The average slope of a district was measured by a procedure based on the density of contour lines on a topographic map. The agricultural productivity indices had to be determined through the use of data from many sources since the Census did not provide exact information on gross or net incomes per district. Prices of agricultural commodities for the year 1963, as well as, costs of production per manzana for each agricultural commodity were derived from various published and unpublished works. The gross and net incomes for each district were converted to indices by dividing by the area of cultivation and pasture.

The statistical measure of the correlation coefficient was used to determine the relationship of the variables as expressed in the hypothesis. Correlation coefficients for the relationship between gross and net income indices and the average slope index of sample districts were obtained for the following areas: a) the meseta central, b) the area outside the meseta central and c) all of Costa Rica.

The relationship of terrain slope to agricultural productivity was carried one step further by the calculation of correlation coefficients for 21 individual agricultural activities. Further analysis involved a field observation test of a sample of 150 points in the meseta central which was conducted to determine if different agricultural activities are found on a limited range of terrain slopes. Most of the agricultural activities recorded were found on a wide range of terrain slopes. Five of the major land-use activities recorded in the field observation test were investigated in more detail by an analysis of the relationships between the yields, gross and net income indices and the average slope index.

The final step in the analysis involved the selection of anomalies from a scattergram of the relationship between the gross income index and the average slope index for all of Costa Rica. The study of the anomalies focused on some of the factors which may have influenced the results of the association of the relationship in question.

CONCLUSIONS

It was concluded from the analysis that there is a slight tendency for productivity indices to increase as the average slope index decreases for all of Costa Rica. The relationship was stronger in the meseta central than in the areas outside the meseta central. This was explained by the fact that agricultural activities were not located on all slopes in the areas outside the meseta central. Thus the slope index was not representative of the actual slopes being used for agricultural purposes.

The idea that costs of production are higher on level land than on steep land is a possible explanation of why the gross income index relationship was stronger than the net income relationship in the meseta central. However, in areas outside the meseta central the factor of lower farm prices may explain the reverse of the relationship results, as mentioned above.

The correlation coefficients of the 21 agricultural land-uses indicated that the influence of slope varied quite drastically. Most of the agricultural activities indicated negative relationships, however, there were a number which indicated positive relationships. The presence of these positive relationships of a number of crops tended to weaken the overall relationship.

In the detailed study of the five individual agricultural activities, four of the five agricultural activities indicated a tendency toward a negative relationship which was in line with the hypothesis made at the beginning of the study. However, the crop sugar cane showed a positive relationship in the relationship between the yield, gross income and net income indices and the average slope index. The factor of the mechanization of the farming operations for sugar cane on level lands was considered to be an explanation of this positive relationship.

The analysis of the anomalies in the scattergram of the relationship between the gross income index and the average slope index revealed a number of factors that influenced the relationship. The internal factors to the system of analysis, namely, the idea that the whole district is not used for agricultural purposes and the idea that the average slope index is not representative of the actual slopes in the district seemed to have very little significant effect on the relationship. On the other hand, the external factors to the system of analysis tended to be of greater importance, with regards to the explanation of the anomalies. A very important factor seemed to be the choice of farmers to raise cattle rather than to grow crops, regardless of slope. Other factors which explained some of the anomalies were soil fertility, the application of fertilizer and the effect of the severity of the dry season.

The analysis of the anomalies pointed out that the explanation of the difference in the relationships in question between the area within the meseta central and the area outside the meseta central, was not necessarily correct. It was assumed that the factor of the use of all slopes for agricultural purposes explained the weaker relationship for the areas outside the meseta central. In the analysis of the anomalies it became evident that the effect is the reverse. Therefore, possibly the other factors were responsible for the difference in the relationship namely, the crop-pasture choice, the soil fertility, application of fertilizer and the severity of the dry season.

This study has indicated that an overall negative relationship exists between agricultural productivity and terrain slopes in Costa Rica. The relationship is stronger in the densely populated area of the country. Certain land uses such as sugar cane seem to indicate positive relationships, contrary to the hypothesis postulated in this study. A number of factors, such as the choice of the crop-pasture combination, the soil fertility, the application of fertilizer and the effect of the dry season, tend to explain anomalies which do not fit the relationship in question. The use of different size statistical units did not seem to affect the relationship between agricultural productivity and terrain slopes.

BIBLIOGRAPHY

Aid Resources Inventory Centre. *Costa Rica: Analisis Regional de Recursos Fisicos*. Series AID/RIC GIPR No. 4, Washington: Engineer Agency for Resources Inventories, 1965.

Aguilar, L.A. *Estudio Para el Desarrollo Agropecuario de la Cuenca del Rio Canas, Nicoya, Provincia de Guanacaste, Costa Rica*. M.S. Dissertation, Department of Rural Growth, Instituto Interamericano de Ciencias Agricolas, 1968.

Aguirre, J.A. and Plath, C.V. *Mapa de Uso Potencial de la Tierra, Cuenca del Rio Canas, Nicoya, Provincia de Guanacaste, Costa Rica*. Turrialba: Instituto Interamericano de Ciencias Agricolas, 1966.

Arkin, H. and Colton, R. *Tables for Statisticians*. New York: Barnes and Noble Inc., 1965.

Barrantes, M. *Evolucion de la Division Territorial en la Provincia de San Jose*. San Jose: Instituto Geografico Nacional, 1968.

Bennett, H.H. *Soil Conservation*. Toronto: McGraw Hill Book Co., 1939.

Brunsden, D. *Slopes: Form and Process*. Special Publication No. 3. London: Institute of British Geographers, 1971.

Bunting, B.T. *The Geography of Soil*. Chicago: Aldine Publishing Co., 1965.

Calef, W. and Newcomb, R. "An Average Slope Map of Illinois", *Annals of the Association of American Geographers*. Vol. 43, 1953.

Carvajal, M.J. and Ross, J.E. *Public Institutions Affecting Agricultural Development in Costa Rica*. University of Florida Report. San Jose: Alliance for Progress, 1968.

Carvajal, M.J. and Ross, J.E. *Fact Sheets on Costa Rican Agriculture*. University of Florida Report, San Jose: Alliance for Progress, 1968.

Carson, M.A. and Kirby, M.J. *Hillslope Form and Process*. London: Cambridge University Press, 1972.

Castro, J.J. *Planificacion del Uso de la Tierra, Peninsula de Nicoya, Costa Rica*. M.S. Dissertation, Department of Rural Growth, Instituto Interamericano de Ciencias Agricolas, 1968.

Centro Cientifico Tropical. *Investigacion Preliminar de la Zona Norte de las Provincias de Alajuela y Heredia.* San Jose: Centro Cientifico Tropical, 1968.

Chandler, W.H. and De la Loma, J.L. *Frutales de Hoja Perenne.* Mexico: Union Tipografica Editorial Hispano Americana, 1962.

Coto, J.A. *Diagnostico y Programacion Para el Desarrollo Agricola de las Zonas Adyacentes a Puerto Limon, Costa Rica.* M.S. Dissertation, Department of Rural Growth, Instituto Interamericano de Ciencias Agricolas, 1968.

Cozzens, A.B. "An Angle of Slope Scale", *Journal of Geomorphology.* Vol. 3, 1940.

Direccion General de Estadistica y Censos. *Anuario Estadistico de Costa Rica 1964.* San Jose: Ministerio de Economica y Hacienda, 1965.

Direccion General de Estadistica y Censos. *Censo Agropecuario 1963.* San Jose: Direccion General de Estadistica y Censos, 1965.

Direccion General de Estadistica y Censos. *Indices de Precios Al Por Memor 1968.* Nos. 181 to 186, San Jose: Direccion General de Estadistica y Censos, 1968.

Directorio Comercial, Industrial y Turistico: Costa Rica. San Jose: Instituto Costarricense de Turismo, 1971-72.

Dondoli, C. and Torres, J.A. *Estudio Geoagronomico de la Region Oriental de la Meseta Central.* San Jose: Ministerio de Agricultura y Industrias, 1954.

Dury, G.H. "Quantitative Measurement of Available Relief and Depth of Dissection", *Geological Magazine.* Vol. 88, 1951.

Dykman, E., Ochse, F., Soule, J. and Wehlburg, S. *Tropical and Subtropical Agriculture.* Toronto: The MacMillan Co., 1961.

Ezekiel, M. *Methods of Correlation Analysis.* New York: John Wiley and Sons, Inc., 1947.

Garrigus, W. *Average Slope: A Morphometric Index Useful in Analyzing Areal Variations of Agricultural Productivity, as Applied to the State of Ohio.* Ph.D. Thesis, Department of Geography, Clark University, 1958.

Gonzales, H. *Zonificacion Agropecuaria y Forestal en el Salvador: Guia Para una Planificacion del Uso de la Tierra.* M.S. Dissertation, Department of Rural Growth, Instituto Interamericano de Ciencias Agricolas, 1968.

Gregory, S. *Statistical Methods and the Geographer.* Toronto: Longmans Canada Ltd., 1963.

Hamilton, C.H. "A Statistical Index of Topography", *Social Forces.* Vol. 9, 1930-31.

Hook, J.C. *The Relationship Between Roughness of Terrain and Phenomena Related to Agriculture in Northeastern United States.* Ph.D. Thesis, Department of Geography, State University of Iowa, 1955.

Horton, R.E. "Derivation of Run-Off from Rainfall Data - Discussion", *American Society of Civil Engineering, Transactions.* Vol. 77, 1914.

Instituto Geografico Nacional. *Mapa Especial: Valle Central (Scale 1:150,000).* E561 Edition 1 - IGNCR, 1965.

Instituto Geografico Nacional. *Mapa Fisico - Politico (Scale 1:500,000).* Edition 1 - IGNCR, 1965.

King, L.J. *Statistical Analysis in Geography.* Toronto: Prentice Hall of Canada, Ltd., 1969.

Lombardo, H.A. *Analisis de una Economica Agricola Dentro de la Meseta Central de Costa Rica.* Turrialba: Instituto Interamericano de Ciencias Agricolas, 1965.

Lundberg, D.E. *Costa Rica.* San Jose: Juan Mora, 1968.

Ministerio de Agricultura y Ganaderia y la Oficina del Cafe. *Estudio de Costos de Produccion de Cafe.* San Jose: Ministerio de Agricultura y Ganaderia, 1968.

Ministerio de Gobernacion, *Division Territorial Administrativa de la Republica de Costa Rica.* No. 176, San Jose: Instituto Geografico Nacional, 1963.

Ministerio de Obras Publicas. *Plan Vial Proyecto de Caminos Vecinales Tomo I.* San Jose: Ministerio de Obras Publicas, 1962.

Mueggler, W. "Cattle Distribution on Steep Slopes", *Journal of Range Management.* Vol. 18, No. 5, 1965.

Neunschwander, G. *Morphometrischer Begriffe.* Zurich: Emil Ruegg and Co., 1944.

Ospino, F. *Manual de Costos Basicos de Actividades Agropecuarias y Industriales.* Cartago: Banco Credito Agricola de Cartago, 1964.

Ospino, F. *Manual de Costos Basicos de Actividades Agropecuarias.* Cartago: Banco Credito Agricola de Cartago, 1967.

Pan American Union. *Costa Rica - Annotated Index of Aerial Photographic Coverage and Mapping of Topography and Natural Resources.* Washington: Pan American Union, 1965.

Pitty, A.F. *A Scheme for Hillslope Analysis II. Indices and Tests for Differences.* Occasional paper No. 17, Hull: University of Hull publications, 1970.

Plath, C.V. and Van der Sluis, A. *Uso Potencial de la Tierra, Parte II: Costa Rica.* Rome: United Nations Publications, 1967.

Plath, C.V. and Van der Sluis, A. *Uso Potencial de la Tierra, Parte VII: Istmo Centroamericano.* Rome: United Nations Publications, 1968.

Raisz, E. and Henry, J. "An Average Slope Maps of Southern New England", *Geographical Review.* Vol. 27, 1937.

Runge, E.C. and Rieckew, F.F. "Influence of Slope on Size and Distribution of Fields in Iowa", *Soil Science (Society of America) Proceedings.* Vol. 31, No. 4, 1967.

Saenz, A. *Suelos Volcanicos Cafeteros de Costa Rica.* Series No. 6, San Jose: University of Costa Rica Publications, 1966.

Selby, M.J. *Slopes and Slope Processes.* Publication No. 1. Hamilton: Waikato Branch of the New Zealand Geographical Society, Inc., 1970.

Servicio Meteorologico. *Anuario Meteorologico 1966.* San Jose: Ministerio de Agricultura y Ganaderia, 1966.

Servicio Meteorologico. *Anuario Meteorologico 1967.* San Jose: Ministerio de Agricultura y Ganaderia, 1967.

Smith, G.H. "The Relative Relief of Ohio", *Geographical Review.* Vol. 25, 1935.

Smith, G.H. "The Morphometry of Landscape: An Analysis of Slope", *Annals of the Association of American Geographers.* Vol. 28, 1938.

Smith, V.A. *Beef Cattle Production and Marketing in Guanacaste, Costa Rica.* Ph.D. Thesis, Department of Geography, University of Florida, 1970.

Strahler, A.N. "Quantitative Slope Analysis", *Bulletin of the Geological Society of America.* Vol. 67, 1956.

Torres, J.A. and Vargas, O. *Estudio Preliminar de Suelos de la Region Occidental de la Meseta Central.* Technical Bulletin No. 22, San Jose: Ministerio de Agricultura y Ganaderia, 1958.

Torres, J.E. *Estudio Agroeconomico y Regionalizacion en San Carlos, Alajuela, Costa Rica, 1968.* M.S. Dissertation, Department of Rural Growth, Instituto Interamericano de Ciencias Agricolas, 1968.

Tosi, Jr., J.A. *Un Estudio de Reconocimiento de los Recursos Naturales y Potenciales de las Tierras de la Reserva Indigena de Salitre, El Valle del General, Costa Rica.* San Jose: Instituto de Tierras y Colonizacion, 1967.

Tosi, Jr., J.A. *Capacidad de Uso de la Tierra Determinada por los Condiciones de Clima, Fisiografia y Suelos en la Parte Noreste de la provincia de Guanacaste, Costa Rica.* San Jose: Instituto de Tierras y Colonizacion, 1967.

Uribe, G. *Regionalizacion y Programacion Agropecuaria para el Area Nicoya - Puerto Jesus, Provincia de Guanacaste, Costa Rica.* No. 46, Turrialba: Instituto Interamericano de Ciencias Agricolas, 1967.

Walker, P.H., Hall, G.F. and Protz, R. "Relation Between Landform Parameters and Soil Properties", *Soil Science (Society of America) Proceedings.* Vol. 32, No. 1, 1968.

Wentworth, C.K. "A Simplified Method of Determining the Average Slope of Land Surfaces", *American Journal of Science.* Series 5, Vol. 20, 1930.

Wilkowske, H.H. *Developing a Cheese Industry in Costa Rica.* San Jose: Ministerio de Agricultura y Industrias, 1958.

Wood, H.A. *Northern Haiti: Land Use and Settlement, A Geographical Investigation of the Department du Nord.* Toronto: University of Toronto Press, 1963.

Yang, W.Y. *Methods of Farm Management Investigations.* Agricultural Development Paper No. 64, Rome: Food and Agriculture Organization of the United Nations, 1958.

APPENDICES

CHART A

SLOPE INDEX CALCULATION

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
005	2	2.67	100.0	200.0
		2.67	100.0	200.0
007	1	0.12	19.0	19.0
	2	6.68	79.6	159.2
	24	1.59	1.4	33.6
		8.39	100.0	211.8
008	2	3.04	100.0	200.0
		3.04	100.0	200.0
010	2	3.97	100.0	200.0
		3.97	100.0	200.0
011	2	4.48	100.0	200.0
		4.48	100.0	200.0
012	10	0.57	15.4	154.0
	11	0.18	4.9	53.9
	24	0.64	17.3	415.2
	2	2.31	62.4	124.8
		3.70	100.0	747.9
013	11	0.18	1.9	11.0
	8	0.28	1.5	12.0
	24	8.04	44.0	1056.0
	10	5.79	31.7	317.0
	2	3.99	21.8	43.6
		18.28	100.0	1439.6
014	10	1.85	13.8	138.0
	2	10.73	80.3	160.6
	24	0.76	5.7	136.8
	1	0.02	0.2	0.2
		13.36	100.0	435.6

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
021	2	4.30	22.3	44.6
	7	1.32	6.8	47.6
	4	0.04	0.2	0.8
	5	1.07	5.5	27.5
	6	4.92	25.5	153.0
	20	5.70	29.5	590.0
	18	1.96	10.2	183.6
		19.31	100.0	1047.1
026	11	8.07	33.4	367.4
	21	5.40	22.3	468.3
	14	5.42	22.4	313.6
	9	4.75	19.6	176.4
	23	0.56	2.3	52.9
		24.20	100.0	1378.6
029	9	7.04	24.9	224.1
	14	4.38	15.5	217.0
	25	15.71	55.7	1392.5
	1	0.56	2.0	2.0
	12	0.50	1.8	21.6
	13	0.01	0.1	1.3
		28.20	100.0	1858.5
031	10	3.84	33.5	335.0
	9	1.51	13.2	118.8
	21	5.96	52.0	1092.0
	26	0.15	1.3	33.8
		11.46	100.0	1579.6
035	24	6.84	23.9	573.6
	8	1.49	5.2	41.6
	9	2.28	8.0	72.0
	14	5.57	19.5	273.0
	4	4.29	15.0	60.0
	20	7.88	27.6	552.0
	5	0.23	0.8	4.0
		28.58	100.0	1576.2

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
040	24	36.48	60.9	1461.6
	1	4.10	6.8	6.8
	8	1.03	1.7	13.6
	4	6.88	11.5	46.0
	15	5.93	9.9	148.5
	11	0.79	1.3	14.3
	2	1.90	3.2	6.4
	13	0.01	0.0	0.0
	9	1.15	1.9	17.1
	21	1.65	2.8	58.8
		59.92	100.0	1773.1
045	2	2.35	100.0	200.0
		2.35	100.0	200.0
046	2	0.52	100.0	200.0
		0.52	100.0	200.0
047	2	2.42	100.0	200.0
		2.42	100.0	200.0
048	2	0.76	10.0	20.0
	3	2.26	29.7	89.1
	4	0.73	9.6	38.4
	5	3.85	50.7	253.5
		7.60	100.0	401.0
049	2	1.60	29.4	58.8
	3	0.37	6.8	20.4
	4	2.65	48.7	194.8
	5	0.82	15.1	75.5
		5.44	100.0	349.5
053	1	8.28	64.7	64.7
	2	0.01	0.1	0.2
	10	3.64	28.4	284.0
	24	0.87	6.8	163.2
		12.80	100.0	512.1
054	1	3.82	54.8	54.8
	8	1.64	23.5	188.0
	24	1.51	21.7	520.8
		6.97	100.0	763.6

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. Kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
056	1	2.29	63.9	63.9
	8	0.26	7.3	58.4
	24	1.03	28.8	691.2
		3.58	100.0	813.5
058	2	1.24	22.7	45.4
	8	0.40	7.3	58.4
	9	0.37	6.8	61.2
	10	1.08	19.8	198.0
	24	2.37	43.4	1041.6
		5.46	100.0	1404.6
059	10	1.82	28.2	282.0
	24	4.62	71.8	1723.2
		6.44	100.0	2005.2
061	2	3.72	70.9	141.8
	10	1.53	29.1	291.0
		5.25	100.0	432.8
070	2	3.14	80.5	161.0
	24	0.76	19.5	468.0
		3.90	100.0	629.0
072	2	1.34	100.0	200.0
		1.34	100.0	200.0
076	2	4.57	100.0	200.0
		4.57	100.0	200.0
078	2	1.41	100.0	200.0
		1.41	100.0	200.0
079	2	0.37	5.2	10.4
	3	1.51	21.3	63.9
	5	4.90	69.1	345.5
	18	0.31	4.4	79.2
		7.09	100.0	499.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
085	2	0.03	0.1	0.2
	11	0.26	0.8	8.8
	14	0.75	2.2	30.8
	5	8.64	25.9	129.5
	18	10.47	31.3	563.4
	6	3.93	11.8	70.8
	20	4.01	12.0	240.0
	13	5.31	15.9	206.7
		33.40	100.0	1250.2
087	2	4.83	99.2	198.4
	3	0.04	0.8	2.4
		4.87	100.0	200.8
088	3	1.28	23.4	70.2
	2	4.20	76.6	153.2
		5.48	100.0	223.4
089	3	0.64	16.7	50.1
	5	0.45	11.8	59.0
	2	2.73	71.5	143.0
		3.82	100.0	252.1
092	25	8.14	11.2	280.0
	2	0.64	0.9	1.8
	8	3.40	4.7	37.6
	11	23.75	32.8	360.8
	4	10.43	14.4	57.6
	3	7.71	10.7	32.1
	1	18.32	25.3	25.3
		72.39	100.0	795.2
093	0	1.72	4.0	0.0
	1	24.59	56.3	56.3
	8	5.60	12.8	102.4
	14	1.40	3.2	44.8
	4	0.60	1.4	5.6
	3	9.73	22.3	66.9
		43.64	100.0	276.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
097	14	1.69	10.8	151.2
	7	0.43	2.8	19.6
	16	0.76	4.9	78.4
	25	12.70	81.5	2037.5
		15.58	100.0	2286.7
105	2	22.22	82.8	165.6
	24	2.17	8.1	194.4
	6	2.43	9.1	54.6
		26.82	100.0	414.6
107	4	12.37	29.6	118.4
	6	10.30	24.6	147.6
	12	12.09	28.9	346.8
	9	3.45	8.2	73.8
	3	3.24	7.8	23.4
	24	0.37	0.9	21.6
		41.82	100.0	731.6
109	2	4.37	89.9	179.8
	7	0.49	10.1	70.7
		4.86	100.0	250.5
113	24	2.81	8.4	201.6
	2	13.01	38.7	77.4
	3	11.56	34.4	103.2
	8	0.24	0.7	5.6
	5	5.97	17.8	89.0
		33.59	100.0	476.8
121	6	4.85	67.6	405.6
	16	0.37	5.2	83.2
	3	0.78	10.9	32.7
	12	1.17	16.3	195.6
		7.17	100.0	717.1
124	16	0.56	3.0	48.0
	3	4.14	22.2	66.6
	12	12.05	64.8	777.6
	6	0.53	2.8	16.8
	4	0.50	2.7	10.8
	5	0.83	4.5	22.5
		18.61	100.0	942.3

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
129	7	1.25	6.5	45.5
	4	8.40	43.8	175.2
	11	7.22	37.6	413.6
	5	0.40	2.1	10.5
	18	0.85	4.4	79.2
	2	0.03	0.2	0.4
	8	1.03	5.4	43.2
		19.18	100.0	767.6
130	4	8.69	69.7	278.8
	7	0.97	7.8	54.6
	5	0.09	0.7	3.5
	11	2.71	21.7	238.7
	2	0.01	0.1	0.2
		12.47	100.0	575.8
131	24	0.27	1.0	24.0
	2	3.18	12.0	24.0
	7	0.25	0.9	6.3
	11	4.44	16.7	183.7
	4	4.03	15.1	60.4
	5	2.43	9.1	45.5
	18	11.94	44.9	808.2
	8	0.07	0.3	2.4
		26.61	100.0	1154.5
135	3	0.85	2.8	8.4
	4	2.03	6.8	27.2
	5	0.07	0.2	1.0
	11	5.67	18.8	206.8
	6	1.75	5.8	34.8
	8	1.07	3.6	28.8
	18	18.65	62.0	1116.0
		30.09	100.0	1423.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
136	2	234.57	14.8	29.6
	3	41.87	2.6	7.8
	8	133.92	8.4	67.2
	4	82.52	5.2	20.8
	5	29.95	1.9	9.5
	18	8.07	0.5	9.0
	6	95.84	6.0	36.0
	0	518.07	32.6	0.0
	7	25.45	1.6	11.2
	9	12.49	0.8	7.2
	15	107.95	6.8	102.0
	1	129.98	8.2	8.2
	22	57.04	3.6	79.2
	12	27.04	1.7	20.4
	10	7.03	0.4	4.0
	26	4.26	0.3	7.8
	1.5	21.48	1.4	2.1
	20	26.51	1.7	34.0
	19	14.27	0.9	17.1
	25	5.25	0.3	7.5
	24	1.05	0.1	2.4
	17	2.13	0.1	1.7
	27	0.83	0.1	2.7
		1587.57	100.0	487.4
143	10	0.06	0.8	8.0
	24	0.32	4.2	100.8
	12	1.66	22.1	265.2
	4	0.37	4.9	19.6
	11	0.25	3.3	36.3
	2	0.11	1.5	3.0
	3	4.75	63.2	189.6
		7.52	100.0	622.5
145	24	8.59	38.4	921.6
	3	8.68	38.8	116.4
	6	0.26	1.2	7.2
	8	4.82	21.6	172.8
		22.35	100.0	1218.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
146	18	6.85	46.9	844.2
	5	1.15	7.9	39.5
	8	4.31	29.5	236.0
	2	1.64	11.2	22.4
	12	0.65	4.5	54.0
		14.60	100.0	1196.1
147	5	0.03	0.2	1.0
	18	3.43	25.9	466.2
	24	0.92	7.0	168.0
	2	7.72	58.4	116.8
	8	0.20	1.5	12.0
	12	0.92	7.0	84.0
		13.22	100.0	848.0
149	16	2.17	6.7	107.2
	6	8.02	24.7	148.2
	18	7.90	24.4	439.2
	9	5.25	16.2	145.8
	3	7.23	22.3	66.9
	24	1.10	3.4	81.6
	11	0.78	2.3	25.3
		32.40	100.0	1014.2
151	6	4.32	14.0	84.0
	12	16.45	43.2	638.4
	9	1.12	3.6	32.4
	18	5.55	17.9	322.2
	5	3.48	11.3	56.5
		30.92	100.0	1133.5
156	18	1.21	12.9	232.2
	6	0.56	6.0	36.0
	13	2.02	21.6	280.8
	8	5.42	57.9	463.2
	3	0.15	1.6	4.8
		9.36	100.0	1017.0
158	6	1.37	25.6	153.6
	3	3.93	73.3	219.9
	18	0.06	1.1	19.8
		5.36	100.0	393.3

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
159	4	3.62	21.4	85.6
	5	5.65	33.4	167.0
	12	1.88	11.1	133.2
	3	2.78	16.4	49.2
	24	0.07	0.4	9.6
	9	0.34	2.0	18.0
	6	2.59	15.3	91.8
		16.93	100.0	554.4
161	5	0.03	0.3	1.5
	11	4.60	41.8	459.8
	4	3.80	34.5	138.0
	6	2.57	23.4	140.4
		11.00	100.0	739.7
162	2	2.26	23.8	47.6
	24	1.15	12.1	290.4
	4	2.62	27.5	110.0
	3	2.15	22.6	67.8
	12	0.75	7.9	94.8
	5	0.58	6.1	30.5
		9.51	100.0	641.1
163	9	0.45	2.2	19.8
	12	0.90	4.5	54.0
	6	10.89	54.1	324.6
	11	4.28	21.3	234.3
	5	1.82	9.0	45.0
	8	1.06	5.3	42.4
	19	0.56	2.8	53.2
	0	0.10	0.5	0.0
	18	0.06	0.3	5.4
		20.12	100.0	778.7
171	19	0.64	1.7	32.3
	7	13.27	34.6	242.2
	10	3.17	8.3	83.0
	5	5.44	14.2	71.0
	25	8.98	23.4	585.0
	8	3.12	8.1	64.8
	15	0.44	1.2	18.0
	11	3.24	8.5	93.5
		38.30	100.0	1189.8

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
184	11	1.00	3.6	39.6
	6	5.76	20.7	124.2
	12	4.77	17.1	205.2
	7	4.42	15.9	111.3
	18	10.21	36.6	658.8
	8	1.70	6.1	48.8
		27.86	100.0	1187.9
185	24	0.09	0.5	12.0
	11	2.98	17.6	193.6
	6	7.79	46.0	276.0
	10	0.65	3.9	39.0
	18	5.35	31.6	568.8
	12	0.06	0.4	4.8
		16.92	100.0	1094.2
189	8	1.01	21.3	170.4
	18	0.17	3.6	64.8
	9	0.31	6.6	59.4
	4	1.64	34.7	138.8
	2	1.60	33.8	67.6
		4.73	100.0	501.0
190	2	5.14	17.5	35.0
	18	5.64	19.3	347.4
	4	5.98	20.4	81.6
	9	9.21	31.5	283.5
	7	3.31	11.3	79.1
		29.28	100.0	826.6
192	2	13.87	43.6	87.2
	18	5.05	15.9	286.2
	6	2.31	7.3	43.8
	20	8.45	26.5	530.0
	8	2.15	6.7	53.6
		31.83	100.0	1000.8

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
195	7	0.09	0.2	1.4
	29	8.74	22.4	649.6
	16	4.91	12.6	201.6
	6	1.87	4.8	28.8
	9	2.49	6.4	57.6
	11	0.23	0.6	6.6
	4	0.89	2.3	9.2
	8	0.40	1.0	8.0
	20	10.63	27.3	546.0
	2	8.73	22.4	44.8
		38.98	100.0	1553.6
196	12	0.45	1.6	19.2
	18	9.56	34.0	612.0
	7	10.16	36.1	252.7
	9	6.28	22.3	200.7
	5	1.67	6.0	30.0
		28.12	100.0	1114.6
197	29	0.02	0.1	2.9
	20	2.86	8.3	166.0
	2	18.03	52.2	104.4
	6	7.94	23.0	138.0
	9	0.42	1.2	10.8
	8	0.27	0.8	6.4
	11	3.29	9.5	104.5
	4	1.70	4.9	19.6
		34.53	100.0	552.60
198	2	4.39	17.3	34.6
	20	0.31	1.2	24.0
	4	5.61	22.1	88.4
	9	6.10	24.0	216.0
	6	0.25	1.0	6.0
	8	4.21	16.6	132.8
	3	0.57	2.2	6.6
	29	3.98	15.6	452.4
		25.42	100.0	960.8

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
200	14	0.18	0.5	7.0
	16	1.46	4.0	64.0
	2	1.95	5.3	10.6
	4	3.87	10.6	42.4
	9	2.26	6.2	55.8
	29	21.71	59.3	1719.7
	8	0.89	2.4	19.2
	10	1.75	4.8	48.0
	13	2.53	6.9	89.7
		36.60	100.0	2056.4
202	2	5.09	38.2	76.4
	18	7.60	57.1	1027.8
	6	0.62	4.7	28.2
		13.31	100.0	1132.4
204	18	2.60	28.2	507.6
	4	1.48	16.0	64.0
	2	3.50	37.9	75.8
	9	0.87	9.4	84.6
	6	0.78	8.5	51.0
		9.23	100.0	783.0
206	2	1.84	22.4	44.8
	5	0.34	4.1	20.5
	6	0.93	11.3	67.8
	9	5.11	62.2	559.8
		8.22	100.0	692.9
207	5	2.49	62.4	312.0
	2	0.74	18.5	37.0
	3	0.76	19.1	57.3
		3.99	100.0	406.3

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
216	28	7.85	20.6	576.8
	2	0.39	1.0	2.0
	9	0.47	1.2	10.8
	5	0.35	0.9	4.5
	4	3.74	9.8	39.2
	8	3.31	8.7	69.6
	14	13.27	34.7	485.8
	29	4.95	13.0	377.0
	24	2.07	5.4	129.6
	7	1.79	4.7	32.9
		38.19	100.0	1728.2
220	4	3.20	39.6	158.4
	8	4.89	60.4	483.2
		8.09	100.0	641.6
221	28	63.71	43.0	1204.0
	6	28.90	19.5	117.0
	4	3.01	2.0	8.0
	9	24.97	16.9	152.1
	16	3.34	2.3	36.8
	15	4.73	3.2	48.0
	11	2.09	1.4	15.4
	8	7.59	5.1	40.8
	14	1.43	1.0	14.0
	13	8.26	5.6	72.8
		148.03	100.0	1708.9
223	7	18.06	13.6	95.2
	11	7.90	6.0	66.0
	16	7.67	5.8	92.8
	12	2.54	1.9	22.8
	6	4.17	3.2	19.2
	5	4.81	3.6	18.0
	29	10.72	8.1	234.9
	9	14.76	11.1	99.9
	13	16.79	12.7	165.1
	20	41.62	31.4	628.0
	4	0.25	0.2	0.8
	2	3.19	2.4	4.8
		132.48	100.0	1447.5

CHART A (cont'd)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
228	2	4.44	75.6	151.2
	3	1.00	17.1	51.3
	4	0.43	7.3	29.2
		5.87	100.0	231.7
229	24	0.62	4.9	117.6
	2	9.32	73.5	147.0
	3	0.81	6.4	19.2
	4	1.92	15.2	60.8
		12.67	100.0	344.6
234	2	1.40	100.0	200.0
		1.40	100.0	200.0
235	2	1.65	43.3	86.6
	3	1.62	42.5	127.5
	6	0.54	14.2	85.2
		3.81	100.0	299.3
236	18	0.86	1.9	34.2
	6	8.56	19.3	115.8
	9	5.29	11.9	107.1
	13	0.56	1.3	16.9
	12	11.70	26.4	316.8
	4	1.85	4.2	16.8
	5	1.24	2.8	14.0
	8	13.81	31.2	249.6
	3	0.46	1.0	3.0
		44.33	100.0	874.2
239	2	10.56	76.0	152.0
	24	2.79	20.1	482.4
	9	0.10	0.7	6.3
	3	0.44	3.2	9.6
		13.89	100.0	650.3
245	3	4.03	89.4	268.2
	2	0.48	10.6	21.2
		4.51	100.0	289.4

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
246	3	3.34	41.7	125.1
	8	3.10	38.7	309.6
	5	1.57	19.6	98.0
		8.01	100.0	532.7
252	28	1.03	4.3	120.4
	22	3.84	15.8	347.6
	10	7.73	31.9	319.0
	8	0.15	0.6	4.8
	6	9.53	39.3	235.8
	3	1.97	8.1	24.3
		24.25	100.0	1051.9
255	28	0.32	3.0	84.0
	22	1.45	13.7	301.4
	10	3.01	28.3	283.0
	6	3.98	37.5	225.0
	3	1.79	16.8	50.4
	2	0.07	0.7	1.4
		10.62	100.0	945.2
257	2	3.72	88.2	176.4
	7	0.50	11.8	82.6
		4.22	100.0	259.0
261	2	1.73	100.0	200.0
		1.73	100.0	200.0
262	6	0.02	0.2	1.2
	3	3.46	39.2	117.6
	2	5.36	60.6	121.2
		8.84	100.0	240.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
270	0	71.34	68.2	0.0
	3	5.34	5.1	15.3
	2	0.28	0.3	0.6
	10	1.36	1.3	15.0
	5	0.35	0.3	1.5
	16	4.42	4.2	67.2
	1	11.64	11.1	11.1
	4	0.60	0.6	2.4
	9	0.53	0.5	4.5
	20	4.95	4.7	94.0
	12	0.82	0.8	9.6
	24	0.37	0.4	9.6
	6	1.61	1.5	9.0
	22	0.98	0.9	19.8
	7	0.06	0.1	0.7
		104.65	100.0	258.3
289	5	0.89	2.4	12.0
	3	2.75	7.5	22.5
	13	2.24	6.1	79.3
	18	3.54	9.6	172.8
	11	4.74	12.8	140.8
	12	0.79	2.1	25.2
	6	3.72	10.1	60.6
	7	0.77	2.1	14.7
	21	8.94	24.2	508.2
	0	5.26	14.2	0.0
	10	3.29	8.9	89.0
		36.93	100.0	1125.1
290	0	32.53	55.2	0.0
	16	2.15	3.7	59.2
	14	3.98	6.7	93.8
	21	3.90	6.6	138.6
	12	0.73	1.2	14.4
	11	7.29	12.4	136.4
	5	0.59	1.0	5.0
	9	0.64	1.1	9.9
	6	0.87	1.5	9.0
	7	3.46	5.9	41.3
	4	1.35	2.3	9.2
	18	1.39	2.4	43.2
		58.88	100.0	560.0

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
306	8	1.04	2.4	19.2
	12	12.05	27.6	331.2
	24	1.12	2.6	62.4
	16	6.38	14.6	233.6
	9	3.42	7.8	70.2
	19	3.03	6.9	131.1
	14	2.43	5.6	78.4
	11	2.52	5.7	62.7
	2	3.62	8.3	16.6
	1	4.11	9.4	9.4
	6	2.44	5.6	33.6
	3	0.53	1.2	3.6
	4	1.01	2.3	9.2
		43.70	100.0	1061.2
310	0	5.64	3.4	0.0
	1	1.91	1.2	1.2
	17	4.64	2.8	47.6
	6	9.83	6.0	36.0
	15	10.46	6.4	96.0
	27	9.73	5.9	159.3
	12	5.70	3.5	42.0
	24	2.32	1.4	33.6
	9	9.52	5.8	52.2
	8	20.23	12.3	98.4
	16	53.07	32.3	516.8
	21	1.26	0.8	16.8
	23	1.50	0.9	20.7
	11	6.24	3.8	41.8
	14	4.72	2.9	40.6
	7	7.44	4.5	31.5
	2	0.91	0.6	1.2
	10	2.98	1.8	18.0
	4	2.20	1.3	5.2
	28	2.59	1.6	44.8
	5	1.31	0.8	4.0
		164.20	100.0	1307.7

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
318	0	139.83	42.0	0.0
	2	14.66	4.4	8.8
	9	22.59	6.8	61.2
	5	21.90	6.6	33.0
	25	23.57	7.1	177.5
	6	2.26	0.7	4.2
	23	0.34	0.1	2.3
	3	26.31	7.9	23.7
	18	25.67	7.7	138.6
	8	6.73	2.0	16.0
	1	0.89	0.3	0.3
	22	4.21	1.3	28.6
	7	42.14	12.6	88.2
	10	0.15	0.1	1.0
	12	1.51	0.4	4.8
		332.76	100.0	588.2
323	0	262.36	22.7	0.0
	2	6.13	0.5	1.0
	6	31.52	2.7	16.2
	8	31.13	2.7	21.6
	3	2.83	0.3	0.9
	5	51.94	4.5	22.5
	12	147.03	12.7	152.4
	18	28.46	2.5	45.0
	4	101.11	8.8	35.2
	7	47.64	4.1	28.7
	14	94.53	8.2	114.8
	10	17.60	1.5	15.0
	9	43.46	3.8	34.2
	24	1.34	0.1	2.4
	16	1.37	0.1	1.6
	13	16.96	1.5	19.5
	29	251.01	21.7	629.3
	1	10.12	0.9	0.9
	17	7.90	0.7	11.9
		1154.44	100.0	1153.1

CHART A (cont'd.)

DISTRICT	SLOPE CATEGORY NUMBER	AREA (in sq. kil.)	PERCENTAGE OF TOTAL AREA	AVERAGE SLOPE INDEX
326	0	1882.98	79.1	0.0
	8	15.61	0.6	4.8
	7	1.40	0.1	0.7
	3	31.71	1.3	3.9
	6	65.49	2.7	16.2
	9	21.56	0.9	8.1
	11	14.27	0.6	6.6
	4	6.69	0.3	1.2
	1	84.29	3.5	3.5
	2	33.57	1.4	2.8
	15	13.46	0.6	9.0
	5	54.36	2.3	11.5
	0.5	27.85	1.2	0.6
	1.5	63.98	2.7	4.1
	12	27.83	1.2	14.4
	28	33.10	1.4	39.2
	25	0.71	0.0	0.0
	13	1.53	0.1	1.3
	10	0.04	0.0	0.0
		2380.43	100.0	127.9

CHART B

AREA (IN MZAS) AND PERCENTAGE OF TOTAL AREA OF CROPLAND, PASTURE AND FOREST LAND FOR THE SAMPLE DISTRICTS OF COSTA RICA

	CROPLAND		PASTURE		FOREST LAND	
DISTRICT NUMBER	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA
005	48.90	97	0.50	1	0.80	2
007	863.00	94	24.20	3	30.00	3
008	259.30	78	70.20	21	4.00	1
010	164.30	76	41.50	19	10.00	5
011	142.80	85	17.00	10	7.00	5
012	201.90	68	68.00	23	23.10	9
013	897.80	39	1117.90	49	258.00	12
014	488.10	40	299.30	26	415.20	34
021	784.10	43	742.20	40	289.80	17
026	968.70	30	2038.80	64	135.90	6
029	891.80	26	1828.50	55	599.50	19
031	461.80	38	678.80	55	71.60	7
035	1621.40	44	975.80	27	1013.80	29
040	998.20	14	5237.90	77	522.40	9
045	69.70	86	11.10	14	0	0
046	51.30	96	2.00	4	0	0
047	195.10	98	3.50	2	0	0
048	312.40	32	657.20	67	3.90	1
049	532.30	68	237.20	30	6.10	2
053	471.70	40	580.90	50	101.90	10
054	386.60	49	266.30	34	128.20	17
056	72.10	27	175.90	67	11.60	6
058	315.40	63	173.70	34	8.80	3

CHART B (cont'd.)

	CROPLAND		PASTURE		FOREST LAND	
DISTRICT NUMBER	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA	AREA (in mzas.)	PERCENTAGE OF TOTAL AREA
059	182.80	57	125.30	39	11.10	4
061	333.40	63	188.90	36	2.30	1
070	432.30	96	7.20	2	6.30	2
072	88.30	92	3.80	4	3.80	4
076	257.50	88	31.90	10	1.00	2
078	147.60	87	19.50	11	1.00	2
079	274.40	58	192.50	40	6.00	2
085	76.70	3	939.50	44	1096.50	53
087	425.80	76	65.60	11	66.00	13
088	311.90	62	86.90	17	101.60	21
089	125.90	84	19.60	13	3.20	3
092	1715.80	22	3114.60	40	2820.00	38
093	1704.70	26	3070.60	48	1568.00	26
097	630.00	45	327.00	23	427.90	32
105	1184.80	42	1551.60	55	63.30	3
107	2153.80	35	3282.10	53	714.50	12
109	276.30	55	223.10	44	0.50	1
113	1244.20	38	1803.60	55	194.50	7
121	624.80	69	215.30	24	54.10	7
124	406.10	15	1692.80	62	599.50	23
129	1162.30	47	1047.50	42	244.30	11
130	1091.00	58	600.00	32	172.50	10
131	1201.20	49	913.10	37	298.80	14
135	1019.70	29	2109.90	61	277.20	10
136	21585.20	26	15019.00	18	43920.00	56

CHART B (cont'd.)

DISTRICT NUMBER	CROPLAND AREA (in mzas.)	CROPLAND PERCENTAGE OF TOTAL AREA	PASTURE AREA (in mzas.)	PASTURE PERCENTAGE OF TOTAL AREA	FOREST LAND AREA (in mzas.)	FOREST LAND PERCENTAGE OF TOTAL AREA
143	344.40	37	558.00	60	21.30	3
145	318.60	12	1943.00	78	217.10	10
146	690.60	34	1114.80	55	215.90	11
147	363.40	36	560.00	56	71.60	8
149	1821.70	52	1344.40	38	297.80	10
151	767.20	17	2955.30	67	639.60	16
156	571.10	51	535.80	48	1.60	1
158	304.30	68	122.80	27	17.50	5
159	1424.00	60	511.20	21	420.80	19
161	1035.20	68	306.50	20	163.50	12
162	1055.70	73	199.90	13	181.70	14
163	321.40	17	1116.10	61	384.40	22
171	159.10	3	2585.10	55	2176.00	45
184	1719.20	52	1304.10	40	220.80	8
185	850.70	38	1022.80	45	356.60	17
189	216.80	31	472.00	68	4.50	1
190	1018.40	29	1997.50	58	387.20	13
192	1354.10	42	1391.90	43	443.10	15
195	767.10	26	851.80	29	1283.20	45
196	1516.30	42	1824.60	50	257.40	8
197	1676.00	35	2205.00	46	867.40	19
198	1298.90	43	1025.90	34	690.90	23
200	1206.70	34	976.80	27	1352.60	39
202	333.80	59	117.90	21	108.10	20
204	545.50	44	389.40	31	294.20	25
206	319.80	35	569.50	63	9.20	2
207	162.40	30	361.60	68	6.80	2
216	206.00	14	1038.40	73	172.80	13

CHART B (cont'd.)

DISTRICT NUMBER	CROPLAND AREA (in mzas.)	CROPLAND PERCENTAGE OF TOTAL AREA	PASTURE AREA (in mzas.)	PASTURE PERCENTAGE OF TOTAL AREA	FOREST LAND AREA (in mzas.)	FOREST LAND PERCENTAGE OF TOTAL AREA
220	215.40	22	751.30	77	3.00	1
221	473.50	16	2006.60	68	449.60	16
223	1128.60	13	4302.90	50	3060.70	37
228	1374.40	96	47.50	3	3.80	1
229	977.40	91	80.80	7	12.50	2
234	132.30	93	10.70	7	0	0
235	258.90	69	105.50	28	10.00	3
236	273.50	8	2668.50	84	202.60	8
239	1321.80	69	567.20	29	17.20	2
245	197.90	75	61.20	23	3.00	2
246	734.80	68	267.40	25	63.20	7
252	790.20	47	862.90	51	8.90	2
255	288.00	31	563.90	62	51.20	7
257	367.30	79	94.50	20	1.10	1
261	173.20	76	45.50	20	6.60	4
262	779.00	80	189.20	19	2.70	1
270	2026.30	17	7812.00	68	1503.60	15
289	882.70	21	2747.10	65	555.50	14
290	1480.10	23	3682.10	59	1029.80	18
306	773.00	13	4154.00	70	924.60	17
310	6101.90	44	1515.20	10	6183.10	46
318	17747.60	41	14888.60	34	10114.50	25
323	27273.40	53	8220.40	16	15198.00	31
326	14857.10	20	38571.90	52	19711.00	28

CHART C

TOTAL AGRICULTURAL LAND, GROSS INCOME PER MANZANA, TOTAL COSTS OF PRODUCTION AND NET INCOME PER MANZANA FOR THE SAMPLE DISTRICTS OF COSTA RICA

DISTRICT NUMBER	TOTAL AREA IN CROPLAND AND PASTURE (in mzas.)	GROSS INCOME (per mza.)	TOTAL COSTS OF PRODUCTION FOR ALL AGRICULTURAL ACTIVITIES (in colones)	NET INCOME (per mza.)
005	44.9	1,110.70	78,818.55	- 644.76
007	757.9	2,837.20	1,277,708.53	+1,151.37
008	317.9	1,466.70	432,534.42	+ 106.10
010	205.8	2,552.90	290,831.25	+1,139.72
011	145.1	2,397.90	239,290.29	+ 748.79
012	252.1	1,461.80	326,029.04	+ 168.49
013	1,768.2	719.30	1,040,247.72	+ 130.91
014	726.5	1,291.20	679,857.92	+ 355.36
021	1,311.7	856.80	1,208,053.43	- 64.23
026	3,028.1	498.10	1,196,310.28	+ 103.01
029	2,426.2	301.80	611,117.08	+ 49.87
031	3,145.2	595.40	1,317,645.79	+ 176.47
035	2,475.1	713.70	3,181,063.31	- 571.58
040	5,691.5	234.40	1,232,125.81	+ 17.90
045	84.4	1,299.40	128,135.85	- 218.84
046	51.8	3,910.90	88,919.32	+2,194.35
047	198.7	3,300.10	346,717.85	+1,051.91
048	918.4	1,125.40	530,491.53	+ 547.75
049	706.0	1,923.70	849,927.78	+ 719.85
053	954.8	689.40	473,786.98	+ 193.16
054	563.5	1,231.50	587,841.77	+ 188.35
056	313.5	354.30	138,079.93	- 86.11

CHART C (cont'd.)

DISTRICT NUMBER	TOTAL AREA IN CROPLAND AND PASTURE (in mzas.)	GROSS INCOME (per mza.)	TOTAL COSTS OF PRODUCTION FOR ALL AGRICULTURAL ACTIVITIES (in colones)	NET INCOME (per mza.)
058	473.6	631.80	518,862.31	- 463.73
059	294.2	680.40	276,803.13	- 260.50
061	523.4	1,377.40	586,031.47	+ 257.72
070	442.6	3,394.30	763,295.02	+1,669.71
072	92.4	2,061.30	155,266.76	+ 380.90
076	294.0	2,533.00	462,296.97	_ 960.54
078	162.4	1.708.10	255,582.02	+ 134.30
079	457.5	1,601.60	505,294.79	+ 497.02
085	592.2	232.00	33,325.01	+ 175.71
087	494.7	2,301.20	768,191.87	+ 748.38
088	397.4	2,318.70	556,928.40	_ 917.28
089	145.5	2,065.00	229,930.56	+ 484.67
092	3,733.0	448.90	1,334,699.44	+ 91.34
093	3,783.3	537.90	1,482,901,29	+ 145.93
097	741.4	872.70	452,993.17	+ 261.70
105	2,772.6	1,037.40	1,435,854.56	+ 519.52
107	4,944.4	1,086.60	2,751,563.50	+ 530.05
109	432.9	1,198.90	447,530.54	+ 165.14
113	2,703.2	441.70	1,030,144.44	+ 60.61
121	899.5	2,012.20	1,042,969.37	+ 852.67
124	1,968.6	263.00	353,985.69	+ 83.17
129	1,941.9	1,280.90	1,094,636.08	+ 717.19
130	1,536.0	1,043.40	1,089,788.18	+ 333.86
131	1,723.5	1,163.30	1,438,939.61	+ 328.41

CHART C (cont'd.)

DISTRICT NUMBER	TOTAL AREA IN CROPLAND AND PASTURE (in mzas.)	GROSS INCOME (per mza.)	TOTAL COSTS OF PRODUCTION FOR ALL AGRICULTURAL ACTIVITIES (in colones)	NET INCOME (per mza.)
135	2,428.0	663.50	1,405,394.91	+ 84.62
136	22,140.0	529.70	7,757,463.42	+ 179.27
143	991.7	415.90	422,996.67	- 10.63
145	2,314.9	234.70	392,886.51	+ 65.16
146	1,851.1	618.20	1,015,619.66	+ 69.55
147	935.0	364.00	335,678.30	+ 4.96
149	2,905.2	1,050.60	2,482,479.32	+ 196.12
151	3,337.2	334.40	1,301,845.60	- 55.73
156	1,137.2	1,462.40	1,018,694.48	+ 566.59
158	496.5	1,704.70	584,926.26	+ 526.64
159	1,614.1	1,450.80	1,283,480.91	+ 655.61
161	1,224.0	1,504.00	1,212,441.04	+ 513.42
162	1,110.4	1,996.70	865,267.81	+1,217.47
163	1,365.8	580.20	338,832.49	+ 332.10
171	1,931.8	258.60	233,050.09	+ 137.99
184	2,390.4	1,558.70	2,098,737.87	+ 680.75
185	1,489.9	979.30	1,136,054.91	+ 216.75
189	596.3	727.10	235,686.98	+ 331.88
190	2,527.3	699.80	827,137.01	+ 372.47
192	2,497.7	959.80	1,821,751.93	+ 230.41
191	1,490.8	967.00	930,860.36	+ 342.63
196	2,724.5	1,208.30	233,961.95	+1,122.37
197	3,287.7	1,248.90	1,751,825.35	+ 716.08
198	1,951.9	1,442.50	1,219,569.34	+ 817.70
200	2,011.7	1,583.80	1,834,304.94	+ 671.95
202	409.1	1,026.40	515,716.50	- 234.21
204	911.3	1,414.90	966,938.61	+ 353.89

CHART C (cont'd.)

DISTRICT NUMBER	TOTAL AREA IN CROPLAND AND PASTURE (in mzas.)	GROSS INCOME (per mza.)	TOTAL COSTS OF PRODUCTION FOR ALL AGRICULTURAL ACTIVITIES (in colones)	NET INCOME (per mza.)
206	887.8	1,362.80	566,785.96	+ 724.38
207	466.8	1,028.00	217,948.69	+ 561.10
216	1,140.3	520.70	185,752.24	+ 357.85
220	962.7	1,572.90	455,983.82	+1,109.63
221	2,186.4	965.80	566,900.60	+ 706.52
223	3,291.9	408.80	781,258.21	+ 171.45
228	1,409.0	3,451.50	2,416,684.63	+1,736.34
229	1,058.4	2,866.60	1,730,029.88	+1,232.01
234	143.6	2,223.50	239,152.88	+ 558.09
235	332.5	1,993.90	417,868.86	+ 737.12
236	2,631.0	570.90	485,077.05	+ 386.54
239	1,854.1	2,035.30	2,275,249.56	+ 808.17
245	246.7	2,232.80	311,266.78	+ 971.11
246	891.0	1,738.20	950,569.90	+ 671.37
252	1,599.7	935.70	1,211,261.67	+ 178.52
255	821.5	541.40	431,088.51	+ 16.66
257	519.6	1,941.10	666,245.33	+ 658.83
261	218.2	1,789.30	306,091.11	+ 377.51
262	965.1	1,988.70	1,383,530.06	+ 555.12
270	9,093.6	276.10	1,519,306.97	+ 109.00
289	3,272.0	250.40	620,696,62	+ 60.68
290	4,467.2	239.20	748,007.30	+ 71.76
306	4,522.6	348.70	606,922.74	+ 214.48
310	2,590.9	644.20	780,412.02	+ 342.97
318	25,786.1	3,301.40	7,631,599.04	+3,005.44
323	25,933.7	1,709.20	12,057,457.70	+1,244.24
326	16,267.2	337.80	4,291,574.07	+ 73.99

CHART D

THE YIELDS, GROSS INCOME AND NET INCOME, PER MANZANA, FOR THE AGRICULTURAL ACTIVITIES, BEANS, CORN, COFFEE, SUGAR CANE AND CATTLE FOR THE SAMPLE DISTRICTS OF COSTA RICA

	BEANS			CORN			COFFEE			SUGAR CANE			CATTLE		
DISTRICT NUMBER	Yields per mza. (in cajuelas)	Gross Income per mza. (in colones)	Net Income per mza. (in colones)	Yields per mza. (in fanegas)	Gross Income per mza. (in colones)	Net Income per mza. (in colones)	Yields per mza. (in fanegas)	Gross Income per mza. (in colones)	Net Income per mza. (in colones)	Yields per mza. (in metric tons)	Gross Income per mza. (in colones)	Net Income per mza. (in colones)	Head of cattle per mza.	Gross Income per mza. (in colones)	Net Income per mza. (in colones)
005	25.0	376.0	+ 36.95	5.0	870.00	+ 492.50	5.3	1144.23	- 639.58	--	--	--	10.0	2903.04	+2093.34
007	--	--	--	--	--	--	14.8	3174.03	+1390.22	--	--	--	3.1	1820.07	+1567.61
008	--	--	--	--	--	--	10.0	2154.09	+ 370.28	--	--	--	1.2	261.00	+ 162.93
010	--	--	--	--	--	--	15.0	3230.85	+1447.09	40.7	1951.59	+1362.09	0.1	4.65	- 3.49
011	--	--	--	5.0	870.00	+ 494.50	11.7	2514.87	+ 731.01	1.7	79.98	- 509.52	3.1	2064.07	+1818.22
012	30.7	462.44	+123.37	2.7	473.54	+ 96.02	8.9	1909.27	+ 125.46	21.1	1010.32	+ 420.82	1.3	182.36	+ 74.24
013	13.7	206.41	-132.66	4.8	843.84	+ 466.32	7.1	1521.28	- 262.53	--	--	--	0.9	319.17	+ 248.65
014	13.7	206.28	-132.79	2.3	409.12	+ 31.60	11.3	2431.55	+ 647.74	12.1	581.79	- 7.71	1.2	242.54	+ 142.76
021	10.2	154.36	-184.71	1.7	301.37	- 92.57	5.6	1194.13	- 589.68	6.3	299.94	- 289.56	0.9	263.04	+ 188.28
026	12.7	150.40	- 25.08	2.0	355.64	+ 82.82	7.5	1601.40	+ 396.40	20.4	978.19	+ 388.89	0.6	100.05	+ 46.58
029	14.5	217.89	+ 0.75	1.9	345.87	+ 73.05	5.7	1232.46	+ 27.46	23.4	32.43	+ 532.33	0.5	108.41	+ 64.04
031	10.4	156.75	- 60.39	2.0	356.39	+ 83.57	7.0	1507.95	+ 302.95	29.2	1400.14	+ 810.64	0.8	140.26	+ 76.93
035	8.8	133.14	-137.89	1.9	335.11	- 323.61	4.9	1045.31	-1132.94	14.2	679.95	+ 90.45	0.7	79.46	+ 18.66
040	13.5	202.84	- 68.19	1.7	301.59	+ 28.77	7.3	1563.59	- 220.22	23.9	1145.94	+ 556.44	0.6	90.29	+ 35.66
045	20.0	300.80	- 38.30	--	--	--	6.0	1287.44	- 496.37	--	--	--	0.7	229.36	+ 172.66
046	--	--	--	--	--	--	19.0	4085.43	+2301.62	--	--	--	2.0	170.94	- 9.49

CHART D (cont'd.)

ISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
047	--	--	--	--	--	--	16.0	3426.56	+1642.75	--	--	--	2.0	114.00	- 49.92
048	--	--	--	--	--	--	8.4	1807.29	+ 23.48	14.3	685.57	+ 96.07	1.6	863.10	+ 732.26
049	--	--	--	6.3	1107.27	+ 340.89	10.7	2295.60	+ 511.79	10.0	479.90	- 109.60	--	--	--
053	20.3	306.09	- 32.98	2.8	488.22	+ 110.70	6.9	1483.98	- 299.83	10.0	479.90	- 109.60	0.9	274.24	+ 203.92
054	36.7	552.34	+213.27	1.7	310.93	- 66.59	7.6	1625.47	- 158.34	10.0	479.90	- 109.60	1.3	216.69	+ 110.10
056	23.4	352.33	+ 13.26	2.1	379.36	+ 1.84	2.2	464.95	-1318.86	--	--	--	0.9	209.91	+ 137.72
058	17.5	264.41	- 74.66	3.6	626.40	+ 248.88	4.3	933.77	- 850.04	27.1	1301.65	+ 712.15	0.9	94.99	+ 18.22
059	--	--	--	1.5	267.69	- 109.83	4.6	988.47	- 795.34	28.8	1382.57	+ 793.07	1.1	190.98	+ 100.09
061	25.0	376.00	+ 36.93	1.5	261.00	- 116.52	7.3	1564.46	- 219.35	8.0	383.92	- 205.58	0.2	46.57	+ 31.98
070	20.0	300.8	- 38.27	5.0	870.00	+ 103.60	16.5	3545.09	+1761.28	2.0	95.98	- 493.52	1.4	121.43	+ 12.18
072	--	--	--	--	--	--	9.7	2086.66	+ 302.85	50.0	2399.50	+1810.00	1.8	428.97	+ 277.99
076	--	--	--	--	--	--	14.1	3030.67	+1246.86	--	--	--	0.4	50.08	+ 13.75
078	--	--	--	--	--	--	8.9	1909.99	+ 126.13	--	--	--	0.8	62.66	- 0.21
079	--	--	--	--	--	--	8.5	1835.25	+ 51.44	5.0	239.95	- 349.55	2.0	894.99	+ 736.54
085	3.0	45.12	-225.41	1.0	174.00	- 494.72	8.0	1717.44	+ 512.44	2.0	95.98	- 460.46	0.5	121.26	+ 79.90
087	--	--	--	--	--	--	11.9	2550.50	+ 766.69	10.0	479.90	- 109.60	1.6	624.91	+ 489.60

CHART D (cont'd.)

DISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
088	--	--	--	--	--	--	11.8	2537.71	+ 753.90	--	--	--	1.0	131.65	+ 49.95
089	--	--	--	--	--	--	11.0	2361.65	+ 577.84	--	--	--	3.5	159.13	- 113.78
092	13.1	197.73	+ 13.57	2.1	379.2	- 143.48	6.7	1442.82	+ 91.07	18.7	895.05	+ 341.42	0.8	184.06	+ 116.29
093	11.0	166.15	- 18.01	2.5	439.41	- 83.27	10.0	2148.85	+ 797.10	19.3	927.44	+ 373.81	0.8	146.64	+ 79.94
097	18.9	285.35	+ 14.32	2.6	461.95	- 196.77	7.1	1528.00	+ 323.00	10.8	517.24	- 39.20	1.5	217.03	+ 92.59
105	21.2	319.58	-108.28	2.8	489.91	- 349.11	10.8	2320.75	+ 536.94	50.2	2410.34	+1820.84	1.1	202.26	+ 114.47
107	18.1	273.28	-154.57	3.4	596.73	- 242.29	13.5	2890.29	+1106.48	28.7	1379.51	+ 790.01	0.7	421.90	+ 369.35
109	25.3	381.78	- 46.08	5.2	912.32	+ 73.30	9.3	2002.71	+ 218.90	19.5	937.30	+ 347.80	0.7	225.45	+ 171.20
113	28.1	422.67	- 5.19	2.4	426.57	- 412.45	6.6	1424.19	- 359.62	34.1	1637.72	+1048.22	1.1	123.30	+ 33.44
121	19.8	298.83	- 34.79	2.1	376.76	- 1.80	11.9	2565.19	+ 781.38	48.1	2307.21	+1717.71	1.3	193.75	+ 87.98
124	14.5	218.67	-114.95	1.7	311.47	- 67.09	4.8	1022.59	- 761.22	15.6	746.42	+ 156.92	0.6	79.12	+ 29.26
129	--	--	--	7.5	130.50	+ 862.00	12.7	2717.43	+ 933.62	47.1	2261.52	+1672.02	0.6	264.34	+ 217.62
130	--	--	--	2.0	348.00	- 94.99	10.1	2162.92	+ 379.11	26.6	1274.14	+ 684.64	0.9	160.97	+ 81.87
131	16.6	250.67	-194.52	2.1	372.86	- 70.14	9.7	2092.23	+ 308.42	41.9	2009.79	+1420.29	0.7	106.32	+ 52.04
135	3.1	47.27	-397.92	2.0	365.19	- 77.80	7.7	1648.94	- 134.87	23.9	1140.18	+ 550.68	0.5	103.12	+ 58.60
136	29.9	449.88	+144.06	3.0	528.18	+ 139.34	3.2	691.49	- 212.70	8.5	406.28	- 147.35	0.7	118.47	+ 56.79

CHART D (cont'd.)

DISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
143	15.3	231.05	-209.62	2.0	349.80	- 93.19	5.4	1164.26	- 619.55	14.8	709.31	+ 119.81	0.9	118.62	+ 41.38
145	26.5	399.12	- 41.55	1.4	251.28	- 191.71	5.4	1164.37	- 619.44	11.5	552.98	- 36.52	1.1	152.54	+ 60.36
146	19.3	290.71	-149.96	2.2	395.13	- 47.87	9.8	2047.59	+ 313.78	14.7	705.29	+ 115.79	0.7	95.35	+ 34.34
147	26.4	397.43	- 43.24	1.8	327.53	- 115.46	3.8	805.05	- 978.76	22.1	1062.70	+ 473.20	0.7	77.66	+ 14.91
149	17.6	266.09	- 67.53	1.8	329.71	- 289.37	10.1	2178.51	+ 394.70	34.0	1633.79	+1044.29	0.5	57.07	+ 16.20
151	10.7	161.97	-171.65	2.6	457.89	- 161.19	5.8	1253.33	- 530.48	8.3	400.21	- 189.29	0.5	108.36	+ 65.38
156	11.1	168.16	-277.03	1.8	315.38	- 303.71	14.4	3090.71	+1306.90	13.8	663.39	+ 73.89	0.9	167.11	+ 93.93
158	10.3	155.91	-289.28	1.9	344.81	- 274.27	13.2	2835.05	+1051.24	--	--	--	1.3	468.71	+ 361.13
159	12.5	188.00	-207.35	--	--	--	10.0	2140.46	+ 356.65	36.5	1749.91	+1160.41	0.8	282.52	+ 219.33
161	--	--	--	4.2	732.63	- 106.39	10.9	2349.66	+ 565.85	24.0	1153.45	+ 563.95	1.0	295.05	+ 214.47
162	16.9	254.18	-141.17	2.1	373.46	- 465.56	13.4	2883.09	+1099.28	29.4	1409.18	+ 819.68	1.4	276.69	+ 160.25
163	--	--	--	2.3	406.00	- 433.02	9.6	2065.50	+ 281.69	32.1	1541.78	+ 952.28	0.4	347.40	+ 313.57
171	13.2	199.18	- 72.90	4.0	696.00	+ 401.52	7.3	1564.38	+ 665.19	29.8	1427.82	+ 838.32	0.9	194.32	+ 122.36
184	13.5	204.11	-129.51	4.1	716.47	+ 97.39	12.6	2710.26	+ 926.45	58.9	2827.42	+2237.92	0.6	133.26	+ 80.59
185	12.0	180.48	-153.14	2.8	497.14	- 121.94	7.1	1515.91	- 267.89	17.2	824.51	+ 235.01	0.6	627.19	+ 577.86
189	19.2	289.55	-226.05	1.6	285.45	- 43.55	6.0	1288.08	- 578.62	--	--	--	1.2	377.23	+ 283.08
190	10.6	159.82	-355.78	2.4	433.11	+ 104.11	8.1	1737.19	- 129.51	--	--	--	1.0	601.83	+ 524.96

CHART D (cont'd.)

DISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
192	16.6	250.73	-264.87	2.4	434.36	+ 105.36	10.7	2303.15	+ 436.46	43.6	2094.11	+1537.67	1.0	299.34	+ 220.74
195	25.8	389.51	-126.09	3.5	619.44	+ 290.44	8.4	1805.39	- 61.31	26.9	1291.48	+ 735.04	0.8	458.49	+ 394.30
196	7.8	118.53	-397.07	2.5	441.24	+ 112.24	14.5	3105.33	+1238.63	--	--	--	0.9	378.91	+ 304.71
197	29.9	450.64	- 64.96	2.3	407.53	+ 78.53	12.1	2595.09	+ 728.39	39.8	1911.29	+1354.85	1.0	825.19	+ 744.12
198	18.2	274.96	-240.64	2.4	424.39	+ 95.39	13.5	2892.14	+1025.44	52.0	2494.21	+1937.77	0.8	412.51	+ 344.52
200	18.5	278.93	-236.67	2.0	364.19	+ 35.19	15.2	3264.57	+1397.87	26.4	1260.25	+ 712.81	0.6	130.64	+ 82.76
202	12.0	180.48	-335.12	1.5	261.00	- 505.38	6.7	1442.59	- 341.22	20.0	959.80	+ 370.30	1.2	188.30	+ 86.67
204	--	--	--	--	--	--	10.2	2197.32	+ 413.51	--	--	--	0.7	321.43	+ 262.05
206	--	--	--	--	--	--	11.6	2486.22	+ 702.41	--	--	--	1.0	911.41	+ 834.90
207	--	--	--	--	--	--	6.3	1358.37	- 425.44	--	--	--	1.4	977.03	+ 868.82
216	32.2	485.38	-281.82	1.9	341.34	- 361.24	6.9	1477.50	- 389.20	51.7	2480.37	+1923.93	0.8	402.15	+ 334.45
220	14.5	218.26	-297.34	3.3	579.25	- 264.10	--	--	--	--	--	--	1.4	1301.31	+1190.81
221	11.7	176.56	-339.04	4.0	707.89	- 135.46	--	--	--	--	--	--	0.9	691.35	+ 621.50
223	11.1	167.02	-104.01	2.1	376.49	- 17.45	8.7	1886.17	+ 1947	10.0	479.90	- 76.50	0.9	288.89	+ 214.26
228	14.6	220.59	-190.59	0.6	116.00	- 650.38	16.4	3519.63	+1735.82	6.0	287.94	- 301.56	1.6	3789.04	+3657.31
229	--	--	--	--	--	--	14.7	3161.28	+1377.47	--	--	--	0.7	175.92	+ 121.75

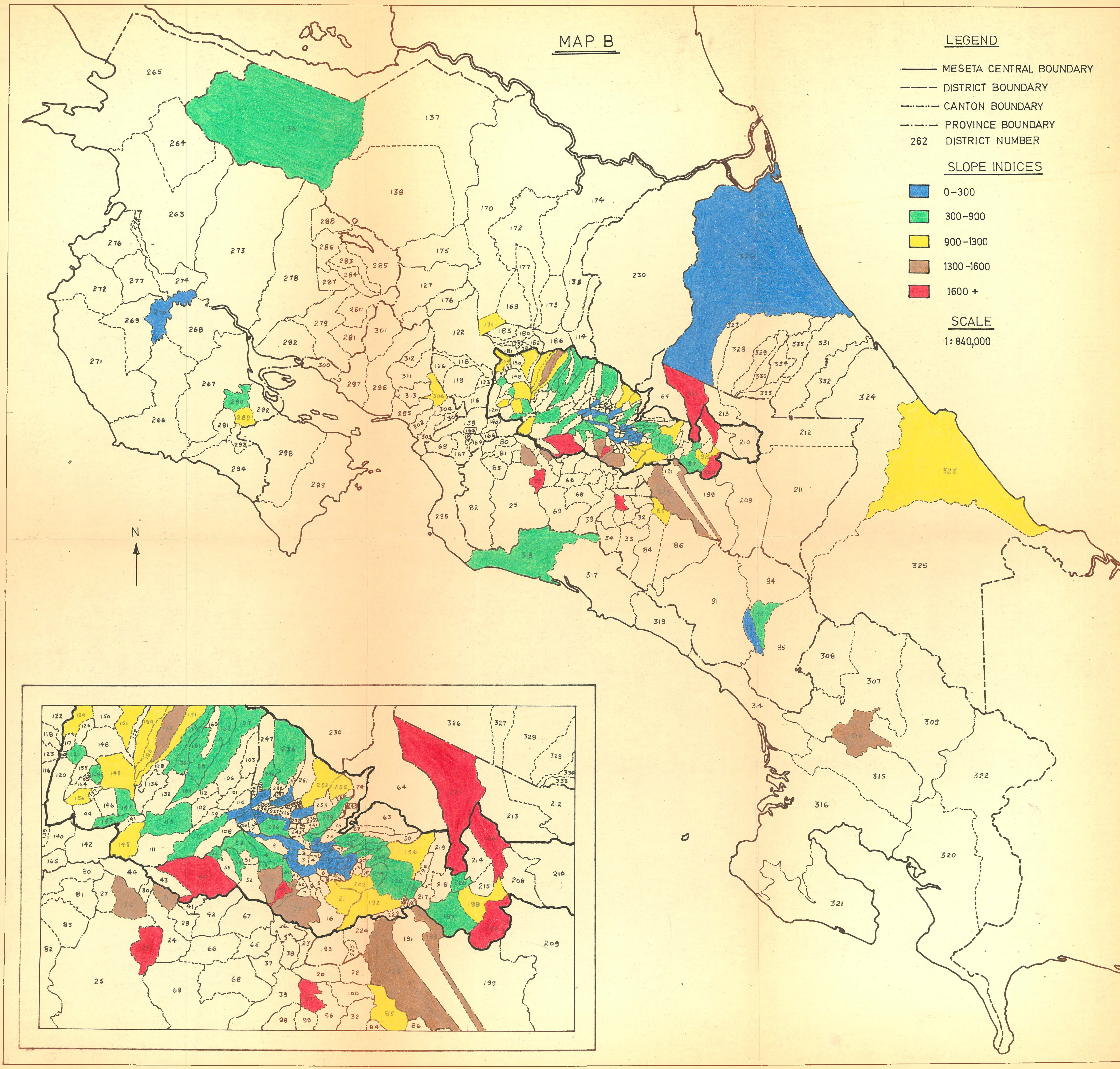
CHART D (cont'd.)

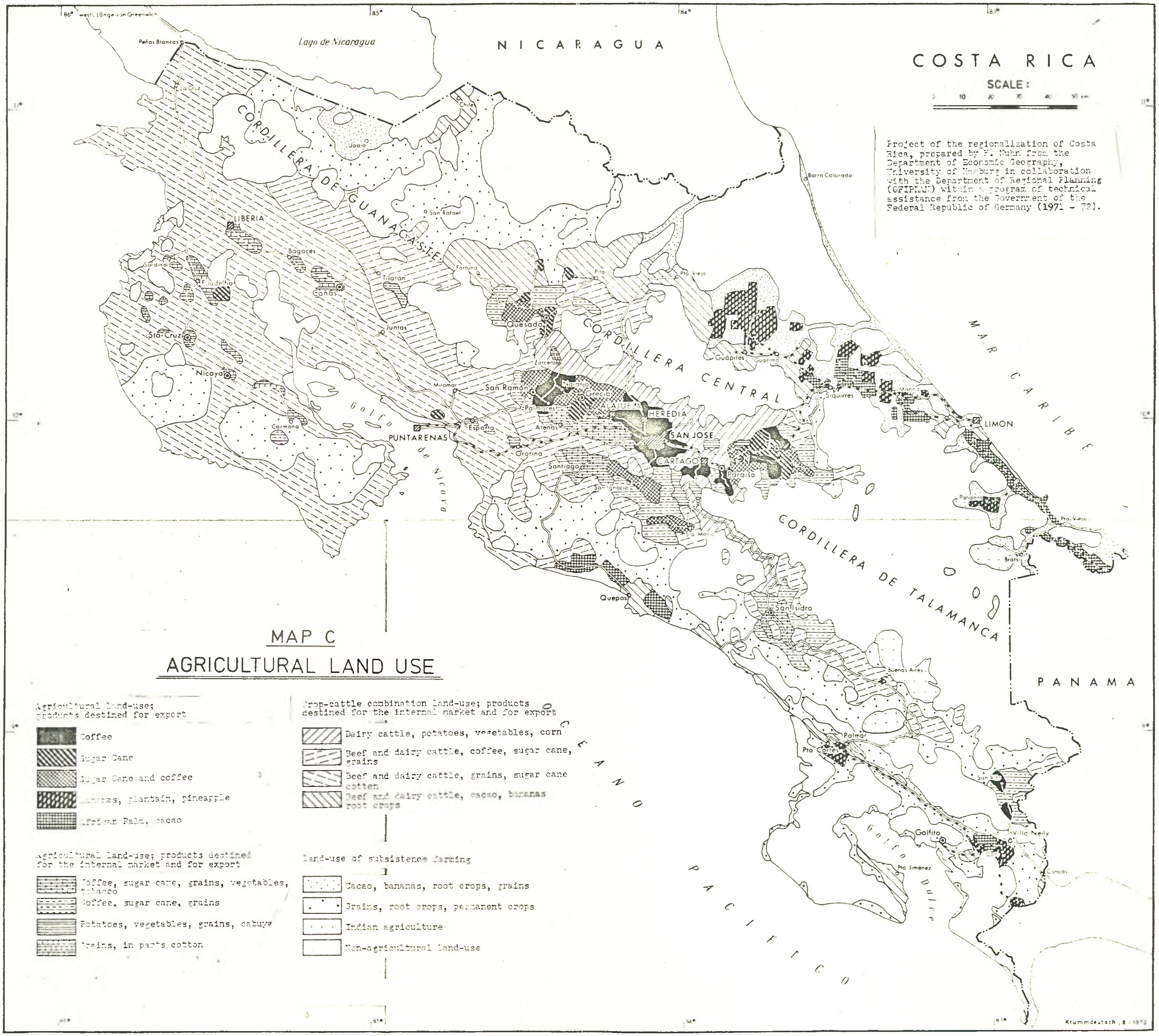
DISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
234	--	--	--	--	--	--	10.2	2181.08	+ 397.27	--	--	--	3.2	965.64	+ 700.96
235	--	--	--	--	--	--	13.4	2868.53	+1084.72	10.0	479.90	- 109.60	1.8	517.14	+ 368.14
236	--	--	--	1.2	214.15	- 552.23	7.3	1575.78	- 208.03	15.8	756.63	+ 167.13	0.6	471.57	+ 423.25
239	21.0	316.51	- 94.67	2.6	456.53	- 309.85	13.4	2892.79	+1098.98	14.2	682.93	+ 93.43	1.3	302.76	+ 198.01
245	31.6	475.26	+ 64.08	3.5	624.62	- 214.41	13.2	2841.56	+1057.75	68.5	3287.63	+2698.13	1.7	474.87	+ 335.05
246	7.0	105.28	-305.90	2.0	348.00	- 491.02	11.9	2559.67	+ 775.86	14.1	674.78	+ 85.28	1.2	452.09	+ 357.95
252	13.5	204.11	-207.07	2.4	431.27	- 335.11	10.5	2250.70	+ 466.89	14.8	711.01	+ 121.51	1.0	187.60	+ 108.04
255	22.8	344.25	- 66.93	2.5	442.91	- 323.47	6.4	1373.86	- 409.95	62.4	2995.74	+2406.24	0.7	164.59	+ 106.12
257	26.3	396.00	- 15.18	2.5	446.52	- 319.86	13.4	2883.77	+1099.96	30.2	1447.44	+ 857.94	2.4	928.19	+ 730.65
261	24.0	360.96	- 50.22	--	--	--	10.1	2168.75	+ 384.94	12.5	599.88	+ 10.38	1.0	246.54	+ 167.70
262	12.0	180.48	-230.70	3.6	638.00	- 128.38	11.6	2488.96	+ 705.15	6.3	299.94	- 289.56	1.0	68.30	- 9.00
270	13.3	201.02	+ 34.60	2.5	448.24	- 126.00	--	--	--	--	--	--	1.0	158.54	+ 69.90
289	23.8	358.58	+154.00	1.8	316.11	- 6.09	4.2	902.54	- 1.64	14.1	677.91	+ 124.28	1.1	111.66	+ 18.30
290	13.8	208.18	+ 3.60	2.0	354.38	+ 32.18	2.9	614.72	- 289.47	7.5	359.93	- 193.71	0.7	109.31	+ 46.57
306	15.8	238.64	-196.10	1.7	310.19	- 81.81	3.5	759.35	- 445.65	13.5	648.50	+ 94.87	0.7	81.55	+ 37.22
310	24.6	370.25	+ 81.31	2.1	366.27	+ 94.05	2.6	565.76	- 785.99	22.3	1068.30	+ 514.67	0.5	64.29	+ 24.14

CHART D (cont'd.)

DISTRICT NUMBER	BEANS Yields per mza. (in cajuelas)	BEANS Gross Income per mza. (in colones)	BEANS Net Income per mza. (in colones)	CORN Yields per mza. (in fanegas)	CORN Gross Income per mza. (in colones)	CORN Net Income per mza. (in colones)	COFFEE Yields per mza. (in fanegas)	COFFEE Gross Income per mza. (in colones)	COFFEE Net Income per mza. (in colones)	SUGAR CANE Yields per mza. (in metric tons)	SUGAR CANE Gross Income per mza. (in colones)	SUGAR CANE Net Income per mza. (in colones)	CATTLE Head of cattle per mza.	CATTLE Gross Income per mza. (in colones)	CATTLE Net Income per mza. (in colones)
318	12.9	195.40	- 17.18	1.5	262.98	- 34.16	2.4	522.94	- 682.06	8.4	405.17	- 148.46	1.0	133.79	+ 45.33
323	11.3	171.28	-100.80	2.5	437.52	+ 73.26	11.4	2450.23	+1098.48	1.4	68.56	- 485.07	0.9	168.07	+ 96.66
326	22.0	332.04	+ 59.95	2.1	372.75	+ 8.48	3.5	759.23	- 144.96	24.8	1190.25	+ 636.62	0.7	106.93	+ 44.48

PRECIO DE VENTA ₡1.00 (UN COLON)


MAP B
LEGEND
MESETA CENTRAL BOUNDARY
DISTRICT BOUNDARY
CANTON BOUNDARY
PROVINCE BOUNDARY
262 DISTRICT NUMBER
SLOPE INDICES
0–300
300–900
900–1300
1300–1600
1600 +
SCALE
1: 840,000
N


COSTA RICA
SCALE:
0 10 20 30 40 50 km
Project of the regionalization of Costa Rica, prepared by H. Nuhn from the Department of Economic Geography, University of Hamburg in collaboration with the Department of Regional Planning (OFIPLAN) within a program of technical assistance from the Government of the Federal Republic of Germany (1971 - 72).
NICARAGUA
Lago de Nicaragua
CORDILLERA DE GUANACASTE
CORDILLERA CENTRAL
CORDILLERA DE TALAMANCA
MAR CARIBE
OCEANO PACIFICO
PANAMA
Golfo de Nicoya
Golfo Dulce
Peñas Blancas
La Cruz
Upala
Chile
Barra Colorado
San Rafael
LIBERIA
Bagaces
Tilarán
Fortuna
Pita
Pto. Viejo
Filadelfia
Cañas
Quesada
Guápiles
Guarimo
Juntas
Sta. Cruz
Nicoya
Carmona
Miramar
San Ramón
Zarcero
Naranjo
Grecia
Palmares
ALAJUELA
HEREDIA
SAN JOSE
CARTAGO
Paraiso
Siquirres
Matina
LIMON
PUNTARENAS
Esparta
Atenas
Orotina
Santiago
San Ignacio
Sta. María
Pandora
Pto. Viejo
Bratsi
Quepos
San Isidro
Buenos Aires
Palmar
Pto. Cortés
San Vito
Golfito
Villa Neily
Pto. Jiménez
Canoas
Krummdeutsch, 8/1972
MAP C
AGRICULTURAL LAND USE
Agricultural land-use; products destined for export
Coffee
Sugar Cane
Sugar Cane and coffee
Bananas, plantain, pineapple
African Palm, cacao
Agricultural land-use; products destined for the internal market and for export
Coffee, sugar cane, grains, vegetables, tobacco
Coffee, sugar cane, grains
Potatoes, vegetables, grains, cabuya
Grains, in parts cotton
Crop-cattle combination land-use; products destined for the internal market and for export
Dairy cattle, potatoes, vegetables, corn
Beef and dairy cattle, coffee, sugar cane, grains
Beef and dairy cattle, grains, sugar cane cotton
Beef and dairy cattle, cacao, bananas root crops
Land-use of subsistence farming
Cacao, bananas, root crops, grains
Grains, root crops, permanent crops
Indian agriculture
Non-agricultural land-use

TOPOGRAPHIC MAPS SHOWING THE MESETA CENTRAL

(MAPS 'D' TO 'N')

SCALE

1 : 200,000

LEGEND

———	TERRAIN UNIT BOUNDARY
—·—·—	DISTRICT BOUNDARY
34.51(3)	AREA (IN SQ.KIL.) OF THE TERRAIN UNIT IN THE DISTRICT (SLOPE CATEGORY NO.)
(67)→	SAMPLE POINT IN THE FIELD OBSERVATION TEST

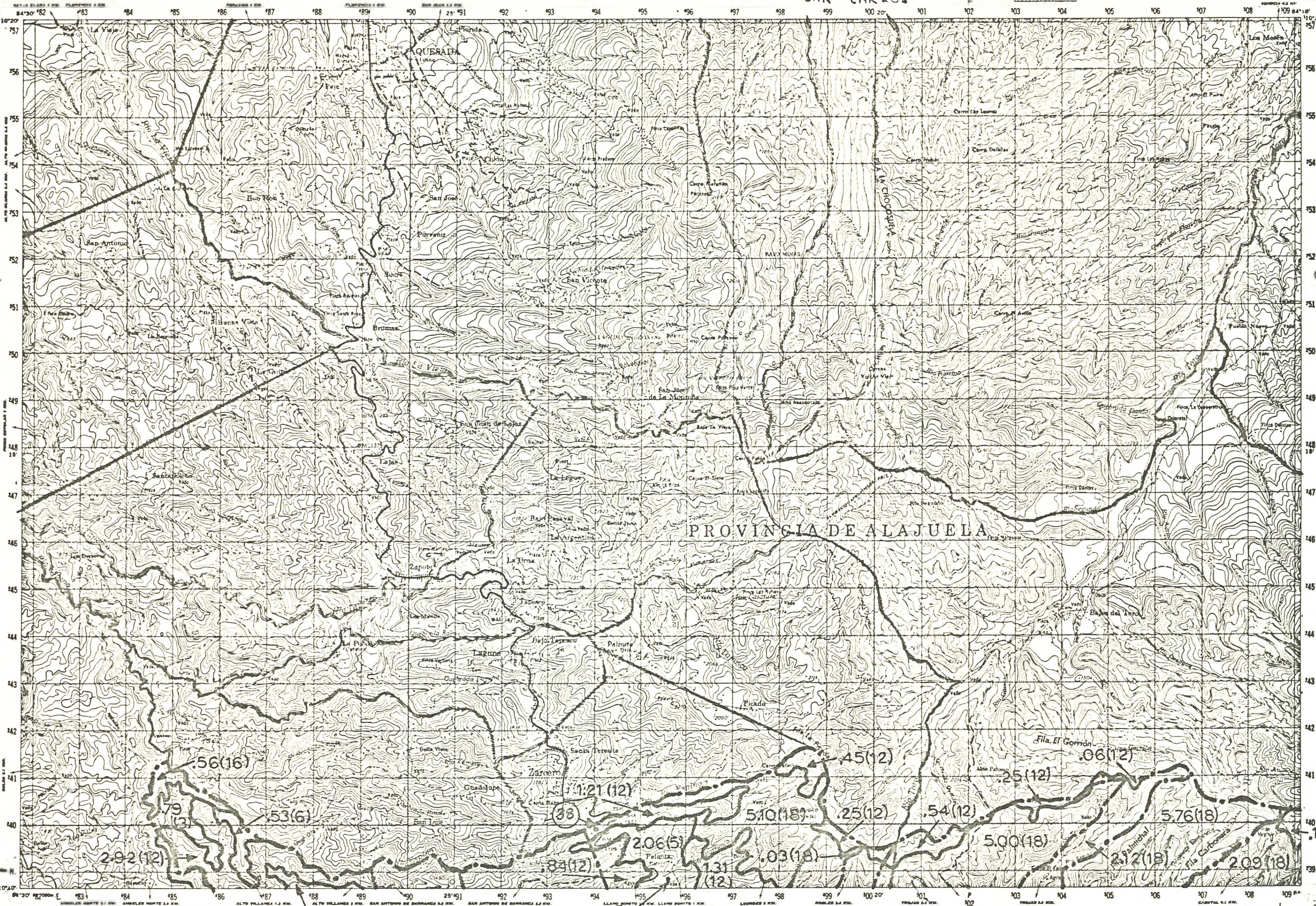
MAP D

COSTA RICA 1:50,000

EDICION 1-IGNCR

QUESADA

HOJA 3346 IV



Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

LITOGRAFIADO POR INSTITUTO GEOGRAFICO DE COSTA RICA

Preparado por el Instituto Geográfico de Costa Rica, dependencia del Ministerio de Transportes, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1956 y 1960 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico de Costa Rica y el Servicio Geodésico Interamericano. Clasificación de campo y actualización fotoplanimétrica 1963-1964-1965.

INSTITUTO GEOGRAFICO NACIONAL

SAN JOSE, COSTA RICA

SIGNOS CONVENCIONALES

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS

COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT

ESFEROIDE CLARKE DE 1866

FUNDAMENTAL DE OCOTEPEQUE

LAS LINEAS NEGRAS NUMERADAS INDICAN CADA KILOMETRO DE LA CUADRICULA LAMBERT, COSTA RICA NORTE

INDICE DE HOJAS ADYACENTES

QUESADA, COSTA RICA

MAP E

COSTA RICA 1:50,000

EDICION 1–IGNCR

NARANJO

HOJA 3346 III

E761
Edición 1–IGNCR 1967

Preparado por el Instituto Geográfico Nacional, dependencia del Ministerio de Transportes, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1945–1956 y 1961 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico Nacional y el Servicio Geodésico Interamericano. Clasificación de campo y actualización fotogramétrica 1963–1964–1966 y 1966

Escala 1:50,000

LITOGRAFIADO POR INSTITUTO GEOGRAFICO NACIONAL

INSTITUTO GEOGRAFICO NACIONAL
SAN JOSE, COSTA RICA

SIGNOS CONVENCIONALES

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS
COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT
ESFEROIDE CLARKE DE 1866
FUNDAMENTAL DE OCOTEPEQUE

INDICE DE HOJAS ADYACENTES

Artículo 18 - Ley No 59 de Julio de 1944
RESERVADA LA REPRODUCCION

NARANJO, COSTA RICA

MAP F

COSTA RICA 1:50,000 — EDICION 1-IGCR — RIO GRANDE — HOJA 3345 IV

Escala 1:50,000

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS

PROYECCION LAMBERT

SIGNOS CONVENCIONALES

INDICE LIMITROFE

INDICE DE HOJAS ADYACENTES

LITOGRAFIADO POR INSTITUTO GEOGRAFICO DE COSTA RICA

E761 Edición 1-IGCR 1965

RESERVADA LA REPRODUCCION

RIO GRANDE, COSTA RICA

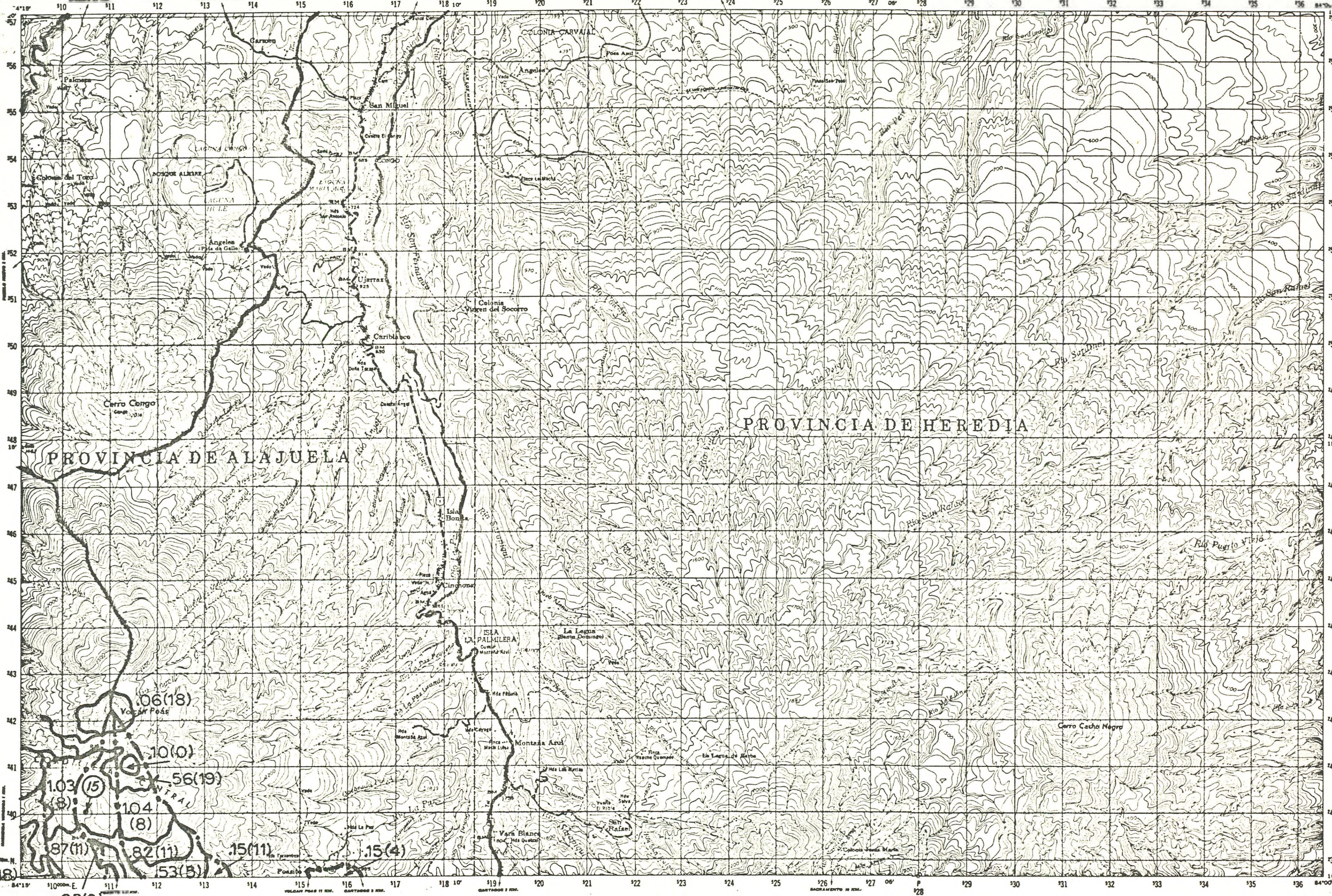
MAP G

POAS

COSTA RICA 1:50,000

EDICION 1-IGNCR

HOJA 3346 I



E761
Edición 1-IGNCR 1967

Preparado por el Instituto Geográfico Nacional, dependencia del Ministerio de Transportes, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1956, 1960 y 1961 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico Nacional y el Servicio Geodésico Interamericano. Clasificación de campo y actualización fotoplanimétrica 1964 y 1966.

Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

1 ½ 0 1 2 3 Millas Terrestres Inglesas

LITOGRAFIADO POR INSTITUTO GEOGRAFICO NACIONAL

INSTITUTO GEOGRAFICO NACIONAL
SAN JOSE, COSTA RICA

SIGNOS CONVENCIONALES

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS
COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT
ESFEROIDE CLARKE DE 1866
FUNDAMENTAL DE OCOTEPEQUE

LAS LINEAS NEGRAS NUMERADAS INDICAN CADA KILOMETRO DE LA CUADRICULA LAMBERT COSTA RICA NORTE

LAS TRES ULTIMAS CIFRAS DE LOS NUMEROS DE LA CUADRICULA HAN SIDO OMITIDAS

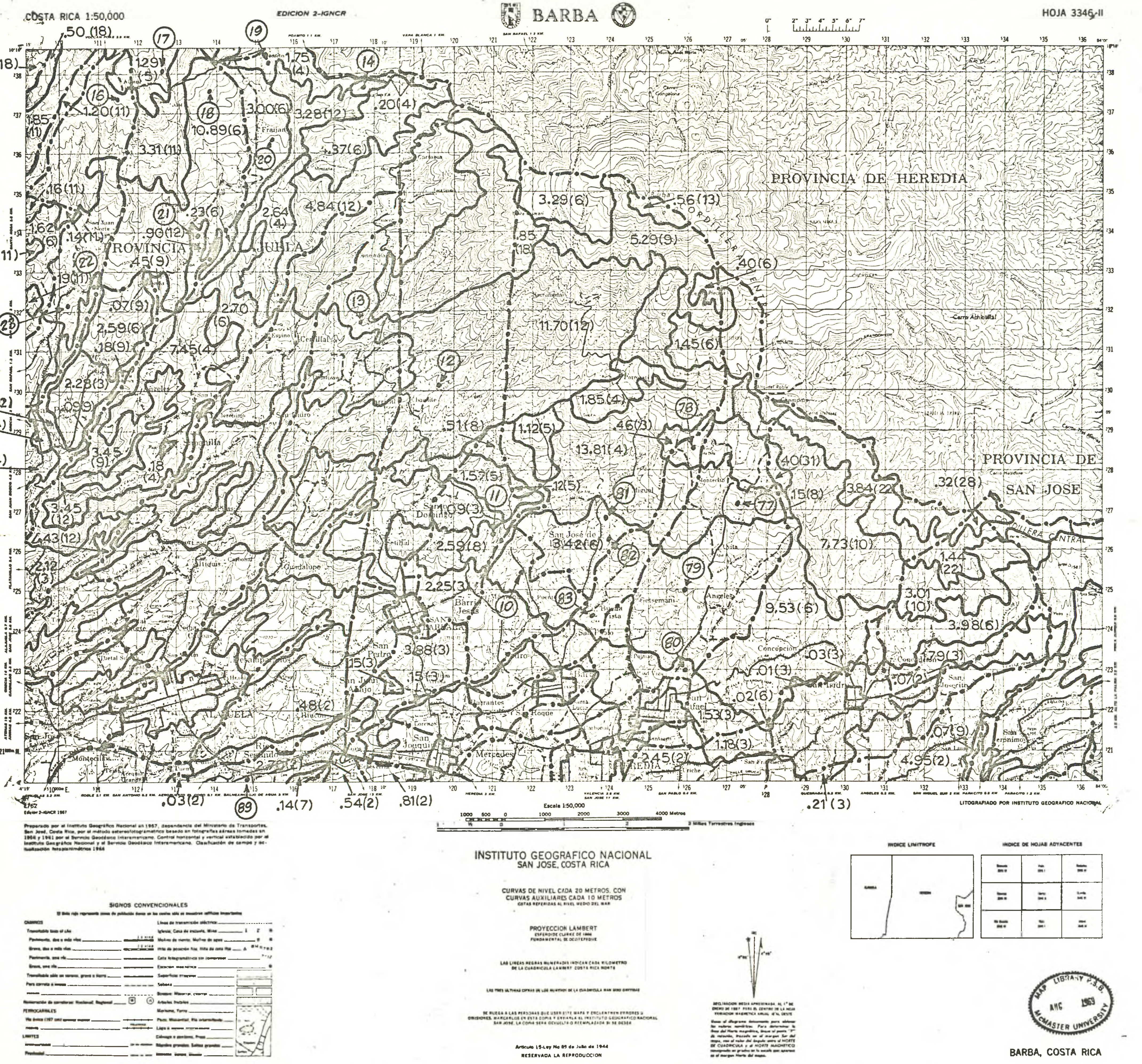
SE RUEGA A LAS PERSONAS QUE USEN ESTE MAPA Y ENCUENTREN ERRORES U OMISIONES, MARCARLOS EN ESTA COPIA Y ENVIARLA AL INSTITUTO GEOGRAFICO NACIONAL SAN JOSE. LA COPIA SERA DEVUELTA O REEMPLAZADA SI SE DESEA

INDICE LIMITROFE

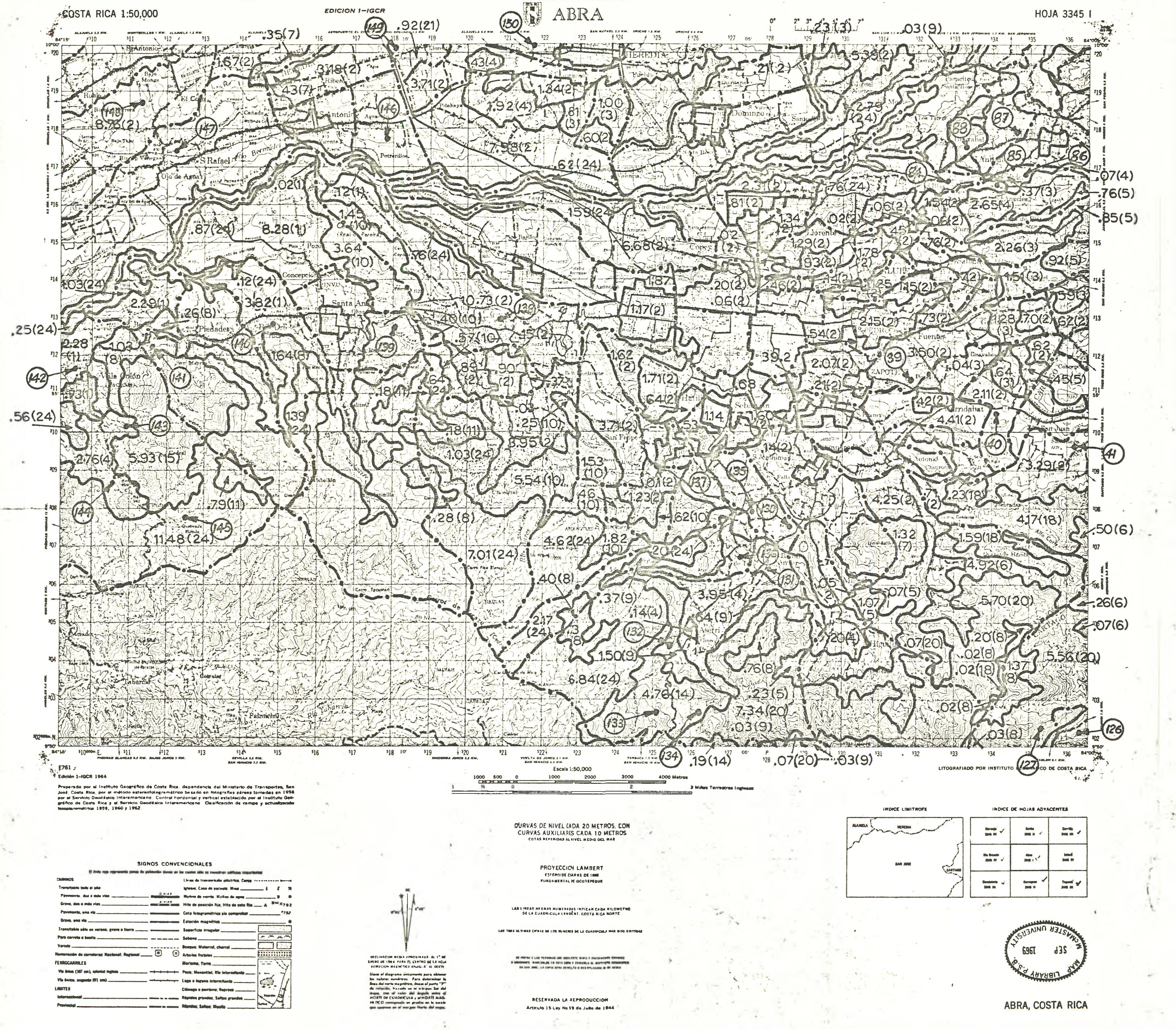
INDICE DE HOJAS ADYACENTES

POAS, COSTA RICA

MAP H


BARBA
COSTA RICA 1:50,000
EDICION 2-IGNCR
HOJA 3346-II
PROVINCIA DE HEREDIA
PROVINCIA DE ALAJUELA
PROVINCIA DE SAN JOSE
CORDILLERA CENTRAL
LITOGRAFIADO POR INSTITUTO GEOGRAFICO NACIONAL
INSTITUTO GEOGRAFICO NACIONAL
SAN JOSE, COSTA RICA
CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS
PROYECCION LAMBERT
SIGNOS CONVENCIONALES
INDICE LIMITROFE
INDICE DE HOJAS ADYACENTES
RESERVADA LA REPRODUCCION
MAP LIBRARY P.S.B.
AUG 1969
McMASTER UNIVERSITY
BARBA, COSTA RICA

MAP I


COSTA RICA 1:50,000
EDICION 1-IGCR
ABRA
HOJA 3345 I
HEREDIA
Escala 1:50,000
LITOGRAFIADO POR INSTITUTO GEOGRAFICO DE COSTA RICA
SIGNOS CONVENCIONALES
CURVAS DE NIVEL CADA 20 METROS. CON CURVAS AUXILIARES CADA 10 METROS
PROYECCION LAMBERT
RESERVADA LA REPRODUCCION
INDICE LIMITROFE
INDICE DE HOJAS ADYACENTES
ABRA, COSTA RICA

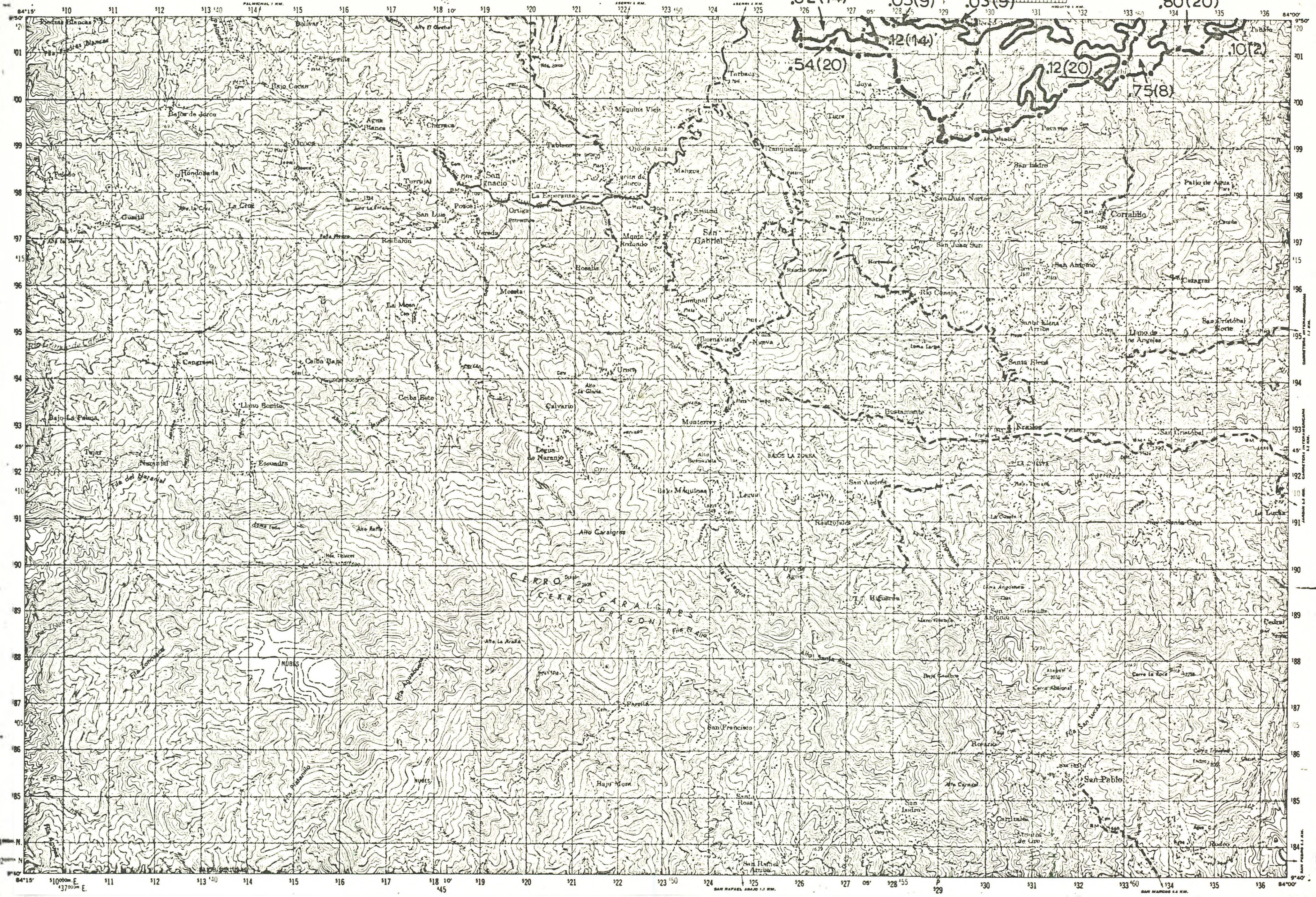
MAP J

COSTA RICA 1:50,000

EDICION 1–IGCR

CARAIGRES

HOJA 3345 II



5761 -
Edición 1–IGCR 1961

Preparado por el Instituto Geográfico de Costa Rica, departamento del Ministerio de Obras Públicas, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1956 y 1957 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico de Costa Rica y el Servicio Geodésico Interamericano.

Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

1 ½ 0 1 2 3 Millas Terrestres

CURVAS DE NIVEL CADA 20 METROS, CON
CURVAS AUXILIARES CADA 10 METROS

COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT

FUNDAMENTAL DE OCOTEPEQUE

LAS LINEAS NEGRAS NUMERADAS INDICAN CADA KILOMETRO
DE LA CUADRICULA LAMBERT COSTA RICA NORTE

LAS TRES ULTIMAS CIFRAS DE LOS NUMEROS DE LA CUADRICULA HAN SIDO OMITIDAS

SIGNOS CONVENCIONALES

CARAIGRES, COSTA RICA

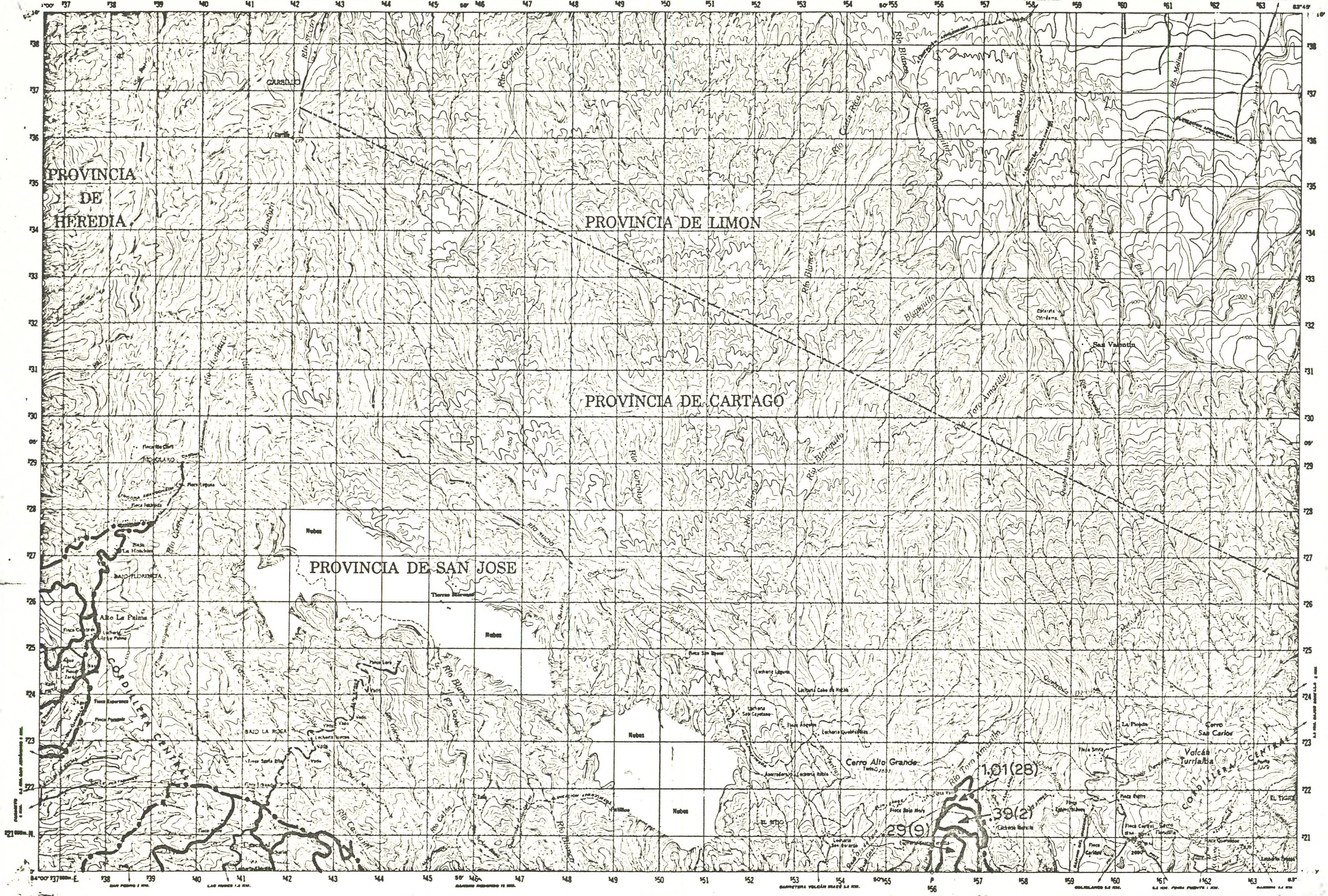
MAP K

COSTA RICA 1:50,000

EDICIÓN 1-IGNCR

CARRILLO

HOJA 3446 III



Edición 1-IGNCR 1967

Preparada por el Instituto Geográfico Nacional, dependencia del Ministerio de Transportes, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1956-1960 y 1961 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico Nacional y el Servicio Geodésico Interamericano. Clasificación de campo y actualización 1965 y 1966.

INSTITUTO GEOGRAFICO NACIONAL
SAN JOSE, COSTA RICA

SIGNOS CONVENCIONALES

Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

1 ½ 0 1 2 3 Millas Terrestres Inglesas

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS
COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT

LAS LINEAS NEGRAS NUMERADAS INDICAN CADA KILOMETRO DE LA CUADRICULA LAMBERT, COSTA RICA NORTE

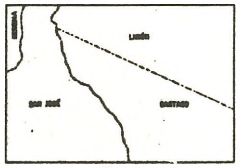
SE RUEGA A LAS PERSONAS QUE USEN ESTE MAPA Y ENCUENTREN ERRORES U OMISIONES, MARCARLOS EN ESTA COPIA Y ENVIARLA AL INSTITUTO GEOGRAFICO NACIONAL SAN JOSE. LA COPIA SERA DEVUELTA O REEMPLAZADA SI SE DESEA

DECLINACIÓN MEDIA APROXIMADA AL 1° DE ENERO DE 1967 PARA EL CENTRO DE LA HOJA
VARIACIÓN MAGNÉTICA ANUAL 6' AL OESTE

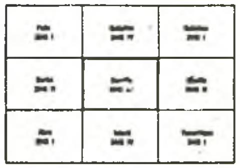
Úsese el diagrama solamente para obtener los valores numéricos. Para determinar la línea del Norte magnético, úsese el punto "P" de rotación, trazado en el margen Sur del mapa, con el valor del ángulo entre el NORTE DE CUADRICULA y el NORTE MAGNETICO consignado en grados en la escala que aparece en el margen Norte del mapa.

LITOGRAFIADO POR INSTITUTO GEOGRAFICO NACIONAL

INDICE LIMITROFE



INDICE DE HOJAS ADYACENTES



CARRILLO, COSTA RICA

MAP L

COSTA RICA 1:50,000

CARTAGO

EDITION 1-AMS

SHEET 3445 IV
SERIES E763

3 Statute Miles

4000 Meters

4000 Yards

3 Nautical Miles

CONTOUR INTERVAL 20 METERS
WITH SUPPLEMENTARY CONTOURS AT 10 METER INTERVALS
CURVAS DE NIVEL CADA 20 METROS
CON CURVAS AUXILIARES CADA 10 METROS

TRANSVERSE MERCATOR PROJECTION

PRINTED BY ARMY MAP SERVICE, CORPS OF ENGINEERS

CARTAGO, COSTA RICA
STOCK NO. E763X34454***01

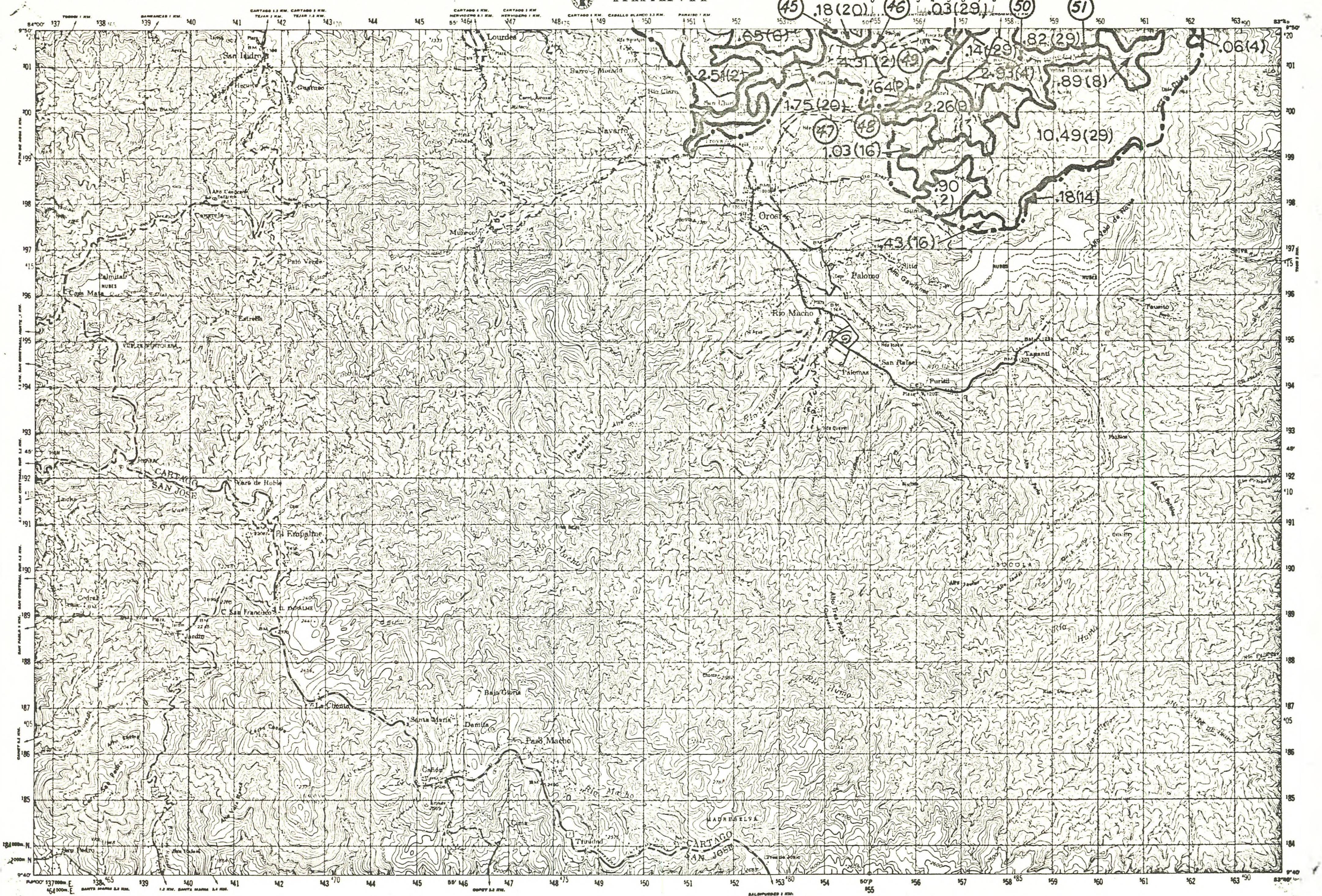
MAP M

COSTA RICA 1:50,000

EDICION 1-IGCR

TAPANTI

HOJA 3445 III



E761
Edición 1-IGCR 1963

Preparado por el Instituto Geográfico de Costa Rica, dependencia del Ministerio de Obras Públicas, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1954 y 1960 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico de Costa Rica y el Servicio Geodésico Interamericano. Clasificación de campo 1954 - 1960 y 1961

Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

1 ½ 0 1 2 3 Millas Terrestres Inglesas

LITOGRAFIADO POR INSTITUTO GEOGRAFICO DE COSTA RICA

CURVAS DE NIVEL CADA 20 METROS, CON CURVAS AUXILIARES CADA 10 METROS.
COTAS REFERIDAS AL NIVEL MEDIO DEL MAR

PROYECCION LAMBERT
ESFEROIDE CLARKE DE 1866
FUNDAMENTAL DE OCOTEPEQUE

LAS LINEAS NEGRAS NUMERADAS INDICAN CADA KILOMETRO DE LA CUADRICULA LAMBERT, COSTA RICA NORTE

INDICE LIMITROFE

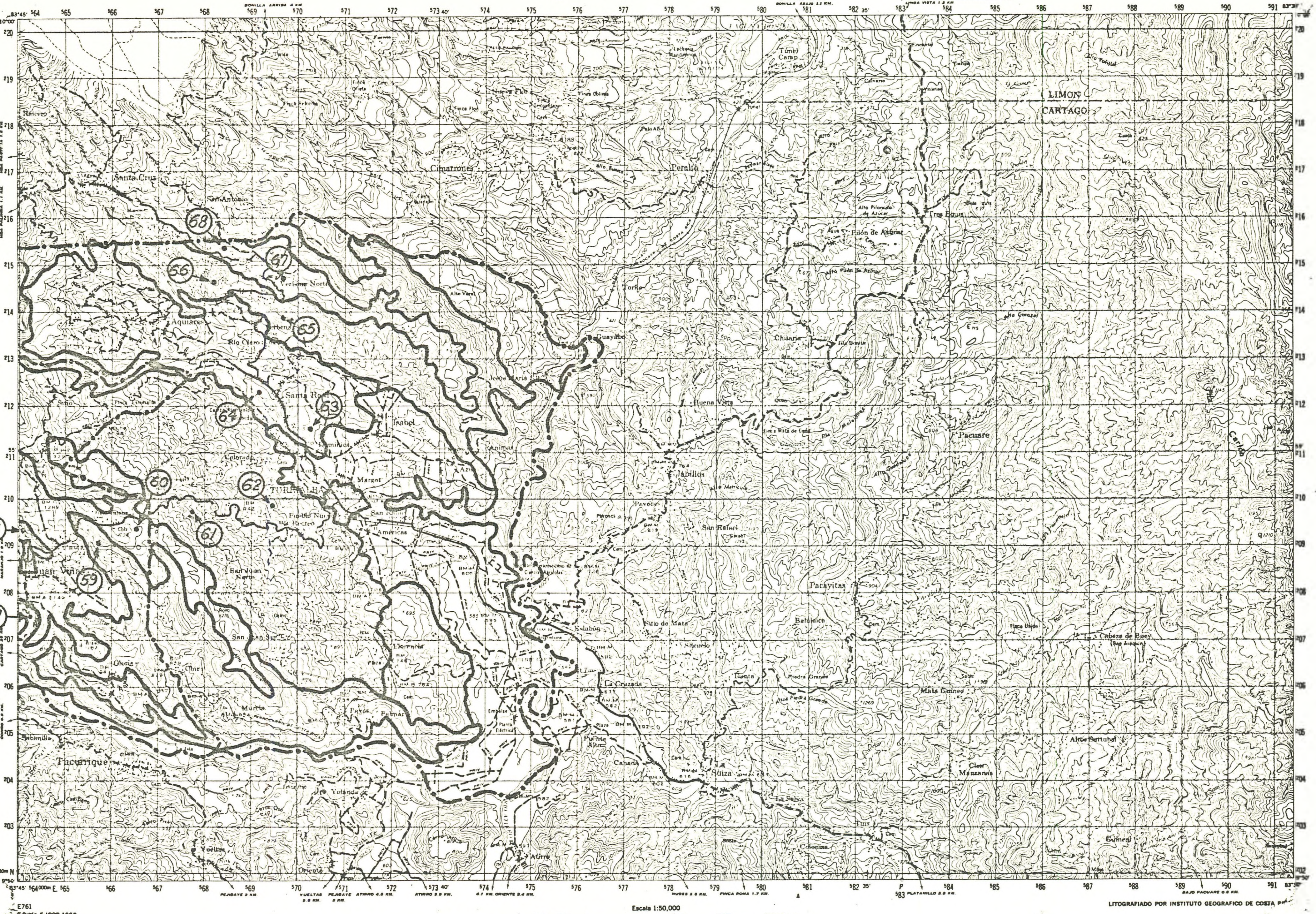
INDICE DE HOJAS ADYACENTES

SIGNOS CONVENCIONALES

TAPANTI, COSTA RICA

MAP N

COSTA RICA 1:50,000 EDICION 1-IGCR TUCURRIQUE HOJA 3445 I



LITOGRAFIADO POR INSTITUTO GEOGRAFICO DE COSTA RICA

E761
Edición 1-IGCR 1963

Preparado por el Instituto Geográfico de Costa Rica, dependencia del Ministerio de Obras Públicas, San José, Costa Rica, por el método estereofotogramétrico basado en fotografías aéreas tomadas en 1956 y 1961 por el Servicio Geodésico Interamericano. Control horizontal y vertical establecido por el Instituto Geográfico de Costa Rica y el Servicio Geodésico Interamericano. Clasificación de campo y actualización fotoplanimétrica 1959 y 1961

Escala 1:50,000

1000 500 0 1000 2000 3000 4000 Metros

1 ½ 0 1 2 3 Millas Terrestres Inglesas

CURVAS DE NIVEL CADA 20 METROS, CON
CURVAS AUXILIARES CADA 10 METROS

PROYECCION LAMBERT

SIGNOS CONVENCIONALES

DIAGRAMA DE COMPILACION

INDICE LIMITROFE

INDICE DE HOJAS ADYACENTES

TUCURRIQUE, COSTA RICA