A TEST OF THE ECONOMIC RELEVANCY OF THE HOLDRIDGE LIFE ZONE SYSTEM

Thesis for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

George R. Gebhart

1966

This is to certify that the

thesis entitled

A TEST OF THE ECONOMIC
RELEVANCY OF THE HOLDRIDGE LIFE ZONE SYSTEM

presented by

GEORGE RICHARD GEBHART

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Economics

Major professor

Date November 10, 1966

O-169

ABSTRACT

A TEST OF THE ECONOMIC RELEVANCY OF
THE HOLDRIDGE LIFE ZONE SYSTEM

by George R. Gebhart

The purpose of this study is to test the economic relevancy of a theory of climatic determinism proposed by Dr. Leslie R. Holdridge of the Tropical Science Center, San Jose, Costa Rica. Holdridge's thesis is that different combinations of the three climatic factors - heat, precipitation, and moisture - between areas will result in different ecological relationships for those areas. Ranges of the three climatic factors are established on a logarithmic base, and the concurrence of these ranges define what Holdridge calls "life zones." Field work in the American Tropics has shown that these life zones correlate well with distinct changes in the natural vegetation. Given this "natural" relationship, Holdridge theorizes that many other variables in the social sciences and natural sciences will be influenced by these specific ranges of the three climatic parameters. Economic variables, especially those in the agricultural sciences, are expected to be related to these ranges in the climatic parameters. This study attempts to establish empirically the degree of this relationship for certain economic variables.

It is hypothesized here that productivity, technology, cost of production, and land-use vary by life zone. To test this hypothesis two life zones are compared for differences in the above variables, and an attempt is made to connect the differences found to the

variations in the climatic parameters. These comparisons are made on the basis of a sample of farms from each of the life zones which was extracted from the Costa Rican Census of Agriculture of 1963. An additional comparison is based on a sample of all farms in those political districts of Costa Rica falling within the two life zones.

Productivity is measured in terms of the output per manzana of rice, corn, and beans. Both samples were compared by life zone for this analysis. Technology is defined as "the method of production," and is compared by life zone in the production of corn. Data on technology were collected by interviewing a sample of thirty farmers in each of the two life zones. Costs of production between life zones in the production of corn are compared using data collected during the same interviews. Land use is compared by life zone for the farms comprising the sample from the Census of Agriculture and the sample of political districts. A classification of land use which exhausts all possible uses of the land is the basis for this comparison.

The variables productivity and costs of production are quantifiable and are compared for statistically significant variations. This consists of computing the t-statistic from the ratio of the difference in the mean to the standard error of the difference, and then either accepting or rejecting the null-hypothesis at the .05 level of probability. Differences in the operations involved in the production of corn are considered as differences in technology, and variations in the percentages of land falling into the various categories are taken as indicative of differences in land-use.

No statistically significant differences were found between life zones in productivity. A distinct difference was found in the technology used in the two life zones, but this seemed to be related more to differences in topography than in the climatic parameters. The difference in the costs of production was statistically significant, but was related to the difference in topography. Differences in land-use, especially the difference in the percentages of the life zones planted in permanent crops, did seem to be related to the difference in heat between the two life zones. The results of this test give very little support to the claims of economic relevancy for the Holdridge Life Zone System.

A TEST OF THE ECONOMIC RELEVANCY OF THE HOLDRIDGE LIFE ZONE SYSTEM

By

George R. Gebhart

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Economics

1966

G43527
4/19/61

ACKNOWLEDGMENT

I would like to express my appreciation and gratitude to Dr. John Hunter for his assistance, encouragement and patience throughout the course of this work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATION

CHAPTER I

INTRODUCTION

The consanguinity of ecology and economics is implicit in much of the research undertaken within either of these two disciplines, but there is a dearth of studies directed towards specifically examining this kinship. The purpose of this study is to investigate this kinship by applying economic analysis to variations on an ecological base.

In 1947, Dr. Leslie R. Holdridge invented what has come to be known as the Holdridge Life Zone System.[1] This system is a method of classifying groups of plant associations into higher order groupings so as to facilitate their identification and use. These life zones (or groupings of plant associations) are determined by certain ranges of the three climatic parameters: heat, precipitation, and moisture; and a given site can be placed within its correct life zone on the basis of data concerning these climatic parameters. A life zone can be defined as a geographical area having amounts of heat, precipitation, and moisture falling within given ranges. Thus, based on the Holdridge system, an area having 1) a mean annual biotemperature above 24 degrees centigrade (heat) 2) an average total annual precipitation of from 2000 to 4000 millimeters (precipitation), and 3) a potential evapotranspiration ratio of between 1.00 and 0.50

---

[1]Leslie R. Holdridge, Life Zone Ecology, Tropical Science Center, San Jose, Costa Rica.

(moisture), would be in the tropical moist forest life zone.[2]

The natural vegetation within a life zone is thought to be distinct from that in any other life zone; and the current research on the system by Dr. Holdridge and his associates is directed towards establishing this difference. They hold that the differences in the three climatic parameters dictate different plant associations and groupings of plant associations in the various life zones, as well as different characteristic species and subspecies. Emanating from this proposition is a whole host of variations that could exist among these life zones. The ecologists believe that these differences do exist, and that they could be useful as a basis for policy-making on the part of governments or others interested in improving and conserving the resource productivity of the earth.

Economics is one of the areas in which the ecologists are especially vociferous concerning important variations by life zones. They feel that these variations are especially numerous in agriculture, but do not restrict their expectations of variation to this area. Thus, they feel that production in industry, the cost of that production, the economics of plant location, transportation costs, and a host of other factors will vary by life zone, and that a knowledge of these variations could be useful in solving a multitude of problems that face industry. They see the Holdridge System as a method of classifying data in many disciplines in such a way that the work and decisions of that discipline

---

[2]A more complete description of this system can be found in Chapter II. This brief description is given to introduce the reader to the system and to illustrate how the climatic parameters delineate the life zones.

might be facilitated. In addition, they are convinced that Holdridge's three climatic parameters have a definite influence on many variables from seemingly unrelated areas, and that policies based on a knowledge of this influence can be used to improve both the performance of the economy and the culture of the people. It is within this context that the present study falls.

The purpose of this study is to provide a partial test of the economic relevancy of the Holdridge Life Zone System. Almost all of the research to date on this system has had to do with its ecological and biological aspects. This study attempts partially to fill this gap by investigating the relationship between this system and certain economic variables.

The economic variables with which this study is concerned are in the field of agriculture primarily because this is the area that has the most obvious and direct relationship to the climatic factors which form the basis of the Life Zone System. An additional reason for choosing agriculture is the urgency felt today to help underdeveloped countries produce more food to save their thousands from famine.

The basic hypothesis of this study is that there are significant differences between life zones in economic variables, i.e., that measurable economic differences exist in various life zones. Definitely these are related to the factors that determine the life zones, and they have economic importance in that they determine what can be produced, the cost of production, the distinct technologies required, etc. If this hypothesis is substantiated, the questions of where to plant what, how much to plant, how much fertilizer to use, what methods to use and many others could be answered by a thorough knowledge of the life zone within which the area falls. The Holdridge system could be very useful to governments in planning for agricultural development and to farmers moving into virgin areas if a close connection could be found between these economic variables and the life zone system.

The more specific hypothesis embracing the variables tested in this study is that there are differences in the productivity, in the technology needed, in the cost of production, and in the use made of the land between the tropical premontane wet forest life zone and the tropical moist forest life zone, as these life zones are defined in the Holdridge Life Zone System.[3]

Productivity is measured for three crops -- rice, corn, and beans - in terms of the output per manzana (an area of approximately 1.7 acres).

The second variable, technology, is defined very broadly as the methods used in planting, cultivating, harvesting, and marketing the crop, and is compared by life zone in the production of corn. Thus, a difference in the method of preparing the land for planting or in the number of times the crop is cultivated makes for a difference in technology. The specific aspects of this definition will be discussed in the chapter on technology.

For the third variable, the cost of production, corn is again the crop chosen for study. Cost of production includes all of the actual and imputed costs of planting, cultivating, harvesting, and marketing the corn. These costs are compared for each of the

---

[3]These life zones are defined more specifically in Chapter II.

distinguishable methods of production in each of the two life zones, and the total cost of production for the various farms in the sample is compared by life zones to see if any differences are present. Cost of production is measured as the cost per unit of output and the cost per manzana.

The last variable, land use, includes all uses to which the land is currently being put in the two life zones. These uses are grouped into appropriate categories reflecting general land use patterns, such as annual crops, permanent crops and pasture. An attempt is made to see if the use of the land by the farmers in their respective life zones differs, and to try to relate any difference found to those factors delineating the life zone.

The methodology used for this study consisted of selecting a sample of farms within each of the two life zones, and then interviewing the farmers concerning their methods of production, the productivity, the use of inputs, and the land use. In addition, the Census questionnaires from the 1963 Census of Agriculture in Costa Rica[4] for the farms in this sample were obtained and certain data extracted from them. A second sample was formed out of certain of the political districts of Costa Rica to supplement the analysis based on the primary sample. A district had to have at least 85 per cent of its land area within one of the two life zones to be included in this sampling. The data were then compared to see if discernible differences between life zones could be discovered in the four variables.

---

[4]This study was carried out in Costa Rica where the author spent a year on the staff of the Associated Colleges of the Midwest Central American Field Program.

The differences that were discovered between the life zones were then related to the parameters that define the life zones in an attempt to find a connecting link between the variation in the parameters and the difference in the variable being studied. In some cases it was possible to make such a connection, but in others an outside factor seemed better to explain the variation in the economic variable.

The Holdridge Life Zone System is a relatively new and almost completely untested theory of climatic determinism. There have been attempts in the past to devise such a classificatory scheme as the Holdridge model, some of which Holdridge mentions in his book,[5] but they have never proved of much value even to the ecologists and biologists. The primary reason for this failure is that they have not been able to establish satisfactorily a natural base; that is, their boundaries have not coincided well with changes in the natural vegetation. According to the ecologists and biologists working with the system, the Holdridge System has overcome this difficulty by the discovery of a logarithmic relationship of change in the natural vegetation which corresponds with a logarithmic change in the climatic parameters. This logarithmic base has its counterpart in other ecological relationships, and is the main factor differentiating the Holdridge System from other unsuccessful classificatory systems.

The only research done specifically on the Holdridge Life Zone System from an other than natural science point of view is contained in several unpublished reports by students connected with this Associated Colleges of the Midwest Central American Field Program at

---

[5] Ibid., pp. 9-13.

the Tropical Science Center in San Jose, Costa Rica. None of these, however, were concerned with agriculture, or even closely related to economics.

Moreover, since the system devised by Dr. Holdridge has never received much support from the rest of the scientific community, there has been a paucity of research directly relating the climatic parameters of heat, precipitation, and moisture to productivity in agriculture, etc. There has been considerable research both in the United States and in other countries on what to plant in a given area, how much fertilizer to use, at what depth to plant, etc., but nothing has been done to relate the various combinations of these climatic parameters to economic variables in the way envisioned by Dr. Holdridge and his associates. For example, the Rockefeller studies on hybrid corn in Mexico discovered which types of corn grow best in the climate that is found in that area of Mexico where the studies were carried out, but there was no attempt to generalize the results of that research to other areas of the world with similar climate. The fact that some of the varieties that have proved best for that area have also been successful in other areas of the world is prima-facie evidence in favor of an approach along the lines proposed by the ecologists for the Holdridge System.

The contribution that could be made to the science of agriculture by the relationship foreseen in the Holdridge System is very great indeed. If the research were carried out in sufficient detail, simply by knowing the values for the climatic parameters one would know what yields to expect from certain crops, what types of fertilizer to use and in what quantities, which insects and other plagues to expect, and one would have a host of other valuable information concerning production, input and output, and related matters. Considering the role that agriculture plays in developing nations, such information would be invaluable as a planning device. Its importance is echoed by Douglas H. K. Lee who writes: "There is even need for far more complete and particularized climatological information on tropical countries, in form and detail that will allow adequate analysis of the effect of these conditions on agricultural, pastoral, industrial, and social development."[6]

Another contribution that could be made by studies such as those anticipated here, would be toward the knowledge of the technology that has been developed by the farmers indigenous to the areas who have presumably adapted their practices as best they could to the climatic and cultural conditions as they have found them. This knowledge would provide a substantial base upon which to launch a program of improvement in agriculture, that would have a good chance of success. Then from the variety of practices being used in a given area those that show the most promise could be subjected to more careful scrutiny and promotion. Some students of the subject feel that this is a prerequisite for successful research in this area. Sufrin and Wolf write: "Special stress was placed in the foregoing analysis on the need to select from available technological alternatives those which would maximize productivity of existing capital and of new capital formation. The first requirement for implementing this approach is a selective study of comparative

---

6 Douglas H. K. Lee, Climate and Economic Development in the Tropics, Council on Foreign Relations, (Harper and Brothers, N. Y., 1957), p. 174.

technologies."[7] Such information would indicate which transplanted technology would be most likely to work in an underdeveloped country and which would not. The choice of technology actually used of course, would depend on input prices as well as the productiveness of the technology.

Chapter II presents a more thorough description of the life zone system and its relationship to economic development, with emphasis upon both its theoretical and its practical aspects. Chapter III is a description of the methodology used in comparing the two life zones. Chapter IV takes up the relationship between productivity and the life zone system, and Chapter V deals with differences in technology by life zone. Chapter VI relates cost of production to life zones, and Chapter VII discusses variations in land use between life zones. Finally Chapter VIII presents the conclusions of the analysis, along with the limitations to them. Appendix A contains reproductions of the two questionnaires used in the interviews, and Appendix B contains the computations for the standard errors for the various statistical analysis.

---

[7] Sidney C. Sufrin, and Charles Wolf, Jr., Capital Formation and Foreign Investment in Underdeveloped Areas; Maxwell School Series, (Syracuse University Press, 1958), p. 50.

CHAPTER II

LIFE ZONE ECOLOGY - THE LIFE ZONE SYSTEM[1]

The life zone system used as a basis for comparative analysis of economic variables in this study was invented by Dr. Leslie R. Holdridge, who first described it in Science[2] in 1947. Since that time there has been considerable research done on the system, but there have been no major changes made in its basic thesis. Most of the research has involved testing the accuracy of the system, mapping various countries in Central America and northern South America with reference to the system, and refining certain measures used in delineating its parameters. Practically all of this research has been done by ecologists and geographers, and only recently have social scientists become interested. Thus, while it has been tested thoroughly (and proved of value) from an ecological point of view, almost nothing has been done to see if it has social and economic significance. At the present time there are a few studies of an economic and social nature being carried out on the system in Costa Rica.[3]

---

[1]This chapter draws heavily upon the following two works: Leslie R. Holdridge, Life Zone Ecology, Central American Field Program, Associated Colleges of the Midwest, San Jose, Costa Rica, 1964 and, Joseph A. Tosi, Jr., "Climatic Control of Terrestrial Ecosystems: A Report on the Holdridge Model", Economic Geography, Vol. XL, No. 2 (1964).

[2]Leslie R. Holdridge, "Determination of World Plant Formations from Simple Climatic Data", Science, 105 (2727), (1947), pp. 367-368.

[3]At the Tropical Science Center, Apartado 2732, San Jose, Costa Rica.

The purpose of this chapter is to describe as simply yet as thoroughly as possible the mechanics of the Life Zone System and to discuss the theoretical relationships between the system and economic development. The rest of the study seeks to explore these relationships and to test their validity.

The life zone system is essentially a division of the climatic spectrum along lines that seem to correspond with natural divisions of the earth's vegetation. Dr. Holdridge theorized that each species-population should have evolved (i.e., should have become specialized through selective adaptations)... "to successfully compete and survive as a member of the natural community within only a limited sector of the earth's broad climatic spectrum."[4] Therefore, he felt that the vegetation within these limited climatic ranges... "should precisely reflect the integrated operation of the climatic conditions prevailing over that vegetation."[5] In other words, there should be distinctive characteristics of the vegetation within each of these limited climatic ranges, and furthermore, these characteristics should have evolved over long periods of time due to the influence of certain climatic factors. Wherever the same climatic factors exist on the surface of the globe these distinctive characteristics of the vegetation should be found.

The purpose of classifying the vegetative mass is the purely pragmatic one of providing a basis on which comparisons between areas can be made. Ecology has long suffered from the lack of a system for

---

[4]Joseph A. Tosi, Jr., "Climatic Control of Terrestrial Ecosystems: A Report on the Holdridge Model," Economic Geography, Vol. XL, No. 2 (1964), p. 174.

[5]Ibid.

classifying vegetation, and while there have been sporadic attempts to devise such a system, not one has won universal acceptance by ecologists. Dr. Holdridge's system may fill this void, but much more research needs to be done to determine the full extent of its significance.

BASIC DETERMINANTS OF LIFE ZONES

To provide a system by which the tremendous masses of vegetation can be classified there must be established some order out of the complex vegetation, (i.e., some distinctive characteristics of the vegetation must be delineated), and some of the ecological factors which have a primary influence on the characteristics must be recognized. Only then will it be possible to correlate natural characteristics of the vegetation with the ecological factors responsible for their evolution.

One approach toward establishing this correlation is to determine first the distinctive characteristics of the vegetation, and then to relate these to the various ecological factors. Ecologists generally agree that the plant association is the basic unit of vegetation.[6] Due to the large number of distinct associations, however, groupings of these are necessary to facilitate the organization of data and for general comparative work. But this is not as easy as it might seem. Holdridge points out several reasons why it is impossible to construct

---

[6]"A plant association is a dominant community of plants which, in its natural state, has a physiognomy distinct from that of all other plant associations. Such an association may be characterized regionally or locally by certain indicator species of the community. There are four types of plant associations: climatic, edaphic, atmospheric, and hydric...Furthermore, there are various combinations of the latter three types." _Ibid._, p. 175.

these groupings by working upward from specific association descriptions.[7] The tremendous amount of work and expense involved precludes the collection and study of plant associations in a museum. In addition, man has been very active in altering these associations in the field so that at the present time, except in the most remote places, it is impossible to find them in an untouched state. In fact, in some areas the natural vegetation has long since been removed completely, and it would take centuries before nature could restore it. The large number of plant associations is another obstacle to this approach.

Another possibility would be to group the plant associations scientifically on the basis of taxonomic species. However, the same associations on different continents may comprise two or more almost entirely distinct sets of species. In addition, man's past interference makes it difficult to determine whether a species has ever existed in a given area, or whether man's activity has eliminated it. Again the tremendous number of species is an obstacle.

Since the above approaches presented serious problems, Holdridge looked to the possibility of organizing the various ecological factors into a system that permitted the grouping of the natural units of vegetation. In other words, he reversed the process by concentrating first on determining which ecological factors could be used in the system, and then relating some vegetational characteristics to the parameters of these factors. The various factors that could be used

---

[7] Leslie R. Holdridge, Life Zone Ecology, Central American Field Program, Associated Colleges of the Midwest, San Jose, Costa Rica, (1964), p. 8.

include climatic, edaphic, and atmospheric, but since the system was intended for use on a global basis, only those factors which affect the entire area could be used. Only a few of the climatic factors satisfy this requirement, all other factors being local in extent. As Holdridge points out, "...this does not mean that they (other factors) are not significant in defining the associations, but simply that they do not lend themselves to global categorization."[8] Of the climatic factors, only heat, precipitation, and moisture seem to be world wide and capable of subdivision into equivalently valued groupings. These factors produce universal characteristics in the vegetation that are quite distinct from those produced by the more localized effects of the less extensive ecological factors.

The solution was to divide the climatic spectrum into equally valued ranges with which vegetative characteristics could then be correlated. Thus, he deduced, "...that the general characteristics of climate in any given locality might be determined objectively from comparative observations of quantified vegetational parameters in the natural plant communities and, conversely, that weather station data might be employed to determine, in terms of these same parameters, what the vegetational climaxes had been and might again become in the absence of human disturbances of natural community equilibrium"[9] Holdridge's system differs from other accepted classificatory systems in that, "...it is neither a classification of climate nor a classification of vegetation but is, rather, a classification of the relationship which

---

[8] Ibid.

[9] Tosi, op. cit., p. 175.

exists between them. It differs in another important respect also: the classification was derived experimentally from comparative observations of natural vegetation as related to climatic factors over a very wide range of geographical environments. Its bases have not been drawn arbitrarily but accord with observable phenomena in nature."[10] Thus, the system is "natural" in the sense that the limits of the equivalently valued groupings of climatic data correspond to observable limits in certain parameters of the natural vegetation, and therefore, the limits to a life zone can be determined either from climatic data or from field observations of the vegetation. This "naturalness" is important, for it provides a basis for believing that other social, economic, and ecological variables may be related to life zones, whereas if this base did not exist - if the system were completely arbitrary - there would be no a priori reason why these other types of variables might be related to the climatic parameters.

The Climatic Parameters[11]

Holdridge's application of his theory in the field involved trying to set down the correct parameters of temperature and rainfall as boundaries between the major units of vegetation. In doing so he found that these parameters, and the related vegetational units, increased logarithmically. This logarithmic base found in nature is nothing new

---

[10] Tosi, op. cit., p. 175.

[11] The reader should refer to the life zone chart on page 25 in reading this section.

to the biological sciences,[12] which again leads one to appreciate the "naturalness" of the Holdridge system. His three (climatic) factors - heat, precipitation, and moisture - which determine the boundaries of the vegetational units increase logarithmically in delineating those boundaries. Having made this discovery it was relatively easy to extend the parameters to encompass the range of climate found on earth. Recent work on the system by ecologists has been confined to proving the correlation between the vegetational units and the parameters, and to mapping large areas of the American tropics. Invariably the identification of the life zone in the field for this mapping was confirmed by subsequent reference to climatic data.

Temperature

The measure of heat used in the Holdridge system is the sum of the average daily positive temperatures (Centigrade) divided by the number of days in the year, which is designated as the mean annual biotemperature. This differs from mean annual temperature in that only positive temperatures are used. In areas where the temperature never falls below 0° Centigrade mean annual temperature and mean annual biotemperature are the same, but where there are below 0° Centigrade temperatures, the two differ. This is an important distinction for the Holdridge system since at temperatures below 0° Centigrade vegetative life is inactive, and this period of dormancy must be taken into

---

[12] For example, it has been found that when an element is a limiting factor in plant nutrition, additions of the element up to the amount that could be utilized by the plant must be increased in logarithmic progression to obtain a sequence of equal increase in yield.

account in developing vegetative characteristics for correlation with the temperature parameters.

As was mentioned earlier, these temperature values increase logarithmically to cover the range of temperatures found on earth. The earth's climate is divided into seven latitudinal regions from tropical to polar; tropical, low subtropical, temperate, cool temperate, boreal, subpolar, and polar. In addition, there exists a sequence of altitudinal belts rising above the basal, sea-level biotemperature belt of climates in each latitudinal region that contains mountains or plateaus reaching up into cooler and less-dense air. For example, in the tropical basal latitudinal region where there are mountains it is possible to find all six altitudinal belts: subtropical, lower montane, montane, subalpine, alpine, and nival. For each latitudinal belt away from the tropical toward the poles the number of altitudinal belts that can possibly exist is reduced by one. Thus, above the cool temperate latitudinal belt there can be only three altitudinal belts - subalpine, alpine, and nival. What this means is that if you consider an area within the tropical latitudinal belt which is devoid of elevations much above sea-level, then it is impossible to have anything but the tropical basal life zones existing within that area. But if in the same area higher elevations do exist, it is possible to have any or all of the life zones existing within that latitudinal area.

The existence of these altitudinal belts is important from a socio-economic point of view, as well as from an ecological point of view. It is wrong to conceive of the "tropics" as having a uniform, hot humid, wet climate, as has been done much too often in the past. There is a wide variety of climate within the latitudinal range

generally included in the definition of "tropic."[13] In like manner, it follows that there is a broad spectrum of socio-economic differentiation based on, or related to, these differences in climate. For example, different climates certainly contribute to differences in demographic patterns since people have a preference for cooler, drier climates and avoid the hot, wetter climates.

One other heat characteristic of importance to the Holdridge scheme is the presence (or absence) of killing frosts. In the field work of correlating vegetational changes with the climatic parameters, it was found that there were definite changes in vegetation when one moved from an area without killing frosts to an area with such frosts. Also, it was found that this change did not always occur at the same temperature, nor did the critical temperature (killing-frost temperature) coincide with the logarithmically spaced climatic parameter. Moreover, in the wetter districts it was found that the line of vegetational change did not coincide with the line of killing frosts, but occurred at a lower level of elevation than the latter. Holdridge concluded that a combination of high humidity and <u>near</u> frost temperature could bring about a change in vegetation similar to that of a killing frost. Thus, the critical temperature line which provides the boundary between the two sub-life zones, subtropical (premontane) and lower montane (see chart on page 25), occurs over a range of biotemperature, and its

---

[13] A recent conference on productivity and innovation in agriculture in the underdeveloped countries recognized this diversity to a limited extent when it considered four different climatic areas. The varying problems of these areas were studied, and recommendations made for them separately. (See David Hapgood (ed.), <u>Policies for Promoting Agricultural Development</u>, Center for International Studies, Massachusetts Institute of Technology, Cambridge, Massachusetts.) 1965.

position indicates an average value for frost occurrence.

Precipitation

Precipitation is the second major climatic factor determining life zones, and its measure is the mean annual total of water in millimeters which falls from the atmosphere as rain, snow, hail, or sleet. Dew and other water that condenses on the surface of the earth are excluded from this measure because standard precipitation measuring devices are not designed to measure them. As with the mean annual biotemperature values, the precipitation values delineating the life zones increase logarithmically, and include almost the entire range of precipitation found on earth. The exceptions are so rare that it was not considered necessary to include them.

Moisture

The third climatic factor determining life zones is humidity. Humidity is the relationship between temperature and precipitation, and one must be careful in trying to correlate either of these singly with humidity. As Holdridge points out, "There is often a bit of confusion in the linking of humidity directly with precipitation. Although within any given region or along a given temperature line, there is a direct correlation of humidity with precipitation, when the total world environment is considered, such is not the case. The same mean annual precipitation which gives rise to wet humidity conditions in the Subpolar Region or Alpine belt results only in arid conditions when it falls in the lowland tropics."[14] The reason for this is that whenever

---

[14] Holdridge, <u>op. cit</u>., p. 27.

the temperature is above freezing moisture is constantly being returned to the atmosphere by evaporation (from the soil and other surfaces) and by transpiration (the physiological return of water from plant tissues to the atmosphere). As Tosi reminds us, "...the supply of moisture available to plants is not exclusively a function of precipitation."[15]

Holdridge uses the potential evapotranspiration ratio as his measure of moisture (humidity). This ratio is the theoretical quantity of water that would be given up to the atmosphere from a zonal climate and a zonal soil by the natural vegetation of the area if sufficient but not excessive water were available throughout the growing season. It is determined by dividing the mean annual potential evapotranspiration in millimeters by the mean annual precipitation in millimeters. The mean annual potential evapotranspiration has been found to have a direct logarithmic relationship to mean annual biotemperature, and thus can be determined by multiplying the mean annual biotemperature of any site by a constant, 58.93.[16] This ratio gives a reliable estimate of the moisture conditions at any site, and makes possible comparisons of this factor at different sites. Again, as with the other factors, the limiting values of this factor increase logarithmically. There are nine humidity provinces delineated in the life zone system: semiparched, superarid, perarid, arid, semiarid, subhumid, humid, perhumid, and superhumid.

---

[15]Tosi, op. cit., p. 178.

[16]This logarithmic "base" is found very frequently in nature and seems to be a natural law. For example, the cell, which is the most basic unit of living things, divides itself logarithmically, and thus multiplies itself on this base. There are innumerable other examples. (See n. 10)

A potential evapotranspiration ratio of 1 indicates a situation where the amount of water evaporated and transpired back into the atmosphere is just equal to the amount of water made available in the form of precipitation. This is a rather ideal situation since there is neither a shortage of water with the resulting parched conditions, nor is there an over abundance of water leading to leached and eroded soils. In areas where this ratio is greater than one, the water made available is less than what is needed resulting in arid conditions, and where the ratio is less than one the water made available is more than is needed resulting in excessively wet conditions.

These then are the global climatic factors that delineate the boundaries of the life zones. Obviously, any two of the three can determine the life zone. The following section on the life zone chart will show how these factors are integrated in determining life zone boundaries.

The Life Zone Chart

Figure 1 is a graphical representation of the three major climatic factors, and how they determine the 120 or so life zones on the planet earth.[17] It should be kept in mind that this is a three-dimensional figure, which indicates latitudinal divisions, as well as altitudinal divisions. Considered latitudinally, the chart establishes life zone divisions as one moves from the equator to the poles in either hemisphere. Altitudinally the chart establishes life zone divisions as

---

[17] Holdridge and some of his associates believe that the system can be extended to other planets, as well as back in time on our own planet when climatic conditions were different from what they now are.

one moves to higher altitudes within a given latitudinal division.

The mean annual biotemperature at sea level determines the latitudinal basal region. For example, if the mean annual biotemperature at sea-level is over 24° Centigrade, it indicates the tropical basal region, between 6° and 12°, the cool temperate basal region, etc. As the chart shows, the biotemperature values dividing the basal regions decrease logarithmically as one moves from the equator toward the poles, with the exception of the frost line with its related vegetational change.

These same biotemperature values determine the altitudinal belts which are shown on the right hand side of the chart. A basal region can have only those altitudinal belts that lie above the minimum temperature limit for that region. Thus, one does not find the montane altitudinal belt in the cool temperate basal region, or the lower montane in the boreal basal region. The tropical basal region, of course, has all of the altitudinal belts associated with it. These altitudinal belts correspond with logarithmic changes in biotemperature as the chart indicates.

A problem of nomenclature arises in connection with these altitudinal belts. The correct ordering of the life zone names is as follows: the basal region, the altitudinal belt, and then the humidity province. This presents no problem when the life zone to be named falls within the basal region for the area. For example, there is no problem in naming an area close to sea-level, with an average annual biotemperature of 10° Centigrade, an average annual rainfall of 750 millimeters, and a potential evapotranspiration ratio of .75. From the chart we can very quickly see that this is the cool temperate montane moist forest life zone. However, if we take the same measurements of the climatic data, but at an altitude of 3000 meters, the basal region is no longer the cool temperate. It now becomes the tropical basal region, and the name of the life zone is tropical montane moist forest. As a rule of thumb, in determining the correct life zone, a correction factor of 6^{o} Centigrade for every 1000 meters of elevation must be added to the mean annual biotemperature. For example, using the above data the correction factor would be 18^{o} ($3000/1000 \times 6^{o}$), which would give a sea-level biotemperature of 10^{o} plus 18^{o}, or 28^{o} which falls within the tropical basal region. Hence, whenever measurements of the climatic factors are made at altitudes much above sea level, the temperature data must be corrected to sea-level to determine the correct basal region.

Running diagonally downward from left to right on the chart are the humidity provinces, measured by the potential evapotranspiration ratio values. In the opposite direction, running diagonally from right to left, are the divisions based on rainfall, measured by the average total annual precipitation.

Measurements of any two of the three climatic factors, along with knowledge of the altitude of the site, will permit the determination of the life zone. Using the same data as before for temperature (10^{o}) and rainfall (750 mm), one need only locate these values on the chart, and note their intersection to determine that this site is in the montane altitudinal belt and the moist forest humidity province. Then, with knowledge of the elevation, one can determine the correct basal region. The intersection of values for the potential evapotranspiration ratio and average total annual precipitation for a given site will determine

the altitudinal belt and the humidity province, and will also determine the mean annual biotemperature which can then be corrected for elevation to determine the relevant basal region. A few moments study of the chart is all that is necessary to permit one to determine readily the life zone corresponding to data from a given site.

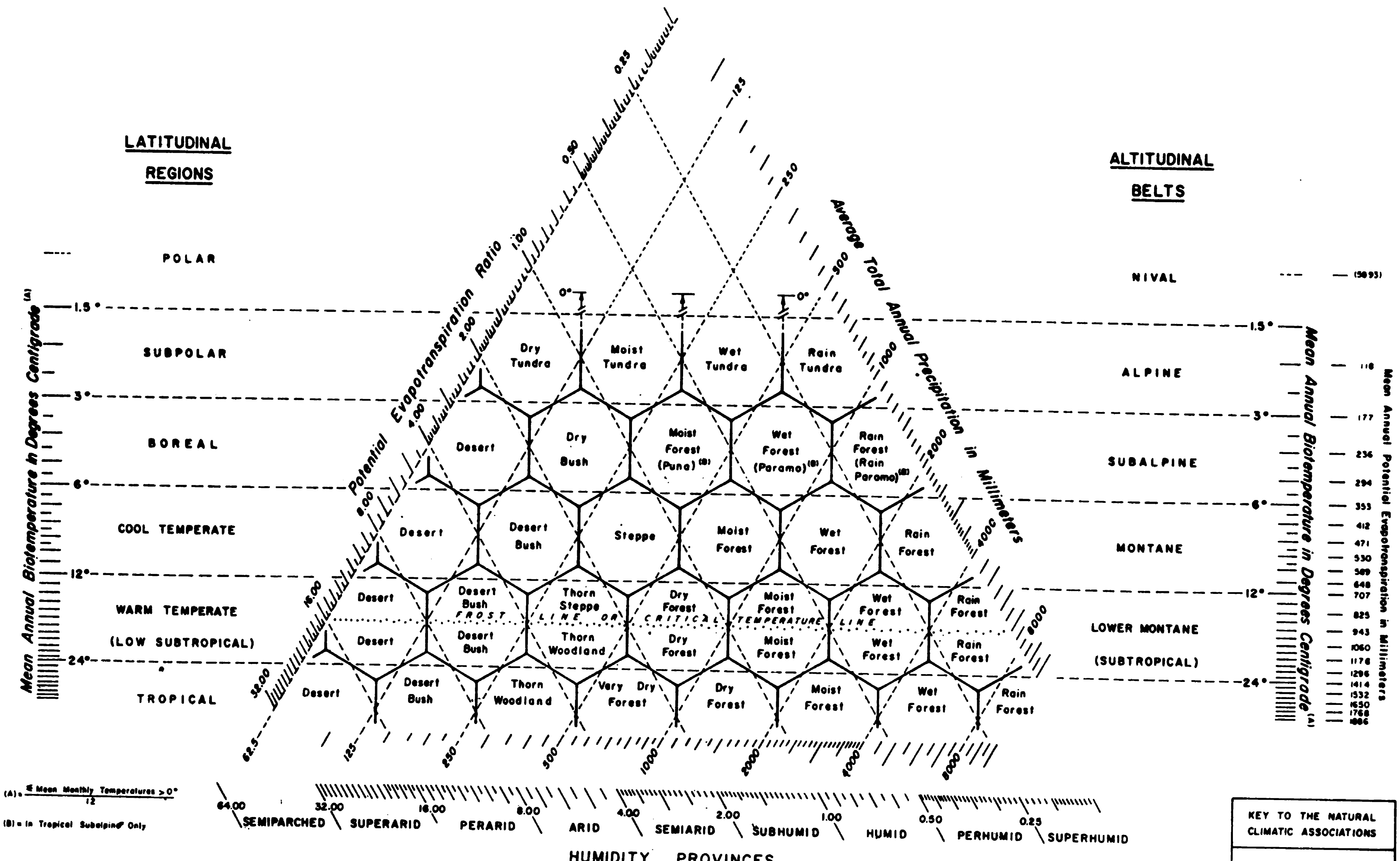
The dotted line running horizontally across the chart at about 18^{o} mean annual biotemperature should be noted. This is the frost line or critical minimum temperature line that was mentioned earlier. It should be remembered that this line can occur anywhere within the range of 12^{o} to 24^{o} Centigrade, depending upon humidity conditions, warm air currents, etc., which might affect a given site. The unity line of the potential evapotranspiration ratio should also be noted. Both of these have socio-economic importance which will be brought out later in this study.

One other characteristic of the chart should be discussed. It will be noted from the chart that the representations of the life zones are hexagonal in shape, and that the guidelines for the average annual precipitation, the potential evapotranspiration ratio and the mean annual biotemperature are not coincident with the boundaries of the hexagons, but bisect them. This characteristic creates within each life zone a series of six small triangles. These triangles represent transitional zones, i.e., areas in which the life zones begin to transform themselves into the adjacent life zone. Within these areas the vegetation begins to take on a different appearance, but the change is not great enough to remove the area from its life zone. It is of course, more difficult to distinguish the correct life zone in this area, but in moving from an area well within the life zone across these transitional zones, they are easily observable and can be readily mapped.

Diagram for the Classification of

World Plant Formations or Natural Life Zones

by L. R. Holdridge



(A) = $\frac{\Sigma \text{ Mean Monthly Temperatures} > 0°}{12}$

(B) = In Tropical Subalpine Only

THE VEGETATIVE CHARACTERISTICS

In the Holdridge system, the climatic parameters specifically and precisely define the limits of the life zones. However, in order to be other than an arbitrary division of climate, the life zones must be "natural divisions of significance,"[18] i.e., they must correspond as closely as possible to divisions made by nature in the earth's vegetation. Holdridge's basic hypothesis was that such natural divisions did exist, and subsequent work on the system has proved that there are such ecological differences between life zones. Anyone with a little training in the system, can learn to recognize the different life zones in the field. Large areas of the American tropics have been mapped on the basis of field observations,[19] and where the availability of climatic data permitted and checks were run on the field work, it was invariably found that the areas had been correctly mapped.[20]

The vegetative characteristics used in discriminating between life zones are more subjective than objective at the present time. The ecologists who are working with the system say it is the general look of the vegetation, or the "feel" of an area that indicates to them which

---

[18] Holdridge, op. cit., p. 9.

[19] Practically all of the work on the system has been carried out in the western hemisphere. However, after a recent reconnaissance trip through Africa and the Far East, Holdridge and Tosi believe that the system is equally applicable there.

[20] In fact in certain areas where the vegetation did not correlate with the climatic parameters, computational errors were discovered in the weather station data, which when subsequently corrected, provided the correct correlation.

life zone they are in. There are some quantifiable characteristics, however, that help one to arrive at this "feel" for the life zone. There are certain "indicator species" for various life zones whose density of occurrence changes abruptly when one crosses the boundary of the life zone. The extensiveness and intensiveness of edaphic[21] growth is another such factor, as is the measure of the cover heights of the dominant trees, bushes, and herbs. In areas where the natural vegetation has been completely cleared by man, similar characteristics of the cultivated vegetation indicate the life zone.

Very recently, Holdridge and his associates have been introducing more quantitative measurements into their study of the vegetation. They have devised a "complexity" index which is a combination of measurements over various aspects of the vegetation. This index, along with some other measurements of relationships between certain characteristics, is now being correlated with the climatic parameters in order to determine a more quantifiable description of the vegetation within the various life zones. This data then will be analyzed statistically to determine if the greater rigor is useful in describing the significant differences in the vegetation between life zones.

The Life Zone System

The life zone system then, is a method of classifying vegetation[22]

---

[21]An edaphic growth or plant is one that lives in parasitic fashion on another plant.

[22]This is not exactly correct since the proponents of this system contend that animal life and behavior, as well as that of humans, can be classified profitably on this basis.

on the basis of certain global ecological factors. These factors are the climatic factors of heat, precipitation, and moisture; and the vegetational units are groupings of plant associations. Extensive field work has shown this to be an effective and natural classificatory system. A life zone can be defined in terms of the relevant climatic factor values, but it may also be thought of as, "...a group of associations related through the effects of these three major climatic factors... These leave a definite mark on all the associations even though the group may comprise a quite diverse group of associations."[23] Holdridge and his associates expect further research on the system to show that other natural science variables and social science variables are correlated with life zones.

Costa Rica has been completely mapped on the basis of the Holdridge system. It is entirely within the tropical basal region, and contains the premontane (subtropical), lower montane, montane, and subalpine altitudinal belts. It is excellently suited for research on the life zone system because of the wide variety of climatic conditions existing in a relative restricted geographical area.

Definitions of the Tropical Moist Forest and Tropical Premontane Wet Forest Life Zones

The tropical moist forest and tropical premontane wet forest life zones are the ones used for comparative purposes in this study.

The tropical moist forest life zone is in the tropical basal area and the moist forest humidity province. There is no altitudinal

---

[23]Holdridge, op. cit., p. 14.

belt associated with this basal region (as there are for all of the other basal regions) in the nomenclature, since it is impossible for this series of life zones to be found in an altitudinal belt corresponding to some lower altitude basal belt. The tropical basal belt is at the upper limit of the biotemperatures found on earth (at sea-level), which precludes the existence of a hotter basal belt.

In terms of the climatic parameters, the mean biotemperature of this life zone is above 24^{o} Centigrade, it belongs to the humid humidity province with a potential evapotranspiration ratio between 1.00 and 0.50, and it has an average annual precipitation of between 2000 and 4000 millimeters. It is adjacent to the unity line of the potential evapotranspiration ratio, and at no time does this life zone feel the effects of a killing frost. It should be pointed out that the values for the climatic parameters given above describe the range of these parameters, and that there can be variations to the extent of this range between any two sites within the life zone. This is, of course, true of any of the life zones, and leads one to suspect that differences within life zones may be rather large from this factor alone.

In Costa Rica, the tropical moist forest covers approximately 12,577 square kilometers, or 24.4 per cent of the total area of the country. This, of course, includes the transitional areas associated with this life zone, since the vegetative characteristics defining the life zone include these transitional areas.

The tropical premontane wet forest life zone is in the tropical basal region, the premontane altitudinal belt, and the wet forest humidity province. Thus, the mean annual biotemperature for this life zone is between 12° and 24° Centigrade, the average annual precipitation is between 2000 and 4000 millimeters, and the potential evapotranspiration ratio is between 0.50 and 0.25. The fact that the altitudinal belt is premontane (subtropical), and the basal region is tropical (and not low subtropical), means that this life zone exists at an elevation somewhat above sea-level. In Costa Rica the boundary between this altitudinal belt and the basal region generally occurs at an elevation of from 600 to 700 meters. As the chart shows, however, it is possible for the transitional area of this life zone (altitudinal belt) to extend downward into the basal region (i.e., at temperatures greater than 24° Centigrade), even to the extent of having this area reach sea-level. Thus, along the Atlantic coast of Costa Rica we find this transitional area at sea-level.

In Costa Rica this life zone including transitional areas covers approximately 8,179 square kilometers, which is almost 16 per cent of the total surface area of that country. Thus, in Costa Rica these two life zones cover 40 per cent of the area of the country, indicating their importance to the economy of that country.

The differential vegetative characteristics due solely to the effects of the climatic factors are difficult for the untrained, non-ecologist to discern, and there is practically no completed, systematic research on the differential animal and human behavior characteristics by life zone. Local factors play a big part in determining the structural and other characteristics of the vegetation that are used by the ecologists in recognizing a given life zone. In very general terms it is possible to describe the differential effects of the climatic factors on the various life zones, but it should be remembered that local variations are very important and can have dominating influence on the vegetation. In general, as one moves from the dry to the wet humidity provinces within a given basal region, the vegetation becomes more dense, the trees grow to greater heights, they contain more leaves, the stems are thicker, soils become more clayish and less sandy, etc. As one moves within the same humidity province to progressively lower temperatures, the vegetation becomes less dense, less tall, and takes on characteristics to permit it to withstand the colder temperatures. There are numerous of these characteristics that could be used to describe the differences due to climatic factors between life zones, and current research on the system is oriented to discovering what these characteristics are and how they differ by life zone.

The most precise method of distinguishing between life zones is on the basis of the climatic parameters. These parameters delineate the life zones, and therefore can be used as a basis for correlating other variables with the life zones. In terms of the parameters, the two life zones chosen for this study are relatively similar, however, there are some crucial differences. It was thought that for this type of study it would be best to have a modest amount of difference between the two life zones, i.e., not to choose the most similar, nor the most different life zones.

The tropical moist forest and the tropical premontane wet forest life zones are similar in that they both have the same average annual precipitation of between 2000 and 4000 millimeters. They are different, however, in that the tropical moist forest life zone has a mean annual biotemperature above 24^{o} Centigrade, whereas the tropical premontane wet forest life zone has a mean annual biotemperature between 24^{o} and (approximately) 18° Centigrade. This difference in biotemperature is thought by the ecologists to be of primary importance in distinguishing life zones. This difference in temperature, given the same mean annual precipitation, leads to a difference in humidity province - the tropical moist forest being humid, and the tropical premontane wet forest being perhumid. This difference in humidity province is reflected in different potential evapotranspiration ratios for the two life zones. The tropical premontane wet forest is one space removed from the unity line of potential evapotranspiration, whereas the tropical moist forest is adjacent to it. What this means is that in the tropical premontane wet forest life zone the potential for evaporation and transpiration (from the vegetation and other surfaces) related to the amount of water made available (through rainfall, etc.) is much lower than in the tropical moist forest life zone. In other words, the evaporation and transpiration <u>to</u> precipitation ratio is lower in the tropical premontane wet forest life zone, and thus there would be more likelihood of excessive water conditions here than in the tropical moist forest, which has the same average annual precipitation.

In addition, since the basal region for both of these life zones is "tropical", this means that the premontane wet forest life zone must occupy an area with an elevation somewhat above sea-level. Therefore, except for limited areas near sea-level along the Atlantic coast, this life zone will be found at altitudes ranging from 600 meters to close to 2000 meters. The fact that this life zone is an altitudinal belt above a basal region has important implications for farm technology, etc., as will be seen in a later chapter.

Another factor of some importance to the premontane wet forest life zone is that it borders on the critical minimum temperature line - the frost line. There is a distinct change in vegetation where this line occurs, even though it is not logarithmically spaced from the other boundaries, and there is a relatively wide band of biotemperature over which the line ranges depending on more localized conditions. The ecologists working with the system like to combine this premontane wet forest zone with the lower montane wet forest zone, and to consider the entire area as one life zone. In effect they are considering the change in vegetation that occurs along the critical minimum temperature line to be of less importance than the changes that occur at the logarithmically spaced climatic parameters. They consider the change to be due more to local factors than to the global factors. Thus Holdridge says: "Theoretically the best solution appears to be that of maintaining the complete hexagonal divisions as life zones and to consider any ecosystems within the Warm Temperate region or Tropical Lower Montane belt which are free from killing frosts as well as any portion of the basal tropical region with occasional freezing temperatures as atmospheric association only. Fundamentally, the change involved may be basically no more significant physiologically to plants than that of the monsoon or Mediterranean climate variations caused by differences in the annual rainfall pattern."[24] He goes on to say that it is of practical importance to recognize this change in vegetation because of its seeming importance in many of man's activities, but he adds that as yet it is difficult to know how to handle this change in vegetation since very little research has been done on the effects of killing frosts.[25]

---

[24] Holdridge, op. cit., p. 22.

[25] Ibid.

In choosing the life zones for this study it was thought that the changes resulting from the existence of killing frost could obscure or negate the changes that might otherwise be noted, and so it was decided to choose only that part of the life zone that was without frosts. Therefore, the premontane wet forest life zone was chosen, rather than the combination of this and the lower montane wet forest zone.

THE LIFE ZONE SYSTEM AND ECONOMIC DEVELOPMENT

The developers of the Life Zone System consider it to be an important classificatory system for classifying animal and human behavior as well as for classifying vegetative characteristics. Human behavior is thought by them to be classifiable by life zone from several different points of view, e.g., demographic, racial, political, economic, and social or cultural, some of which Holdridge discusses briefly in his Life Zone Ecology. This study is, of course, primarily interested in economic aspects of the Life Zone System about which very little research has been done.[26]

Holdridge and his associates believe that all economic variables are influenced to some degree by the climatic parameters that delineate the life zones. Moreover, they feel that the degree of this variation for most of these variables will be great enough that profitable

---

[26]However, see Joseph A. Tosi, Jr. and Robert F. Voertman, "Some Environmental Factors in the Economic Development of the Tropics, "Economic Geography, Vol. 40, No. 3, July, 1964.

Also, Joseph A. Tosi, Jr., Zonas de Vida Natural en el Peru: Memoria Explicativa sobre el Mapa Ecologico del Peru, y Mapa Ecologico del Peru, Boletin Technico No. 5 del Institute Interamericano de Ciencias Agricolas de la O.E.A.Zona Andina, Programa de Cooperacion Tecnica, Lima, Peru, 1960.

economic decisions can be made on the basis of them. They are rather strongly convinced that the life zone system has an important contribution to make in the area of agricultural economics, but they have no concrete evidence to support this conviction. A more specific discussion of their position concerning the relationship between agriculture and the life zone system will be presented later in this study. Before doing so, however, there are other areas in the general field of economics which they feel to be related to the life zone system, and which should be mentioned here so as to capture the full breadth of the role they foresee for the Holdridge System.

The ecologists who have been working with the Holdridge System think that the major immediate contribution it can make to economics is in the determination of correct land-use systems. Using an extremely long run and ecological concept of land use, they feel that the existence of life on earth for the next few decades depends upon man adapting more to the environment rather than adapting the environment to himself. They think that the first task facing man is to determine which land use is "natural" for each area, i.e., which uses can the land support over an indefinite period of time without permanent damage to its productive powers. Thus, if a given area will perpetually support only the natural forest, then according to this concept of land use, it should be used only for this purpose. Agricultural land, land for grazing cattle, watershed areas, and other uses of the land would be determined on the same basis. All of these various land uses could be correlated with life zones, so that one could eventually come up with a classification of land use such that simply by knowing the values of the climatic parameters, one could determine the "correct" land use for an area.

This could then become the basis for policies and planning to insure an everlasting ecological system for the earth.

Since a corollary to this proposition is that man is rapidly destroying large areas of natural forest that had best be left to (or exploited as) natural forest, a problem arises concerning how to deal with the mounting pressure of population on the land. If large areas that are now being forced into agricultural production are to be left as natural forest, one of the most important means of staving off widespread famine (the opening up of new lands to agricultural production) will be lost to many countries. There are three methods for solving this problem: 1) to limit population growth, 2) to increase agricultural production on "natural"[27] agricultural land, 3) to change the dietary habits of the people so that they will consume those products "naturally" produced. Of these three, the first and third are stressed by the ecologists as solutions to the problem, while the second is relatively neglected by them.

A major objection to these two approaches is that they <u>are</u> long run solutions, or rather solutions that can be implemented only in the long run, whereas the problem is one that requires a stop-gap short-run solution. Hence, the immediate objective should be to concentrate on the second of the three alternatives, while permitting whatever inroads into the natural forest might be necessary to stave off famine

---

[27]Natural agricultural land is land that can support intensive agricultural production over very long periods of time without permanently destroying the productivity of the land. This does not preclude the use of fertilizer to maintain this productivity. Also, this concept should not be confused with the natural vegetative cover that would exist on the land if it were left in an untouched state.

until solution number one, and possibly number three, can be implemented. This seems to be the only rational and politically feasible approach, since before the other two alternatives could be implemented there would be widespread famine and possibly anarchy.

Nor can one arbitrarily assume short of a totalitarian system that either of the two solutions favored by the ecologist, will work. Population control has been talked about for a number of years but very little has been done in the way of initiating it. Only in recent years have attitudes started changing in the direction of acceptance of birth control, and there are still major power blocks aligned against it. Solution number three seems even more difficult to implement. The argument is that there must be a change in dietary habits away from the grains, and toward the fruits, fibers, tubers, etc., that abound in the natural forest. This shift in taste would be very difficult to accomplish in a short period of time, and perhaps impossible even in the long run.

The other alternative is to concentrate research on the possibility of increasing productivity on "natural" agricultural land, and to gain time by permitting agriculture to expand temporarily into the less favorable areas. This time could be used to introduce changes in technology that are necessary to high productivity agriculture in tropical areas. This proposal has several advantages. It could achieve results in a relatively short period of time, which is a crucial factor given the increasing pressure on food supplies. It could very well permit the type of increase experienced by agriculture in the United States when research was finally directed toward this end, and it could very well allow the reversion of land not permanently suited to agriculture (and perhaps some of the marginal agricultural land) back to its original vegetative state. This plan is also much more feasible, politically as well as practically, than either of the other two alternatives.

Thus, the ecologists fail to consider the market as the regulator of production. They favor an environmental determinism which in effect would subordinate the price system to an ecological system answering the questions of what, when, who, where, and how. There would, of course, still be a certain amount of land used for agricultural output, but the main burden of the ecologists approach rests on making much greater use of the foods and fibers that nature provides. In other words, let nature grow what it can naturally and concentrate on finding ways to consume and otherwise use this production. The life zone system should be able to provide us with a method of determining which areas to convert to agriculture, which to use for lumber production, which to leave with their original growth, etc. The ecologists feel that if production is not oriented on this base, the productive powers of the earth will soon be severely diminished.

Demographic patterns are thought by the ecologists to be determined by life zones; that is, the climatic parameters affect the desire and the ability to live in certain areas. There should be variations in population pressures by life zone, with the accompanying variations in land tenure systems, unemployment and underemployment on farms and in the cities, public works and welfare programs, housing conditions, wage rates, rental rates, etc. Throughout the history of any given country the people should have populated first those areas within the more favored life zones. Holdridge points out that early settlements in the western hemisphere were in the more favored life zones (cool dry life zones), and that most of the capital cities in that hemisphere lie in life zones adjacent to the unity line of the potential evapotranspiration ratio - the area most favorable for agricultural development. Thus, he concludes that the people favor these areas because they are more comfortable to live in and they are easier to make a living in.[28] This hypothesis could be tested in various ways, and this research could be used to develop policies for the newly developing, still underpopulated countries.

Also, due to the deleterious effect of the climatic parameters (especially rainfall) on roads in certain life zones, the ecologists feel that transportation problems will be greater in these zones. This could have important implications for plant location, the distribution of public funds for road construction, road maintenance, the private and/or social returns to private and/or social investment in the various areas, the technology of production along with the costs of production, the establishment of enterprises and subsidiary enterprises in the transportation industry, the pricing of materials and products, and the many other variables too numerous to mention. Many of the less developed countries in the tropical region are faced with certain areas of heavy rainfall which completely destroys the roads that do exist, and these usually are repaired by the central government only after a considerable lapse of time. In many of these areas the funds for road maintenance are channelled far too much into the urban

---

[28]Holdridge, op. cit., pp. 15-16.

areas, with continuing neglect of the poverty-stricken rural areas. A knowledge of the variation by life zone in this transportation variable would help in planning the distribution of these funds on a more equitable basis.

A given industry or firm could be strongly affected by the climatic parameters governing the area within which it has located its plant or sells its product. Costs, prices, factor proportions (and therefore marginal productivities of the various factors), the necessity for and the type of maintenance, marketing times and methods, spoilage, storage, depreciation, etc., could all be related to life zones. For example, heavy rainfall and high temperatures could force a manufacturing firm to use a higher grade of construction material, resulting in higher costs of construction in a given life zone. Many other examples of similar influences come readily to mind. The price and availability of labor, could vary by life zone depending upon the degree to which people favor one or the other life zone, and assuming, of course, a free labor market.

A policy to bring the quantity of each factor of production into line with the varying optimum factor proportions as determined by the life zone system would be of great value to some of the less developed countries that today have inefficient factor markets.

These are some of the more important economic variables which the ecologists feel are influenced by heat, precipitation, and moisture, and they are subject to testing to determine if a significant variation exists in them by life zone. If significant variations between life zones were found, policies based on this discovery could prove useful for economic development.

The ecologists position on the relationship between differences in the climatic parameters and differences in variables surrounding agriculture is more specific and held more strongly. It is in this field that the climatic parameters determining the life zones probably have their most direct effect on economic variables. Here heat, precipitation, and moisture are important growth factors that determine the basic productivity of the land, whereas in industry and commerce the effect is more indirect, working through such factors as depreciation, spoilage, and transportation.

In addition, given the importance of agriculture to the less developed countries, this is one of the most important fields in which research on the life zone system should be conducted. The growing food crisis demands that more research be directed toward improving agricultural productivity, and the life zone system provides a possible means of doing so. Agricultural economists and ecologists would agree that there are many variables within the field of agriculture that could be analyzed for variation by life zone, but they would probably not agree on the order of priority for the investigations. A few of these which are mentioned most often in the writings and discussions of the ecologists will be discussed here to provide some idea of the type of relationship expected to exist between the climatic parameters and agriculture.

Productivity, measured as the number of units of output per unit of land, is a very important variable which should differ by life zone. For each individual crop there is a theoretical optimum of the three climatic factors which would provide, other things equal, the highest average productivity per given unit of land. Since the climatic parameters differ by life zone, the productivity per acre of corn (with all other factors, such as the amount of fertilizer, labor, seed, shade, held constant) should differ by life zone. Of course, these other factors that are held constant must not include any artificial additions to the climatic parameters (water or heat) as this would negate the purpose of the research which seeks to determine the effects of the climatic parameters as provided by nature.

From a practical point of view this is the agricultural variable that should receive top priority for research. Extremely low productivity is characteristic of the underdeveloped tropical countries, and any quick means of improving productivity would be greatly welcomed.

Agricultural technology, or the method of producing, is another variable that should vary by life zone. The concept of technology includes the amounts of the factors of production that are used, and the way in which they are combined to produce a unit of output. The optimum amounts of the factors and the optimum combination could be expected to vary by life zone. It also includes the operations performed by these factors in producing a given crop, as well as the timing of these operations. There is a considerable amount of detail that could be investigated in depth between life zones, but time and foreseeable benefits limit these to relatively few.

As a corollary to differences in technology, there should exist differences in costs of production between life zones. Costs of production per unit of output or per unit of a given input should vary by life zone because of the different amounts of the factors of production used which in turn are caused by the different amounts of heat, precipitation, and moisture, assuming relative prices of the factors of production are the same in the life zones. For example, one life zone that is hotter and wetter than another might require shading or a drainage system, or more fertilizer, resulting in higher costs of production for that life zone. Irrigation might be required by another life zone receiving less rainfall, which would again increase costs. The point is that there should be differences in costs of production for a given crop by life zone which are measurable and of some use economically.

Variations in the optimum amounts of fertilizer to use on a given crop per given land unit might be significant between life zones, as might the correct spacing of plants and rows for a given crop. Rotation systems, the possibilities of intercropping and mixed farming, the best growing pasture for cattle, and a host of other variables might profitably be compared by life zone.

If it were found that there were significant differences between life zones in some or all of these variables, then planning and policy could be designed to capitalize on these differences. For example, if it were found that there were differences in productivity between life zones for the various crops grown in an economy, the government could encourage the production of that crop that grows best in each separate life zone. This is simply allocating resources into those areas which can most economically use them, i.e., according to marginal principles. This assumes, of course, that it is necessary to so direct resources. Schultz[29] feels that in traditional agriculture resources are

---

[29] Theodore W. Schultz, Transforming Traditional Agricultural, (New Haven and London: Yale University Press, 1964), See Chapter 3, pp. 36-52.

efficiently allocated, given the effective decisions that are available to the farmers.

This study is concerned with testing the Holdridge Life Zone System with respect to its relationship to certain economic variables. One must accept (through ignorance of the field) the biological validity of the system, so that point is not in contention in this paper. What is tested is the hypothesis that there are significant variations in economic magnitudes among life zones. Before proceeding to the methodology to be used in these tests there are two points which need further discussion to set the stage for the analysis which follows.

The first of these is the difficulty of holding certain factors constant when one wants to compare the relationship between only two variables. This is especially difficult in a study such as this where some of the variables to be compared are very general in application, whereas some of the variables to be held constant are of local application. The climatic parameters of the Holdridge System affect large areas, while some of the factors assumed to be constant (such as slope and wind) vary considerably within and among the life zones. It is much easier to compare the more local variables while holding constant the more general ones. For example, to determine the productivity effects of the climatic parameters (life zones), it would be best to have the same technology used in each of the life zones being studied. If this condition does not exist, differences in productivity could be due to the different technologies, rather than to the different climatic parameters. The same is true of any of the applied factors. If the amount of fertilizer applied differs by life zone, this could be responsible for any differences in productivity that might be discovered.

Thus, to obtain a true picture of the influence of the climatic parameters, all other factors should be held constant.

The same is not true, however, of factors that are themselves directly influenced by the climatic factors. The best example of this is the effect that rainfall and heat have upon soil. The soil in a given area will vary in fertility depending upon the amount of heat and rainfall it receives, as well as upon their periodicity. The greater the amount of rainfall and the more concentrated it is, the greater will be the leaching of the soil, and the lower will be its fertility. But this is a direct or natural effect of the climatic parameters, and should not be eliminated (or held constant) in measuring differences in productivity by life zones.

The ecologists argue that to get a true picture of the effects of the climatic parameters in isolation, it is necessary to hold constant all exogenous factors, and would extend this to include differences in soils that were due to local conditions. Thus, if there had been recent volcanic activity within a life zone that affected the soils of only a part of the life zone, this would have to be taken into account. They would treat variations in topography in the same way. In their view, not to eliminate variations in topography, would be to falsify the differences found between life zones since these topographic differences are not caused by the climatic parameters. The end result of this view is to reduce the comparisons to very localized areas, and to conclude that little affective research on the life zone system itself is possible. The only possible solution is to proceed with the comparisons on the assumption that these things are constant or that they offset one another when aggregated over the entire life zone.

The other matter to be disposed of before proceeding has to do with the fact that what might be a statistically significant difference in a variable might not be an economically significant one and vice-versa. In other words, statistical tests might indicate a difference is significant, but when the difference is translated into its effect upon the economy, it may have a negligible potential for improving the economy and thus be economically insignificant. Presumably, if a difference is statistically significant - (i.e., if it is not due to chance - it is a difference that can be expected to occur repeatedly over a considerable period of time, making it significant - in the use of resources for example) in the long run if not in the short run. Besides, where improvement is so needed and so hard to obtain, the smallest difference would become of importance. The point is that what one considers economically significant must be related to the need for improvement. Under certain conditions even the smallest variation can be important.

CHAPTER III

METHODOLOGY

The basic hypothesis of this study is that in certain economic variables there are significant differences between life zones. This hypothesis includes practically all economic variables, not only those associated with agriculture where the influence of the life zones is most evident. The purpose of this study is to test in a limited way, the life zone system as a classificatory system for economic variables.

Since the most direct effect of the climatic parameters on the economic system is in agriculture, this is the most logical area within which to begin research on the system. The system suggests that productivity and technology are influenced by the differences in the climatic parameters and that variations in these by life zone should be measurable. Since the hypothesis is all encompassing, it was necessary to limit the scope of this study to keep it within the bounds of the resources available. Thus, it was decided to concentrate on only one crop in two life zones.

A stratified random sample of farms was selected from the two life zones, and data on productivity and technology were collected for these farms. The data for the two life zones were then compared and analyzed to determine if differences did or did not exist. In addition, several farms, some in each of the two life zones that were growing corn, were visited and the farmers interviewed concerning their methods of production. These data and observations are also included in the analysis. Some agricultural extension agents and delegates from the Consejo Nacional de Producción were also interviewed concerning agricultural production and practices within their area.

The word "significant" which appears above in the statement of the hypothesis is used in two different senses. First, a "difference" in a variable between life zones, computed from a sample from each, is defined as being significant if it could not likely have happened by chance from two samples taken from a given population, but rather indicates that there are two distinct populations from whence the samples came (each represented by one of the life zones). Thus, where it was possible to analyze the differences statistically, a .05 level of probability was accepted as determining if the differences were significant. In the many cases where the data did not lend itself to statistical analysis, they are analyzed more subjectively and presented on that basis. In this case, a difference is considered significant if it seems important enough that it could contribute to improving the performance of the economy.

Selection of the Life Zones

There were three primary considerations governing the selection of the life zones. The first was that the life zones chosen had to exist in Costa Rica where the research was to be carried out. There

are twelve life zones in Costa Rica.[1]

The second consideration was that the life zones selected should have a moderate amount of difference between them. There is a continuum over which the differences in the various combinations of life zones range, i.e., between some of the life zones the difference is small and between others it is rather large; and there are intervening differences of varying degree. The ecologists position is, of course, that the variation in the variables being measured will correspond in degree to the extent of the difference between the climatic parameters. In other words, the greater the difference in the parameters delineating the life zones, the greater will be the difference in the variable being measured. This hypothesis would seem to be true, but needs to be verified.

The choice of the amount of difference on which to base this study was made arbitrarily, for theoretically any two of the life zones could have been compared. Those life zones showing the greatest difference were not chosen so as to avoid the appearance of having "picked" the life zones in such a way that the possibilities of finding differences were maximized. The choice of two life zones with a minimum of difference was avoided for a similar reason. If these had been chosen, it would have appeared that the study had been designed so as to not find differences between life zones. Both such

---

[1]The twelve life zones that exist in Costa Rica are: tropical dry forest, tropical moist forest, tropical wet forest, tropical premontane moist forest, tropical premontane wet forest, tropical premontane rain forest, tropical lower montane moist forest, tropical lower montane wet forest, tropical lower montane rain forest, tropical montane wet forest, tropical montane rain forest, and tropical subalpine rain parame.

selections were excluded by the choice of life zones with a "moderate" amount of difference.

The last, but by no means least important factor in choosing the life zones was their extensiveness in Costa Rica and in tropical areas generally. There are two reasons why the life zones chosen should cover large areas. First, to obtain the widest applicability for the results, the farms chosen should be representative of a large number of farms in the country; and second, the coverage of large areas would insure the representation of most of the geographical variation in the variables being measured. Thus, the conclusions would be important for reason of their applicability to a wide geographic area. In Costa Rica, the two life zones chosen (tropical moist forest and tropical premontane wet forest) account for 40 per cent of the total area. Moreover, these two life zones are important throughout Central America, covering approximately 54 per cent of the land area of that isthmus.[2] There are also large areas of these two life zones in the South American countries. Since there are common characteristics for each of these life zones wherever they are found, any variations based on these characteristics should exist wherever the life zones exist. Thus, these variations and policies based on them are applicable in many different places on the globe.

For example, if research on the life zone system were to show that in certain crops given factors were more productive in the tropical moist forest life zone as compared with the tropical premontane wet forest life zone using the same technology, the agricultural extension

---

[2] Tosi and Voertman, op. cit., p. 194.

service could recommend to the farmers those crops best suited for these respective areas. Or if technology varies from one life zone to another for a given crop, these differences could be used to increase productivity. In other words, it would be possible to bring about a more efficient allocation of resources within and between countries if differences between life zones were found in productivity and technology.

Selection of the Crop

The vastness of the research needed to improve agriculture in the tropical areas is staggering, even from a purely technological point of view. If the economic aspects are included, the obstacles seem insurmountable, and where to begin the research becomes a serious problem. An argument can be made, however, for concentrating the earlier research on those crops that are a part of the basic diet of the people. With the rapidly rising world population it is imperative that food supplies be increased.

I decided, therefore, to concentrate on the basic foods of the Costa Rican diet: rice, corn, and beans. Furthermore, the scarcity of resources required that, except for the measurement of productivity, the study be limited to only one of these. Corn was chosen because it is grown rather extensively in the two life zones, and because it has a better defined technology than either rice or beans, which facilitates the measurement of that technology. For example, the various operations involved in growing corn occur in more distinct steps than is true of the operations surrounding the growing of rice or beans, and the use of the factors of production (especially capital) is more varied in the production of corn. Thus, in most of its aspects this study concentrates on corn with the exception that productivity by life zone is compared for each of the three basic crops - corn, rice, and beans. Of course, for the variable land-use, all possible uses of the land are considered.

Corn is not a profitable crop as it is now grown in Costa Rica. Only about 40 per cent of the corn produced in that country in 1963 was sold, with about 52 per cent of the production being consumed on the farms by the producers and their families. The remainder was used on the farms for seed and forage. The technology in use in the production of corn in Costa Rica does not produce yields great enough to make corn commercially profitable when compared with some competitive crops. Some of what is sold is the result of the farmer selling the surplus production that his family does not need for consumption, or of his planting corn in a field to help keep the weeds down or the insects out. Corn also requires a relatively small cash outlay compared with some competitive crops, which makes it popular with some farmers even though it returns little in the way of profit. Many farmers are more interested in maximizing the difference between cash outlay and cash return rather than the difference between total cost and total revenue. Farmers with large amounts of land seldom devote more than one or two manzanas[3] to corn. When interviewed both large and small farmers reported the lack of profit as the reason for their not growing more corn. Most of the large producers of corn in Costa Rica produce for the Consejo Nacional de Producción with whom they

[3]One manzana is approximately 1.7 acres.

have purchase contracts at relatively high prices, and for whom they produce seed corn. This seed is then sold by the Consejo to other farmers for planting.

There is, however, some evidence that new technology would permit a substantial profit per acre. But this technology is not now "effectively" available to the farmer in the sense that he knows of it and can see even a remote possibility of using it. The problem is to get the small farmer to recognize these other opportunities and to provide him with the means of them. The lack of cash coupled with the high cost of introducing new technology and the absence of effective agricultural credit makes it difficult for the farmers to introduce new technology.

The loss of foreign exchange due to the necessity of importing corn to meet domestic consumption requirements represents a real loss to the economy of Costa Rica. In 1963 there were approximately 2,170,000 bushels of corn produced on about 131,000 acres for an average production of around 16.6 bushels per acre. Most of this was grown on very small patches of land using very primitive technology. In addition to this production, Costa Rica imported 437,700 bushels of corn in 1964 which raised total consumption of this grain to around 2,607,000 bushels. Thus, imports were nearly 17 per cent of the total consumption, and represented an expenditure of over half a million dollars of valuable foreign exchange. Between the years 1951 and 1964, Costa Rica imported 3,603,336 bushels of corn at a total value of $6,640,850. While corn represents a relatively small percentage of the total imports of Costa Rica, productivity could be improved relatively easily to make the country self-sufficient in this crop.

Selection of the Sample

The selection of the sample of farms was made relatively simple because a stratified random sample of farms producing rice, corn, and/or beans was recently taken by the Costa Rican Department of Census[4] for a study it was conducting. Their study was designed as a between census check on the data from the 1963 Census of Agriculture which theoretically entailed 100 per cent coverage. Except in certain small areas of Costa Rica, the expansion of the data obtained indicated that the Census of Agriculture of 1963 was accurate.[5]

DESCRIPTION OF THE DEPARTMENT OF CENSUS SAMPLE

For the purposes of the Census study, the 36,417 farms producing either rice, corn, and/or beans were stratified on the basis of size to improve the reliability of the estimates. The farms were broken down into large, medium and small, with the boundary between medium and small falling at five manzanas (8.5 acres) regardless of crop or province. The upper limit of the medium-sized farms, or the boundary

---

[4]Jose, G. Baptista and Mario Murillo M., Diseño de la Encuesta Agrícola por Muestreo de Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, December, 1965; and Jose G. Baptista and Mario Murillo M., Encuesta Agrícola por Muestreo Arroz, Maiz y Frijol, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, May, 1966. The first of these details the design of the study of these crops, and the latter gives the results.

[5]Underenumeration was anticipated in the 1963 census because of the lack of training and involvement of the enumerators, i.e. They lacked the initiative necessary to insure a complete enumeration. However, expansion of the data from this interim study indicated only one province in which there was some doubt that the area had been adequately covered in the 1963 census.

between the medium and the large, varied by province because of the variation by province in the average size of farms. This upper limit also varied by crop; that is, the upper limit of the medium-size farms within a given province varied by crop. Thus in one province for rice, corn, and beans, this upper limit was 40, 30, and 15 manzanas (68, 51, 26 acres) respectively. This difference allows for the fact that the average size of planting for the various crops varies among the provinces. Table 1 shows the limits by province and by crop separating the large from the medium farms. Table 2 shows the breakdown into the three size categories of the farms producing these crops, and indicates the area planted in the crops for each of the categories.

The large farms comprise only .4 per cent of the total number of farms, but contain 19 per cent of the total area devoted to these crops, whereas the small farms represent 89.1 per cent of the farms, but only 44 per cent of the total area. The medium and large farms together are 11 per cent of all farms, with 56 per cent of the total acreage.

After dividing the farms into large, medium, and small on this basis, Census officials decided to include in the sample all 159 farms designated as large, primarily because of the large percentage of the total area planted in the three crops accounted for by these farms. They adopted a 10 per cent sampling fraction for the medium-sized farms because this seemed to give them the best balance between the cost of the survey and the validity of the results. A larger sampling fraction would have given them a more valid sample, but at a disproportionate increase in the cost of the sample. They used a 5 per cent sampling fraction for the small farms for similar reasons. The methods used by the Costa Rican Department of Census to extract these two samples were similar.

TABLE 1

MINIMUM LIMITS FOR SEPARATING LARGE AND MEDIUM SIZE FARMS BY CROP AND BY PROVINCE (IN MANZANAS)

Provinces	Rice	Beans	Corn
San José	20.0	20.0	20.0
Alajuela	40.0	40.0	20.0
Cartago	15.0	15.0	20.0
Heredia	40.0	15.0	30.0
Guanacaste	50.0	50.0	50.0
Puntarenas	50.0	30.0	50.0
Limón	20.0	15.0	50.0

Sources: José G. Baptista and Mario Murillo M., Diseño de la Encuesta Agrícola por Muestreo de Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, December, 1965; and José G. Baptista and Mario Murillo M., Encuesta Agrícola por Muestreo Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, May, 1966.

TABLE 2

CLASSIFICATION OF FARMS INTO
LARGE, MEDIUM, AND SMALL

Type of Farm	Number of farms		Area under the three crops (in manzanas)	
	Absolute	Percent	Absolute	Percent
Large farms	159	.4	32.600	19.0
Medium farms	3.780	10.5	62.600	37.0
Small farms	32.478	89.1	73.200	44.0
TOTAL	36.417	100.0	168.400	100.0

Sources: José G. Baptista and Mario Murillo M., Diseño de la Encuesta Agrícola por Muestreo de Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, December, 1965; and José G. Baptista and Mario Murillo M., Encuesta Agrícola por Muestreo Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, May, 1966.

For the medium-sized farms the first step in stratification was to obtain the provincial area under each crop. Then the provinces were classified according to the two crops most extensively cultivated in one of the following three groups: rice-maize, maize-beans, and rice-beans. Next the farms were arranged in decreasing order of area under the most extensively cultivated crop, and divided into groups of 40 farms. The farms in each group were then arranged similarly for the second most extensively grown crop, and then divided into groups of

20 farms. From each of these groups two farms were chosen, resulting in a 10 per cent sample of the medium-sized farms.

For their sample of small farms, a multi-stage probability sample[6] was designed, with the ultimate sampling units[7] containing approximately 10 farms. In effect, the procedure here was to select randomly a number of small geographic areas with recognizable boundaries, each of which contained about 10 farms, and then to interview all the small farmers within those areas. There was a total of 163 ultimate sampling units selected, with an expected 1,624 farms within them to be enumerated. This resulted in a 5 per cent sampling fraction for small farms.

The method used to select the ultimate sampling units was as follows: The political districts of Costa Rica were designated as primary sampling units,[8] and in each province homogeneous groups of these were formed into strata based on the average area per farm for each of the three crops: rice, corn, and beans. In carrying out this process, a factorial design was adopted using the factors a_m, a_r, and

---

[6]For a more detailed description of the method used in selecting this sample see José G. Baptista and Mario M. Murillo, Diseño de la Encuesta Agrícola por Muestreo de Arroz, Maiz y Frijól, 1965, op. cit., p. 10.

[7]An ultimate sampling unit is a small geographic area containing approximately 10 farms, and the total of these make up the universe of the last strata from which a sample (in this case of 5 per cent) is selected. (see the following footnote)

[8]The political districts of Costa Rica were designated as primary sampling units. A sample of these units was selected, and then from this sample a sample of the ultimate sampling units was selected. In other words, the multi-stage probability sample method provides for the selection of a sample from a sample.

a_b, (where a_m is the average area per farm for corn, a_r is the average area per farm for rice; and a_b is the average area per farm for beans). The final stratification did not appear with eight strata corresponding to the eight factor combinations since a restriction was imposed on the size of the strata. This restriction was that each strata should contain at least fifty ultimate sampling units so that in selecting with a 5 per cent sampling fraction at least two sampling units per stratum would be in the sample. Thus, if any of the above eight strata had less than 500 farms (since $500 \div 10 = 50$ ultimate sampling units which is the minimum number possible under the limitation imposed), the corresponding districts were distributed among the other strata. In most cases only three strata were finally left in each province. Then within each province the selection of primary sampling units was done with probability proportional to the number of small farms, and in such a manner that the sample of ultimate sampling units was proportionally allocated among the strata within the provinces.

The selection of the ultimate sampling units was made independently within each sample district. The first step was to arrange census segments into ultimate sampling units as nearly as possible. This meant that when a census segment had less than 10 farms it was grouped with one or more others to form a unit. These were then listed according to their geographic proximity by using the census district maps. Then the selection of segments or groups of segments within districts was made randomly with probability proportional to the number of ultimate sampling units in the district. Once this was completed, one ultimate sampling unit per census segment was chosen at random. Some census segments contained only one ultimate sampling unit and thus there was no selection problem. When there were more than one ultimate sampling unit within a census segment, the segment had to be sub-sampled. This usually involved dividing the segment into ultimate sampling units on the basis of recognizable boundaries on the census segment maps and randomly choosing one of them. Where there were no recognizable boundaries on the maps, the segments were divided into parts containing the expected number of farms and one of these was then selected. When even this was not possible, a complete list of the farms within the segment was made by a worker in the field, and a random sample of these taken with a number of farms chosen equal to the number in the other ultimate sampling units.

In addition to the above sample, a small sample (1/25 sampling fraction) was taken of those districts not reporting these three crops in the 1963 census. This was done as a check on faulty coverage by the 1963 census. The very simple method of listing the segments of these districts and then selecting the sample from this list was used. A random number between 01 and 25 was selected and then increased by 25 for a sufficient number of times to cover the total number of these segments.

This, in brief, was the method used by the Costa Rican Department of Census in selecting the sample for its study of the production of rice, corn, and beans. The present study used this sample as a starting point for its selection of a sample of farms producing corn.

Selection of the sample employed herein

A list of the medium and large-sized farms in the Department of Census sample producing either rice, corn, and/or beans was obtained from the Department of Census. This list contained all of the 159 farms in Costa Rica defined as large by the Department of Census study, as well as its sample of 375 medium-sized farms.

The next step was to determine in which life zones these farms were located. The list of farms contained the name of the owner or administrator, his address, the name of the administrator if this differed from the owner, and the address of the farm. This latter was used to determine in which life zone the farm was located. The Costa Rican Department of Census had available detailed maps of the entire country, and by comparing the address of the farm with these maps in most cases it was relatively easy to fix the geographic position of the farm. It was even possible in some cases to locate the name of the farm on the census segment maps. In addition, it was sometimes necessary only to determine in which census segment the farm was located, since the entire segment fell within a given life zone. The few farms impossible to locate precisely were eliminated from consideration, but this resulted in the elimination of fewer than ten farms that could possibly have fallen into one of the two life zones.

The next step was to compare the geographic location of the farm, and the life zone map to determine in which life zones the farms were located. This was accomplished by taking the census segment maps with the locations of the farms marked on it, and comparing these with the life zone map. Again, in most cases it was easy to determine the correct life zone for each farm. Again where the life zone was questionable, the farm was eliminated from consideration.

In this way the large and medium-sized farms from the Department of Census sample were put into the correct life zone, whereupon those

producing corn and falling into the tropical moist forest and tropical premontane wet forest life zones were extracted to form the sample for the present study. In all, there were 10 large farms and 108 medium-size farms in the tropical moist forest life zone, and 6 large farms and 54 medium-size farms in the tropical premontane wet forest life zone. The absolute number of farms is small, as is the percentage of the total estimated for these two life zones, but the percentage selected from the total estimate for each life zone is nearly the same namely, around 1 per cent.

A question arose as to whether to include small farms as defined in the Department of Census study in this study. In terms of the percentage of the total farms producing corn these small farms are important. However, they represented less than half of the total output of corn, and less than half of the area planted in corn.

A case could be made for excluding them. Since the purpose here is to measure differences by life zones on a limited number of variables, it could be argued that this could be done solely on the basis of the large and medium-sized farms as long as the definitions of these were consistent. The question would then become: are there differences between life zones <u>for large and medium-sized farms</u> in the particular variables? The fact that this sample might or might not be representative of <u>all</u> farms in Costa Rica would be immaterial since the results would not be generalized to include all farms. For example, in the case of the more limited sample, the results might show that technology differs (or does not differ) between life zones for large and medium-sized farms. Since the purpose of this study is to distinguish, if possible, differences between life zones, it is not necessary to include small farms, as it would be for example in an analysis of land tenure or productivity with the view of generalizing for all of the country.

It is advantageous to concentrate only on the large and medium-sized farms from the practical viewpoint that the farms are more easily located and identified. The small farm sample taken by the Department of Census was made up of small geographical areas containing approximately ten farms. In the first instance it would have been difficult to locate some of these areas totally within a given life zone, much more so than in the case of a single farm. In addition, it would have required locating the boundaries of the areas in the field, and then locating the various farms within the area without the advantage of having addresses for them. Another disadvantage of including these areas is that this would have meant a reduction in the number of the large and medium-sized farms that could be visited in the time available, while still permitting only a very small number of small-farm visits.

The obvious advantage of including the small farms (so defined) in the sample is that broader coverage of the formal producing corn is obtained. If the purpose of the study were to make generalizations concerning productivity, technology, etc., it would be necessary to include a sample of the 89 per cent of the farms that are defined as small. The practical advantage of limiting the study to the smaller sample greatly outweighs the gain from including some of these areas.

A peculiarity in the method used by the Department of Census of Costa Rica partly obliterates the argument for including these areas of small farms in the sample, but at the same time it also dilutes the sample of large and medium-sized farms. This peculiarity involves the

classification of farms by size by the Costa Rican Department of Census. The farm sizes were determined by the number of acres planted in the various crops, with the boundaries as given earlier in this paper, and varying by province and crop. According to the method used, a farm was considered medium-sized if the farmer planted more than five manzanas of any of the three crops. Therefore, if a given farm contained more than five manzanas of rice, but only two manzanas of corn, it was still considered a medium-sized farm; this designation being based on the five manzanas of rice. In other words, a farm did not have to have more than five manzanas of each of the three crops to be classified as a medium-sized farm. Thus, when the present sample of medium-sized farms was taken from the Department of Census sample, some farms were included that had less than five manzanas of corn but more than five manzanas of either rice or beans, or possibly both.

Thus, this sample includes farms of less than 5 manzanas of corn, and to this extent small farms are included.

To be theoretically correct there are two ways of justifying this method. The first is to define the sample exactly as it has been chosen, i.e., that the sample is made up of those farms producing corn in any amount which were included in the sample taken by the method used by the Department of Census. If the sample is defined in this way, it must stand or fall on its own merits. Or secondly, one could make the assumption that the small farms so selected (i.e., all those farms in the sample with less than 5 manzanas of corn planted) are representative of all the small farms in the country. The first of these seemed the better alternative and was followed.

The result of this procedure was a sample of farms of all sizes.

When size was measured by the total extension of the farm they ran from 13 acres to over 4,012 acres, and when measured on the basis of the acreage planted to corn, they ran from 2 acres to 170 acres.

A questionnaire was then devised to gather data on the pertinent economic variables related to the production of corn. The original objective was to interview fifty farmers in each life zone, but this proved impossible in the time available. The two life zones, tropical premontane wet forest and tropical moist forest, were scattered over the entire country, and the farms selected from the Department of Census sample were widely separated. Some of the farms were accessible only by horseback and reaching them would have required three or four days even if the exact location of the farm had been known. The extension agents did not know the locations of many of these farms and refused to make the trip to locate them. When it was discovered that many of the farms in the sample were impossible to get to except at a high cost in terms of the size of the sample only those farms (in the sample) that were readily accessible were visited. This permitted a sampling of 30 farms in each life zone as compared to 10 or 15 had I tried to adhered to the earlier approach.

In order to cover all of the possible variations in technology existing in the production of corn in Costa Rica, the farms to be visited were selected from all of the major corn producing <u>areas</u> of that country. These areas were identified by looking at data from the Census of Agriculture of 1963 and through conversations with the extension agents and the delegates from the Costa Rican National

Production Council.[9]

In the final analysis, then, there are two distinct samples used in this study. The sample of 59 farms in the tropical premontane wet forest life zone and 114 farms in the tropical moist forest life zone taken from the Department of Census sample is used for the analysis of productivity and land-use. This sample is a sample of farms producing corn, and includes farms of 1 _manzana_ and over. For those farms with less than 5 _manzanas_ of corn, there is the additional requirement that they be producing at least 5 _manzanas_ of one of the other two crops, rice or beans. This means that small farms which do not have the required amounts of either of the other two crops are excluded from the sample. The randomness of the sample suffers to this extent.

There are approximately 5,000 farms of less than 5 _manzanas_ producing corn in all of Costa Rica which is less than 17 per cent of all farms producing corn in that country. In addition, about one-half of all farms producing corn in Costa Rica are in either the tropical moist forest or the tropical premontane wet forest life zone, and if the 5,000 farms mentioned above are distributed throughout the country in the same proportion, about 2,500 of these farms fall within these two life zones. Of the remaining farms, all those with more than 5 manzanas of either rice or beans are represented in the sample. The remaining farms, of indeterminate number, were completely excluded from the possibility of being selected. In all probability then, less than 5 per cent of the farms producing corn in the two life zones

---

[9]The Consejo Nacional de Producción.

were summarily excluded. It is unlikely that the inclusion of a small sample of these farms would have materially changed the results of this study; still there is that possibility.

The effect of this sampling procedure on the results of this study is to understate the influence of the particular characteristics of small farms on the variables being studied. It was discovered that there is no correlation between size of farm and productivity, thus, small farms are not significantly less nor more productive than large farms. In the comparison of productivity by life zones the exclusion of these small farms would have no substantial effect, unless for some reason these farms in one of the two life zones were extremely productive or unproductive. This would mean a reversal of the lack of correlation between farm size and productivity and would be highly unlikely since there are some rather small farms included in the study for which there is no such reversal.

The variable, land-use, was compared for all farms in the sample of 50 farms in the tropical premontane wet forest, and 114 farms in the tropical moist forest life zones. In addition, those political districts falling 85 per cent or more within the tropical premontane wet forest life zone were compared with their counterparts in the tropical moist forest in the search for variation in land-use. The data analyzed on the basis of this latter sample includes all farms from 1 manzana to over 5,000 manzanas, and thus the picture of land-use obtained from this analysis is fairly reliable.

The sample that was used in the analysis of technology and cost of production was extracted from this larger sample, and consisted of 30 farms in each of the two life zones. All of these farms were in the

original list of farms taken from the Department of Census study. This is in no sense a random sample, but it does have the characteristic that all of the major corn-producing areas within these two life zones are included. In addition, several farms within the two life zones were visited which were not in the original list of farms, but which were producing corn. The methods of production for these farms corresponded well with those used on the 60 farms comprising the sample. The fact that these methods of production were representative of their respective life zones was confirmed by the extension agents as well as by the delegates of the National Production Council.

For the analysis of the methods of production, the above sample, I believe, is adequate, but this is not the case for the analysis of the costs of production. The small size of the sample used for comparing costs of production, the wide variability in the data, and the lack of a random sample make the validity of the results of this analysis highly uncertain.

Cost of production is the area where the lack of a random sample would do the most damage to the validity of the study. It is possible that the small farms which were excluded from the sample might have substantially higher or lower costs of production. Since these farms do not grow much in the way of other annual crops, it is possible that they spend more of their time (labor, and capital) in the production of corn, thus raising their cost of production significantly above that of the rest of the sample. Or it is possible that these farms specialize in a permanent crop or in dairying, and grow corn solely as a means to keep the weeds down or to control insects. In this case the cost of production would be substantially lower than the rest of the sample.

The exact amount and direction of the bias introduced by excluding these small farms cannot be determined without additional research.

Hence, the analysis for this variable should be taken as indicative of the costs of production rather than as an accurate representation of them. The cost of production for those farms for which usable data was obtained is accurate, but the small size of the sample plus its lack of randomness precludes its being accepted as representative of all farms producing corn in the two life zones.

This lack of randomness is a serious weakness of this study, but the choice was either to forego the random sample and visit a reasonable number of farms or to concentrate on randomizing the sample with the result that the number of farms actually visited would have been out severely. With the exception of the variable "cost of production", I consider the data presented to be reliable indicators of the universe.

CHAPTER IV

THE LIFE ZONE SYSTEM AND PRODUCTIVITY

The relationship between the life zone system and productivity is very difficult to measure due to the problems involved in isolating the effects of the climatic parameters on this variable. Certain factors such as the texture of the soil, the existence or non-existence of nutrients in the soil, the degree of erosion, the rate of photosynthesis, and the rate of evaporation and transpiration, are directly related to the climatic parameters involved in the life zone system. The amount and seasonality of rainfall directly and strongly affects all of the above factors, and the amount and intensity of heat directly or indirectly affects all of them.

Since the life zones are defined as differences in these two parameters, it follows that there should be differences in productivity between the life zones.

But it is not that simple. There are many other factors which are not influenced by the climatic parameters but which do have an effect upon productivity. Of these perhaps the most important natural factor is topography. Productivity is affected by topography in several ways. Erosion is a much more serious problem in hilly or mountainous areas than it is in relatively flat areas. The pattern of rainfall in a given area is influenced by the existence of areas of higher elevation, which causes the rain to fall in one area rather than another. The ability to use advanced technology which includes mechanization is affected by topography. In hilly regions it is often impossible to use tractors to pull plows, harrows, and planters, and many times the slope is too steep to permit the use even of oxen. In these areas when a crop is planted it is done by the crude method of simply dropping the seed into a hole poked into the ground with a stick. Cultivation is also made more difficult in these areas because of the inability to use mechanization. All of these factors are influenced by topography and affect productivity.

This would make no difference to this study if there were no differences in topography between the two life zones. But there is a marked difference. From its very nature, the tropical premontane wet forest life zone is more hilly than the tropical moist forest life zone, because the former is an altitudinal belt within the tropical basal region, which necessarily means that it exists some distance above sea-level. Thus, wherever this life zone exists, it means that some of the land will be relatively steep. Of course, it could happen that a plateau might exist at just the right altitude so that a large and level area could be found within this life zone. If such were the case it would be much easier to compare the two life zones since the influence of gradient could be eliminated. But such a condition is highly unlikely, since not only must the altitude be correct but the amount of rainfall must also be such as to fall within the limits of that parameter for the life zone. Since mountains usually influence the pattern of rainfall, the likelihood of a combination of the two requirements over a large level area is remote. In fact, there are no such areas in Costa Rica.

The tropical moist forest life zone on the other hand is a basal region life zone. This means that this life zone exists fairly near sea level and that any mountains that do exist are relatively low. Thus, this life zone is usually flat or perhaps rolling, but seldom is it mountainous. This is in fact the case for this life zone throughout Costa Rica. It is often flat or slightly rolling, but never mountainous.

Thus, these two life zones are topographically distinct. The only evidence available on this aspect of the life zone system is contained in a study done for the United States Department of Defense.[1] In this study sites were chosen from each life zone varying in size from 4 to 14 square kilometers, and mapped in detail for land use patterns, topography, and other characteristics. Two of these sites are in the tropical premontane wet forest life zone; one is in the tropical moist forest life zone and another is on the borderline between these two life zones. Table 3 shows the extensiveness of selected degrees of slope at the various sites. The table shows that for the two tropical premontane wet forest sites there are 27 and 29 per cent of the areas with a slope greater than 24 per cent. At the one site completely within the tropical moist forest life zone there is only 14 per cent of the area with a 24 per cent or more slope. The borderline site has 28 per cent of the area with slope greater than 24 per cent. If we consider a slope of 12 per cent or greater, we get

---

[1]Joseph A. Tosi, Jr., "Aerial Photographic Interpretation of Life Zones," Research on a Bio-Ecological Classification for Military Environments Found in Tropic Latitudes, Advanced Research Projects Agency, Army Research Office, OCRD, Department of the Army, (Arlington, Virginia, 1965.)

the same picture. The table shows that 72 and 75 per cent of the two tropical premontane wet forest sites have this slope or greater, while the one tropical moist forest site has only 41 per cent of the area in this category. It is interesting to note that while the borderline site has a relatively large per cent of its area with slope of 24 per cent or more, it has a relatively small per cent of its area with slope of 12 per cent or greater. This is explained by the fact that this site includes a relatively flat area that is quickly transformed into some rather rugged mountains. Thus, the approach to the mountains is relatively limited in extension. This gives further support to the hypothesis that the tropical premontane wet forest life zone must be quite different in topography from the tropical moist forest life zone. If this site had extended farther up the mountain side, it would have run into the tropical premontane wet forest life zone, and if it had extended in the other direction it would have encountered the tropical moist forest life zone.

Since topography is not affected by the climatic parameters, but does affect productivity, its influence should be allowed for in the determination of the effect of the climatic parameters on productivity. Life zones are defined solely in terms of the climatic parameters; therefore, to test the hypothesis that there is a relationship between the life zones and productivity the influence of all extraneous factors should be eliminated. This would permit an accurate analysis of the influence of the life zones.

Nevertheless, a case can be made from a practical point of view for taking the life zones as they are found - that is, with variations in topography, assuming that what has been said before about life zones

and topography is true. So, if the tropical premontane wet forest life zone wherever found has more rugged terrain, then for practical purposes any analysis should include this characteristic as part of the life zone. In this study no adjustment was made for topography.

TABLE 3

SLOPE VARIATIONS BETWEEN THE TROPICAL PREMONTANE WET FOREST AND TROPICAL MOIST FOREST LIFE ZONES

Slope Site	Greater than 24% slope	Greater than 12% slope
Site #1	14.1 per cent	40.6 per cent
Tropical Moist Forest		
Site #2	28.7 per cent	37.2 per cent
Tropical Moist Forest (borderline)		
Site #3	27.0 per cent	72.6 per cent
Premontane Wet Forest		
Site #4	29.3 per cent	75.7 per cent
Premontane Wet Forest		

Source: "Aerial Photographic Interpretation of Life Zones", Research on a Bio-Ecological Classification for Military Environments Found in Tropic Latitudes, J. A. Tosi, Jr., Advanced Research Projects Agency, Army Research Office, Arlington, Virginia, 1965.

Another factor which affects productivity but which is not related to the climatic parameters (at least to an extent great enough to be accurately measured) is the degree of technical knowledge on the part of the farmers. This, of course, is reflected in the methods used in the various life zones, and includes not only the knowledge but the economic ability to implement this knowledge. Thus, if the knowledge (due to greater access to sources of information for example), or the economic ability (due to past successes in agriculture) of the farmers in one life zone surpasses that in another life zone, productivity could differ by life zone from this factor alone. The ecologists hold that productivity should differ by life zones, and moreover, that the tropical moist life zone should be more productive than the tropical premontane wet life zone. If this is true, in any given year it could reflect differences in past economic success or knowledge rather than the life zone parameters. There is no a priori reason why knowledge should be more advanced in one life zone in Costa Rica than in another, since the country is relatively small and both life zones are about equally dispersed with no obvious differences in their development of communications. But it is possible that a difference does exist between the two life zones in the ability to implement whatever knowledge does exist since the tropical moist forest life zone would appear to be better suited to agricultural production, and thus more profitable. Nevertheless, it will be seen later in this chapter that this conclusion cannot be substantiated.

There are other factors that could be mentioned which influence productivity but which are themselves not influenced by the climatic parameters. For example, the establishment of governmental or private institutions to assist the farmer, the extension of credit systems into various areas, the development of community projects for the farmer to become involved in the general health of the people, and the use of fertilizers and other applied inputs have an influence on productivity but are only remotely influenced by the climatic parameters. Enough has been said to indicate the difficulty in isolating the effects of the climatic parameters on productivity, and also, to give some a priori expectation that the differences within life zones may be greater than the differences between life zones, since any of these variables could have a strong effect on production and could vary as much within the life zones as between them.

Productivity is a concept often confusing and always difficult to measure. In economic theory productivity is generally thought of in two different senses. In one of these, productivity is used to refer to the output resulting from the application of one unit of a particular resource - all other resources being held constant. Thus, the marginal productivity of labor is the increase in output due to the addition of one more unit of labor with all other factors held constant. In the other sense, productivity is used to refer to the differences in output due to different combinations of resources. Thus, we say that one combination of resources is more productive than another in the production of a given product. In a theoretical sense both of these concepts are useful, but in a practical sense they present formidable problems of measurement. It is difficult to increase a given resource by one unit, and to hold all other resources constant. In terms of the various combinations of resources and their differing productivity, measurement is equally difficult because of the infinite number of possible combinations that could be studied. In addition, these problems are overshadowed by the difficulty of measuring the input of certain factors - especially capital.

The concept of productivity used in this study is that of a

combination of resources and is measured in terms of the output per manzana of land. The output per manzana for the farms in the one life zone is compared with the output per manzana for the farms in the other life zone. Productivity on the farms in the two life zones is measured given the combination of resources being used on the farms. No attempt is made to hold the methods of production constant, nor is there any attempt made to ascertain whether the most efficient combination of resources is being used. The assumption is made that the farmers have adjusted to that combination of resources that best fits their life zone, and that therefore, the technology used reflects the effects of the climatic parameters. This assumption is crucial to the following analysis. Thus, productivity might vary by life zone because the farmers must adjust their technology because of the differences in the climatic parameters. In other words, the assumption is that the differences in the climatic parameters have caused the farmers to use different technology, and that they always use the technology best suited to the climate within their life zone. Given this assumption one can be sure that any effect of the climatic parameters on productivity through technology will be registered. Productivity on all farms in those political subdivisions falling at least 85 per cent within the two life zones is compared on the basis of the output per manzana of corn. The same important assumption is made concerning the influence of the climatic parameters on the technology used in the two life zones.

Before proceeding to a more detailed description of the method used to compare productivity by life zone and the results of that comparison, there is another ticklish matter to dispose of. It has often been assumed by economists that there is a positive relationship between

productivity and farm size and that there is an optimum farm size in terms of productivity. Very small farms are thought to be inefficient, with low productivity and high per unit costs, as are very large farms. The application of economic theory to agriculture leads one to the conclusion that economics of scale are possible up to a certain point, and that to have high productivity agriculture, farms must approximate the optimum size. The communist countries especially have been experimenting with large scale agriculture, while in the United States farms are gradually becoming larger. The family-sized farm, which is majority of farms in the underdeveloped countries today, is no longer considered the ultimate in efficiency. The large corporate farm is now a prevalent and efficient type of farming in this country. In many of the developing countries the trend is toward smaller and smaller farms, but for political rather than economic reasons. The usual procedure is to expropriate the large farms and to divide them into many small (usually too small) farms. In some cases this has led to a reduction in output, especially where the large farmer had originally been using the land relatively efficiently.

Schultz suggests that there is no necessary relationship between farm size and efficiency. He states that: "In searching for the economic attributes of traditional agriculture, it became clear that small farms, or for that matter large farms, are not essential attributes... The size of farms may change as a consequence of the transformation (of traditional agriculture) they may become either larger or smaller - but changes in size are not the source of the economic growth to be had from this modernization process."[2]

For this study the matter of farm size is important, since if farm size does effect productivity, and farms are on the average larger in one life zone than in the other, productivity could differ for this reason alone. In order to provide for this possibility, a comparison is made between the two life zones to determine if there is a difference in the average size of farms, and in addition, tests are made to see if there is a correlation between farm size and productivity.

The sample taken from the Costa Rican Department of Census is used to determine if there is a difference in the average size of farm. Size of farm for this purpose is defined in two ways: in terms of the total area of the farm, and in terms of the area of the farm planted in corn. Under the first definition, in the tropical moist forest life zone the farms range from 8 manzanas to 2,360 manzanas, whereas in the tropical premontane wet forest life zone, they range from 11 manzanas to 896 manzanas. Under the second definition, the farms in the tropical moist forest life zone range from 1 manzana to 100 manzanas, and in the tropical premontane wet forest life zone they range from 1 manzana to 32 manzanas. In terms of range, then, the tropical moist forest farms exceed the tropical premontane wet forest farms under both definitions. This does not mean that there is a difference in the average size farm, however, since a large number of smaller-sized farms could offset the few

[2]Theodore W. Schultz, Transforming Traditional Agriculture, (Yale University Press, New Haven and London, 1964), p. 110.

larger farms in the tropical moist forest life zone, or the opposite of this could mean a higher average in the tropical premontane wet forest life zone.

The method used to determine if these two samples of farm size are significantly different from each other is as follows: first, the null hypothesis is made that there is no difference between the two life zones in the average size of farm. Then to test this hypothesis the standard error of the difference of the means of the two samples is computed and compared with the actual difference in the two means. This value is distributed according to the t-distribution, however, in the computations made here the samples are large enough that the distribution closely approximates the normal curve. The .05 level of probability is used as the level of significance.

The results of these computations,[3] with farm size defined as the total area of the farm, are interesting. In the tropical moist forest the standard error is 31.17 or 17.96 per cent of the mean, while in the tropical premontane wet forest it is 21.68 or 16.70 per cent of the mean. This is somewhat of a measure of the accuracy of the sample in describing the true mean of the population. The standard error of the difference, which is the standard deviation of a distribution of differences for a large number of pairs of random samples of means independently drawn from the same population, is 37.97. The test statistic (t-value) is 1.15 which, since the number of degrees of freedom is relatively large (171), proves not to be within the area of rejection of the null hypothesis. Thus, the null

[3]The statistical analysis is presented in Appendix B.

hypothesis must be accepted, as there is probably no appreciable difference in the average size of farm for the two life zones.

When farm size is defined as the area planted in corn, similar results are obtained. In this case the standard error of the mean for the tropical moist forest is 1.04 which is 13.16 per cent of the mean, and in the tropical premontane wet forest it is .768 which is 9.8 per cent of the mean. The standard error of the difference is 1.29, and the test statistic is .0775. Given the large number of degrees of freedom (171), we again accept the null hypothesis. That is, the evidence again is that there is no significant difference in the average size of farm between the two life zones.

Under either definition of the size of farm the conclusion is the same. Nevertheless, the large standard errors in relation to the mean indicate some lack of reliability on the part of the four means. This suggests considerable variability in the distribution of sample means, and it is possible that the means deduced from our samples differ significantly from the true population mean. Therefore, the means of the samples of the sizes of farms, using either definition, may not give a valid picture of the average size of farm in the two life zones.

To avoid the possibility of not detecting an influence of the size of farm on productivity because of the unreliability of the means of the farm sizes as described above, correlations are calculated between the size of farm and productivity in each of the life zones. If such a correlation does exist, there will remain some doubt concerning the differences in productivity by life zone since the average size of farm <u>could</u> differ by life zone. The large standard

errors prevent us from making definitive statements on this latter point. If such a correlation does not exist, then any difference in farm size between the life zones will be inconsequential since the difference could have no effect on productivity.

Correlations are calculated for both life zones between size of farm and output per manzana on the farms, with the size of farm defined in two ways, total area and area planted in corn, rice, and/or beans, whichever the case happened to be. Thus, in each life zone six correlations are run - one for each of the three crops under each of the two definitions of farm size. This gives a total of twelve correlations in all. Table 4 shows the results of these computations. As can be seen, all of the correlations are very low; in fact, in five of the six correlations between area planted and output per manzana, the correlations are negative. The correlation between total area and output per manzana of corn in the tropical moist forest is the highest, but it still is far from being conclusive.

To test the significance of these coefficients, the null hypothesis is made; that is, it is hypothesized that the coefficients are not significantly different from zero. The .05 level of probability is accepted as the level of significance, or in other words, if the probability is less than 5 in 100 that the coefficient could have happened by chance from a situation where there is actually no correlation between the two variables, the hypothesis is rejected. On the contrary, if the probability of obtaining this coefficient by chance out of an actual situation of no correlation between the variables is greater than 5 out of 100, the hypothesis is accepted. The t-distribution is used since in several of the correlations the number of degrees

of freedom was fairly low.

The values for the t-statistics are given in Table 5. Of the twelve coefficients of correlation only two, one in each life zone, are significantly different from zero as measured by this test. In the tropical premontane wet forest life zone the correlation between total area and output per manzana of rice is significantly different from zero; whereas the same is true of the correlation between total area and output per manzana of corn in the tropical moist forest life zone. Most of the other t-values are very low, and thus there is a very large probability of these coefficients of correlation occurring by chance when no actual correlation exists. The one correlation in the premontane wet forest life zone is significant at the .05 level of probability, and that in the tropical moist forest life zone at the .02 level.

The coefficient of correlation does not indicate cause and effect, but merely indicates that a relationship exists between the two variables being compared. Also, it is difficult to label the degree of relationship as being "low" or "high regardless of the value of the coefficient since a "low" value for the coefficient may indicate an important relationship between the variables. The null hypothesis test described above is one way, however arbitrary, of establishing the value of these coefficients.

The conclusions to be drawn from the investigations of the relationship between the size of farm and productivity are as follows: First, there seems to be no difference in the average size of farm between the two life zones using either of the two definitions of size. Secondly, there is little evidence of a relationship between

TABLE 4

CORRELATIONS BETWEEN SIZE OF FARM AND OUTPUT PER MANZANA BY LIFE ZONE

Correlation / Life Zone	Total Extention Corn	Total Extention Rice	Total Extention Beans	Area Pltd. Corn	Area Pltd. Rice	Area Pltd. Beans
Tropical Moist Forest	.225	.028	-.092	-.062	-.059	-.155
Tropical Premontane Wet Forest	.135	.407	.242	.058	-.101	.264

TABLE 5

t-STATISTICS FOR THE TEST OF SIGNIFICANCE OF THE CORRELATION COEFFICIENTS FOR THE CORRELATION BETWEEN FARM SIZE AND PRODUCTIVITY BY LIFE ZONE

Tropical Moist Forest	t = 2.44	t = .262	t = .800	t = .657	t = .558	t = 1.36
Tropical Premontane Wet Forest	t = 1.02	t = 2.14	t = 1.34	t = .435	t = .478	t = 1.47

the size of farm, however defined, and productivity. Of the twelve correlations, only two are significantly different from a zero. Thus, we can tentatively say that differences in farm size will not disrupt our comparisons of productivity differences between life zones resulting from differences in the climatic parameters.

With this matter disposed of we can proceed to the comparison of the productivity of the farms between life zones. Life zones are compared on the basis of two different sets of data over productivity. The first and most important comparison is made on the basis of the data collected for the sample of farms that was drawn from the sample designed by Costa Rican Department of Census.[4] The other comparison is made on the basis of data gathered from the Costa Rican Department of Census on the output per manzana of corn in those districts that are at least 85 per cent within either of the two life zones. The method used for these comparisons is the same as that used in comparing the size of farm between life zones described earlier in this chapter, and these comparisons are made under the assumption that all extraneous forces have little or no influence on productivity.

Data on the output per manzana of corn, rice and beans were collected from the Costa Rican Department of Census for the farms in this sample and verified where possible when the farmers were interviewed. These data were gathered by the Department of Census for the

---

[4]José G. Baptista and Mario Murillo M., Diseño de la Encuesta Agrícola por Muestreo de Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, December, 1965; and José G. Baptista and Mario Murillo M., Encuesta Agrícola por Muestreo Arroz, Maiz y Frijól, 1965, Dirección General de Estadística y Censos, Republica de Costa Rica, May, 1966.

1963 Census of Agriculture, but were not published in the form necessary for use in this study. The original data were given in _fanegas_ for corn, _sacos_ for rice, and _cajuelas_ for beans, but the measure for each crop was converted to pounds for the purpose of this study. Thus, the number of pounds per manzana of corn, rice, and beans, produced during the year 1963 was obtained for the farms in this sample. The group of farms in the tropical moist forest life zone was then compared with the group from the tropical premontane wet forest life zone on the basis of this data, using the standard error of the difference and the t-statistic again.

The first step in this procedure is to compute the standard error of estimate for the mean of the sample in each life zone and for each crop. These values, along with the ratio of the standard error of the mean to the mean, are given in Table 6. There are two items of importance to be noted in this table. One is that, except in the case of beans, the standard error is much greater in the tropical premontane wet forest life zone than in the tropical moist forest life zone, and in addition, the standard error as a percentage of the mean (coefficient of variance) is greater for each of the three crops in the tropical premontane wet forest life zone than it is for these respective crops in the tropical moist forest life zone. This indicates that the variability in the characteristic being measured is much greater in the tropical premontane wet forest life zone than in the tropical moist forest life zone. This would lead one to believe that there _should be_ significant differences in in productivity between life zones.

TABLE 6

STANDARD ERRORS OF THE MEAN AND THE RATIOS OF THESE STANDARD ERRORS TO THEIR MEANS BY LIFE ZONE FOR SELECTED CROPS (RATIOS IN PARENTHESIS)

Crop / Life Zone	Corn	Rice	Beans
Tropical Moist Forest	91.11 (7.10%)	66.77 (6.84%)	55.57 (9.61%)
Tropical Premontane Wet Forest	134.07 (8.86%)	122.68 (11.33%)	54.22 (10.59%)

The null hypothesis is made, that is, that there is no difference between the means of the two samples of farms producing corn in terms of this characteristic. To test this hypothesis the standard error of the difference is computed, along with the t-statistic. The .05 confidence level is taken as the level of significance, and output per manzana is used as the measure of productivity. In comparing the two samples for the output per manzana of corn the standard error of the difference between the two means - the mean pounds per manzana of corn produced in each life zone based on the sample of farms - is 162.10.[5] The t-statistic, which is computed by dividing the actual difference between the means by the standard error of the difference, has the value 1.42. The size of the sample in the tropical premontane wet forest is 59, and that in the tropical moist forest 114, which

[5]Those computations are presented in full in Appendix B.

gives a number of degrees of freedom equal to 171 (59 plus 114 minus 2). With this number of degrees of freedom, the t-distribution approximates the normal curve closely enough that the values for the confidence levels of the normal curve can be used. Under the normal curve the t-statistic must have a value of 1.96 or greater to reach the .05 level (or greater) of significance.

Since the t-statistic has a value of 1.42 and we are accepting the .05 level of significance, we accept the null hypothesis. In other words, we accept the hypothesis that there is no significant difference between the means of our two samples. These two means could have occurred with a relatively high degree of probability, by chance, out of the same population. If the t-statistic had been such that the probability was less than .05 (5 per cent) that these two means could have come by chance out of the same population, then we would have rejected the hypothesis and considered the two means to be significantly different. This was not the case, however, and so we postulate that the two samples are very similar in output per manzana of corn.

The method for analyzing the productivity (output per manzana) in rice is identical to that used in corn, with the same level of probability accepted in determining significance. The standard error of the difference between the two means of the samples of farms producing rice is 139.61, and when this is divided into the actual difference between the two means, it provides a t-statistic of 0.77. Again the number of degrees of freedom is large (115), resulting in a close approximation between the t-distribution and the normal curve. The result is that the t-value again fails to reach the size necessary for

the rejection of the null hypothesis, and therefore we accept it. The conclusion drawn is that there is no significant difference between these life zones in productivity in rice. This is borne out by the fact that the two means of our two samples could very well have occurred by chance out of the same population. In fact, there is a high degree of probability that this could have happened.

Using the same definition of productivity and the same level of probability for determining significance, the result is the same for the production of beans in the two life zones. In this case the standard error of the difference is 77.64, and the t-statistic is 0.85. The number of degrees of freedom is again large enough (109) that the normal curve can be used. In this case, as in the case of corn and rice, the t-statistic is not near large enough to permit rejection of the null hypothesis. Thus, the hypothesis is accepted, and the conclusion is that there is no difference in the two life zones in productivity in beans.

It was pointed out earlier in this chapter that the standard errors of the means in the tropical premontane wet forest life zone were larger than in the tropical moist forest life zone for corn and rice, and about equal for the two samples for beans. In addition, the coefficient of variation - the ratio of the standard error of the mean to the mean - was larger for all three crops in the tropical premontane wet forest life zone than in the tropical moist forest life zone. Since the size of the sample is inversely related to the standard error of the mean and the samples in the tropical premontane wet forest are much smaller than in the tropical moist forest, even though as a percentage of the total number of farms in the life zones they were

equal), this relatively smaller size of sample in the one life zone might be exerting an undue influence on the standard errors, and hence on the t-statistic. The relationship between the size of the sample and the standard error of the mean is such that a quadrupling of the sample will half the standard error. It is assumed for the following analysis that a doubling of the sample will cut the standard error by one-fourth. In the case of corn doubling the size of the sample in the tropical premontane wet forest is sufficient to bring that sample up equal in size to the sample in the other life zone. When this is done, using the assumption given above, the t-statistic for this comparison rises to only 1.69, which is still well below the 1.96 necessary for rejection of the null hypothesis. The difference in the sizes of the two samples of farms producing rice is such that a quadrupling of the sample in the tropical premontane wet forest is necessary to bring the samples to approximately equal size. This, of course, will cut the standard error of the mean in half, but even so it increases the t-statistic to only 1.20 which is much below that necessary for rejection of the hypothesis. In the case of the sample for beans a doubling of the sample for the tropical premontane wet forest is necessary to draw them close together in size. When this is done the t-statistic increases to only 1.00, which is again far below that necessary for rejection of the null hypothesis. The conclusion then is that the existence of a relatively small sample in the one life zone is not sufficient to account for the lack of a significant difference between the means.

We see then that in each of the three comparisons - corn, rice and beans the result is that there is no significant difference

between the two life zones in productivity. It seems then that the climatic parameters which determine the life zones are either not strong enough to cause a difference in productivity, or are offset by factors of equal strength pulling in the opposite direction.

As a further test of productivity difference by life zone, it was decided to compare output of corn per manzana for all farms in those political districts that fall at least 85 per cent within one of the two life zones. Thus, all those districts which are geographically 85 per cent or more within the tropical moist forest life zone are compared with their counterpoints in the tropical premontane wet forest life zone. In the first of these two life zones there are 24 such districts, and in the latter there are 16. The standard error of the mean is 84.97 and the coefficient of variation 5.70 for the tropical moist forest sample; and 304.14 and 14.52 respectively for the tropical premontane wet forest. The standard error of the difference for the two samples is 316.10, and the t-statistic was 1.93. With the 38 degrees of freedom and using the .05 level of significance, this t-value is not significant. That is, the null hypothesis is that there is no difference in the two means is accepted. The two means could have occurred by chance from the same population with a frequency greater than 5 out of 100.

Based on the above analysis the conclusion is reached that there is no discernible difference between these two life zones in the output per manzana of corn, rice, and beans. The reasons for this lack of difference in productivity will be discussed fully in later chapters.

CHAPTER V

FARM TECHNOLOGY AND THE LIFE ZONE SYSTEM

This chapter deals with the influence of the life zones on farm technology. The term technology as used here is synonymous with the methods of production of the various crops and includes the various steps involved in planting, cultivating, harvesting, and marketing. More specifically, it includes the particular combination of factors (land, labor, capital and entrepreneurship) being used in the life zone; however, the measurement of factor combinations is very difficult because of the problem of accurately measuring certain of the factors involved. Later in this chapter the many aspects involved in the definition of farm technology will be made more specific.

It is assumed in this analysis that the farmers have adapted their techniques to the life zone, and that they are motivated to use the most productive methods known to them. These assumptions are critical to the following analysis since if the farmers are not forced by the profit motive to use the most efficient methods in the respective life zones, one can conclude nothing by comparing them on this basis. This is so because one would not know the relative degree of development of the methods between the two zones. The farmers in one life zone might be using methods that are very efficient for that zone, while the farmers in the other life zone might be using methods that are inefficient for their life zone. Not being able to judge the

degree of efficiency or inefficiency of the farmers one would have no common basis for comparing the methods of production in the two zones. Under the assumption that the farmers are using the most efficient methods in the two zones, we have a common basis for making comparisons.

There was no evidence uncovered in this study to indicate that the farmers were not motivated to use the best methods known to them. On the contrary, the farmers seem to take their lack of productiveness very seriously, and show a vital concern over the obstacles to increasing their productivity. Based on their obvious desire to improve, it seems unlikely that they would fail to take advantage of an improved method of production if it were made available to them. Corn is not the primary crop of the farmers in either of the two life zones, but there is no reason to believe that its cultivation is neglected in either life zone. On this basis it seems that the assumption made above is realistic.

The ecologists concerned with the life zone system have made no concrete statements with respect to its relationship to farm technology, and have carried out no studies on this aspect of the system. However, they have made some general statements of the expected relationship, and one can easily speculate on the sort of variations that would probably exist. The ecologists say that when we consider the spectrum of life zones over which the amount of rainfall is becoming progressively heavier, we find that the soils become increasingly leached of nutritious material. It follows then that the respective soils will be progressively less productive, or that maintaining a given level of productivity will require a larger and larger amount of fertilizer.

Thus, we should find that as one moves from drier to wetter life zones, the use of fertilizer should increase. We should also find a different combination of crops being grown in the wetter life zones, with more emphasis on crops better suited to that condition. This aspect will be discussed more fully in the chapter on land use.

We should expect other differences as temperature is increased over the range of life zones. For example, as temperature increases the rate of evaporation and transpiration increases so, with a given amount of rainfall, growing conditions become drier. This is reflected in the life zone system by the potential evapotranspiration ratio, which, with a given amount of rainfall, becomes larger as temperature is increased. This means that the ratio of the amount of water being evaporated and transpired into the atmosphere to the amount of water made available in the form of rainfall increases. The effect of this condition on technology is to require the use of irrigation to maintain a given level of productivity, or to lower productivity whenever irrigation is not used. In addition, one would probably find more frequent cultivation in an attempt to conserve or to make better use of the available water. The primary difference in the two life zones considered in this study is in temperature, and one should find the greatest differences in technology to be based on the difference in this factor. Since temperature affects many variables indirectly and in obscure ways, some variables seemingly unrelated to heat are investigated for differences between life zones.

The data on technology is divided into sections which correspond to the four major operations performed by the farmers in growing corn. These are planting, cultivating, harvesting, and marketing. In general

there is a considerable amount of similarity between the two life zones in the methods of production. Most of the differences that exist are the result of variables other than those which define the life zones. As mentioned in an earlier chapter, topography plays a large role in determining the technology used in the two life zones. In addition, there is some variation in the influence which the extension agents have been able to exert upon the farmers to adopt certain practices. In general however, these agents seem to be rather inefficient in getting their message across. Even where they have been most influential they usually have confined themselves to recommending certain fertilizers, seeds, and distances between plants and rows, while neglecting some other equally important, but less technical, practices. For example, seldom does an agent recommend the use of credit to the farmer, even though this is generally available from the local banks for use in the production of corn. The agents do not seem to consider this as one of their tasks, but rather limit themselves to the actual techniques of production as defined in the bulletins of the Costa Rican Ministry of Agriculture. In other words, they are not so much interested in the economics of producing corn as they are in the technology involved. Thus, although there are differences in life zones, very few of these can be said to result from the three climatic parameters.

There are two distinct methods of production used in growing corn in the two life zones, with one method more prevalent in the tropical moist forest and the other more prevalent in the tropical premontane wet forest. There are of course, some variations in the specific details of these methods which will be discussed later in

this chapter, but in general the methods are as presented here. Also, the two methods used overlap in both life zones, but one method predominates in one life zone and the other predominates in the other life zone. The method prevailing in the tropical premontane wet forest life zone will be called the labor intensive method, and that in the tropical moist forest life zone will be called the capital intensive method recognizing, however, that this is only a matter of degree and that neither of the two methods can be considered capital intensive.

In the tropical premontane wet forest life zone the method of producing corn is more primitive than that in the tropical moist forest life zone. The method in general use is as follows: The land to be planted is first cleared of weeds by cutting them with a machete and burning them. If the weeds are relatively low, less than knee-high, the farmers do not bother to burn them. The weeds are often somewhat taller than this however, and are burned. This is usually done between mid-March and mid-April, shortly before the rains begin and while the weeds are dry. The farmers try to plant their corn just a few days before the rainy season begins so as to have good germination for the seed. This means that they plant around the early part of April.

The actual planting of the seed by most of the farmers in this life zone (80 per cent of the thirty farms interviewed) is done by the use of a macana. This is a long pole with a flat, narrow blade about an inch-and-a-half wide and six inches long, and is evidently a carry-over from the stick used years ago by the Indians. The blade of the macana is jabbed into the ground at an angle of approximately 60 degrees and then pushed forward to a position perpendicular to the ground. This opens a small hole beneath the blade into which the seeds

are then dropped. The macana is then jerked out of the hole permitting the dirt to fall down over the seed. The farmer then takes a step forward and repeats the process. This is continued until the entire field has been planted.

On the other twenty per cent of the farms in this life zone the land is plowed using a team of oxen and a single blade plow. Not one of the thirty farmers interviewed in this life zone uses a tractor to pull a plow. There is one farmer who uses a corn planter, but he pulls this with his oxen. After the land is plowed, the farmer walks along in a straight line dropping seeds into the plowed earth at intervals of about three feet, covering the seed by pushing some dirt over it with his feet, and then stepping down on the seed lightly. As one can imagine, the ground is very poorly prepared prior to the actual planting of the seed, even where the farmer plows his fields. A few farmers use a rastra (drag) to break down some of the larger clods of earth, but even this is not a common practice.

Cultivating corn in this life zone is accomplished in two different ways, the most common of which is to cut the weeds between the plants and rows with a machete. This leaves an inch or so of the weed standing, and of course leaves the roots of the weed intact. About two-thirds of the farmers in this life zone cultivate their corn in this manner. The other third use a shovel with which they skim off the top inch or so of soil which removes the roots of the weed and slows its regrowth. Most often this latter method is used in conjunction with the building of mounds around the base of the plant to help support it. Thus, the farmer is performing two operations in one: first he gets rid of the weeds around his corn, and second, he uses the scraped-up dirt as support for the stalks of corn. These supports are necessary in some areas because of the prevalence of high winds which knock the stalks down.

Corn is usually cultivated twice in this life zone. The first cultivation occurs twenty-two days after planting, and the second about one month after the first. These times of twenty-two days and one month are those recommended by the Ministry of Agriculture for the entire country, which indicates that some of the recommendations of the Ministry are getting through to the farmers. A few farmers cultivate either once or three times instead of twice, but these are exceptions, and occur in less than twenty per cent of the cases. Two farmers said that they cut the weeds whenever they got too high, but would not specify a number of times saying that this depended on how fast the weeds grew.

The method of harvesting corn is similar for almost all farmers throughout this life zone. It consists of walking through the corn-field, pulling the ears off by hand, and tossing them on to a pile to be picked up later with a team of oxen and a cart. Where the topo-graphy is very steep, the farmer will carry a sack hanging down his back into which he puts the ears of corn. A couple of farmers take the oxen and cart into the field with them when picking the corn, and throw the corn directly into the cart. This latter occurs only when the topography is such as to not burden the oxen standing for a long time in the field. One farmer reported taking a jeep into the field with him and tossing the ears into the back of the jeep. If the corn is to be sold soon, it is husked immediately (often in the field when picked); but if it is to be stored for later sale or for future home consumption, the husk is left on as protection against insects.

Harvest time in this life zone is usually in the latter part of August or the first week in September; however, there are some farmers who harvest in mid-July and sell their corn as "sweet" corn. These farmers then plant a second crop of corn to be harvested in December. About one-third of the farmers harvesting in late August or early September also plant a second crop, in most cases using the broadcast method of planting to save time. This method consists of simply throwing the seed on top of the ground, and hoping for something to grow.

The method of marketing corn is in some ways very uniform and in others very different. All of the corn is shelled before it is sold, and unless it is to be sold specifically as forage for animals, it is cleaned before being sold. The shelling of the corn is done by machine on slightly more than half of the farms in the sample, and in some cases the machine is elevated so that the grains of corn are cleaned by the wind as they fall from the bottom of the machine to the ground. Most of the time, however, the grain is cleaned by pouring it from a tray or gourd that is held above the head, with the wind cleaning the corn as it falls. Every farmer interviewed was reported selling corn (including those in the tropical moist forest life zone) puts it in sacks prior to selling it. If the farmer sells to a middleman, he is furnished the sacks, but if he sells to the National Production Council he must buy his own sacks. Many of the farmers gave this as the reason for not selling to the Council.

The method of transporting the corn to market varies considerably in this life zone, but the variation is due more to the differing

topography than it is to the climatic parameters. The most common method is to haul the corn to the place of sale in a cart pulled by a team of oxen, but in several cases where the terrain is extremely hilly the corn is taken out on horseback. A couple of the farms visited are so isolated that the lack of effective means of transportation prohibits the farmers from selling their produce, and therefore everything they grow is for their own consumption.

The actual selling of the corn varies considerably from farm to farm. In some accessible areas the middlemen come to the farms to make a deal for the corn, but where the farms are more isolated, the farmers must take their corn into the cities to sell it. If the middleman buys the corn at the farm, his truck will appear at the appointed time to pick it up, thus saving the farmer the task of transporting it to market. This method of sale is used on about twenty per cent of the farms visited. A majority of the farmers must haul their corn to the point of sale, usually the nearest fair-sized town, and make a deal with a middleman or a merchant. In some cases the farmers sell to the same individual year after year, and in others the farmer shops around for the best price.

Most of the farmers visited sell their corn to middlemen, who then sell to the several merchant clients with whom they have arrangements. The Costa Rican National Production Council has set a minimum price for corn, and is theoretically ready to buy corn at that price. The price that the council has set, however, is much too low to permit the farmers to make a profit, so they try to sell to private buyers who pay more. Even then, under the methods of production used by these farmers, the price they receive is not enough to cover the costs of

production. There is some evidence that this price would be high enough to cover the cost of production if the farmers could be persuaded to increase their use of fertilizer. This would substantially increase productivity and lower the unit cost of production. Fertilizer is available to the farmers in Costa Rica; however, its purchase requires the farmers to make use of credit. This will be elaborated upon in the following chapter on cost of production.

The farmers failure to use fertilizer in producing corn does not contradict the assumption made earlier that the farmers use the methods best adapted for the life zones. The earlier assumption is restricted to those practices that the farmers know to be available to them. Most of the farmers do not consider using fertilizer because they do not have the cash to purchase it with, and credit for this purpose is not effectively available. Thus, the farmers do use the best technology they know to be available. Many farmers recognize that fertilizer will increase their output but report that they can not afford to buy it. The number of farmers using fertilizer on corn in each of the life zones is extremely small.

About one-half of the farmers in each of the two life zones said that they shopped around for the best price for their corn. This is usually done by word of mouth among the farmers themselves, but a few of the farmers obtain information from the middlemen who come to the farms to purchase their corn. Some of the farmers, again in each of the two life zones, hold their corn off the market for one to three months to take advantage of an expected increase in price. They recognize that the heavy supply right at harvest time lowers the price, and that by waiting until a later date, they can obtain a higher price. Thus, some of the farmers seem to respond to anticipated price differentials and to recognize the effect of the forces of supply and demand on price. There is little difference between life zones in the extent to which the farmers take advantage of these price variations.

The technology used in the tropical moist forest life zone is very similar to that used in the tropical premontane wet forest life zone, with one major exception. In the tropical moist forest life zone the preparation of the soil prior to planting is handled somewhat differently, especially in the area of this life zone that is relatively flat. Almost two-thirds of the farmers in this life zone plow the land before planting corn, in contrast to the tropical premontane wet forest where only 20 per cent of the farmers interviewed plow their land. About 50 per cent of the farmers in the tropical moist forest use tractors for plowing and 20 per cent plow with oxen, whereas all of the farmers in the tropical premontane wet forest life zone who plow, do so with oxen. On none of the farms visited in the latter life zone do the farmers use tractors for plowing. This, of course, does not mean that none of the farmers in that life zone use tractors, but it does indicate that tractors are in limited use. Also, due to the widespread use of tractors in the tropical moist forest life zone there is a relatively small amount of plowing by oxen. This seems to be the one factor responsible for the greater capital intensity of the technology in this life zone. The conclusion in the last chapter that there was no significant difference in productivity between the two life zones becomes particularly interesting given this wide variation in the use of tractors in the two zones. Assuming that there are no factors offsetting the influence of tractors on productivity, this indicates that the use of tractors is, in itself, not a significant factor in increasing output per unit of land. But it remains to be seen what effect their use will have on the cost of production. This matter will be discussed in the following chapter.

About one-half of the farmers using tractors own them. Of course, only the larger more diversified farmers are able to own their own tractors, primarily because they can spread the cost of purchasing, operating, and maintaining it over several different crops. It is interesting to note in comparison, that not one farmer interviewed in the tropical premontane wet forest life zone mentioned the possibility of renting a tractor, or expressed any interest in so doing. When asked about the possibility they would say either that it was too expensive or that their land was too rugged for a tractor. This latter reason seems to be the predominant reason why the farmers in the tropical premontane wet forest life zone do not use tractors. Their land is too steep to permit the use of tractors. Thus it does not seem to be heat, precipitation, or moisture - as these are defined in the life zone system - that determines the use or non-use of tractors, but the topography; and as was pointed out in Chapter IV, there may be a substantial difference in topography between life zones.

The most common procedure for planting corn in this life zone is similar to that used in the tropical premontane wet forest life zone in plowed ground. The ground is first plowed using either a tractor-drawn plow or one drawn by a team of oxen.[1] On about one-third of the farms the ground is then dragged. This process seems to correlate well with the ownership of tractors, probably because the farmers consider it too expensive to rent a tractor for this operation which appears to add little to output. The actual planting of the corn is the same for all of the farmers who plow their land, regardless of whether or not they drag their land, and regardless of whether they use a tractor or oxen for plowing. The farmer simply walks along dropping seed every yard, covering it with dirt with his foot, and then stepping down lightly on the seed. The corn is planted in rows to the extent that the farmer walks in a straight line.

In the few cases in this life zone where the farmer does not plow the ground before planting, the planting process is identical to that in the other life zone. The farmer sticks his macana into the ground, pushes it forward opening a small hole under the blade into which he drops the seed, whereupon he removes the macana allowing the dirt to fall back over the seed. In this case the only preparation done prior to the actual planting is to cut and possibly burn the weeds if they are too high. In both life zones the farmers indicated that weeds were not a serious problem to growing corn.

The method of cultivation in this life zone is identical to that in the tropical premontane wet forest life zone with the exception of three or four of the farmers interviewed who use cultivators pulled by a tractor. As in the other life zone, the usual practice is to

---

[1]The ox-drawn plow has one steel blade with a wooden shaft, while the usual tractor-drawn plow has three steel blades. Most of the tractors are lightweight.

cultivate twice, once twenty-two days after planting and then again one month later. The customary method is to cut the weeds with a machete, however, there are some farmers who skim the upper layer of dirt off with a shovel as a means of cultivation. Thus, even though a larger proportion of the farmers in this life zone use tractors for preparing their land for planting, they revert back to traditional methods when cultivating. This can be attributed to the high cost of renting a tractor for this job compared with the expected return in terms of output. Of all the farmers interviewed only one thought that frequent (four to eight times) cultivation was necessary for high productivity agriculture. This one farmer cultivates his corn five or six times, depending upon the rains and growth of the weeds, and reported production of 13 fanegas (178 bushels) per manzana. This is about 105 bushels per acre and is extremely high for a farm in Costa Rica. This output is over twice as high as the next highest output of any of the farmers interviewed.

The method of harvesting is also similar in this life zone to that in the tropical premontane wet forest life zone. All of the farmers pick their corn by hand, after which most of them throw it in piles to be collected later by ox-cart. The only variation of this method is the use of a jeep or other motorized vehicle to pick up the corn (or the combination of these two steps into one with the farmer picking the corn and tossing it immediately into the cart or other vehicle). Variations in harvesting, however, are very infrequent in either of the two life zones.

The processing and marketing of the corn varies little from that in the other life zone. The corn is shelled, cleaned, and sacked in the same manner as was described previously, with the same problem arising concerning the non-return of the sacks by the Council. There is a difference, though, in the transportation facility, since the topography is more favorable in this life zone. No farmer here is prohibited from selling his corn because of the impossibility of getting it to market, although there are some areas where the choice of markets is limited because of the distance to the major markets and the poor condition of the roads. One farmer in the tropical moist forest life zone transports his corn to market in a boat, and three or four others are located along a railroad and use this means of transportation.

Thus the less rugged topography in this life zone gives the farmer a wider range of choice in marketing his corn, because transportation problems are not so serious. Not only does the farmer have access to a greater number of markets, but his costs are reduced correspondingly.

The actual selling process here is similar to that in the other life zone, with slightly more emphasis on visits to the farms by middlemen buyers. This again can be attributed to the facility of transportation in this zone. These middlemen usually come from the larger market centers and provide their own transportation for the products. Lacking this opportunity, the farmers have to sell in a local market nearer to the point of production. In contrast, the farmers who live near the railroad can sell their corn in the San Jose market. In fact, they have an agent in San Jose to sell the corn for them, and he sends the money back to them by a workman friend on the train. The farmer who transports by boat happens to live near a small port on the Gulf of Nicoya from which he sends his corn to a city across the Gulf. These arrangements are by far the most efficient that these farmers could make, for to transport their corn by land would require much more time and expense.

Some of the farmers in this life zone, like some in the other life zone, try to determine where the highest price is being paid for corn and to sell their grain there. In this life zone more corn is grown for sale because of the easier access to markets, but only a few of the farmers actually look around for the best price. In both life zones there is a strong tendency for the farmers to sell to the same person year after year, and one relationship seems to be based more on tradition or friendship than on the economics of the situation. Over half of the interviewees selling corn in both of the life zones indicated that they sell to the same person each year.

This is in general the technology in use in each of the two life zones, but there are some specific aspects of technology that should be investigated to show more closely the extent of the difference between these zones. Both of these zones are areas of high rainfall (averaging from 79 to 157 inches annually) spread out over a substantial wet season which obviates the use of irrigation. This was borne out in the study since not one farmer interviewed in either of the two life zones used irrigation, and when questioned on this point they always replied that the lack of water was no problem. As further evidence of this, in the data taken from the Census of Agriculture of 1963 not one farm in either of the two life zones was reported as using irrigation. Likewise, there is no recognized problem with excessive water since only two farmers (both in the tropical premontane wet forest life zone) use drainage ditches to carry off excess water. When questioned on this point, the farmers stated that this was no problem.

The use of fertilizer is similar in the two life zones with about 20 per cent of the farmers in each using fertilizer on their corn. This percentage as found in the study is probably higher than that which actually exists throughout the country. This is partly the result of a lack of rapport between the interviewer and the interviewee. In a few cases it seemed that the farmer was parroting back information given him by the agricultural agent for his area since the information was identical to that given by the agents. The agents themselves, as well as the delegates of the National Production Council, indicated that the percentage of actual use of fertilizer among the farmers was much lower than this figure. In addition, the increase in production due to the use of fertilizer was minimal except on a couple of farms. Herbicides, fungicides, and insecticides are seldom used on corn except when the corn is being stored for a period of time. Then the corn is sprinkled lightly with powdered Aldrin to prevent insects from eating the grains. Other than this precaution, which is usually unsuccessful, no attempt is made to fight plagues which, the farmers report, are not too serious a problem. The extension agents and Council delegates report just the opposite however, and there is evidence that insects do a lot of damage. In many cases in both of these life zones the leaves of the corn were badly eaten, and insects had penetrated the husks and were eating the kernels of the grain. The most commonly mentioned insect affecting corn in these two life zones is the Gusano Cogollero (maggot) which seems equally prevelant in both life zones. Some other insects were mentioned occasionally, but did not seem so prevalent or destructive. Fungicides, insecticides, and especially herbicides are used in the production of rice and coffee in these two life zones.

The time of planting regardless of the life zone is when the rains begin, and that is at slightly different times in the two zones. In the tropical premontane wet forest, the rains begin somewhat earlier than in the tropical moist forest - around the first of April as compared with the first of May. Among the many factors that could be responsible for the earlier rainy season in the former life zone are the distance to large bodies of water, the extent and direction of the prevailing winds, the elevation above sea level, and the extent and height of intervening land areas.

The rotation systems used in the two life zones are also very similar, however, a majority of the farmers in each of the two life zones do not rotate their crops. This is either because the farm is too small to permit rotation, or because in light of the extra effort involved the benefits of such a system do not seem large enough to justify it. In the interviews the farmers who had enough land to rotate but did not, usually replied that the land was still good, and thus there was no need to rotate their crops. Most of the farmers who did employ rotation felt that a field should lie idle for a period of from two to three years, and there seemed to be little difference in opinion or practice in this matter between the two life zones.

None of the farmers in either life zone use shade for their corn, feeling that corn needs the sun, which is undoubtedly true. However, since according to the ecologists the tropical moist forest life zone differs significantly in terms of temperature from the tropical

premontane wet forest life zone, it would seem to follow that perhaps the corn would be affected by this difference. But, it is not affected to the extent of needing to be shaded. Likewise, not one farmer in either of the life zones planted two or more crops in the same field at the same time; that is, they do not use mixed farming. There were, though, some farmers who planted beans after harvesting corn, but again this practice seems to be equally prevalent in both life zones. The stalks of the corn are used to support the vines of the beans.

Few of the farmers use special (select or hybrid) seed for growing corn even though such seed is available from the National Production Council of Costa Rica. The usual practice is to use the best ears from the past harvest for seed. Only about 20 per cent (6 and 8 out of 30) of the farmers in each of the two life zones purchase hybrid seed from the Council. This seed is recommended by the Ministry of Agriculture of Costa Rica, as are various other types of seeds for various geographical regions of the country. There is a considerable amount of overlap in these recommendations, with practically every type of seed being recommended for each life zone. Thus, it is difficult to say that certain varieties are best for a given life zone. What is needed, of course, is a research program similar to the Rockefeller studies in Mexico to determine the best varieties for the diverse conditions in Costa Rica. For the few farms that use selected seed, T-76 is preferred in both life zones, but the basis for selection is not what will produce the most, but what will sell the best. The people prefer white corn for eating and so most of the farmers grow white corn. Thus, on the basis of present knowledge and practices, life zones cannot be distinguished on the basis of corn varieties.

One peculiar difference that was discovered concerned the use of by-products from the corn. Several farmers in the premontane wet forest life zone use their corn stalks in compost for fertilizer, but not one farmer of those interviewed in the tropical moist forest does so. The farmers in the premontane wet forest who reported doing this are from different parts of the country, eliminating the possibility of a local influence (agent, etc.) being responsible. It is possible that this life zone has the optimum humidity conditions for the decomposition of vegetable materials, but it seems highly unlikely that it is significantly different from several other life zones including the tropical moist forest life zone. It cannot be explained by a greater felt need for fertilizer in that life zone for, as was indicated previously, there is no evidence of a difference in the use of or need for fertilizer. It could be sample error.

There is little variation between life zones in the depth of planting or in the spacing of the seed, and the difference that does exist is due to the method of planting rather than to the climatic factors. This difference in method is due to the differing topography and not to the difference in climatic factors, even though there is some correlation between the methods of production and life zones. Where the farmer uses the labor intensive method of planting using a macana, the seed is planted an average of three inches deep. The range of response to this question was from one inch to five inches, but the majority of farmers said they planted three inches deep. Upon observing several farmers using this method, it became obvious that three inches is more nearly correct. Where the farmer uses the capital intensive method of planting, which involves plowing with tractor or oxen, the seed is planted an average of five inches deep. In this case the farmer plants in a furrow that is about that depth.

The spacing of the plants is very uniform within and between the two life zones, with approximately 10 per cent of the farms in each life zone varying from the norm. The usual practice is to plant one vara by one vara. (A vara is a normal step or slightly less than a yard) These distances are used by the farmers regardless of the technology used, and of course, regardless of the life zone. In addition, the recommendations of the Ministry of Agriculture are ignored on this point, in contrast with their acceptance on other points. The Ministry recommends 18 inches between plants, and 24 inches between rows. The few farmers who do differ from the norm follow the recommendation of the Ministry.

A list of tools or machinery used in growing corn would be very similar for the two life zones, with the most obvious difference being the use of tractors and tractor-drawn plows in the tropical moist forest life zone. Other than this the lists would be identical, and would include machetes, plows (ox-drawn), shovels, ox carts, hand-cranked machines for shelling corn, and wooden trays or gourds for cleaning the corn. There are farmers who use jeeps or other means of transporting corn to market, but this is an exceptional thing. The tropical moist forest is considered capital intensive because of the widespread use of tractors in that life zone.

The agricultural credit system in Costa Rica is very inefficient, and is heavily biased toward the export crops. Thus, even though some credit is available to farmers for growing corn, it is seldom used. Of the sixty (thirty in each life zone) farmers interviewed only three use credit, even though most of them are aware that it is available. The farmers are invariably critical of the credit system, with the most common criticisms being: the poor timing in the approval of credit applications, the poor timing in the distribution of the money, the favoritism given to the larger farmers, and the strict requirements the farmer must meet to obtain credit. The most serious of these requirements is the necessity of having a co-signer where the farmer has no clear title to the land - a requirement most of the small farmers cannot meet. In addition, there is the perennial problem of lack of sufficient funds, and many of the farmers are left without credit even if they can meet the requirements. This latter problem leads to graft and misdirection of funds, which further intensifies the problem. The rate of interest on these loans is fixed by the government, and thus is uniform throughout the country. The bank rate for this type of loan is 8 per cent. Thus, the evidence from the interviews indicates that credit is not used in either life zone.

Another variable related to technology that might be expected to vary by life zone is the size of the areas on farms within the two life zones devoted to corn. In Chapter IV we saw that there is no significant difference in the size of farm when defined as the areas planted in corn. This is based on the sample of 59 farms in the tropical premontane wet forest life zone and 114 farms in the tropical moist forest life zone. The results of that analysis show that the farmers in the two life zones plant about the same average amount of land with corn.

One might also expect the percentage of the area devoted to corn to vary by life zone. About 5 per cent of the total area is planted to corn in the tropical moist forest life zone, whereas in the tropical

premontane wet forest life zone about 6 per cent of the area is used for this crop. These percentages are based on the sample of farms extracted from the Department of Census study, and not only on the farms visited.

For those political districts at least 85 per cent within the life zones - of which there are 23 in the tropical premontane wet forest life zone and 25 in the tropical moist forest life zone - the percentages of the land devoted to corn are very similar. In the tropical premontane wet forest life zone slightly over 4 per cent of the land is used for corn, whereas in the tropical moist forest life zone slightly over 3 per cent is so used. These percentages are based on the total area of farms in the districts, and they correspond very well to the same computations covering the sample mentioned in the preceeding paragraph. They are slightly lower, however, because they include all farms in the districts and not only those farms producing corn.

These figures indicate that there is very little difference in the average sizes of the areas devoted to corn in the two life zones, in absolute terms and in the percentages of the areas devoted to corn.

The comparison of farm technology made here reveals few differences between life zones that can be traced directly to differences in the climatic parameters. There is a difference in the general technology used in the two life zones due to the greater use of tractors for plowing in the tropical moist forest life zone. This is attributed, however, more to the variation in topography than to the factors determining the life zones. The other aspects of technology investigated show no significant differences between these two life zones. The minor variations that exist in certain variables can be traced to factors other than the life zone determinants. Certain variables

included in the questionnaire were not discussed here because no useable responses were forthcoming from the farmers.

CHAPTER VI

COST OF PRODUCTION AND THE LIFE ZONE SYSTEM

The purpose of this chapter is to determine if differences exist between life zones in the costs of producing corn. The hypothesis is that there are significant differences between life zones in the costs of producing corn and that these differences are caused by those factors that differentiate the life zones.

To accomplish this dual purpose we need first to measure the costs of production in the two life zones, and then to try to relate whatever differences are found between life zones to the differences in heat, precipitation, and moisture which determine the life zones. If no significant differences are found in the costs of producing corn between the two life zones, then our hypothesis must be rejected forthwith. If differences exist but cannot be connected to variations in the life zone parameters, or if other variables exist that can equally well explain the variation in costs, then we can draw no conclusions as to the validity or lack of validity of the hypothesis. Only if differences exist that can be shown to be the direct result of the climatic parameters can we consider our hypothesis supported. Therefore, the procedure to be used in this chapter is to determine first if there are differences between life zones in the costs of producing corn and then to relate whatever differences are found to the life zone parameters.

Differences between life zones in the costs of production for a given crop will depend upon there being a difference in the combination or amounts of the inputs used to produce the crop, or upon there being a difference in relative prices of the inputs between the two life zones, or both. It is possible, but unlikely, that there would be a difference in both of these factors with one difference exactly offsetting the other, with the resulting equality of costs of production for the two life zones. The probability of this occurring is so remote that it is ignored in this study. If one life zone uses a different combination of inputs, or if the prices of the inputs differ by life zones, then the costs of production will differ by life zone. For example, if one life zone requires the use of more capital and less labor than another life zone and relative prices of the inputs are not such as to offset this difference in the amounts of the inputs used, then the costs of production will be different in the two zones.

It is obvious that the costs of production are closely related to technology, and that a difference in technology will be reflected by a difference in the costs of production, assuming factor prices are everywhere the same. Technology is embodied in the factors of production in two senses: first, the latest discoveries are incorporated in the factors and put into use when the factors of production are used (this can be considered as an increase in the quality of the factor), and secondly, the various combinations of the factors that could be used to produce a given product can be considered to be different technologies since these combinations require different amounts of the various factors of production. Also, a certain amount of knowledge is required for an awareness of these combinations and for their effective

use. Thus, a change in the quality of any of the factors of production or in the alternatives of combining these factors (or in the actual combination being used) is a change in technology, and will be reflected by a change in the costs of production.

There can, of course, be a difference in the costs of production that is not brought about by a difference in technology but by a difference in the prices of the factors of production in the two life zones. In other words, supply conditions for the factors of production can cause differences in the costs of production(and in technology in the sense in which this term is used here). This could occur, for example, if one of the life zones had such adverse climate that it was difficult to get workers to move into that area. This would push up the price of labor service, raise the costs of production, and probably require the use of a different technology. The influence of variations in the supplies of the factors of production is not considered in this study, and each input cost is measured at the actual price paid by the farmer.

Costs of production are usually measured in terms of some base such as the cost per unit of one of the inputs, or the cost per unit of output. The latter is usually preferred since it can then be compared directly with the price at which the product is sold. The base to be used depends upon the purpose of the investigation. If one wants to compare average revenue with average cost, he would want to know the cost per unit of output. If he would want to compare the relative profitability of different land-use systems, he would want a measure of the cost per unit of land as well as a measure of the revenue per unit of land in its various uses. This study will use both the

costs per unit of output and the costs per unit of land.

The method used here to compute the costs per unit of output of corn is the usual one of collecting data on the amounts of the various inputs used per given land area, multiplying the amounts of the inputs by their respective prices, and then dividing the resulting total cost by the number of units of output obtained from that unit of land. Thus, if one wants to know the costs per bushel of corn he collects data on the amounts of land, labor, capital, and entrepreneurship used on an acre or other land measure of land planted to corn, multiplies these inputs by their respective prices, and then divides the result by the number of bushels of corn produced on the acre of land.

In this study data on the amounts of the various inputs used were gathered from the farmers during the interviews, and recorded on the supplementary questionnaire reproduced in Appendix A.[1] To measure the labor input the farmers were asked for the number of days and the number of hours per day one man would have to work to perform the various tasks involved in growing corn. These tasks were broken down into the following distinct operations; preparing the land prior to planting, planting the seed, cultivating the land, harvesting the crop, and marketing the produce. The farmers were asked to respond to this question on the basis of their experience in the most recent growing season for corn. This was done in order to get data that reflected

[1]Due to the inaccuracy or incompleteness of the data, the costs of production could be computed for only 23 of the 30 farms interviewed in the tropical premontane wet forest life zone and for only 21 of the farms interviewed in the tropical moist forest life zone. Many of the farmers were reluctant to answer questions on costs or receipts from their operations.

actual experience rather than an off-the-cuff estimate from the farmer, and to avoid the answer that there is a lot of variation from year to year. This type of questioning provided data on the amount of labor used in the production of corn on the farms visited.

Data on the price of labor were obtained from two different sources which were consistent with one another. The farmers interviewed were asked how much they had to pay for hired labor when they used it, or how much they were paid when they worked for other farmers, or if they did neither of these, they were asked what the price of labor was in their area. To supplement this data the farm extension workers in the area and the delegates from the Costa Rican National Production Council were asked. In addition, sometimes the owner of a near-by Pulperia (all-purpose store) or the owner of the feed store in the nearest town was questioned. Invariably the price reported for labor was the same not only within one of the areas but between areas, and it can safely be said that the price for agricultural labor in Costa Rica is one colon (about 15 cents) per hour. This is also most likely a subsistence wage since there is substantial unemployment of farm workers in Costa Rica, and hence, the wage has been bid down to a minimum. This wage is lower than the minimum wage set by the Costa Rican government by about 20 per cent which is an indication of the lack of enforcement powers of the government in this area. On several occasions the first response of the extension workers or NATIONAL PRODUCTION COUNCIL delegates to this question was to give the minimum wage, but eventually they would admit that the employers were not paying this amount.

Cost was imputed to the farmers own labor at the market price

for agricultural labor. This assumes that the value of the owners labor is equal to the value of the labor of hired workers. Also, the use of market wages is questionable since they may not accurately reflect the farmers opportunity cost since he may not have any real alternatives for his labor. In any event, since the wage was found to be identical in the two life zones, the relative labor costs would depend solely upon the amounts of labor used in the two zones, and thus, so would relative costs.

Once the data were collected on the amounts of labor used and the price of labor, it was a simple matter to compute the direct labor cost involved in growing corn. It was impossible to measure the cost of labor used on the farm in incidental jobs that only indirectly contribute to the production of corn or to assign to corn its proportion of these costs, and so this element of cost was ignored. This is tantamount to assuming that there is no difference in this element of cost between the two life zones. In any event little was observed in either life zone that could be considered in this category of cost, since there seemed to be very little productive activity occurring on the farms between major operations on the primary crops.

The amount of capital used in the production of corn on the farms visited in this study was minimal, especially in the tropical premontane wet forest life zone. The greater use of tractors in the tropical moist forest life zone accounted for a somewhat greater use of capital in that life zone, but still corn production could not be considered capital intensive in the sense that it is in the United States. The only other capital in use in corn production on the farms visited was the macana, machete, shovel, a machine for taking the grains off the cob, a team

of oxen and a cart, and occasionally the use of a jeep or boat for transport. There also were individual cases of farmers making use of commercial carriers for transport to market.

When the service performed by the capital could be purchased on the open market, it was valued in that way.[2] Thus, the rental value of a tractor and plow or a team of oxen and cart, was considered as the cost per hour for this type of capital. Data were collected on the rental value of this type of capital and on the number of hours it was needed to perform the relevant operation. Multiplying these two provided an estimate of the cost of this capital.

To measure the cost of the other type of capital - without a current rental price - such as the macana, machete, and shovel, the procedure was as follows. First, a useful life was assigned to the piece of capital based on estimates given by the various people interviewed. Then the current price of the capital item was distributed over its useful life by dividing the useful life into the replacement cost of the item. Finally, this yearly value of the capital item was prorated to corn on the basis of the proportion of the cultivated area of the farm devoted to corn. This method of accounting for the cost of capital was the only feasible method under the circumstances. Because of the low cost of the items of capital involved and the almost identical useful life of this capital

---

[2]For a justification for using opportunity cost or current market value as a measure of the value of the service provided by a factor of production see W. Y. Yang, Methods of Farm Management Investigations, Food and Agriculture Organization of the United Nations, (Rome, 1958), pp. 85-87.

in the two life zones, this aspect of the costs of production could have been ignored in a study of cost differences between life zones. Nevertheless, since the data had been collected for these costs, they were included in the study.

The cost of the land associated with the production of corn was also determined on the basis of opportunity cost, that is, on the basis of the rental value of similar land in the area. Again there was very little difference between the two life zones in the rental value of land. Among other things, this reflects the lack of productivity differences between the two life zones, for if the land in one of the life zones happened to be more productive than in the other life zone, this would be reflected in the relative rental values of the land. There seem to be definite and well-known land rental prices throughout Costa Rica even though the renting of farm land is not too pervasive. In the tropical moist forest life zone 13 per cent of the farms in the sample rented some land from others, whereas in the tropical premontane wet forest life zone, the figure was about 20 per cent. There was a slightly greater tendency in the tropical moist forest life zone for the farmers to pay their rent in kind rather than in cash, but the total number of farms included in the sample was so small and the difference between the two zones so small that no conclusions could be drawn from these figures.[3] It could be that the greater demand for cash

---

[3]It will be remembered that the total number of farms included in the data gathered from the Costa Rican Census of Agriculture was 114 in the tropical moist forest life zone and 59 in the tropical premontane wet forest life zone. The number of farms visited and the farmers personally interviewed was 30 in each of the life zones. The percentages referred to here are taken from the census data.

payment of rent in the tropical premontane wet forest life zone reflects a greater pessimism on the part of the owners towards their land. This is not supported, however, by a difference in productivity or a difference in the amount of rent charged in the two areas.

It was very difficult to obtain data on the value of the buildings and other improvements on the land or to prorate this over the various crops grown. This was because most of the buildings had been built several years in the past and the farmer either had not built the buildings himself or had forgotten their original cost. On most farms the only buildings were the house the family lived in and an open-sided building for storing tools and a team of oxen. An occasional farmer would have a storehouse for his crops, but usually the produce was stored somewhere in the family house.

It was finally decided that the most accurate method to determine this aspect of cost would be to simply ask the farmer to place a value on the buildings on his land,[4] and to prorate this to corn on the basis of the percentage of his land used in growing corn. In addition, an arbitrary useful life of 50 years was set on all buildings. This length of time was discussed with several of the extension agents who seemed to think that it was realistic. Thus, the procedure was to take the estimated value of the buildings as given by the farmer, divide this by the 50-year estimated life of the

---

[4]The problem inherent in using such farmer's estimates are obvious, but in this case, as in most studies in underdeveloped countries, there was no other choice. For a justification of this method of collecting data, see Yang, Ibid., pp. 83-85.

buildings, and then to multiply this by the percentage of the farmer's land planted in corn.

The costs of other direct inputs such as seed and fertilizer (in the few cases in which it was used) were included at the actual cost of the input. Where the seed was not actually bought by the farmer (i.e., he used seed from an earlier harvest), the seed was costed as if he had actually purchased it on the market. The price used for this seed was the price of non-hybrid seed since so few of the farmers actually used selected seed.

No attempt was made to obtain a measure for the service of entrepreneurship because of the difficulty of placing a value on this factor. In an underdeveloped country such as Costa Rica, it is impossible to use the market value of similar service as a measure of entrepreneurship due to the difficulty of obtaining accurate data on the incomes of hired administrators. Not only were they reluctant to tell what their incomes were, but this type of question might have jeopardized the entire interview. On the other hand, it was felt that this factor might have an important influence on the costs of production, and might be responsible for some of the variation between life zones in certain of the variables. Nevertheless, because of the aforementioned difficulties, it was thought best to ignore this element of cost, and the farmers contribution was valued at the market wage rate for agricultural workers. In addition, since only the very large farms utilize administrators, any measure based on their incomes would not be an accurate measure of the value of the entrepreneurial abilities of the small farmer-owner.

The cost of credit was not figured into the costs of production

for these farmers since none of the farmers interviewed used credit in connection with their corn crop. Some of the farmers in each life zone indicated that they would use credit if it were made available under conditions that would permit their effective use of it. The stringent requirements to qualify for the credit and the bad timing of the distribution of the money were the major reasons for their not using it. The interest rate charged by the nationalized banking system of Costa Rica for this type of agricultural loan was 8 per cent, but the farmers did not report this as a deterrent to their using credit. This is clearly an important area for further research leading to the development of a new program of agricultural loans. The non-use of some of the more productive inputs such as fertilizer can be attributed to the lack of an efficient credit system to provide the money for the farmers to purchase these inputs when they are needed. This factor alone could increase tremendously the productivity of agriculture in Costa Rica.

For the purposes of this study, variation by life zone in the costs of production is dependent upon there being different methods of production used in the two areas. As discussed above, the major difference is in the preparation of the land prior to planting, with a larger percentage of the farmers in the tropical moist forest life zone plowing their land than in the tropical premontane wet forest life zone. To portray accurately the costs of production for the two zones that are most representative of the farms in those zones, one should compare the costs of "typical" farms, that is, for the tropical premontane wet forest life zone, a farm using the methods of production most in use in that life zone, and likewise in the

tropical moist forest life zone. In the tropical premontane wet forest life zone this is the method described earlier with the farmer using a _macana_ to plant in unplowed ground, whereas in the tropical moist forest life zone, it would be where the farmer plants in _plowed_ ground by just dropping the seed and stepping on it.

There are, of course, exceptions to these typical farmers, but to attempt to include all the many combinations of practices in effect in the two life zones would do nothing but obscure the problem. The exceptions are especially prevalent in the tropical moist forest life zone where about one-third of the farmers do _not_ plow their ground prior to planting corn. Instead, they do the actual planting with a _macana_ in a way identical to the most common method in the tropical premontane wet forest life zone. Thus, one can say that 80 per cent of the farmers in the tropical premontane wet forest life zone and about 30 per cent of the farmers in the tropical moist forest life zone use the _macana_ method of planting, whereas, 70 per cent of the farmers in the tropical moist forest life zone and about 20 per cent of the farmers in the tropical premontane wet forest life zone use the method wherein the ground is plowed before planting. The other operations involved in the production of corn are remarkably similar between the two life zones, and hence, little cost difference can be expected between them with respect to these operations.

Five cost patterns were found and investigated between the two life zones, and are presented here; two representing the methods in use in the tropical premontane wet forest life zone, and three representing the methods in use in the tropical moist forest life zone. The five are as follows: 1) _macana_ planting with no plowing -

representing 80 per cent of the farms in the tropical premontane wet forest life zone, 2) oxen plowing with seed planted by stepping on it - representing about 20 per cent of the farms in the tropical premontane wet forest life zone, 3) macana planting with no plowing-representing about 30 per cent of the farms in the tropical moist forest life zone, 4) oxen plowing with seed planted by stepping on it - representing about 20 per cent of the farms in the tropical moist forest life zone, and 5) tractor plowing with seed planted by stepping on it - representing about 50 per cent of the farms in the tropical moist forest life zone. Actually, out of the 30 farms visited in the tropical moist forest life zone, sixteen of the farmers plowed with tractors, five plowed with oxens, and nine planted with a macana without plowing. These cost patterns will be described by using the cost worksheet drawn up for a typical farm operating under each of the five situations mentioned above.

Tables 7 through 11 present the various cost components included in the cost of producing corn in the two life zones following the three distinct methods of production most prevalent in Costa Rica. Table 12 presents a summary of the most important totals from the prior five tables, and Table 13 presents the components of cost as a percentage of the total production cost in order to facilitate the comparison of these components between the various methods and life zones.

It will be noticed that marketing cost is kept separate from production cost, and that it is quite variable; ranging from a low of zero on Farm #5 to a high of 66 colones on Farm #2. This cost depends mostly upon the distance to market and the juxtaposition of the farm to a road or to a convenient means of transport, such as a railroad. The distance to market is not dependent upon the life zone in which the farm exists, but the condition of the roads over which the farmer transports his crop might very well be. On the basis of the Costa Rican Department of Census data, it was found that the average distance from the farm to the point of sale in the tropical premontane wet forest life zone was 14.2 kilometers, whereas in the tropical moist forest life zone, it was 13.3. This average includes those farmers who sell on the farm to middlemen, as well as those farmers who do not sell their produce. As to the condition of the roads, 81 per cent of the 59 farmers in our sample (Department of Census data) in the tropical premontane wet forest life zone reported a dirt road as the principal road entering the farm, while in the tropical moist forest life zone, 89 per cent of the 114 farmers in the sample reported such a road. In addition, in the tropical premontane wet forest life zone, 64 per cent of the farmers reported that the road to market was impassable for motor vehicles for certain periods of the year, while the figure for the tropical moist forest life zone was 73 per cent. In other words, in both life zones the farms usually border on dirt roads which are impassable to motorized vehicles during the rainy season. Thus, variations in life zones can play a major role in cost of marketing differences, however, in this study the differences in the condition of the roads do not seem to be too important. More study needs to be given to this aspect of cost, for it is likely that the major differences in costs due to differences in the climatic parameters may well occur in this area. It is felt that the data on marketing cost in this study is so

superficial that it does not merit further analysis, especially in light of the variation that seems to exist in this element of cost and the smallness of the sample involved in this study.

There are several points that should be made concerning Tables 7 through 13. In the first place, there is a great deal of variability in the individual components between the selected farms. For example, in the component "harvesting", which includes shelling, cleaning, and transporting the corn to the house, the labor cost varies from 72 colones to 132 colones, and in the component "cultivating", the labor cost varies from 16 colones to 132 colones. The cost of capital varies from 1.40 colones to 301.35 colones.

In conjunction with the variability within the individual components of the costs of production, we find that the variation within the life zone is often greater than the variation between the life zones. This is true of the components "capital" and "cultivating", as well as some of the others. With this much variability within life zones, it is highly unlikely that there will be significant differences between life zones, especially when the ranges of the values overlap as much as they seem to for the variables. Productivity also varies considerably for these selected farms with the greater variability occurring within the tropical moist forest life zone. As can be seen in Table 12, the variation in productivity is from .833 fanegas per manzana to 3 fanegas per manzana with both of these extremes occurring in the tropical moist forest life zone.

TABLE 7

FARM #1 - COST OF PRODUCTION OF ONE MANZANA OF CORN WITH MACANA PLANTING AND NO PLOWING IN THE TROPICAL PREMONTANE WET FOREST LIFE ZONE

Cost Components	Colones	
Labor cost		
Preparing the land -- 100 manhours at 1 colon/hr.	100.00	
Planting the seed 32 manhours at 1 colon/hr.	32.00	
Cultivating twice 96 manhours at 1 colon/hr.	96.00	
Harvesting plus cleaning and shelling the corn and transport to house 48 manhours at 1 colon/hr.	48.00	
		276.00
Land cost		
Rental cost of 1 manzana per year	100.00	
		100.00
Building cost		
Farmers estimate of value 25,000 colones 50 year useful life, and the farmer has 1/30 of his land in corn	16.67	
		16.67
Capital cost		
Oxen and cart for harvesting - 2 days at rental value of 20 colones/day - includes transport to house	40.00	
Rental cost of various tools used - machete, shovel, machine to shell the corn - at relative useful lives and prices	0.93	
		40.93
Materials cost		
Seed 15 pound at .30 colones per pound No fertilizer or other materials used by this farmer	4.50	
		4.50
Total production cost - per manzana		438.10

TABLE 7 Continued

Marketing cost		
Sacks (10 sacks @ .85 colones/sack)	8.50	
Transport to market		
1 man for 1 day at 1 colon/hr.	8.00	
1 team of oxen and cart, 1 day at 20 colones/day	20.00	
		36.50
Total cost per manzana delivered to market		474.60
Total receipts:		
Total production of 2 fanega sold at 196.00 colones/fanega	392.00	
Total cost per manzana delivered to market	474.60	
Net loss		82.60
Total production cost per fanega		219.05

TABLE 8

FARM #2 - COST OF PRODUCTION OF ONE MANZANA OF CORN USING OXEN PLOWING WITH THE SEED PLANTED BY STEPPING ON IT IN THE TROPICAL PREMONTANE WET FOREST LIFE ZONE

Cost Components	Colones	
Labor cost		
Preparing the land		
Cleaning the land-40 manhours at 1 colon/hr.	40.00	
Plowing the land -16 manhours at 1 colon/hr.	16.00	
Dragging the land (makeshift drag)-5 manhours	5.00	
Planting the seed-24 manhours at 1 colon/hr.	24.00	
Cultivating 1 time-40 manhours at 1 colon/hr.	40.00	
Harvesting plus cleaning and shelling and transport to house 72 manhours at 1 colon/hr.	72.00	
		197.00
Land Cost		
Rental cost of 1 manzana per year	75.00	
		75.00
Building cost		
Farmers estimate of value 136,000 colones-50 year useful life and the farmer has 1/85 of his land in corn	32.00	
		32.00
Capital cost		
Oxen and plow for plowing-3 days at 20 colones/day	60.00	
Oxen for dragging - 5 hours at 2.50/hr.	12.50	
Oxen and cart for harvesting - 3 days at 20 colones/day	60.00	
Rental cost of machete and machine to shell the corn at respective useful lives and prices	.58	
		133.08

TABLE 8 Continued

Materials cost		
Seed 25 pounds at .33 colones/pound	8.25	
No fertilizer or other materials used by this farmer		8.25
Total production cost - per manzana		445.33
Marketing cost		
Sacks (12 sacks at .85 colones/sack)	10.20	
Transport to market		
16 manhours at 1 colon/hr.	16.00	
1 team of oxen and cart-2 days at 20 colones day	40.00	
		66.20
Total cost per manzana delivered to market		511.53
Total receipts:		
Total production of 2.9 fanegas sold at 180.00 colones	522.00	
Net profit per manzana		10.47
Total production cost per fanega		153.56

TABLE 9

FARM #3 - COST OF PRODUCTION OF ONE MANZANA OF CORN WITH MACANA PLANTING AND NO PLOWING IN THE TROPICAL MOIST FOREST LIFE ZONE

Cost Components	Colones	
Labor cost		
Preparing the land-50 manhours at 1.10 colones/hr.	55.00	
Planting the seed - 60 manhours at 1.10 colones/hr.	66.00	
Cultivating 2 times - 120 manhours at 1.10 colones/hr.	132.00	
Harvesting plus cleaning and shelling the corn, includes transport to house* - 120 manhours at 1.10 colones/hr.	132.00	
		385.00
Land cost		
Rental cost of 1 manzana per year	100.00	
		100.00
Building cost		
Farmers estimate of value-5,000 colones - 50 year useful life, and the farmer has 1/10 of his land in corn	10.00	
		10.00
Capital cost		
Cost of machete, macana, and machine for shelling corn-at relative useful lives and prices	1.40	
		1.40
Materials cost		
Seed 18 lbs. at .30 colones/lb.	5.40	
No fertilizer or other materials used by this farmer		5.40
Total production cost per manzana		501.80

TABLE 9 Continued

Marketing cost		
Sacks (5 sacks at .85 colones/sack-used)	4.25	
Rental value of horse for transport to market - 1 day**	10.00	
1 man for 1 day at 1.10 per hour	11.00	
		25.25
Total cost per manzana delivered to market		527.05
Total receipts:		
Total production of .833 fanegas sold at 180.00 colones per fanega***	149.94	
Total cost per manzana delivered to market	527.05	
Net loss		377.11
Total production cost per fanega		602.40

*This farmer carries his corn to the house in a sack.

**This farmer transports his corn to market on horse back.

***His outout is relatively low - only .833 fanegas/manzana.

TABLE 10

FARM #4 - COST OF PRODUCTION OF ONE MANZANA OF CORN USING OXEN PLOWING WITH THE SEED PLANTED BY STEPPING ON IT IN THE TROPICAL MOIST FOREST LIFE ZONE

Cost Components	Colones	
Labor Cost		
Preparing the land		
Cleaning the land-80 manhours at 1 colon/hr.	80.00	
Plowing the land -32 manhours at 1 colon/hr.	32.00	
Planting the seed - 30 manhours at 1 colon/hr.	30.00	
Cultivates 1 time/uses makeshift rake and oxen 16 manhours at 1 colon/hr.	16.00	
Harvesting plus cleaning and shelling and transport to house 120 manhours at 1 colon/hr.	120.00	
		278.00
Land cost		
Rental cost of 1 manzana per year	100.00	
		100.00
Building cost		
Farmers estimate of value 10,000 colones - 50 year useful life and the farmer has 1/9 of his land in corn	22.22	
		22.22
Capital cost		
Oxen and plow for plowing 4 days at 20 colones per day	80.00	
Oxen and rake - 2 days at 20 colones/day	40.00	
Oxen and cart for harvesting - 2 days at 20 colones/day	40.00	
Rental cost of machete, machine to shell corn at respective useful lives and prices	1.17	
		161.17

TABLE 10 Continued

Materials cost		
Seed 20 pounds at .33 colones per pound	6.60	
No fertilizer or other materials used by this farmer		
		6.60
Total production cost - per manzana		567.99
Marketing cost		
Sacks (5 sacks @ 1 colon/sack)	5.00	
Transport to market		
1 man - 8 manhours at 1 colon/hr.	8.00	
1 team of oxen and cart at 20 colones/day	20.00	
		33.00
Total cost per manzana delivered to market		600.99
Total receipts:		
Total production of 1 fanega at 220.00 colones/fanega	220.00	
Total cost per manzana delivered to market	600.99	
Net loss		380.99
Total production cost per fanega		567.99

TABLE 11

FARM #5 - COST OF PRODUCTION OF ONE MANZANA OF CORN USING TRACTOR PLOWING WITH THE SEED PLANTED BY STEPPING ON IT IN THE TROPICAL MOIST FOREST LIFE ZONE

Labor cost		
Plowing the land 5 manhours at 1.50 colones/hr.	7.50	
Dragging the land 4 manhours at 1.50 colones/hr.	6.00	
Using oxen to make furrows 16 manhours at 1 colon/hr.	16.00	
Planting the seed 16 manhours at 1 colon/hr.	16.00	
Cultivating 3 times - 1 time with oxen and makeshift rake 100 manhours at 1 colon/hr.	100.00	
Harvesting including shelling and cleaning and transport to house 128 manhours at 1 colon/hr.	128.00	
		273.50
Land cost		
Rental cost of 1 manzana per year	125.00	
		125.00
Building cost		
Farmers estimate of value 6,000 colones - 50 year useful life and the farmer has 1/7 of his land in corn	17.14	
		17.14
Capital cost		
Tractor and plow 5 hrs. at 20 colones/hr.	100.00	
Tractor and drag 4 hrs. at 20 colones/hr.	80.00	
Oxen and plow to make furrows - 2 days at 20 colones/day	40.00	
Oxen and makeshift rake to cultivate - 2 days at 20 colones/day	40.00	
Oxen and cart for 2 days at 20 colones/day harvesting includes transport to house	40.00	
Rental cost of machete, machine to shell corn at respective useful lives and prices	1.35	
		301.35

TABLE 11 Continued

Materials cost		
Seed 50 pounds at 1 colon per pound	50.00	
No fertilizer or other materials used by this farmer		
		50.00
Total production cost per manzana		766.99
Marketing cost		
This farmer sells to a middleman who comes to the farm to pick up the corn. He also furnishes the sacks. Thus the marketing costs are paid by the middleman		
Total cost per manzana delivered to market		766.99
Total receipts:		
Total production of 3 fanegas sold at 190.00 colones/fanega	570.00	
Total cost per manzana delivered to market	766.99	
Net loss		196.99
Total production cost per fanega		255.66

TABLE 12

SUMMARY DATA SELECTED FROM THE FIVE COST WORKSHEETS IN TABLES 7 THROUGH 11 (COLONES)

	Major Component of Worksheet				
Method of Production and Life Zone	Total cost of production per manzana	Total cost per manzana del/ to market	Output per manzana-Fanegas	Production cost per Fanega	Profit
Farm #1 - TPWF macana planting	438.10	474.60	2.0	219.05	-82.60
Farm #2 - TPWF Oxen for plowing	445.33	511.53	2.9	153.56	+10.47
Farm #3 - TMF macana planting no plowing	501.80	527.05	0.83	604.58	-377.11
Farm #4 - TMF Oxen for plowing	567.99	600.99	1.0	567.99	-380.99
Farm #5 - TMF Tractor plowing	766.99	766.99	3.0	255.66	-196.99

TPWF - Tropical Premontane Wet Forest TMP - Tropical Moist Forest

TABLE 13

COMPONENTS AS A PERCENTAGE OF TOTAL PRODUCTION COST (EXCLUDING MARKETING COST) IN COLONES

	Percentage of total Production Cost for five selected farms				
Component	Farm #1	Farm #2	Farm #3	Farm #4	Farm #5
Labor	63	44	77	49	36
Land	23	17	20	18	16
Buildings	4	7	2	4	2
Capital	9	30	*	28	39
Materials	1	2	1	1	7

* Less than 1%

If we compare a given method of production between life zones, we find that the cost of production is higher in the tropical moist forest life zone. In the two cases where this comparison is possible,[5] it seems that most operations require more time in the tropical moist forest than in the tropical premontane wet forest life zone, that is, both in terms of human labor time and capital use time. A priori, one would expect just the opposite to exist given the difference in topography between the two life zones. No definite conclusions can be drawn on this matter due to the large variations in the total costs of production between and within the two life zones, and the large differences in the costs of the individual components, both between and within the two life zones. Table 12 shows us that the "macana planting" method in the tropical moist forest life zone is more costly than the "oxen plowing" method in the tropical premontane wet forest life zone, even though the use and cost of capital is greater in the latter situation.

Within both life zones as the use of capital increases, the total cost of production increases, and the cost of production per unit of output decreases as one would expect. Table 13 shows clearly the increased use of capital and concurrent decreased use of labor within each life zone as one moves from Farm #1 to Farm #2 in the tropical moist forest life zone. This movement should be compared with the decreases in the cost per unit of output over these same ranges as shown in the last column of Table 12.

---

[5] "Macana planting" method (Farms #1 and #3) can be compared between life zones, as can "oxen plowing" method (Farms #2 and #4).

Table 11 shows that an increased use of capital is profitable for the farmers, as one might expect, since the cost per unit of output decreases as the use of capital increases. Only one of the five farms actually made a profit[6] on its production of corn (which is typical of the production of this crop throughout Costa Rica), but as the farmer moves to more capital intensive methods of production the amount of the loss that the farmer is experiencing is reduced. This is true within the life zones, and as was mentioned earlier, a <u>less</u> capital intensive method in one life zone resulted in a higher total cost than a more capital intensive method in the other life zone.

The rather small size of the sample for which acceptable data was obtained on cost of production (see footnore page 119) precludes any type of meaningful statistical analysis of this variable. Lacking this, what can be said concerning cost of production based on this study? The most obvious thing is the tremendous variability between and within life zones in each individual component of cost and in the

---

[6]This profit or loss is based on an imputed cost of labor equal to the price of hired agricultural labor in the area. In addition, imputed costs are involved in measuring certain of the other costs of production. This procedure assumes that the farmer actually has the alternative of working as an agricultural worker which in many cases in Costa Rica is not true. If this procedure were not used, however, there would no way of measuring the cost associated with family labor, especially since measures of marginal productivity are so difficult to arrive at in underdeveloped countries. In any event, since the problem here is to measure relative costs of production and not absolute costs with the view of determining profits, the comparison of costs by life zones on this basis is valid. The differences in cost by life zone will be determined by the relative amounts of the inputs used, since as mentioned earlier, the wage for agricultural workers is uniform throughout Costa Rica. In other words, the assumption is highly questionable in areas of surplus labor, however, it is of less importance when one is <u>comparing</u> cost than it would be to one computing profit.

total costs of production. This indicates that future research will require a very large sample in order to get the standard errors within manageable range. It also indicates the problems facing the farmer in trying to arrive at the correct combination of inputs with a wide variety of choices available to him. There seems to be no "best" combination to use for a given life zone, at least that has been discovered. In addition, this variability indicates that there is probably no significant difference between life zones in the costs of producing corn.

The evidence indicates that an increase in capital will lower the costs of production per unit of output, but that something more is needed to enable the farmers to make a profit by producing corn. This brings up the question of why they continue to produce corn if they cannot make a profit by doing so. The answer is that they do not calculate on a cost versus return basis, but instead on a cash outlay versus cash return basis. A large percentage of the costs outlined in the preceding tables are inputed to the various factors of production, and do not require a cash outlay. Thus, the farmer who is strapped for cash figures that for a minimal outlay of cash he will receive a certain amount in return after a specified period of time. He does not consider his labor time as a cost of production, but only that of the labor he hires. Of course, most of the farmers do not have to hire labor since their families are usually large enough to provide the necessary labor, which again is not considered as a cost. The cost attributable to his buildings and certain items of capital are also neglected by the farmer.

The element that is needed to make the production of corn profitable is fertilizer. None of the farms whose cost of production is represented here use fertilizer, and as was stated earlier, very few farmers use fertilizer on their corn. The substitution of capital for labor, however, does not seem to be sufficient to increase output by enough to lower per unit cost to where the farmer can make a profit producing corn. There is some evidence that the correct use of fertilizer can make a big difference in productivity, and hence, the cost per unit of output. A study carried out by one of the extension agents in Costa Rica is a case in point. With the farmer using a method of production which did not include the use of fertilizer, the total cost of production was 500.00 colones and output was 12.6 quintales (a quintale is approximately 200 pounds). This output was sold for a total of 289.80 colones for a net loss of 210.20 colones. In an adjacent field, the extension agent used a method of production utilizing 3½ quintales of Urea, which resulted in a total cost of 658.25 colones and an output of 53.5 quintales. This output was sold for 1,230.50 colones (same unit price as the other farmer) for a net profit of 572.25 colones. In this study the extension agent failed to include some of the imputed costs that should have been included, but the important thing is the multiplied increase in output occasioned by the use of fertilizer. Even with the additional imputed cost the farmer would have earned a substantial profit.

The same statistical test used in the chapter on productivity is used here to see if there is a significant difference between the two sample groups in the cost of producing one manzana of corn. The data on the total costs of production for one manzana of corn for

each of the farms for which acceptable data were obtained are presented in Table 14. In the tropical premontane wet forest life zone the range for this variable is from 211.11 colones to 587.63 colones, with the arithmetic mean being 389.44 colones. In the tropical moist forest life zone the range is from 219.65 colones to 774.71 colones, with the arithmetic mean being 505.17. The higher arithmetic mean in the latter life zone along with the preponderance of farms at the upper level of the range reflects the greater cost associated with the greater use of capital in this life zone.

In this test, the standard error of the mean for the tropical moist forest life zone is 37.15 which is 7.35 per cent of the mean, and in the tropical premontane wet forest life zone, the standard error of the mean is 24.83 or 6.37 per cent of the mean. The standard error of the difference between the two means is 44.68 and the t-value is 2.59. With the number of degrees of freedom at 42, the t-distribution approximates the normal curve, and thus we conclude that the null-hypothesis must be rejected. In other words, we can say, based on our two samples, that the probability of these two means occurring by chance out of the same population is very low (right around 1 per cent), and since we are willing to accept the 5 per cent level of significance, we can say that there is a significant difference between the two life zones in the cost of producing one manzana of corn. This difference exists in spite of the wide range of variability in costs within the two life zones and in spite of the overlap in costs between the two zones. *A priori* these characteristics would lead one to predict a lack of difference in the means of the two samples.

TABLE 14

TOTAL COST OF PRODUCTION PER MANZANA, OUTPUT PER MANZANA OF CORN, AND COST PER UNIT OF OUTPUT, BY LIFE ZONE (COLONES AND POUNDS)

Tropical Premontane Wet Forest			Tropical Moist Forest		
Total cost of production per mamzana	Output Per Manzana	Cost Per Pound	Total cost of production per manzana	Output Per Manzana	Cost Per pound
211.11	768	.275	219.65	991	.222
214.83	2304	.093	252.40	768	.329
227.50	515	.442	284.09	637	.446
251.19	476	.528	311.33	1536	.203
263.15	2519	.104	336.36	622	.541
291.47	960	.304	383.21	1920	.200
307.91	1152	.267	401.03	384	1.040
323.61	407	.795	444.12	1536	.289
325.40	1536	.212	469.78	622	.755
340.00	1605	.212	475.50	768	.619
351.11	1290	.272	501.80	637	.788
373.81	1536	.243	517.17	1198	.432
399.90	2304	.174	560.33	1667	.336
438.10	1536	.285	567.99	768	.740
445.33	2227	.200	597.60	2051	.291
473.16	1068	.443	640.12	1536	.417
489.22	899	.544	684.71	2304	.297
502.46	1344	.374	698.33	2051	.340
521.68	1068	.488	721.42	768	.939
522.67	1536	.340	766.99	2304	.332
545.50	2688	.203			
550.30	1444	.381			
587.63	2196	.268			
$\bar{X}$=389.44	$\bar{X}$=1451	$\bar{X}$=.324	$\bar{X}$=505.17	$\bar{X}$=1331	$\bar{X}$=.468

It is obvious from the data on cost of production presented here that this difference between life zones is due to the greater use of capital in the tropical moist forest life zones. As was shown earlier, as the use of capital increases within life zones, the costs of production per manzana increases also. In addition, there is greater use of capital in the tropical moist forest life zone, and the cost of production per manzana is higher in that life zone. It follows that there should be a difference in the costs of production per manzana between the two zones, and the foregoing test bears this out.

It remains therefore to try to relate this difference to those factors that differentiate the life zones, i.e., heat, precipitation, and moisture. Since the difference in costs of production is closely related to the difference in capital intensity, we must look to the factors influencing the use of capital. The primary factor limiting the use of capital in the tropical premontane wet forest life zone is the rugged topography, and it is to this characteristic that we must attribute the difference in costs, rather than to one of the parameters of the life zone system. We cannot say therefore, that the life zone system is a significant variable influencing the costs of producing corn.

In terms of the cost per unit of output we find that for our sample from the tropical moist forest life zone, the standard error of the mean is .0545 which is 11.65 per cent of the mean, and in the tropical premontane wet forest life zone, the standard error of the mean is .0338 which is 10.42 per cent of the mean. These figures give us a standard error of the difference between the means of .0641, and a t-value of 2.25. Since the number of degrees of freedom (42) is again large enough so that the t-distribution approaches a normal curve, we can utilize the normal curve to determine probabilities. This t-value gives us a probability of less than 5 per cent, and so we reject the null-hypothesis. In other words, we again find that the probability of these two sample means coming by chance from the same population is smaller than we are willing to accept, and thus, that the two samples are from different populations.

There are two factors that could account for this difference in cost per unit of output; a difference in productivity between the life zones, or a difference in total production cost between the life zones. We saw earlier that there is no difference in productivity between the two zones, but we have shown in this chapter that there is a difference in the total costs of production by life zone. Thus, we can conclude that this latter is the reason for the difference in cost per unit of output. In trying to trace this to the life zone parameters, we found that the difference in total costs of production was due to the greater use of capital in the tropical moist forest life zone, which was in turn traced back to the difference in topography in that life zone. Thus, again the three parameters of the life zone system do not seem to be the controlling factors in the variation of this variable.

CHAPTER VII

LAND USE AND THE LIFE ZONE SYSTEM

Not making effective use of the land is a problem that affects all nations, rich and poor, and is a problem that is receiving greater and greater attention from all countries of the world. In the past with few exceptions the use to be made of the land was determined by the individual who owned or settled the land, and the government's role in this area was simply to protect the individual's right to the land. Population pressure, however, with its accompanying heavy demand for land and the fruits of the land has forced the government to play a greater part in determining the use of this asset, especially in the underdeveloped countries where population density is usually high and the productivity of the land low.

In some countries changes in land ownership and land use have come about through extra-legal means, such as social revolution or squatting. Mexico is an excellent example of the first of these, and practically all of the Latin American countries are experiencing the latter. In Costa Rica it is estimated that there are more than 15,000 families squatting on land belonging to others, and this is a conservative estimate. It is inevitable that there will be more social revolutions and more squatting unless something is done to control population pressure or to provide the ever increasing mass of humanity with sufficient produce from the land. The underdeveloped

countries are now beginning to see the urgency of this problem, and are taking some measures to control it. The measure most often suggested involves the expropriation of "excess" land from the large hand-holders and distribution of the land in little plots to families for farms. The measures often utilized involve the colonization of government land and the legalization of squatters rights. In addition, there are some feeble attempts at instituting birth control (India), but in general these approaches have been inadequate in scope and implementation.

All of this points to the fact that land use is becoming a very important matter that needs more attention from economists, ecologists, and other scientists. Any type of concensus on the matter of correct land use will be hard to come by, however, since different disciplines approach the problem with different preconceptions as to what correct land use consists of. The land use problem then is twofold: first, the correct land-use system for a given area must be identified, and secondly, the current use of the land must be replaced with the correct pattern of use. The latter part of this problem may well be the more difficult to solve.

The ecologists working with the Holdridge Life Zone System believe that this system could be useful in the determination of correct land-use patterns. They feel that research on the system could provide planners with an easy means of determining what to grow in the various zones, what products are available in the natural vegetation, how best to cultivate this natural output, which areas should be left in the natural state, and the answers to many other questions in as much detail as research permits.

The hypothesis to be tested in this chapter is that there are differences between life zones in the use being made of the land. If it is established that there are differences, the next step will be to relate these to the parameters of the Holdridge system. If no differences are found, the Holdridge system's relevancy for this variable can be dismissed immediately. To test this hypothesis a comparison is made between the two life zones to determine if the land-use patterns in use in these zones differ. Holdridge believes that there are land-use patterns best suited to each life zone and that these patterns should be reflected in the choices made by the land-owners in the two zones. Thus, we should find some differences.

The data from the Costa Rican Census of Agriculture of 1963 is used for this comparison. It will be remembered that this sample includes 114 farms from the tropical moist forest life zone and 59 farms from the tropical premontane wet forest life zone, each representing approximately 1 per cent of the farms in their respective life zones.

The various categories of land use included in this comparison, along with their definitions, are the following:

1. Annual or transitory crops - This includes all those crops whose cycle of vegetation lasts a certain number of months, necessitating for each harvest a new planting. For example: corn, beans, etc. This includes not only those crops both planted and harvested, but also those areas in which the crop was lost in the census year, and those areas planted in annual crops but still to be harvested.

2. Permanent crops - This includes those crops that occupy the area where they have been planted for various years, and do not need a new planting for each harvest. For example: coffee, sugar cane, etc.

3. Area not cultivated - This includes arable land not cultivated this year, but cultivated in a previous year. Land temporarily idle.

4. Natural pasture - Pasture in which the grass is not planted.

5. Planted pasture - Pasture in which some type of grass has been planted by the owner.

6. Cut pasture - Pasture land on which the grass is cut and carried to the animals, rather than having them graze on the land.

7. Cherrales - Land where the forest was previously cut, but now is being left to revert back to the natural plant growth. Bushy and with small trees.

8. Commercial and home use vegetable gardens - Land used to grow vegetables for home use or for sale.

9. Forest - self-explanatory.

10. Other classes of land - This includes all land uses not included above such as swamp land, lakes, roads, yards, etc.

The above ten categories of use to which the land could be put includes all possible uses, and therefore, the total area of each farm can be accounted for by these categories.

The limitations placed upon this analysis by the sample as chosen for this study are especially important for this variable. It should be remembered that this sample consists of farms producing corn, and that any other use of the land on these farms was incidental when they were chosen. Thus, this sample is not a sample of farms as such from the two life zones, but is a sample of farms producing corn. Conclusions cannot be drawn, therefore, that are applicable to all farms in the two life zones. Later in this chapter a comparison of land-use patterns is made for the sample of political districts of Costa Rica that are at least 85 per cent within one of the two life zones. From this comparison conclusions of more general applicability can be made. This does not mean that this present comparison is invalid; it is a valid comparison, but it is subject to the limitations placed on it by the method used in selecting the sample.

Table 15 shows the percentages of the land area of the farms in the sample in the various categories of land use mentioned above. The similarity of these percentages is noteworthy. Of the total area of these farms, 14.3 per cent in the tropical premontane wet forest and 14.1 per cent in the tropical moist forest is planted in annual crops, and 26.6 per cent of the former life zone and 27.7 per cent of the latter is in natural pasture. Many of the other categories are equally alike.

There is a difference in the percentage of the area of the farms planted in permanent crops, and this difference does seem to have some connection to the parameters that determine the life zones. There is 4.1 per cent of the land in the tropical premontane wet forest life zone planted in these crops (primarily coffee), and only 1.7 per cent of the land in these crops in the tropical moist forest life zone. This is related to the difference in temperature between the two zones, since coffee needs to be shaded from the more direct rays of the sun. The temperature in the tropical moist forest life zone is significantly higher than that in the tropical premontane wet forest life zone, with the result that the former life zone is too hot for the farmers to grow coffee profitably. If the coffee trees are not shaded or if it is too hot even with the shade, addition amounts of fertilizer are needed to achieve a given level of production. Thus, other things equal, it would be more expensive to grow this crop in the tropical moist forest life zone.

TABLE 15

PERCENTAGES OF LAND IN VARIOUS LAND USES BY LIFE ZONE FOR THE SAMPLE OF FARMS PRODUCING CORN

Land Use	Tropical Premontane Wet Forest	Tropical Moist Forest
Annual crops	14.3	14.1
Permanent crops	4.1	1.7
Area not cultivated	5.9	9.9
Natural pasture	26.6	27.7
Planted Pasture	21.7	17.9
Cut pasture	0.0	1.6
Charrales	7.5	9.7
Vegetable Gardens	0.0	0.0
Forest	19.5	16.3
Other classes of land	0.4	1.0

A slightly larger percentage of the land in the tropical premontane wet forest has been left in forest (19.5 per cent as compared to 16.3 per cent), which is probably due to the increased need for protection against erosion in this life zone. With a given amount of rainfall the more rugged topography in this life zone would make this added protection necessary. This same rugged topography, however, would also imply that a larger percentage of the area of this life zone is unsuitable for farming.

The only other difference that appears significant is in the category of area not cultivated. Around 6 per cent of the total area of the farms in the tropical premontane wet forest life zone is left idle, whereas about 10 per cent of the total area of the farms in the tropical moist forest life zone is in this category. In the tropical moist forest life zone idle land represents 41 per cent of the area suitable for annual crops (i.e., cleared of trees and available for planting), whereas in the tropical premontane wet forest life zone it represents only 29 per cent of this total. This means that fully 41 per cent of available annual crop land is left idle in the tropical moist forest life zone as against 29 per cent in the other life zone. On the basis of this data it seems that the farmers in the tropical moist forest life zone have the ability to permit the land to rest for a longer period of time than the farmers in the tropical premontane wet forest. Then again, perhaps this longer rest period is necessary in that life zone. There seems to be no reason why they should have a greater ability to do this since there is no significant difference in productivity between the two zones, nor is there a significant difference in the size of farm. Also, the life zone chart shows us that this hotter life zone is better situated with respect to the potential evapotranspiration ratio line of unity then is the tropical premontane wet forest life zone, which indicates that there is a better balance of water in the soil in this life zone. The periodicity of the rainfall could explain this variation, but more research is needed to clarify this point. In addition, research is needed to determine why such large amounts of land are left idle in the two zones.

There is little difference in the combination of annual crops grown in the two life zones for the farms in our sample. Table 16 shows the percentage of the annual crop land planted in various annual crops. There is a greater tendency for the farmers to grow corn in the tropical premontane wet forest life zone, and this is almost exactly offset by a greater tendency to grow beans in the tropical moist forest life zone. There is a greater tendency to grow rice in the tropical moist forest life zone which is offset by the greater plantings of yuca and tobacco in the tropical premontane wet forest life zone. In fact, not one farm in the sample in the tropical moist forest reported plantings of tobacco, which again could be attributed to the greater heat of that life zone.

TABLE 16

PER CENT OF ANNUAL CROP LAND PLANTED IN VARIOUS CROPS BY LIFE ZONE

Crop	Tropical Premontane Wet Forest	Tropical Moist Forest
Rice	30.3	35.9
Tobacco	2.4	0.0
Yuca	3.1	1.0
Beans	16.6	24.6
Corn	47.6	38.6

Two other characteristics of land use on these farms is of interest. The first is that nearly 50 per cent of the land in both

life zones is pasture land, which indicates the importance of dairying and the raising of beef cattle in these two life zones. In the tropical moist forest life zone 65 per cent of the farms reported having beef cattle and 80 per cent reported having milk cows, while the figures were 56 per cent and 64 per cent respectively for the tropical premontane wet forest life zone. The biggest difference, however, comes in the composition of the herds. In the tropical moist forest life zone, 57 per cent of the cattle are beef cattle and 43 per cent are milk cows, whereas in the other life zone, 45 per cent are beef cattle and 55 per cent are milk cows. Thus, the percentage composition of herds reverses itself between the two life zones. The presence of a couple very large herds of beef cattle in the tropical moist forest biased the figures to produce this latter difference. However, there does seem to be a decided preference in favor of beef cattle in the tropical moist forest life zone, and the opposite preference in the other life zone. The reasons for this could be related to the climatic parameters, but more research is needed to substantiate this relationship. An additional factor might be the importance to the marketing of the product of being near to the population centers.

The other characteristic of interest is the almost total lack of vegetable gardens on these farms; either for commercial use or for home consumption. Many of the farms visited had sufficient area near the house where a garden could have been established, but none of the farmers had taken the initiative to start one. Since this type of food could provide some variety to the diet at a fairly reasonable cost (especially as compared to the high prices being asked in the

markets for this type food), the absence of these gardens is surprising. This could be explained by the fact that this is not part of the traditional diet of the people, and thus, they are not motivated to grow these things. The difference in life zones has nothing to do with this characteristic.

In addition to the data from the sample described above, the data for those districts at least 85 per cent within one of the two life zones were compared to see if they differed in land-use. The assumption underlying the use of these districts is that the 85 per cent or more of the area of the district within the life zone is sufficient to dominate the statistics for that district, and therefore, that any characteristic of land use for the pertinent life zone will be reflected in those statistics. This data was gathered from unpublished census reports from the Census of Agriculture of 1963, There are 23 such districts in the tropical premontane wet forest life zone and 25 in the tropical moist forest life zone. Most of these districts are at least 90 per cent within the life zone, and several are totally within the life zone. So it is quite likely that if there are differences between life zones in land use they will be reflected in this data. This comparison is more valid than the one based on the sample described above because the data covers all farms within the district, and not only those producing a given crop. The other comparison is valid, but it is a restricted comparison between life zones on a particular type of farm.

The percentage distribution into the various land use categories of the total farm area within these districts and by life zone is presented in Table 17. This table should be compared with

Table 15 which shows the same breakdown into land-use categories but for the sample of farms producing corn. Table 17 shows that annual crops make up 7.8 and 10.5 per cent of the land in the tropical premontane wet forest and tropical moist forest life zones respectively, whereas the area planted to permanent crops is 17.9 and 5.0 respectively for the two life zones. Thus, there seems to be a decided preference for permanent crops (coffee, sugar, banana, etc.) in the tropical premontane wet forest life zone, and a less distinct but visible preference for annual crops in the tropical moist forest life zone. The heat surely makes a difference in the use of permanent crops (especially coffee) since even in the tropical premontane wet forest life zone, which is much cooler than the tropical moist forest life zone, these crops have to be shaded. This is a difference between the two life zones that is dependent upon the parameters (heat) of the life zones.

When these two categories in Table 17 are compared with their counterparts in Table 15, a considerable decrease in the area planted in annual crops can be seen, but this is to be expected because of the nature of the sample in Table 15, that is, it excludes farms specializing in permanent crops. Also, we no longer find the correspondence in percentages for the areas in annual crops that we did in the earlier sample. This means that the additional farms included in the district sample data have a higher percentage of their land in annual crops in the tropical moist forest life zone than do the additional farms in the other life zone. There also seems to be a greater tendency to combine permanent crops and annual crops in the tropical premontane wet forest life zone, which is probably due to the small amount of

labor time necessary in producing the permanent crop. The crop that accounts for a large percentage of the area planted in permanent crops in the tropical premontane wet forest life zone is coffee, which, at least as it is grown in Costa Rica, requires little labor time prior to harvest.

TABLE 17

PERCENTAGE DISTRIBUTION INTO LAND USE CATEGORIES OF THE TOTAL AREA OF FARMS FOR THOSE DISTRICTS AT LEAST 85 PERCENT WITHIN ONE OF THE TWO LIFE ZONES

Land Use	Tropical Premontane Wet Forest	Tropical Moist Forest
Annual crops	7.8	10.5
Permanent crops	17.9	5.0
Area not cultivated	4.8	8.0
Natural pasture	11.5	28.6
Planted pasture	21.8	17.8
Cut pasture	0.7	0.9
Charrales	11.9	11.8
Vegetable gardens	0.0	0.0
Forest	23.1	16.6
Other classes of land	0.5	0.7

The division between life zones in the area not cultivated or temporarily idle is maintained in this new comparison, but as expected, the percentage of total land area on farms in this category is reduced from the amounts in the earlier comparison. This can be explained by

the fact that for farms specializing in permanent crops it is not as necessary to leave land idle since the soil is not depleted of minerals to the extent that it is for annual crops. This difference between life zones, evident in both comparisons, could be an important difference for the Holdridge system, but requires additional research for its explanation.

In terms of planted pasture and cut pasture, the results of the district comparison are similar to those of the sample of farms producing corn, both in the difference between life zones (which does not seem significant), and in the actual percentages. There is a sharp drop, however, in the percentage of the area on farms in natural pasture (26.6 to 11.5 per cent) in the tropical premontane wet forest life zone, whereas this category remains at about the same level in the tropical moist forest life zone. Thus, there is a strong tendency to substitute permanent crops for natural pasture in the former life zone.

This district sample shows almost identical percentages of land reverting to its original growth (up in both life zones from the farms producing corn sample), and the same complete lack of vegetable gardens evidenced by the previous sample. This sample also shows a greater percentage of the area in forest in the tropical premontane wet forest life zone than is the case in the tropical moist life zone, with the division being greater by life zone than in the earlier sample. This can be explained by the greater need for forest in the tropical premontane wet forest life zone due to the more rugged topography which makes water control a more serious problem. There is very little commercial exploitation of the forests in either of these

two life zones. Inroads are, however, being made in the forest by the clearing of land for homesteads and farms and by the search for fuel for heating and cooking.

Our district sample shows that there are some significant differences between life zones in land use, and that these were somewhat obscured in our sample of farms producing corn. The major differences between life zones are: the greater emphasis on permanent crops in the tropical premontane wet forest life zone, the smaller emphasis on annual crops in the tropical moist forest life zone, the longer period of time at rest (or slower rotation pattern) for land in the tropical moist forest life zone, the greater emphasis on pasture in the tropical moist forest life zone (including all three categories, 47.3 per cent of the land in the tropical moist forest life zone is in pasture, as compared to 34.0 per cent of the land in the tropical premontane wet forest life zone), and the larger percentage of land in forest in the tropical premontane wet forest life zone. As one would expect there is more similarity between life zones in the sample of specialized farms producing corn - than there is in the district sample which includes all farms within the districts.

CHAPTER VIII

CONCLUSIONS

The purpose of this study is to compare certain economic variables between life zones as defined by Dr. Leslie R. Holdridge as a test of the economic relevancy of the Holdridge Life Zone System. The most obvious relationship between the life zone system and economics is in the systems effect on agriculture, and so the variables to be compared are chosen from the field of agriculture. Those variables are: the productivity of farms producing rice, beans and corn in the two life zones, the technology used in producing corn in the two life zones, the cost of production of corn in the two life zones, and the land use systems actually being used by the farmers in the two life zones.

The basic hypothesis is that there exist significant differences in economic variables between life zones, and that these differences are due to the variations in the climatic parameters (heat, precipitation, and moisture) that differentiate the life zones in the Holdridge Life Zone System. The two major steps involved in this analysis are first to discover the differences if such exist, and second to relate the differences to the climatic parameters delineating the life zones. In other words, this latter step involves trying to establish a cause and effect relationship between the parameters and the economic variables in which the variation is found.

Two samples are involved in the study. One is a sample of farms producing rice, corn, and/or beans, and is extracted from a sample of farms taken for a study of food crops by the Costa Rican Department of Census. The second sample consists of political districts falling at least 85 per cent within one of the two life zones being compared. The data for these districts were taken from the Costa Rican Census of Agriculture of 1963.

The statistical analysis presented in some of the chapters of this study (primarily the null-hypothesis test for a difference between two sample means), do not permit any statements concerning cause and effect. It can only indicate the probability or improbability that the sample means come from the same population rather than from two distinct populations. In cases where the probability is high that they come from different populations, the life zones are considered to differ for that particular variable. In the opposite case where the probability is high that the means come from the same population, there is considered to be no variation by life zone for that particular variable. When confronted with the first of the cases cited above, an attempt is made to connect reasons to the observed difference in the economic variable. If that reason turns out to be the difference in either heat, precipitation, or moisture that exists between the life zones, then we can say that the determinants of the life zones have significant influence on the economic variable.

Before we proceed to summarize the results of the study, it would be beneficial to restate the limitations under which these conclusions hold. In the first place, comparisons are made between

only two of the 120 or more life zones defined by the Holdridge system. In addition, the two life zones chosen are rather similar with respect to their values for the climatic parameters delineating the life zone system, and certainly greater differencens can be found by making comparisons between the more extreme life zones. We are testing only a small part of the life zone system.

Some of our conclusions hold only for a specialized type of farm; specifically what might be called a "grain farm". A major requirement for selecting the farms in our sample of farms is that they produce corn; even though many of them have more land planted in rice, beans, or some other annual or permanent crop. Thus, we can say that out conclusions as to difference or lack of difference is true for farms producing corn, but this cannot be generalized to all farms. Farms specializing in cotton, cattle, or some other product may or may not have these or other differences.

Implicit in our comparisons of productivity and technology is the assumption that the farmer makes the best adaptation to the conditions as he finds them in his life zone, that is, that the farmer uses the best technology that he knows to be available for the area within which his farm lies. There is some evidence that the farmers could increase productivity by the use of some factors not now available to them in the production of corn, and if this is true they might be able to make a profit by changing to the new technology. Anyway, it would be misleading to compare a life zone where the technology was well adapted to the conditions of that life zone, with a life zone where the methods were not well adapted. This latter might occur had the technology recently been transposed from some other area or country.

This could well be the case in certain of the life zones if the ecologists belief is true that certain of these life zones are only now beginning to attract people. A difference in productivity or technology could simply be a reflection of the different degree of development in the state of the arts.

Perhaps the major limitation of this study is the lack of randomness in the sample of farms used for comparison between life zones. The original selection of farms producing either rice, corn, and/or beans was made randomly, but when only those farms producing corn were extracted from this larger sample, the resulting sample was not strictly random. Small farms producing from one to five manzanas of corn were included only if the farmer was producing a minimum of five manzanas of one (or both) of the other two crops - rice and beans. This, of course, excluded from the possibility of being selected those farms producing less than five manzanas of corn, and which in addition were not producing at least five manzanas of either rice or beans. Nevertheless, this sample was used because of the extra time involved in starting from scratch in selecting a completely new sample.

Moreover, the randomness of the sample suffered from the fact that it proved impossible to interview all of the farmers selected in the two life zones. When this lack of sufficient time became apparent, an attempt was made to visit at least a few farms in each of the major corn producing areas in the two life zones so that no important area in the production of this grain was neglected. Nevertheless, bias could easily enter into a sample chosen in this way, and our conclusions must be qualified accordingly.

In addition to these limitation on the conclusions of this study there are the usual ones associated with making a study in an under-developed country. The most serious of these is the reluctance of the people to answer questions or to give truthful answers to questions. This is particularly the case for a study dependent in large part on interviews with some segment of the population, and even more so when the interviewees happen to be rural people.

The analysis of productivity of the three crops by life zone presented in Chapter IV leads us to the conclusion that there is no significant difference in this variable between the two life zones studied. The output per manzana of rice, corn, and beans was compared between the two life zones using data from the sample of farms taken by the Costa Rican Department of Census for their study of grain production. Their data pertain to the year 1963. In addition, the productivity per manzana for all farms producing corn within those districts at least 85 per cent within one of the two life zones was compared by life zone to see if a difference existed in that variable for this sample. Again the conclusions was that no significant difference existed.

This lack of variation in productivity between life zones is particularly surprising in view of the existence of differences in certain factors that one would expect to have an important influence on productivity. Besides the difference in the climatic parameters, which one would expect to cause differences in productivity, there is the difference in topography between the life zones which could be expected to exert a decided influence on productivity. The topography is more rugged in the tropical premontane wet forest life zone. Another factor is the difference in technology used in the two life

zones that was pointed out in Chapter V. The tropical moist forest life zone has what would be considered the more "modern" technology simply because it is more mechanized.

Both of these factors, the more rugged topography in the tropical premontane wet forest life zone and the more modern methods in use in the tropical moist forest life zone - would be expected to exert a restraining influence on productivity in the former life zone when compared with the latter. This is not the case however, except in the production of beans. The mean output per manzana of corn for the tropical premontane wet forest life zone was 1,513 pounds to only 1,283 pounds for the tropical moist forest life zone based on the sample of farms selected from the census data. The data on output per manzana of corn in those districts 85 per cent within the life zones showed a mean of 2,095 pounds in the tropical premontane wet forest life zone, as compared with 1,486 pounds in the tropical moist forest life zone. The output per manzana of rice for the farms in the census sample showed a mean of 1,083 pounds in the tropical premontane wet forest life zone, as compared with a mean of 976 pounds in the tropical moist forest life zone. Only in the production of beans was the tropical moist forest life zone more productive than the tropical premontane wet forest life zone, with the mean outputs per manzana of 578 pounds and 512 pounds respectively. Thus, even though the tropical moist forest life zone seems more favorable for the production of these crops, one finds the average productivity of two of the three crops studied here lower in that life zone. There is some other factor acting here of sufficient influence to offset the obvious advantages of the tropical moist forest life zone, but it was not brought out in the data of this study. Additional research is needed to discover what this other factor might be (it could well be one of the climatic parameters, and their individual effects should be studied by life zone), and to discover the marginal productivities of the various factors being used and not being used so as to help determine the correct combinations of resources to use on the various crops. It is especially important that controlled studies be done on fertilizer and the results be made known to the farmer, for this is the key to increased productivity in Costa Rica. These experiments could be carried out by life zone as a further test of the Holdridge Life Zone System.

The comparison of farm technology by life zone in Chapter V showed that a difference does exist in the technology used in the two life zones, but that this difference is limited in extent and does not depend upon the difference in the climatic parameters for its existence. The only significant difference by life zone in the methods of production is in the extent to which the land is plowed prior to planting the corn. A much greater tendency to plow was found in the tropical moist forest life zone, along with a greater use of tractors for plowing. The reason for this however, has nothing to do with the differences in the climatic parameters, but rather is due to the fact that the land in that life zone is flatter and hence more suitable for plowing either by oxen or tractor.

The other aspects of technology that might be expected to differ by life zone turned out to be remarkably similar in the two life zones. Included in these other aspects were: the use of fertilizer, insecticides, herbicides and fungicides, the use of and use made of various

types of capital (machete, macana, etc.), the depth of planting, the distance between plants and rows, the use of support for plants, the use of shade, the use of by-products, the use of animal and electric power, the use of irrigation or drainage, the method of clearing the land, the frequency and method of cultivating the crop, the capital used and method of harvesting the corn, and many others. In none of these was a significant difference found between life zones. There was a difference found in the period of the growing season between life zones, but this seems to be related to the difference in topography.

In conclusion then, there are few differences by life zone in farm technology, and that those that do exist are due to differences in topography, and not to differences in the climatic parameters delineating the life zones.

In Chapter VI the comparisons of costs of production by life zone showed that a significant difference did exist in that variable. This comparison involved the costs of production of one manzana of corn in each life zone and it was found that the null-hypothesis had to be rejected (i.e., that the two sample means could have come from the same population by chance) at the .05 level of probability. Thus, the conclusion was that the two sample means could not likely have come from the same population. A similar result was found for our data on cost per unit of output.

These differences in cost per manzana of corn produced and in cost per unit of output (since there were no differences in productivity by life zone) were traced to the greater use of capital in the tropical moist forest life zone. In turn, as was noted above, this

difference in capital use was due to a difference in topography and not to the difference in the climatic parameters. The sample used here, however, was very small and the results of this analysis should be considered as indicative and not conclusive.

The conclusion is then that while a difference does exist between life zones in the cost of producing corn in Costa Rica, this difference is not dependent upon the factors differentiating the life zones.

The one variable for which a difference was found that was related to the climatic determinants of the life zone system was land use. The comparison made of land use by life zone showed there to be a definite tendency for the farmers in the premontane wet forest life zone to grow more permanent crops - primarily coffee - than the farmers in the tropical moist forest life zone. The former life zone also had a greater percentage of its land in forest and reverting to forest than did the latter. The tropical moist forest life zone on the other hand had more land devoted to pasture and to annual crops, and had almost twice the percentage of land idle that the tropical premontane wet forest life zone had.

These differences in actual land use are related in part at least to the factor heat, which is one of the factors involved in the life zone system. The emphasis on permanent crops in the tropical premontane wet forest life zone particularly seems to be related to this factor. The greater use of forest in that life zone is again related to the more rugged topography however.

In summary, this study has shown that the differences between life zones are minimal with respect to the production of corn and

under the limitations of the study mentioned above. The differences that do exist between life zones in large part do not depend upon those factors that determine the life zones as defined in the Holdridge Life Zone System. Thus, this study does little to confirm the claims for economic relevancy made by advocates of the Holdridge LIFE ZONE SYSTEM.

APPENDIX A

1. Farm code number ___________

2. Location of the farm

   Province __________
   Canton __________
   District __________
   Segment __________

3. Person responsible for farm operations ______________________

4. Is the above person the:

   Owner ____________
   Administrator _____
   Other ____________

5. How many years has the above person been directing the operations on the farm _____

6. If the above person has ever been responsible for farming operations in another place, give the name and location of the place.

   ____

   P   C   D   L.Z.

7. What is the legal relationship of the cultivator to the land?

   Owner
   - With title _________
   - Without title _______

   Ownerlike possession _____
   Rented ____________
   Occupied as squatter _____
   Other ____________

8. Is agriculture the main occupation of the owner of the land?

   Yes ____ No ____

9. Size of the farm (in manzanas)

   Total extension of the farm _______
   Arable land ______________________
   Permanent crop land ______________
   Permanent meadows and pastures _____
   Wood or forest land ______________   All other land _________

10. Is the land parceled? Yes_____ No _____

11. If yes, how many parcels and the sizes of each.

No. of parcels __________. Sizes: __________
____
____

12. PRODUCTION DURING THE PAST AGRICULTURAL YEAR
(from 1 of April 1965 to 31 of March 1965)

Crop	Area Harvested	Production and Destination of Production: Total	For Consumption	For Seed	For Feed	For Sale	Price Unit
I Cotton							
Rice (1st planting)							
Rice (2nd planting)							
Camote							
Potatoes (1st Planting)							
Potatoes (2nd Planting)							
Tobacco							
Yuca							
Beans (1st Planting)							
Beans (2nd Planting)							
Corn (1st Planting)							
Corn (2nd Planting)							
P Coffee							
Cacao							
Banano							
Sugar							
Other							

13. How many dairy cows on the farm? ______

14. List the breeds of these and the number in each breed.

Breed ___________ Number ___________
___________ ___________

15. How many cows were fresh in the past week? _________

16. What was the total production of dairy products in the past week?

Milk _______ Butter _______ Cheese________

17. How many cattle on the farm that are being fattened for meat? List the breeds of these and the number in each breed.

Breed ___________ Number ___________
___________ ___________

18. How long does it take to fatten a calf for market? ______months

19. What does the diet of your cattle and cows consist of?

Cattle_______%______ Cows______ % ______

20. What is the average price received for a ________lb. cow?

21. How many other animals does the farm have?

Pigs _______
Chickens ___
Goats ______
Sheep ______
Other ______

22. What diseases are you bothered with in your animals? ______________

23. What work animals do you use on the farm? (Number)

Oxen _________ Mule _______
Horse ________ Other ______

Which of these are used in raising your corn crop?
None_____________
Specify and how used ____

24. How many workers are permanently employed on the farm? ____________

25. How many hours per week do they work? _______

26. How much are they paid per week? ____________

27. How many workers are temporarily employed on the farm? Including neighbors working on reciprocal basis._______________

28. How many days are they employed per week and how much are they paid per hour.

P_______ Pay: P_____
C_______ C_____
H_______ H_____

29. How many members of the family, including the head of the family work on the farm?___________

30. What types of farm equipment do you have on the farm and use?

Type	Number	Used For
Tractor	______	__________
Plow	______	__________
Disk	______	__________
Drag	______	__________
Rake	______	__________
Planters	______	__________
Other	______	__________

Read list and specify.

31. What types of hand tools do you have on the farm and what do you use them for?

Type	Number	Used for
Sythe	________	___________
Sickle	________	___________
Rake (Hand)	________	___________
Hoe	________	___________
Others	________	___________

32. In the past agricultural year did you use:

Fertilizer: Yes ___ No ___
Insecticides Yes ___ No ___
Herbicides: Yes ___ No ___
Fungicides: Yes ___ No ___

33. Specify the types of these used, the number of pounds per manzana used on corn, the total amounts purchased, and the price.

Type	No. of lbs./m. on corn	Total purchased	Price
Fertilizers	______________	_______________	_______
	______________	_______________	_______
Insecticides	______________	_______________	_______
	______________	_______________	_______
Herbicides	______________	_______________	_______
	______________	_______________	_______
Fungicides	______________	_______________	_______
	______________	_______________	_______

34. Do you use organic fertilizer? Yes ______ No ______

35. Did you use equipment to apply these?

Yes _______ No _______

Specify if yes: ____

36. Do you rotate your crops? Yes _______ No _________

If yes, please describe the rotation system used.

37. Do you shade any of your crops in any way? Yes _____ No _____

If yes, explain which and how please.

38. Do you mix your crops, i.e., plant two or more crops in a field at the same time?

Yes _____ No _____

If yes, describe the system used.

39. Do you make use of any by-products from the crops you plant?

Yes _____ No ______

If yes, please specify the by-product and its use.

40. Do you use any type of support for any of your plants? Yes___No____

If yes, which crops and how are they supported.

41. What were the dates of your planting and harvesting this year?

Crop	Date of Planting	Date of Harvesting

42. What is the earliest possible date you feel you could plant corn?__

Why could you not plant earlier? __________________________________

43. What is the latest possible date you feel you could harvest your corn?________ Why couldn't you harvest later?____________________

44. Do you use special (selected or hybrid) corn seed? Yes _____No____

If yes, what is the name or formula of the seed?___________________

Why did you choose this particular seed?__________________________

Where or from whom did you first learn of this seed?_______________

Do you buy new seed for each planting? Yes_____ No _____

45. Which of the following operations do you perform in preparing a new piece of land for planting corn. Also, indicate the number of times performed.

Operation	Times
Cutting trees	_____
Cutting Brush	_____
Burning	_____
Raking	_____
Plowing	_____
Disking	_____
Dragging	_____
Other - Specify	_____

46. Which of the following operations do you perform in preparing a piece of land for planting corn which was previously planted with either corn or some other crop?

Operation	Times
Cutting trees	_____
Cutting brush	_____
Burning	_____
Raking	_____
Plowing	_____
Disking	_____
Dragging	_____
Other - specify	_____

47. At what depth do you plant your corn? (In inches) ______________

48. How far apart do you place the seeds of corn (In inches) __________

49. How far apart do you place your rows of corn? (In inches)__________

50. Which of the following best describes your planting methods in corn?

Plant in mounds________
Plant in furrows ______
Plant on surface:
cover with dirt ________
cover with brush _______
not covered ____________
other _______ explain ______________

51. What type of machinery or hand tools do you use in planting your corn? Please specify including the way used.

Tool or Machinery	How used
______________________	______________________

52. Please describe fully the method you use in planting your corn, starting with a description of the land prior to commencing your operations.

53. After having planted your corn, how many times do you cultivate prior to harvesting? ______________

54. Approximately how much time elapses between planting and the successive cultivations?

Planting to 1st cultivation ______________
1st cultivation to 2nd cultivation ________
2nd cultivation to 3rd cultivation ________

55. If you use fertilizer, insecticides, herbicides or fungicides on your corn, please specify the timing of application and the amounts applied.

	Timing	Amount/m
Fertilizer	____________________	_________
Insecticides	__________________	_________
Herbicides	____________________	_________
Fungicides	____________________	_________

56. What tools or machinery do you use in cultivating your corn, and how are they used?

Tool or machine	How Used

57. Do you irrigate your crop? Yes_____ No _____

If yes, how many times? ______________

If yes, please indicate the timing of the applications of water____

58. Which of the following are used in your irrigation system?

Ditches _______ Other _______
Reservoirs_____
Dams __________ Specify________
Machinery _____ Specify________

59. Do you have a system to drain water from your fields? Yes____No____

If yes, describe it please ______________________________________

60. Other than the times you cultivate, irrigate or apply fertilizers, etc., do you perform any other operations prior to harvesting; such as pulling weeds, etc? Yes ______ No ______

If yes, please specify ____

61. Please describe fully all of the operations performed on your corn after planting and before harvesting.

62. What type of machinery and/or hand tools do you use in harvesting your corn? Please specify, including use.

Type	How Used

63. Do you harvest all of your corn at one time? Yes_____ No _____

If no, why not?____

64. Please describe fully your method of harvesting your corn, including any problems or obstacles that have to be overcome.

65. In what way do you process your corn after harvesting, and how is this done? (include equipment used)

Process	How done
Shelling	____________________
Cleaning	____________________
Sacking	____________________
Boxing	____________________
Sorting	____________________
Grading	____________________
Other	____________________

66. Do you store your corn prior to selling it? Yes_____ No_____

If yes, for how long ______________________________

If yes, why do you not sell immediately?_____________

67. How do you transport your corn to market?____________

68. To whom do you sell your corn? Give name and address______________

69. Do you always go to the same person (market)? Yes_____ No____

70. Do you ever try to determine where the highest price is being paid for corn, and then sell there? Yes________No_______

71. Do you receive credit of any type? Yes_____No_____

If yes, from whom________________

For what purpose ________________

About how much__________________ What rate of interest?__________

72. Do you belong to any type of cooperative? Yes_____ No_____

If yes, give the name please ______________________________________

73. Could you estimate the cost to you per Fg. delivered to the point of sale? (colones)__________

74. Describe the way in which you market your corn, including any problems or obstacles to be overcome.______________________________

75. Are your fields fenced? Yes_____ No_____

76. Are there any special problems in converting pasture land into crop land? Yes________No_______

If yes, specify please ______________________________________

77. Have you ever planted the same crop in the same field in successive years? Yes______No______

If yes, how did the yield in successive years compare with the previous years? (Estimate the % change)___________________________

78. How many buildings do you have on your farm? ________

Describe their construction and what they are used for - include materials, base, roof, etc.____

79. What types of diseases, plagues, pests, etc., do you encounter on your farm, and how often do they appear?

Type	Frequency (Every harvest, etc.)

80. What forest products have you sold from your farm? Specify________

81. Do you have electric power? Yes___No___

If yes, do you use if in your farming operations in any way? Specify:____________________

81. Specify any equipment you use in your milking operations?

Equipment	How Used

COST OF PRODUCTION-CORN

HUMAN LABOR

		Men used	No. of days worked	hours/day	average wage
Planting:	full time	____	________	______	________
	part time	____	________	______	________
	Comments:				
Cultivating:	full time	____	________	______	________
	part time	____	________	______	________
	Comments:				
Harvesting:	full time	____	________	______	________
	part time	____	________	______	________
	Comments:				
Marketing:	full time	____	________	______	________
	part time	____	________	______	________
	Comments:				

What is the average wage paid in this area for agricultural workers?___

What other expenses do you have with your labor force? Please specify and estimate the average daily cost per worker. Such things as meals, housing,etc.

Expense	Average daily value/worker
__________	______________
__________	______________

Animal Labor

Planting:	Animal	days used	Daily rental value
	____	______	__________
	____	______	__________

	Animal	days used	Daily rental value
Harvesting:	______	______	______
	______	______	______

	Animal	days used	Daily rental value
Cultivating:	______	______	______
	______	______	______

	Animal	days used	Daily rental value
Marketing:	______	______	______
	______	______	______

Land

Number of manzanas under corn.______ Rental value______

Number of buildings________________ Estimated value____

If you were in the market for a farm, and this one was for sale, what would you be willing to pay for it?__________

Capital

Type	Days used in corn			life	value	rental value
	P	C	H			
____	____	____	____	____	____	________

Materials

Type	Quantity	Price/unit	Total
________	________	____________	______

Please list and evaluate any other expenses that you encounter in growing your corn.

____

Number of manzanas in corn.________ Total production._______Fg.

APPENDIX B

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-POUNDS PER MANZANA OF CORN

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \text{ where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{106985575}{113}} = \sqrt{946775} = 973.02$$

$$S\bar{x} = \frac{973.02}{\sqrt{114}} = \frac{973.02}{10.68} = 91.11$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{91.11}{1283} = .0710 = 7.10\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \text{ where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{61490671}{58}} = \sqrt{1060184} = 1029.65$$

$$S\bar{x} = \frac{1029.65}{\sqrt{59}} = \frac{1029.65}{7.68} = 134.07$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{134.07}{1513} = .0886 = 8.86\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1-\bar{x}_2) = \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(91.11)^2 + (134.07)^2}$$

$$= \sqrt{8301 + 17975} = \sqrt{26276} = 162.10$$

$$t = \frac{\bar{x}_1-\bar{x}_2}{S(\bar{x}_1-\bar{x}_2)} = \frac{1513-1283}{162.10} = \frac{230}{162.1} = 1.42$$

Degrees of freedom = $n = n_1 + n_2 - 2 = 114 + 59 - 2 = 171$

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-POUNDS PER MANZANA OF RICE

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{37311440}{91}} = \sqrt{410016} = 640.32$$

$$S\bar{x} = \frac{640.32}{\sqrt{92}} = \frac{640.32}{9.59} = 66.77$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{66.77}{976} = .0684 = 6.84\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{9030132}{24}} = \sqrt{376255.5} = 613.40$$

$$S\bar{x} = \frac{613.40}{\sqrt{25}} = \frac{613.40}{5} = 122.68$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{122.68}{1083} = .1133 = 11.33\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1 - \bar{x}_2) \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(66.77)^2 + (122.68)^2}$$

$$= \sqrt{4458 + 15050} = \sqrt{19508} = 139.61$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S(\bar{x}_1 - \bar{x}_2)} = \frac{1083-976}{139.61} = \frac{107}{139.61} = 0.766$$

Degrees of freedom = $n = n_1 + n_2 - 2 = 92 + 25 - 2 = 115$

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-POUNDS PER MANZANA OF BEANS

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{18541665}{77}} = \sqrt{240801} = 490.71$$

$$S\bar{x} = \frac{490.71}{\sqrt{78}} = \frac{490.71}{8.83} = 55.57$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{55.57}{578} = .0961 = 9.61\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{2736465}{30}} = \sqrt{91216} = 302.02$$

$$S\bar{x} = \frac{302.02}{\sqrt{31}} = \frac{302.02}{5.57} = 54.22$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{54.22}{512} = .1059 = 10.59\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1-\bar{x}_2) = \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(55.57)^2 + (54.22)^2}$$

$$= \sqrt{3088 + 2940} + \sqrt{6028} = 77.64$$

$$t = \frac{\bar{x}_1 + \bar{x}_2}{S(\bar{x}_1 - \bar{x}_2)} = \frac{578-512}{77.64} = \frac{66}{77.64} = .8501$$

Degrees of Freedom = $n = n_1 + n_2 - 2 = 78 + 31 - 2 = 117$

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-POUNDS PER MANZANA OF CORN CENSUS DISTRICTS

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{3986992}{24-1}} = \sqrt{173347} = 416.35$$

$$S\bar{x} = \frac{416.35}{\sqrt{24}} = \frac{416.35}{490} = 84.97$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{84.97}{1486} = .057\ (x\ 100) = 5.7\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{22200084}{15}} = \sqrt{1480006} = 1216.55$$

$$S\bar{x} = \frac{1216.55}{\sqrt{16}} = 304.14$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{304.14}{2095} = .1452 = 14.52\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1-\bar{x}_2) = \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(84.97)^2 + (304.14)^2}$$

$$= \sqrt{741.99 + 92501.1} = \sqrt{99921} + 316.10$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S(\bar{x}_1-\bar{x}_2)} = \frac{2095-1486}{316.10} \quad \frac{609}{316} = 1.927$$

Degrees of Freedom $= n = n_1 + n_2 - 2 = 24 + 16 - 2 = 38$

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-TOTAL COST OF PRODUCTION PER MANZANA OF CORN

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{579119.56}{21-1}} = \sqrt{28955.98} = 170.16$$

$$S\bar{x}_1 = \frac{170.16}{\sqrt{21}} = \frac{170.16}{4.58} = 37.15$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{37.15}{505.17} = .0735 = 7.35\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{312504.66}{22}} = \sqrt{14204.76} = 119.18$$

$$S\bar{x}_2 = \frac{119.18}{\sqrt{23}} = \frac{119.18}{4.80} = 24.82$$

$$\frac{S\bar{x}}{\bar{\bar{x}}} = \frac{24.83}{389.44} = .0637 = 6.37\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1-\bar{x}_2) = \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(37.15)^2 + (24.82)^2}$$

$$= \sqrt{1380.12 + 616.03} = \sqrt{1996.15} \doteq 44.68$$

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S(\bar{x}_1-\bar{x}_2)} = \frac{505.17 - 389.44}{44.68} = \frac{115.73}{44.68} = 2.59$$

Degrees of Freedom = $n = n_1 + n_2 - 2 = 21 + 23 - 2 = 42$

COMPUTATIONS FOR THE SIGNIFICANT DIFFERENCE BETWEEN SAMPLE MEANS USING STANDARD ERROR OF THE DIFFERENCE-COST PER FANEGA OF CORN

STANDARD ERROR OF MEANS - Tropical Moist Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{1.246691}{20}} = \sqrt{.062335} = .2497$$

$$S\bar{x}_1 = \frac{.2497}{\sqrt{21}} = \frac{.2497}{4.58} = .0545$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{.0545}{.468} = .1165 = 11.65\%$$

STANDARD ERROR OF MEANS - Premontane Wet Forest

$$S\bar{x} = \frac{S}{\sqrt{n}} \quad \text{where}$$

$$S = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}} = \sqrt{\frac{.577181}{22}} = \sqrt{.0262355} = .1620$$

$$S\bar{x}_2 = \frac{.1620}{\sqrt{23}} = \frac{.1620}{4.80} = .03375$$

$$\frac{S\bar{x}}{\bar{x}} = \frac{.03375}{.324} = .1042 = 10.42\%$$

STANDARD ERROR OF THE DIFFERENCE

$$S(\bar{x}_1-\bar{x}_2) = \sqrt{S\bar{x}_1^{\,2} + S\bar{x}_2^{\,2}} = \sqrt{(.0545)^2 + (.03375)^2}$$

$$= \sqrt{.00297025 + .00113906} = \sqrt{.00410931} = .0641$$

$$t = \frac{x_1 - x_2}{S(\bar{x}_1 - \bar{x}_2)} = \frac{.468 - .324}{.0641} = \frac{.144}{.0641} = 2.25$$

Degrees of Freedom = $n = n_1 + n_2 - 2 = 21 + 23 - 2 = 42$

BIBLIOGRAPHY

Books

Black, John Donald. Introduction to Economics for Agriculture. New York: The MacMillan Company, 1953.

Boon, G. K. "Alternative Techniques of Production; Choice of Agricultural Technology" Progress Report #6, Rotterdam: Netherlands Economic Institute, Development of Balanced Economic Growth.

Center for International Studies. Policies for Promoting Agricultural Development, Report of a Conference on Productivity and Innovation in Agriculture in the Underdeveloped Countries, Mass: Massachusetts Institute of Technology, Cambridge, 1965.

Foster, G. M. Traditional Cultures and the Impact of Technological Change, New York, 1962.

Lee, Douglas H. K. Climate and Economic Development in the Tropics, Council on Foreign Relations, New York: Harper and Brothers, 1957.

Ministerio de Economia y Hacienda. Censo Agropecuario: 1963, Direccion General de Estadistica y Censos, Republica de Costa Rica, San Jose, Costa Rica, 1965.

Ministerio de Agricultura y Ganaderia. Cultivos Agricolas de Costa Rica: Manual de Recommendaciones, Boletin Tecnico No. 35, San Jose, Costa Rica, 1965.

Schultz, Theodore W. Transforming Traditional Agriculture, Studies in Comparative Economics, Conn: Yale University Press, New Haven, 1964.

Sufrin, Sidney C., and Wolf, Charles Jr., Capital Formation and Foreign Investment in Underdeveloped Areas, Maxwell School Series, Syracuse University Press, 1958.

Tosi, J. A., Jr. Aerial Photographic Interpretation of Life Zones, Advanced Research Projects Agency, Army Research Office, Department of the Army, Arlington, Virginia, 1965.

Yang, W. Y. Methods of Farm Management of Investigations, Food and Agriculture Organization of the United Nations, FAO, Rome, 1958.

Journal Articles, Periodicals and other Sources

Ayres, Clarence. "The Role of Technology in Economic Theory", American Economic Review, May 1953, p. 279.

Brozen, Yale. "Determinants of the Direction of Technological Change", American Economic Review, May, 1953, p. 288.

Domar, E. D. "On the Measurement of Technological Change", Economic Journal 71, December, 1961.

Evans, A. C. "Studies of Intercropping I - Maize or Sorghum with Groundnuts", East African Agricultural Journal, 26, pp. 1-10.

Fei, J. C. H., and Ranis, Gustav. "Capital Accumulation and Economic Development", American Economic Review, June 1963, p. 283.

Griliches, Zvi. "Agricultural Productivity: A Progress Report," University of Chicago, Office of Agricultural Economic Research, Paper No. 6205, (mimeo.), May 29, 1962.

Griliches, Zvi. "Hybrid Corn: An Exploration in the Economics of Technological Change," Econometrica, 25, 1957, pp. 501-522.

Griliches, Zvi. "Measuring Inputs in Agriculture: A Critical Survey," Journal of Farm Economics, 42, December, 1960, pp. 1411-1433.

Griliches, Zvi. "Research Cost and Social Returns: Hybrid Corn and Related Innovations," Journal of Political Economy, 66, October, 1958.

Heady, Earl O., and Shaw, Harold R. "Resource Returns and Productivity Coefficients," Journal of Farm Economics, May 1954, pp. 234-258.

Johansen, L. "A Method for Separating the Effects of Capital Accumulation and Shifts in the Production Function upon Growth and Labor Productivity," Economic Journal, 71, December, 1961, pp. 775-782.

Johnston, Bruce F. "The Choice of Measures for Increasing Agricultural Productivity: A Survey of Possibilities in East Africa," Tropical Agriculture, Vol. 41, No. 2, April, 1964, p. 91.

Kuznets, Simon. "International Income Differences: A Reflection on their Causes," Economic Development and Cultural Change, April,1953, p. 12.

Miracle, Marvin P. "Maize in Tropical African Agriculture," Tropical Agriculture, January,1958, p. 1.

Ruttan, V. W. "The Contribution of Technical Progress to Farm Output," Review of Economics and Statistics, February, 1956.

Salter, W. E. G. "Productivity and Technical Change," Monograph 6 of the Department of Applied Economics, University of Cambridge, Cambridge University Press, Cambridge, 1960.

Schultz, Theodore W. "Reflections on Agricultural Production, Output, and Supply," Journal of Farm Economics 38, August, 1956, pp. 748-762.

Solow, Robert M. "Technical Change and the Aggregate Production Function," Review of Economics and Statistics, 39 August, 1957, pp. 312-319.

Solow, Robert M. "Technical Progress, Capital Formation, and Economic Growth," American Economic Review, 52, May, 1962, pp. 76-86.

Williams, R. R. "Chemistry as a Supplement to Agriculture in Meeting World Food Needs," American Scientist, Vol. 44, No. 3, 1956.