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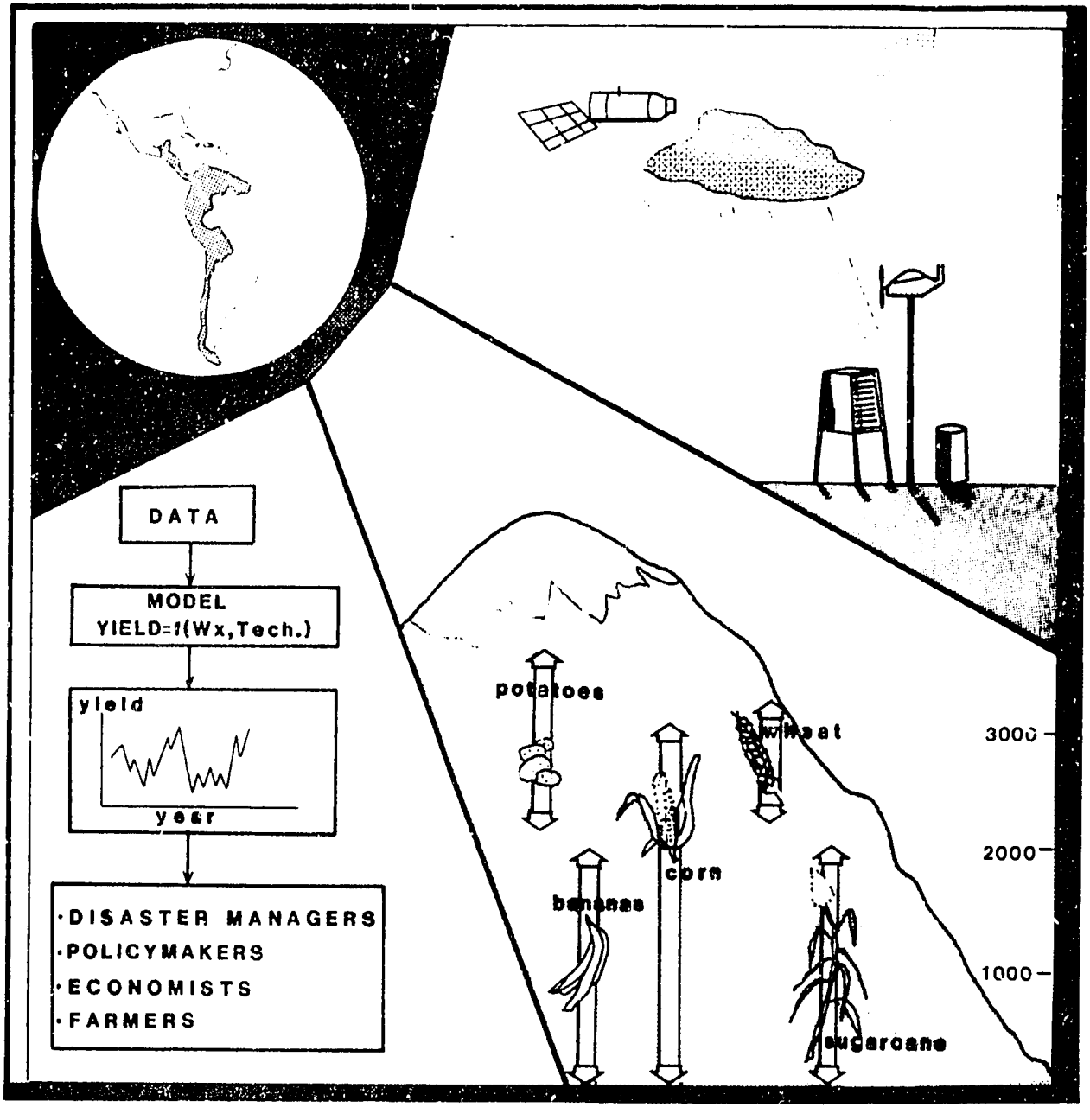
CLIMATE IMPACT ASSESSMENT METHODS FOR DROUGHT/FOOD SHORTAGES IN CENTRAL AND SOUTH AMERICA

PROPOSED EARLY WARNING PROGRAM



DECEMBER 1983

FINAL REPORT

CLIMATE IMPACT ASSESSMENT METHODS FOR DROUGHT/FOOD SHORTAGE EARLY WARNING IN CENTRAL AND SOUTH AMERICA: FINAL REPORT 1/

to

International Development Cooperation Agency
Agency for International Development
Office of U.S. Foreign Disaster Assistance
Washington, D.C. 20523

by

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National Environmental Satellite, Data and Information Service
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2/ Respectively, Research Associate, Atmospheric Science Department, University of Missouri - Columbia and Research Meteorologist, NOAA/NESDIS, Assessment and Information Services Center, Models Branch, Columbia, Missouri 65201.

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EXECUTIVE SUMMARY

CLIMATE IMPACT ASSESSMENT METHODS FOR DROUGHT/FOOD SHORTAGE EARLY WARNING IN CENTRAL AND SOUTH AMERICA: FINAL REPORT

Andres C. Ravelo and Louis T. Steyaert[1/]

The Agency for International Development (AID) needs reliable early warning of potential food shortages to make decisions affecting many of its programs for disaster relief, preparedness, and food security in Central and South America. Many of these agriculturally oriented economies are highly vulnerable to climate variability. Severe drought and flooding have historically led to crop failures, economic losses, and food-security problems. For these reasons, the AID/Office of U.S. Foreign Disaster Assistance sponsored this project, Climate Impact Assessment Methods for Drought/Food Shortages in Central and South America.

The objectives of this project were accomplished. An inexpensive Early Warning Program was developed to provide reliable, timely information on potential food shortages triggered by climatic events. Computerized data bases were assembled and used to determine historical relationships between climate anomalies, crop failures and the causes of abnormal food shortages. Qualitative impact assessments of unusual and severe weather events were provided to AID/OFDA on a biweekly basis during the project.

The Early Warning Program is based on 1) biweekly weather assessments and 2) monthly assessments of crop conditions. Weather assessments begin with an analysis of precipitation amount, the most important meteorological element influencing crop productivity in the subtropics. Regional rainfall estimates are determined from ground station reports received through an international communications network. Satellite cloud data are used to improve the accuracy of precipitation estimates, particularly in those regions where weather data are sparse and unreliable. Weather data are then interpreted by agroclimatic indices which indicate potential crop production in relative terms. Finally, the potential for abnormal food shortages is identified from these indices.

Regional agroclimatic indices are the core of the Program (see Figure). These indices have two forms: statistical climate/crop yield models and crop condition indices. Various historical data bases were developed to determine the appropriate index for each region. Local agricultural practices, historical episodic reports and results of experimental studies were incorporated in the choice of each index. Episodic reports on documented occurrences of famine, drought, crop failure and other events are used to establish critical thresholds for potential food shortages and to interpret indices.

1/ Respectively, Research Associate, Atmospheric Science Department, University of Missouri-Columbia and Research Meteorologist, NOAA/NESDIS, Assessment and Information Services Center, Models Branch, Columbia, Missouri 65201.

Agroclimatic indices and associated crop calendars for major food crops were defined for 59 agroclimatically homogeneous regions throughout Central and South America. Historical meteorological data (1950-1980) from more than 200 stations were used to compute the indices.

The Early Warning Program in Central and South America became operational after the indices were thoroughly tested. The evaluation included: 1) refinement and calibration, 2) routine test assessments, 3) user feedback and 4) continued development. This provided experience in report preparation and improved the assessment procedure.

This program can potentially benefit AID by:

1) increasing lead time for planning food assistance strategies,

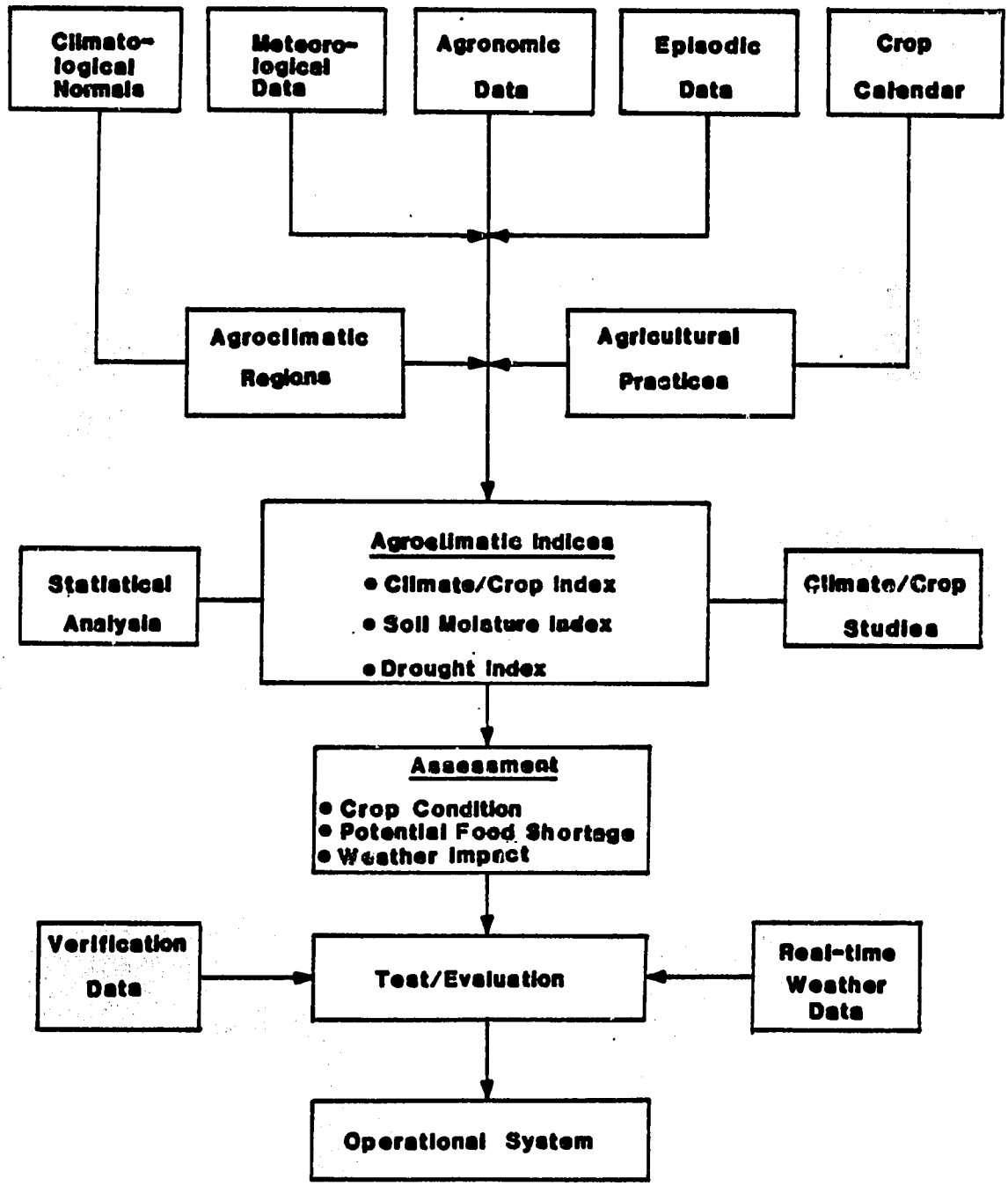
2) enhancing the U.S. capacity to identify disaster conditions, thus improving recommended measures for disaster avoidance and mitigation, and

3) transferring agroclimate modeling and impact assessment technology to developing countries.

The methods proposed in this report provide inexpensive and timely information which is consistent with known local agricultural practices. This Early Warning Program can provide reliable information 30-60 days before harvest of the crop. This could represent a 3-6 month warning prior to drought-related food shortages.

This project report includes two supplements: Meteorological Data and Episodic Data.

AGROCLIMATIC ANALYSIS FOR DROUGHT IMPACT



Components of Agroclimatic Analysis for Investigation of Drought Impact on Crop/Food Shortage Conditions

CLIMATE IMPACT ASSESSMENT METHODS FOR DROUGHT/FOOD SHORTAGE EARLY WARNING IN CENTRAL AND SOUTH AMERICA

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CHAPTER I

INTRODUCTION

The agriculturally oriented economies of many nations in Central and South America are highly vulnerable to annual variations in climate. Severe drought and abnormal flooding can lead to crop failures and economic losses. For example, torrential rains and floods during March, 1981 had a disastrous impact on the economy, agriculture and development plans for many areas in Peru. Conversely, severe drought during 1978 through 1980 resulted in crop failures and threatened food supplies throughout much of that country. More recently, disastrous floods during 1982/83 have impacted agriculture in Ecuador and Northern Peru, while one of the worst droughts in history has impacted Southern Peru. Historically, these anomalous climatic conditions have also been associated with disastrous food shortages in other developing countries of Central and South America. This vulnerability to adverse climate is frequently compounded by other complex factors including increasing population pressure, diminishing natural resources, the rising cost of energy, expansion of agriculture into marginal lands, and less than optimum land conservation practices.

When a country experiences climate-related food shortages, there frequently is a request for international relief assistance. Decisions on such requests must be based objectively on an evaluation of all available information to determine the magnitude of the problem and human needs. A reliable early-warning program designed to alert decision makers to potential problems is a key element of disaster preparedness, as well as a basis to support decisions for assistance. Knowledge of the antecedent conditions associated with the disaster is also important. The sources of information, particularly the data, necessary to develop an operational early-warning system frequently are quite limited in those developing countries where the potential for climate-related food shortages is greatest.

Because of these considerations, the NOAA/NESDIS Assessment and Information Services Center (AISC) was asked by the Office of U.S. Foreign Disaster Assistance (OFDA), Agency for International Development (AID), to investigate early-warning procedures for disaster assistance needs associated with drought in developing countries of Central and South America. This multi-discipline effort is being conducted by the Climatic Impact Assessment Division (CIAD)-Models Branch located in Columbia, Missouri, and the Climatic Assessment Branch (CAB) located in Washington, D.C. Additionally, the Models Branch of (CIAD) works in close cooperation with the University of Missouri-Columbia (UMC) in the development of this program.

The goals of this project for Central and South America include:

1) providing AID/OFDA with qualitative biweekly weather assessment reports on the impact of anomalous weather events such as flooding, frost and short-term climatic conditions,
2) developing agroclimatic and other data bases to investigate the impact of weather and non-weather factors on crop failures and food shortages, and
3) developing a low-cost Climate/Subsistence Food Early Warning System based on agroclimatic analyses to provide timely, reliable information on potential food shortages due to drought.

Countries of Central and South America under study include: Belize, Bolivia, Chile, Colombia, Costa Rica, Ecuador, El Salvador, French Guiana, Guatemala, Guyana, Honduras, Nicaragua, Panama, Peru, Suriname, and Venezuela.

This report summarizes and discusses the accomplishment of the above goals. It is written to provide background information for those potentially involved with weather/crop condition assessment analysis. Chapter II provides information on data bases and the methodology used to develop biweekly weather and climate/crop condition assessment procedures. A regional analysis of climate

and agriculture is provided in Chapter III. The results of climate/crop yield indices for individual countries in Central and South America are discussed in Chapters IV and V, respectively. The proposed early warning program is discussed in Chapter VI followed by a summary and recommended future investigations in Chapter VII. Substantial data bases are provided in various Appendices and Supplements.

This project for Central and South America represents the completion of the model development and test and evaluation work for a fourth major geographic region of the world. The initial project "A Study of the Caribbean Basin Drought/Food Production Problem" (CEAS, 1979a) was completed in May 1979.[1/] The second study, "Development of Weather-Crop Relationships for Drought-Prone Countries of Sub-Saharan Africa" (CEAS, 1979b) was completed in July 1979 and the third study, "Agroclimatic Assessment Methods for Drought/Food Shortages in South and Southeast Asia" (Steyaert, Achutuni and Todorov, 1981) was completed in June, 1981. Assessment procedures for the Caribbean and Sub-Saharan Africa were tested and evaluated for operational use in 1980 and initiated in 1981 (Steyaert, Ravelo, and Sakamoto, 1980). The test and evaluation phase for South and Southeast Asia assessment procedures started in 1981 and became operational in 1982 (Achutuni, Steyaert and Sakamoto, 1982).

1/ NOTE: The NOAA Assessment and Information Services Center (AISC) was formally the NOAA Center for Environmental Assessment Services (CEAS) prior to December, 1982.

CHAPTER II

METHODOLOGY

A. Overview

This early warning program is designed to quantitatively assess the impact of drought on agriculture, thereby providing reliable information on the potential for abnormal food shortages. Agroclimatic assessments are based on a combination of biweekly weather assessments and climate/crop yield forecast models, both of which are objectively determined for agroclimatic assessment regions.

Biweekly weather assessments were initiated by AISC during the early stages of this developmental project to provide immediate assessment information to potential users. These assessments are primarily based on available real-time meteorological and satellite data which are statistically compared to long-term precipitation "normals," usually for the most recent two and eight week periods. The impacts of anomalous weather events such as flooding, tropical storms and temperature extremes are also discussed.

The primary goals of the agroclimatic modeling include development of weather assessment procedures and climate/crop condition indices.

B. Agroclimatic Analysis

The components of agroclimatic analysis used to develop weather assessments and climate/crop models are shown by Figure 2.1. Major components include the data bases, information on agricultural practices for agroclimatic regions, agroclimatic indices, and assessment procedures. Test and evaluation will be required prior to operational implementation.

1. Data

Five major data bases are essential: meteorological, climatological "normals", agronomic, episodic event, and crop calendar.

The meteorological data base includes long-term records of monthly

AGROCLIMATIC ANALYSIS FOR DROUGHT IMPACT

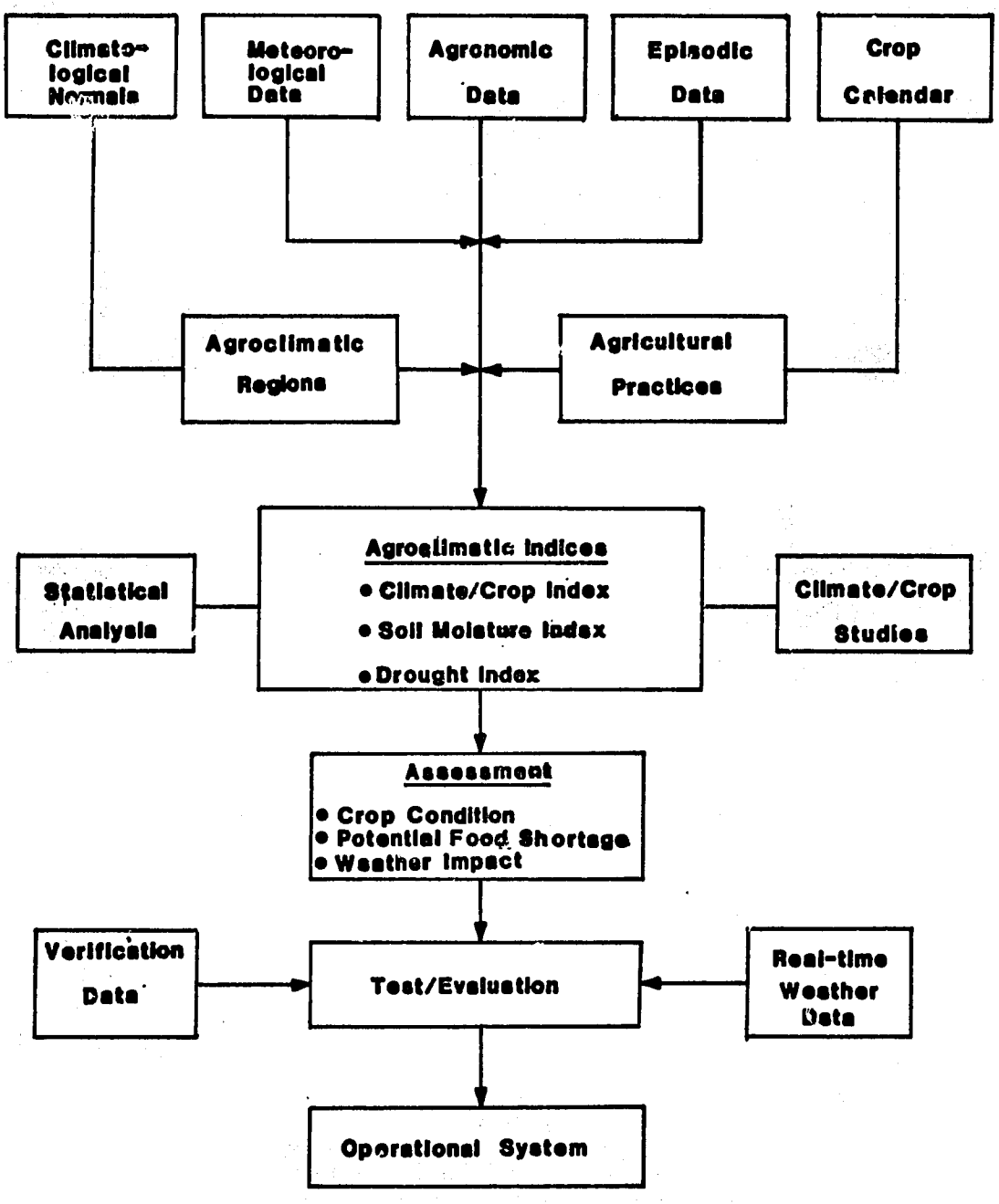


Figure 2.1. Components of Agroclimatic Analysis for Investigation of Drought Impact on Crop/Food Shortage Conditions.

precipitation (1930-1980) for locations indicated by Figures 2.2 and 2.3. Mean monthly temperature records were available for selected locations (Wernstedt, 1972). Data are provided in the Supplement, Part I. Meteorological data for some countries also include monthly records of maximum and minimum temperatures. Because these data are used to investigate crop/weather relationships, extensive historical records displaying a wide range of climatic conditions are essential to the development of crop/food shortage assessment techniques.

Climatological monthly "normals" including precipitation, temperature, solar radiation, relative sunshine, wind velocity, relative humidity, and evaporation were obtained from different sources (Wernstedt, 1972; Schwerdtfeger, 1976; Buxtehude, 1981; WMO, 1971). These data were used to determine the most representative "normals" for agroclimatic assessment regions used in weather analysis (Appendix B).

Agronomic data include crop statistics (i.e., acreage, production, and yield) and "technology" data. Crop statistics for corn, beans, potatoes and wheat were available at the national level. Regional crop statistics and technology data (irrigation and fertilizer application, use of improved varieties, etc.) were obtained for selected countries.

Episodic event data include documented reports on the historical occurrences of drought, flooding, frost and other anomalous weather events associated with crop failure or abnormal food shortages. Additionally, non-weather related factors which can have a disruptive impact on agricultural production/food supplies are also documented, for example, reports of pests and crop disease, inappropriate application of improved technological inputs to agriculture, civil unrest, and others. These data are generally qualitative in nature and obtained primarily through extensive literature searches. They

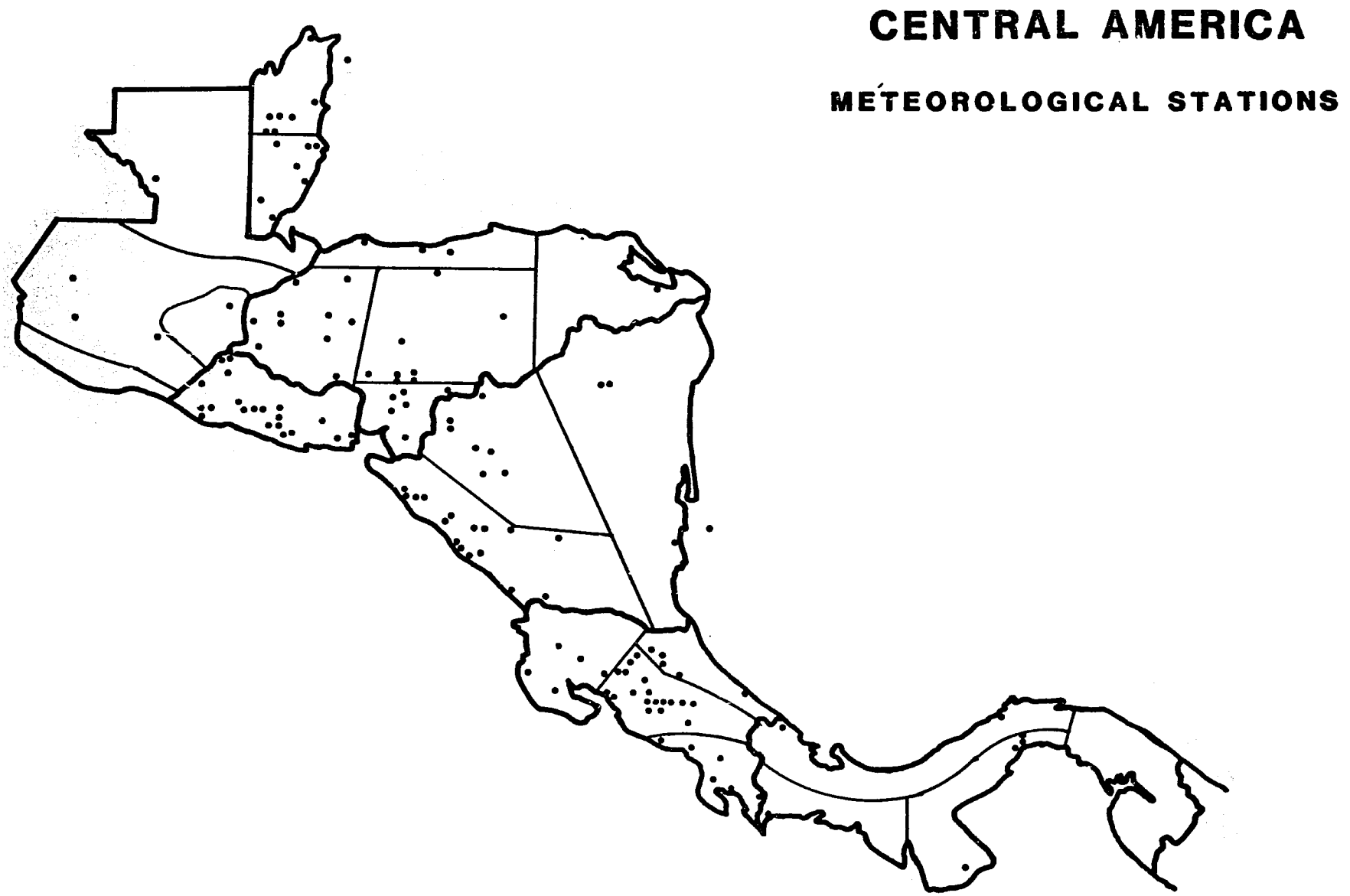


Figure 2.2 Meteorological Stations with Historical Precipitation Data and Agroclimatic Regions in Central America. (See Fig. 3,6).

Figure 2.3 Meteorological Stations with Historical Precipitation Data and Agroclimatic Regions in South America. (See Fig. 3.7).

are used to help select, determine the role, and "calibrate" agroclimatic predictors of potential crop failure and food shortages. The episodic data base is included in Part II of the Supplement to this report.

The final major data base involves regional and national level crop calendars for various crops and crop growing seasons. For example, the crop calendar for corn provides the "normal" planting, growing and harvesting dates. Conflicts among various published sources on crop calendar dates were clarified.

2. Potential Evapotranspiration

a. Overview

The concept of potential evapotranspiration can be summarized by the following definition: Potential evapotranspiration (PET) is an indicator of the maximum possible loss of water from a soil-crop system under conditions where soil water supply is not limiting and the short green crop completely covers the ground.

The amount of water which escapes to the atmosphere from the soil-plant system is very important to a variety of subject areas. Some applications of the PET information are found in agroclimatic indices, assessment of the agricultural potential of underdeveloped regions and other water related problems in agriculture.

The main difficulty which is encountered is that evapotranspiration is a physio-physical process which remains very difficult to measure directly. In the absence of direct observations calculations based on empirical or theoretical equations become quite important. There have been many attempts to develop a methodology for estimating PET (WMO, 1966). Penman's formula (Penman, 1948) has repeatedly given good estimates of daily PET (McIlroy and Angus, 1964). Frequently, however, the necessary data for this equation are not

available. Therefore for many purposes equations which are based on a small number of parameters are more appropriate. This is illustrated by the frequent use of Thornthwaite's method (Thornthwaite, 1948), which is based only on mean monthly temperature. Thornthwaite's estimates are not as precise as Penman's PET estimates (Sellers, 1965). There is a need for simple evaporation equations which are as accurate as possible and can be used for various purposes such as agroclimatic studies in data limited regions. Hargreaves (1975) proposed an equation to estimate PET which is based on solar radiation and temperature data. This equation was used in worldwide studies (Hargreaves, 1977).

b. Methodology

Three methods were examined in this study to determine the most appropriate method for computing PET under tropical and mountain environment conditions.

Penman Method

A simplified version of Penman equation (1948) has the following form:

$$PET = \frac{aRn + bc\,(e_s - e_a)\,(1 + U_2 \times 10^{-2})}{a + b}$$

where:

PET is expressed in millimeters/day,

a = slope of the saturation vapor pressure curve for pure water at mean temperature in mb/°C,

Rn = net solar radiation (mm/day),

b = constant in the hygrometric equation (0.66 mb/°C),

c = constant (0.26),

e_s = saturation vapor pressure (mb),

e_a = actual vapor pressure (mb), and

U_2 = mean wind speed at 2 m (m/sec).

This method has the advantage that it considers both the solar radiation balance and water vapor fluxes within the crop canopy's evapotranspiring surface and the atmosphere near the ground. It does not account for advective fluxes such as sensible and latent energy. An operational disadvantage of the method is that some of the required meteorological elements are not observed at every weather station.

Thornthwaite Method

This method is based only on mean monthly air temperatures and was expressed by Thornthwaite (1948) as follows:

$$PET = 1.6\ (10\ T/I)^a$$

where:

PET is estimated in centimeters/day

T = monthly mean air temperature (°C),

I = annual heat index which is function of T, and

a = polynomial function of I.

An adjustment for latitude is required for locations with daylengths different than 12 hours. This method has the great advantage of using only one meteorological element and the local latitude as input. This is the main reason it has been used worldwide. However, it should be pointed out that mean temperatures do not necessarily correspond to the energy balance near the ground which is closely related to the evapotranspiration process.

Hargreaves Method

Hargreaves (1975) developed an equation for computing PET based on solar radiation (or sunshine hours) and air temperature:

$$PET = 0.0075\ (RSM)TF$$

where:

PET is expressed in millimeters/day,

RSM = solar radiation (mm/day), and

TF = monthly mean temperature (°F).

The method requires solar radiation data that is not always available. If only temperature and sunshine information are available, it is possible to estimate solar radiation. Hargreaves has also developed several empirical formulas to estimate solar radiation from a variety of commonly observed meteorological elements.

c. Data

Long-term mean monthly meteorological data were obtained from different sources (Schwerdtfeger, 1976; Buxtehude, 1981; WMO, 1971) for several locations in Central and South America (Appendix B). Meteorological variables include air temperature, solar radiation, wind speed, air humidity (vapor pressure or relative humidity), evaporation, and sunshine. In addition, monthly extra-terrestrial solar radiation for every location was obtained (Appendix B).

d. Results and Discussion

Thornthwaite PET estimates were obtained for 141 selected stations (Figures 2.4 and 2.5). Penman's method was applied to only 32 stations with the required data. PET estimates by Hargreaves' method were obtained for 74 stations (Appendix B).

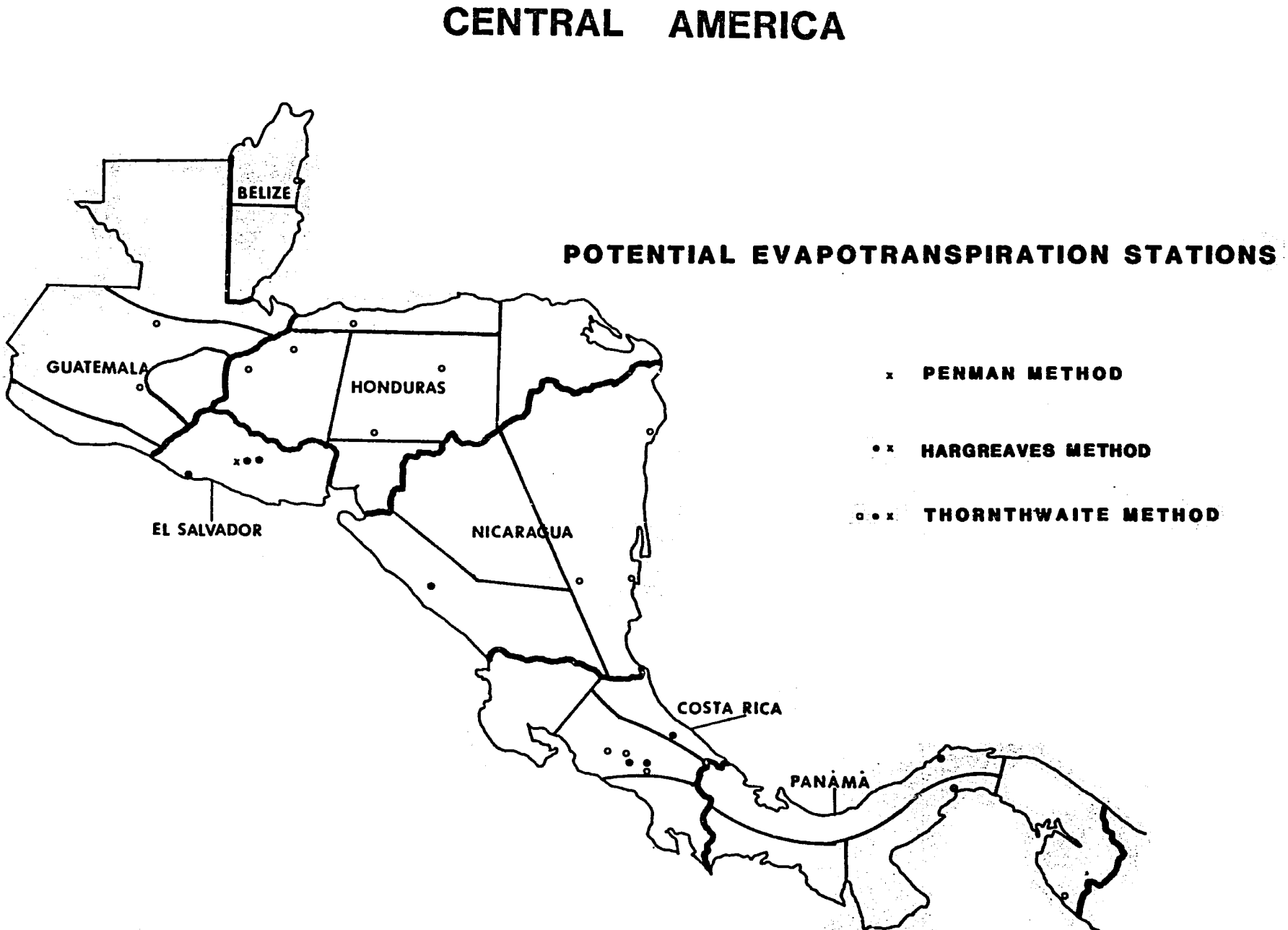


Figure 2.4. Selected Locations with Potential Evapotranspiration Estimates in Central America.

Figure 2.5. Selected Locations with Potential Evapotranspiration Estimates in South America.

It was previously shown (Ravelo, 1982) that Penman and Hargreaves estimates are comparable and have a noticeable yearly oscillation due to the seasonal variation in solar radiation, particularly in mid-latitude stations. Thornthwaite estimates are much smaller and have a lower annual oscillation than those estimates provided by the Penman and Hargreaves techniques. In windy and semiarid areas (i.e., Arequipa, Peru), PET estimates by Thornthwaite amount to less than one half of Penman estimates during the summer months (Figure 2.6). Also, the small annual oscillation of Thornthwaite estimates are particularly noticeable at high altitude locations where there is little annual temperature range and temperature is not a good indicator of solar radiation (see Figures 2.7, 2.8, 2.9). Thornthwaite was of the opinion that his method is not valid for climates much different from the one in which it has been developed. It generally tends to underestimate in arid areas (Brustaert, 1965). The underestimation has been about 40-50 percent of the real values. However, the exact magnitude of underestimation depends on the extent of aridity. In tropical and humid lowland areas, the Thornthwaite method provides estimates comparable to Penman's (Figures 2.10 and 2.11). Figure 2.12 shows that there is good agreement between PET estimates during the rainy season in temperate climates (i.e., Santiago, Chile).

In view of the input data requirements and the results provided by the above mentioned PET techniques, it was decided that Hargreaves techniques be adopted for further agroclimatic analysis (agroclimatic indices, soil moisture balances, etc.).

However, a close relationship between the ratio of PET computed by two different techniques and station elevation was found (Figures 2.13 and 2.14). Station elevation is commonly known and may be used to adjust Thornthwaite estimates.

POTENTIAL EVAPOTRANSPIRATION (PET)

AREQUIPA, PERU

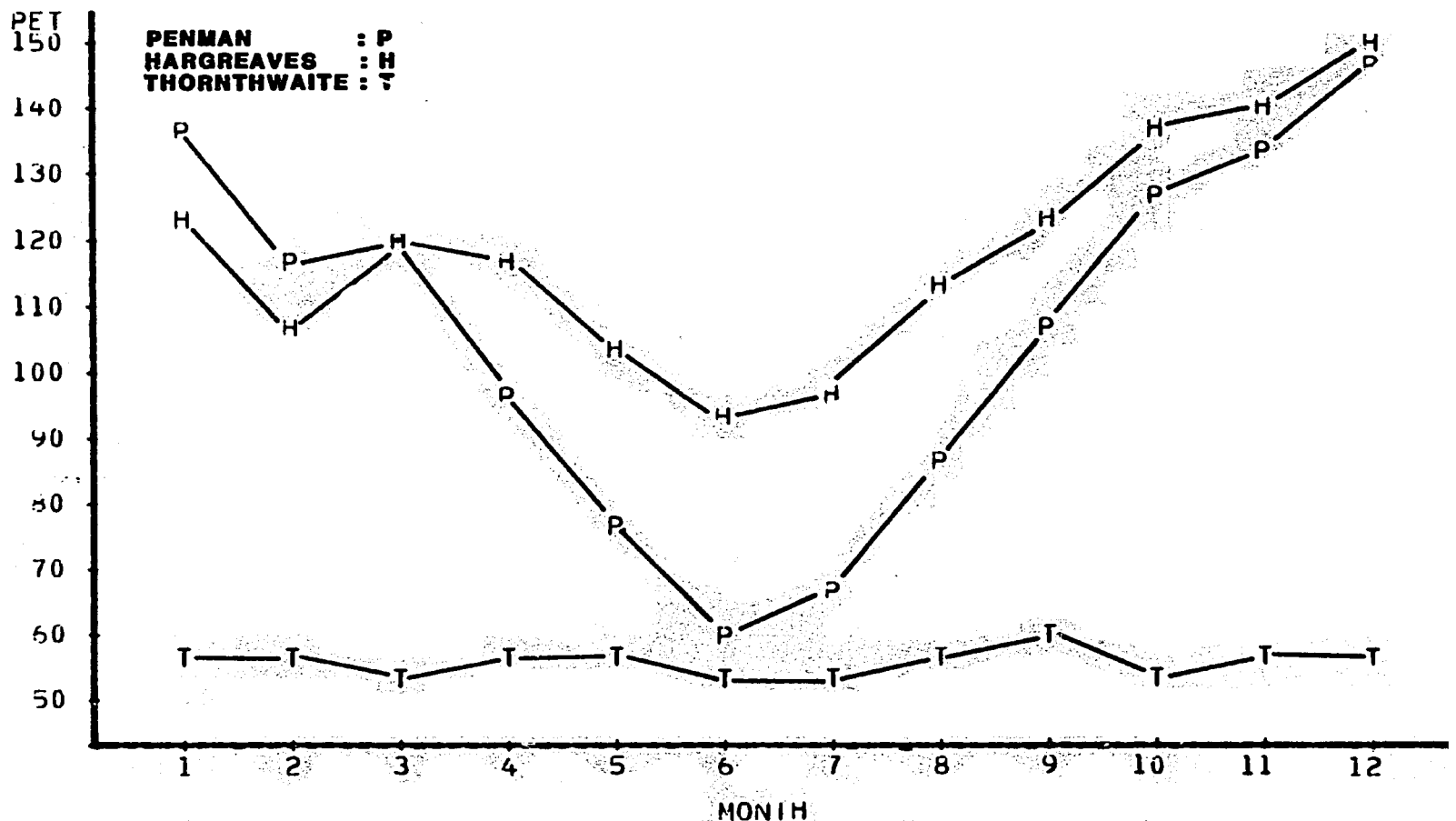


Figure 2.6. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for Arequipa, Peru.

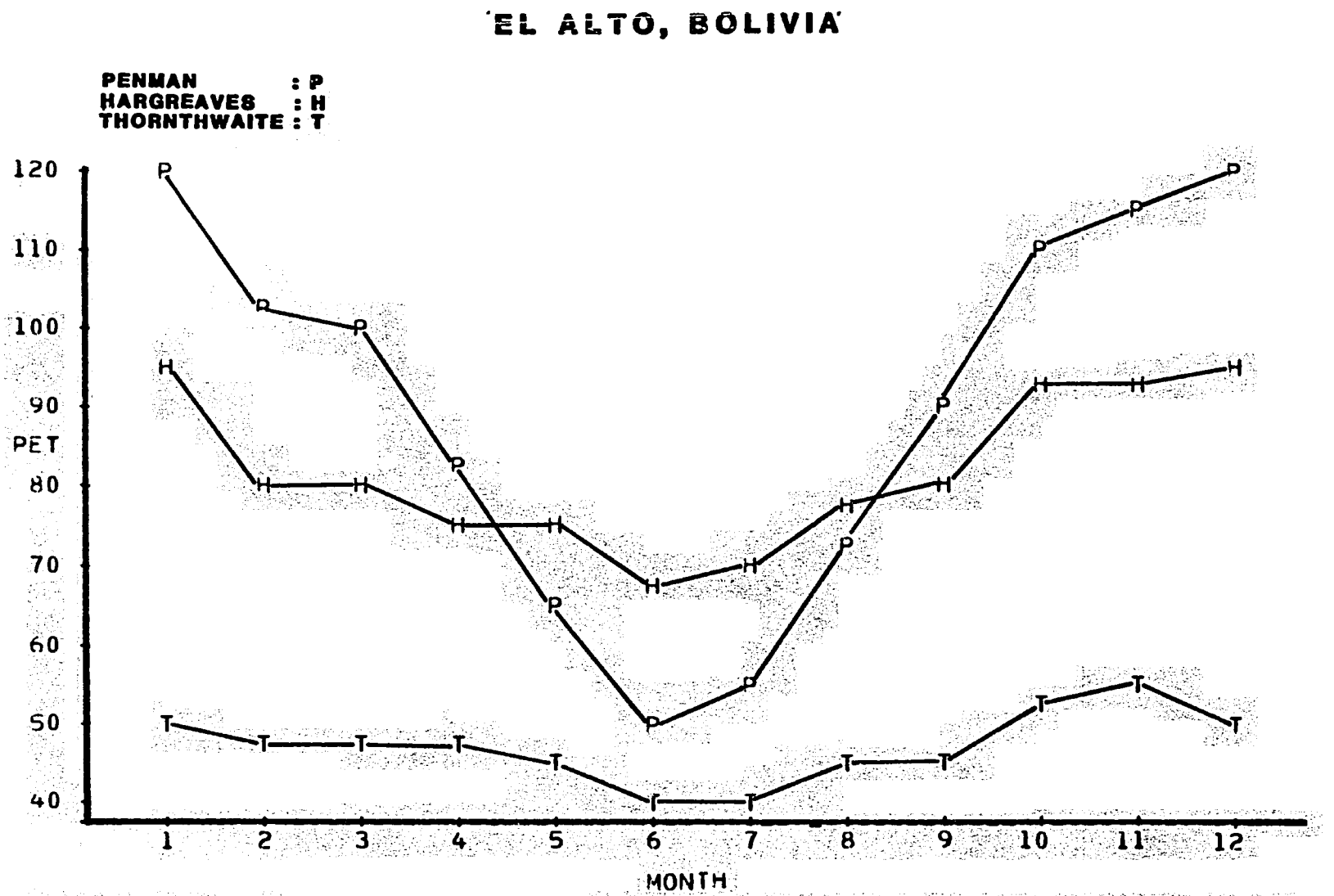


Figure 2.7. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for El Alto, Bolivia.

POTENTIAL EVAPOTRANSPIRATION (PET)

MERIDA, VENEZUELA

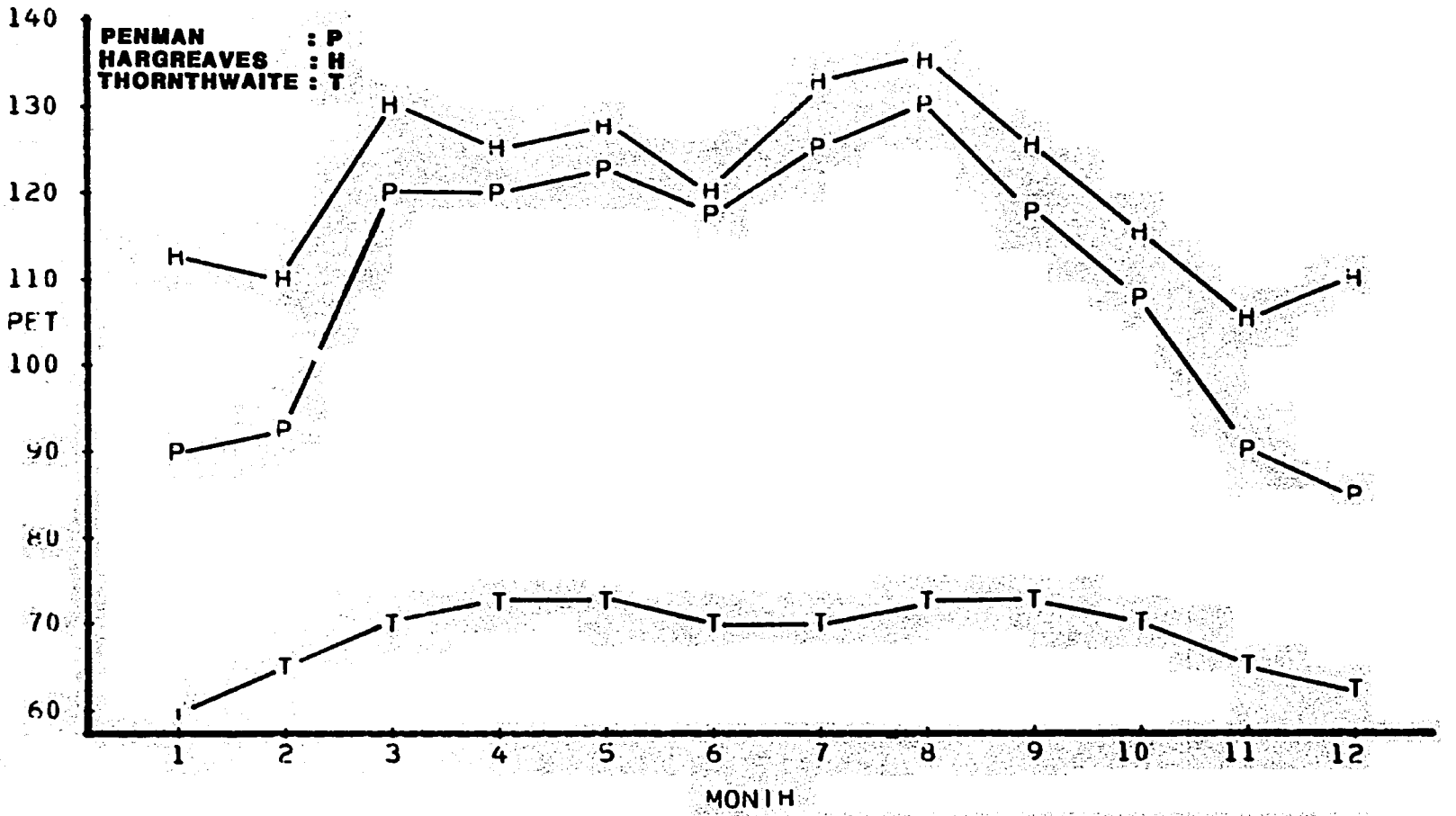


Figure 2.8. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for Merida, Venezuela.

POTENTIAL EVAPOTRANSPIRATION (PET)

CUZCO, PERU

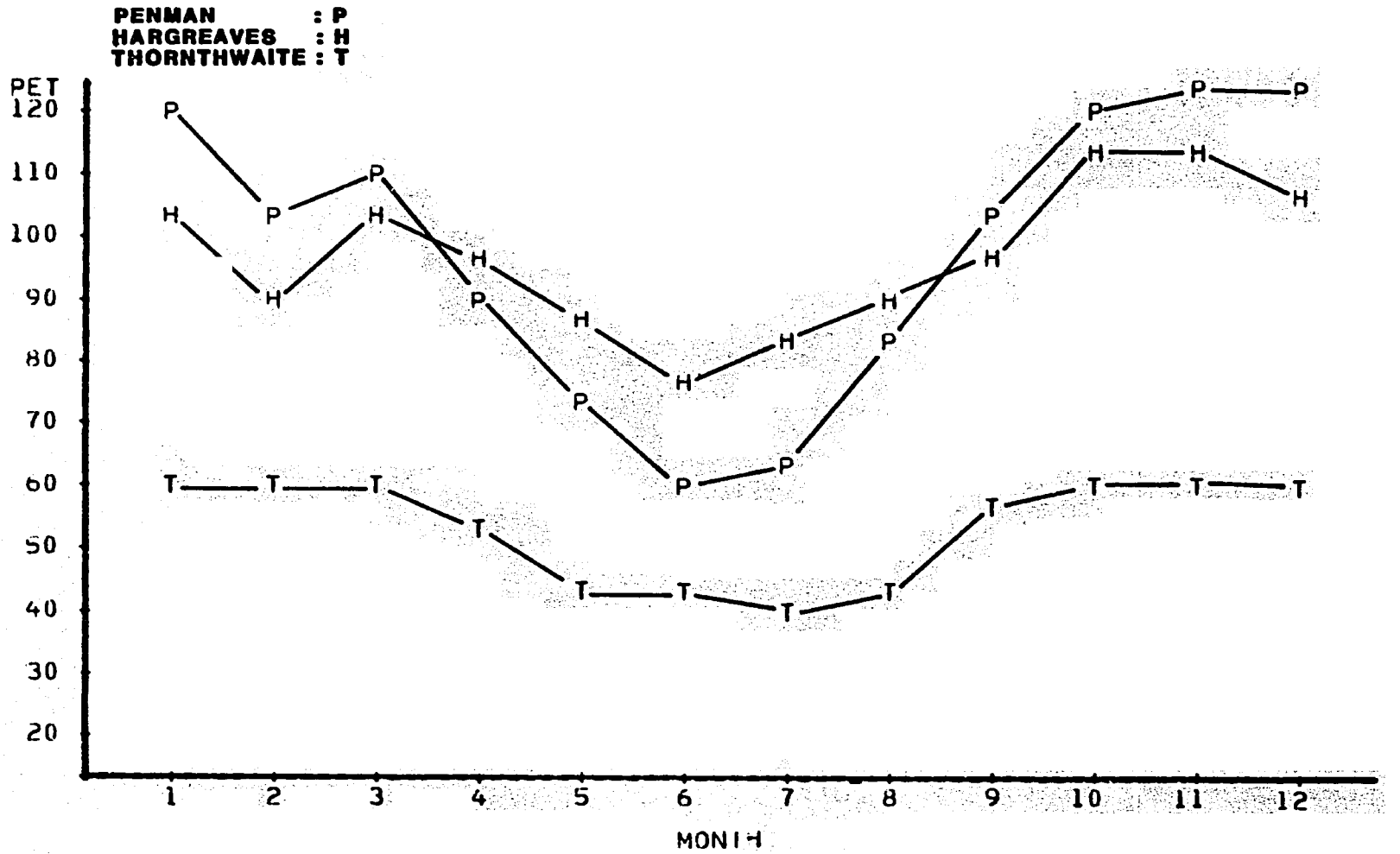


Figure 2.9. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for Cuzco, Peru.

POTENTIAL EVAPOTRANSPIRATION (PET)

SAN FERNANDO, VENEZUELA

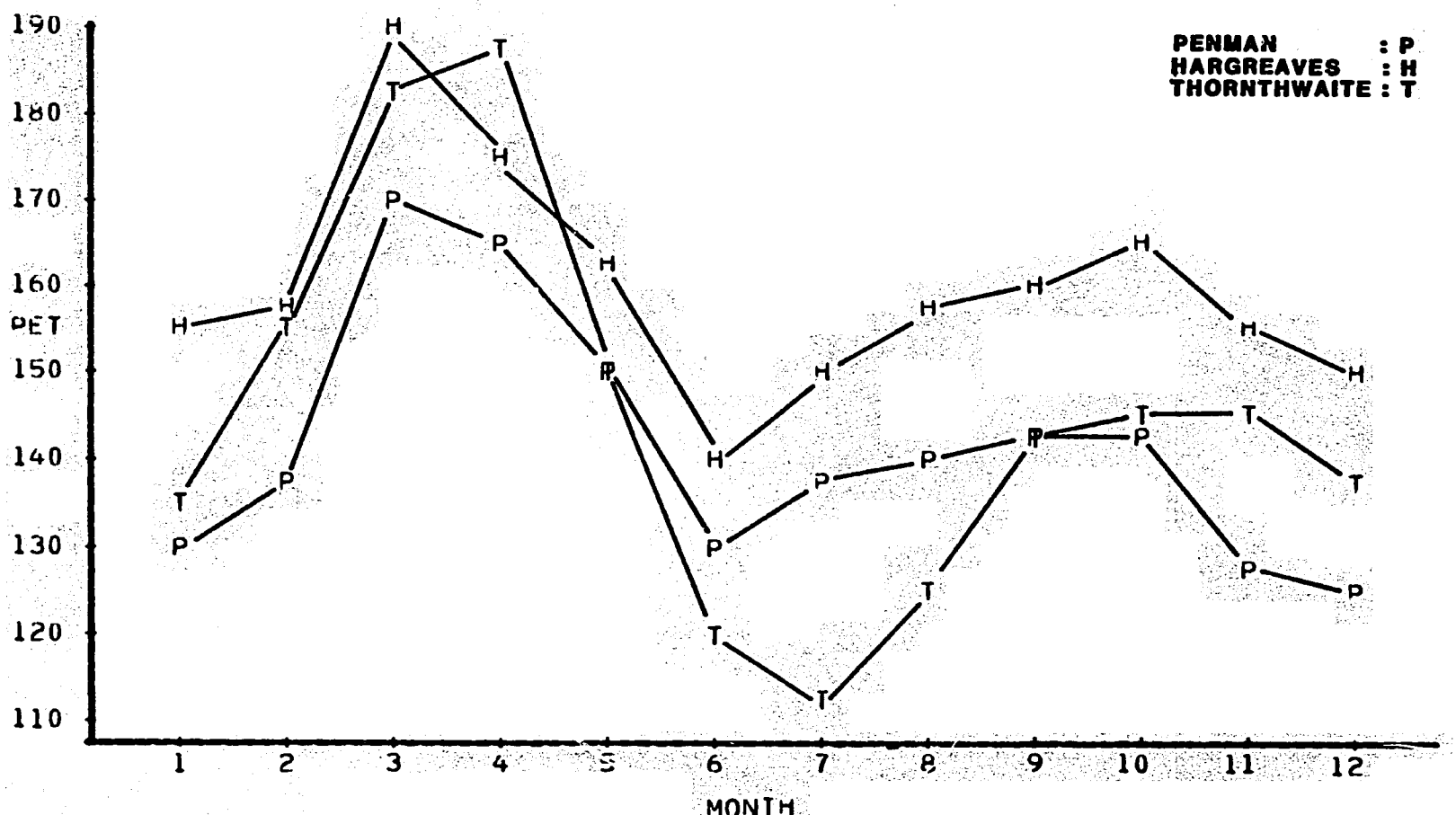


Figure 2.10. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for San Fernando, Venezuela.

POTENTIAL EVAPOTRANSPIRATION (PET)

PARAMARIBO, SURINAME

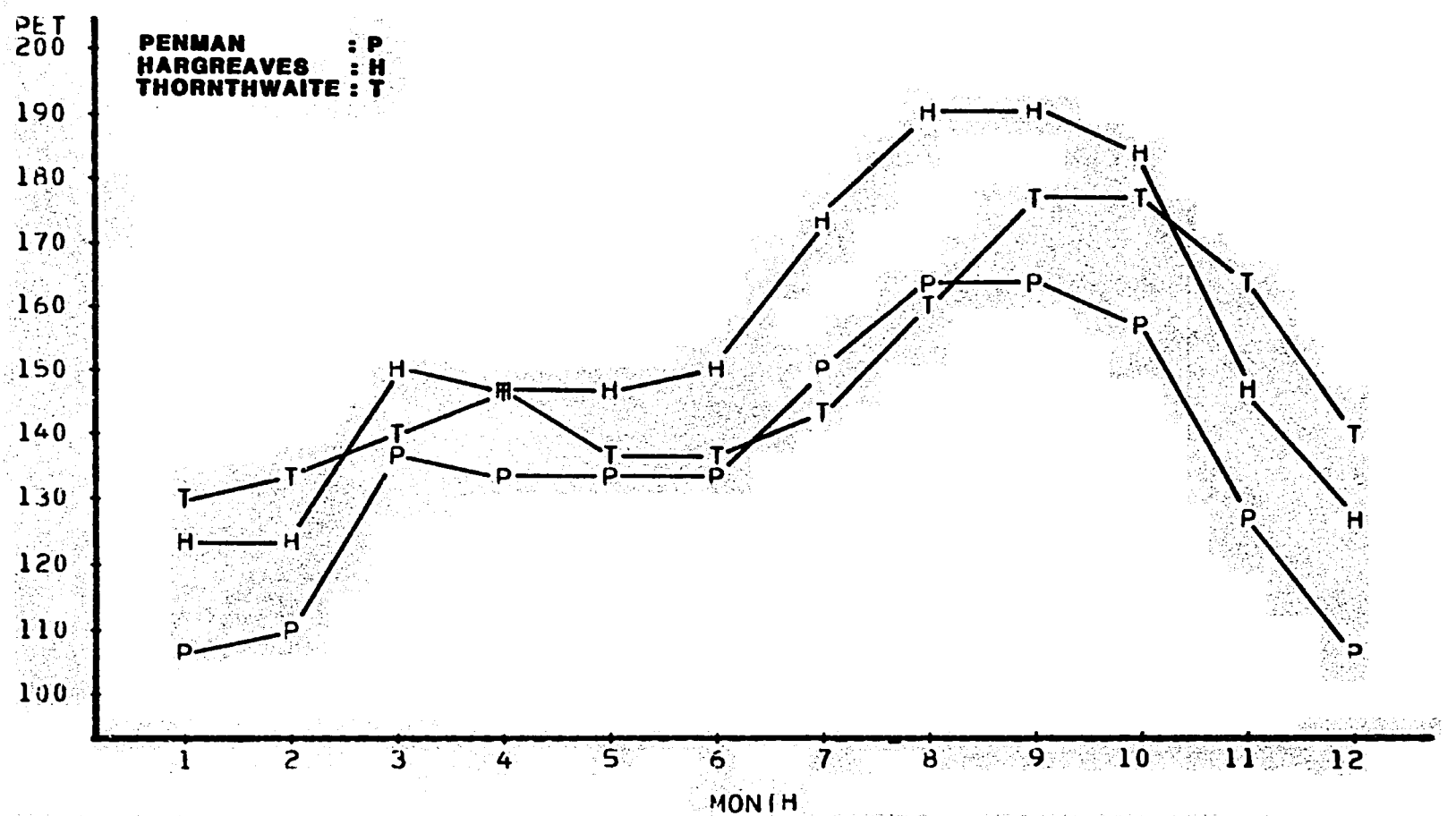


Figure 2.11. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for Paramaribo, Suriname.

POTENTIAL EVAPOTRANSPIRATION (PET)

SANTIAGO, CHILE

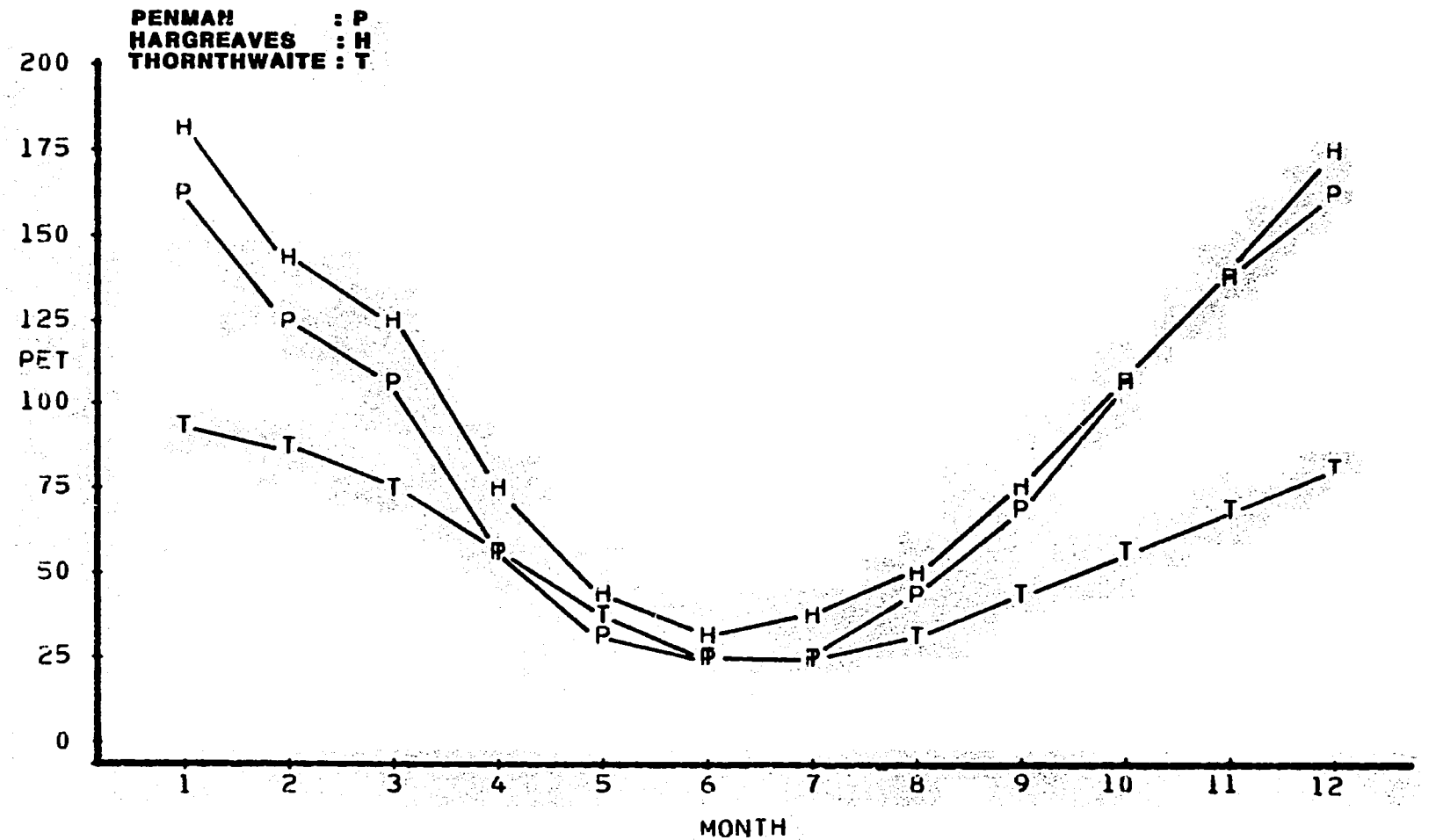


Figure 2.12. Monthly Potential Evapotranspiration (PET) Estimates in Millimeters for Santiago, Chile.

POTENTIAL EVAPOTRANSPIRATION (PET)

RATIO PENMAN/THORNTHWAITE PET VERSUS ELEVATION (m)

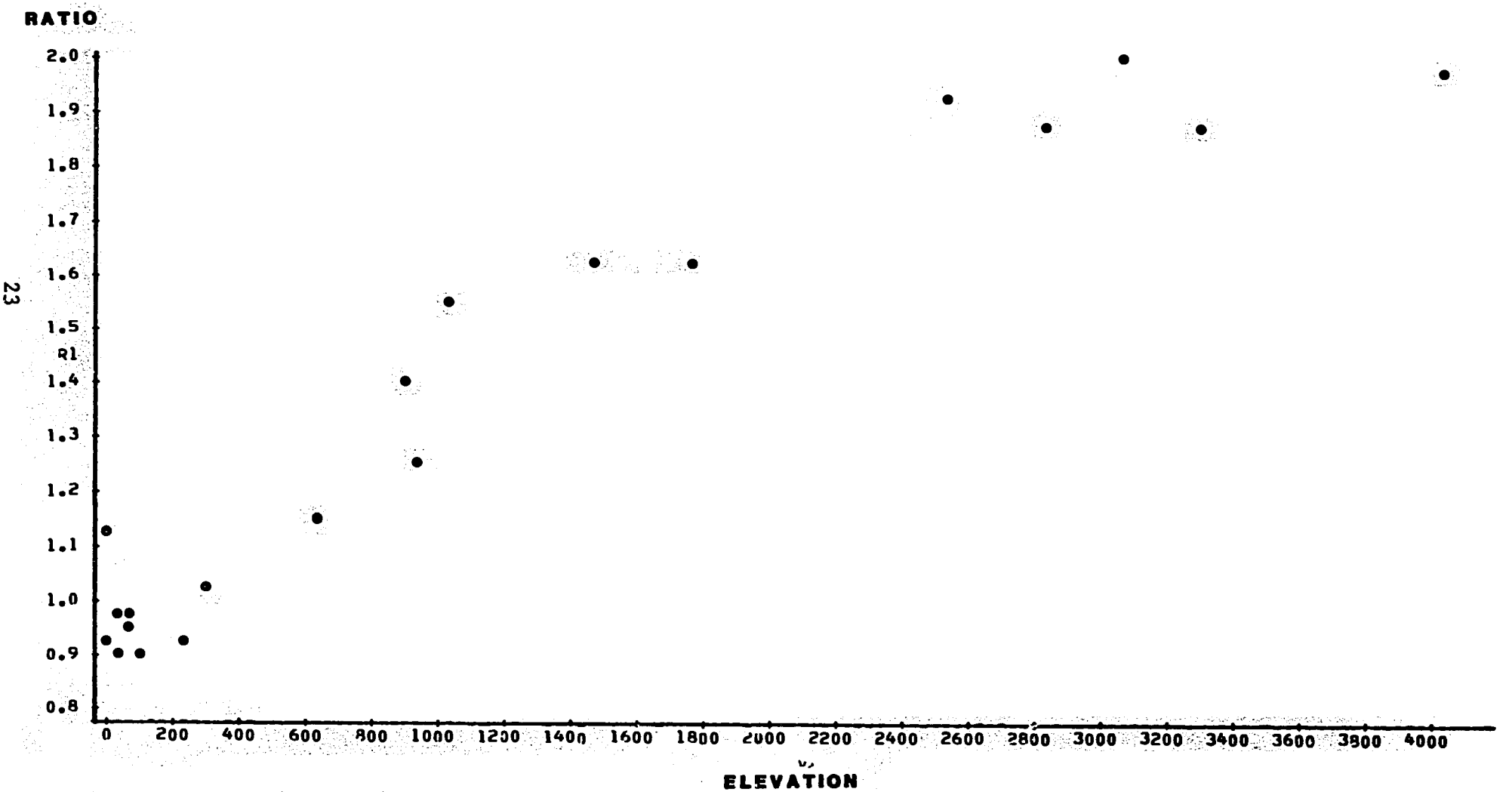


Figure 2.13. Potential Evapotranspiration Ratio (Penman/Thornthwaite) Versus Station Elevation (m).

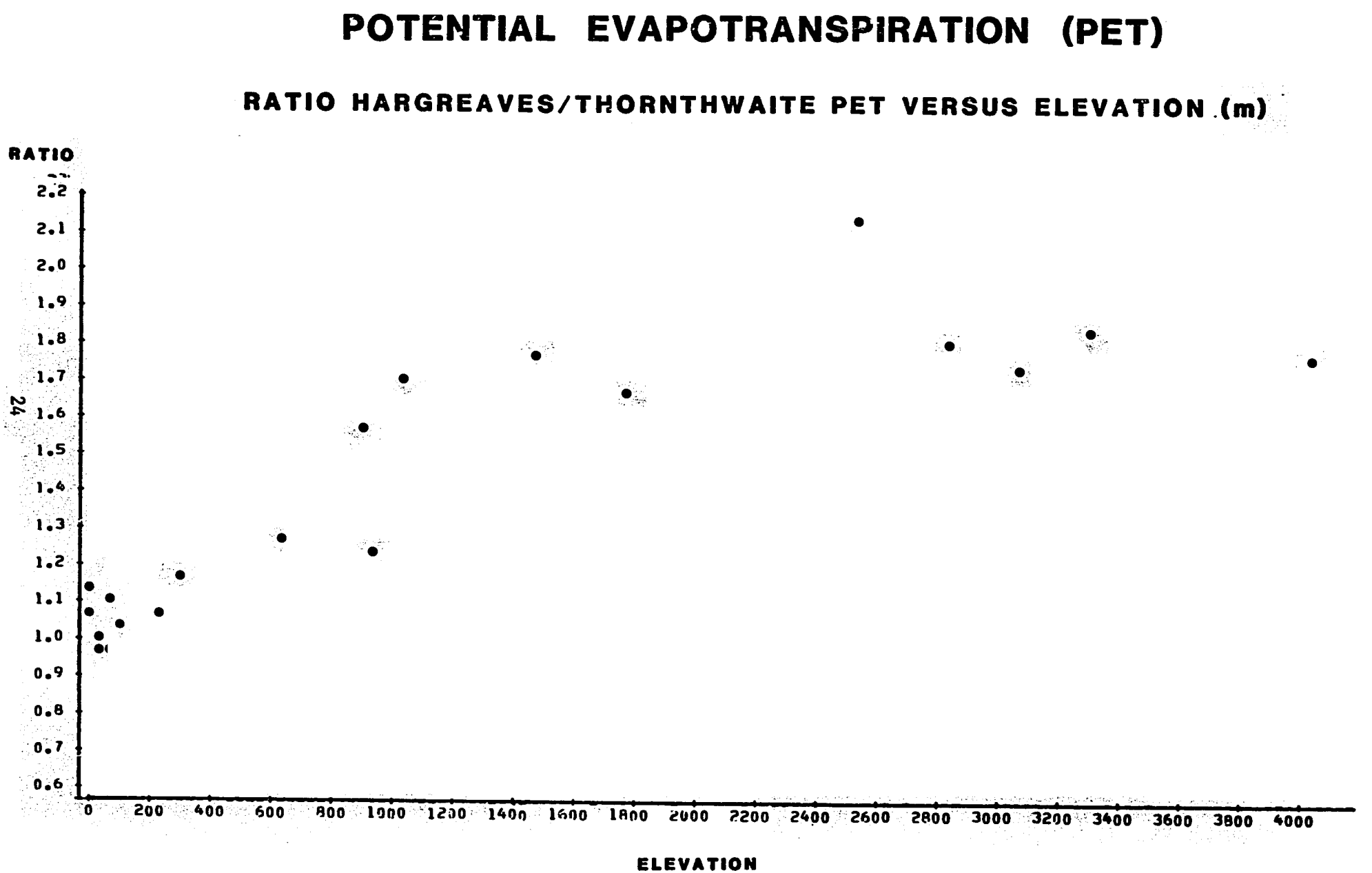


Figure 2.14. Potential Evapotranspiration Ratio (Hargreaves/Thornthwaite) Versus Station Elevation (m).

Regional monthly PET estimates were obtained by averaging monthly Hargreaves PET for all the locations within the agroclimatic region. In a few regions solar radiation or sunshine data were not available; the Thornthwaite method may then be used. The estimated Thornthwaite PET value may be adjusted according to station elevation.

3. Soil Moisture Balance

a. Overview

The soil moisture variability over space and time is one of the most important factors for crop conditions and food production. Direct measurements of soil moisture involve several problems related to instrumentation and the variations in soil characteristics and moisture content which often occur over short distances. Continuous and repeated soil moisture sampling is needed to determine a representative soil moisture regime for a region. Although direct measurements may be feasible in experimental work, estimates from climatological water balance methods are more cost-effective for the regional assessment of soil moisture reserves available for crop growth and development. Numerous methods have been developed to estimate soil moisture from soil and meteorological parameters. Detailed reviews of climatological soil moisture budgeting techniques are presented in Palmer (1965) and Baier and Robertson (1966). A climatology based on soil moisture availability is very important to rural development and land use studies. In addition, a historical soil moisture index can be a useful tool for assessing the weather impact on agricultural activities. An operational assessment system for regional soil moisture reserves can provide valuable information on crop conditions throughout the growing season.

b. Methodology

Available soil moisture for this study was estimated by using Palmer's technique (Palmer, 1965). In this method the plant-soil system is divided into

two arbitrary layers. The upper layer, which is equivalent to the plow layer, is assumed to hold 25 millimeters of plant available water and is lost at a potential rate. It is also assumed that the underlying layer looses water at a potential rate when the profile is saturated. The plant available water in the underlying layer depends on the depth of the root system and on the soil characteristics in the area under study.

The water loss due to actual evapotranspiration for the surface and also the underlying layer is expressed by the following equations:

1) $L_s = S_s'$ or PET_c, whichever is smaller

2) $L_u = (PET_c - L_s)\ S_u'/(PAW_{max} - 2.5)$

3) $AET = L_s + L_u$

where:

L_s = the loss from the soil surface layer,

L_u = the loss from the underlying layer,

S_s' = the actual available soil moisture in the surface layer from the previous month's budget,

S_u' = the actual available soil moisture in the underlying layer from the previous month's budget,

AET = the actual evapotranspiration, and

PAW_{max} = the maximum plant available water or the difference between the field capacity and the permanent wilting point of the soil.

The budget is initiated at some previous time when the soil moisture is at field capacity. Furthermore, in the budget, precipitation (P) is lost as AET before water is removed from the soil. Precipitation exceeding storage capacity of the soil is accounted for as runoff (RO).

Finally, the plant available water is computed as follows:

$$PAW_i = PAW_{i-1} + P_i - AET_i - RO_i$$

where:

PAW_i = the plant available water for the current ith month,

PAW_{i-1} = the plant available water for the previous month's budget,

P_i = the rainfall for the ith month,

AET_i = the actual evapotranspiration for the ith month, and

RO_i = the runoff for the ith month.

c. Data

Monthly rainfall data and monthly Hargreaves PET estimates were the major inputs to the soil moisture budgeting technique. The meteorological station network is shown in Figures 2.4 and 2.5. In this preliminary stage, the total soil water holding capacity in all regions was set at 152 mm (6 inches). As soil information becomes available, adjustments will be made in the soil water holding capacity for individual stations.

d. Results and Discussion

The soil moisture budgeting technique provided monthly actual evapotranspiration (AET) and available soil moisture estimates (PAW) for stations in Central and South America.

Climatic diagrams for selected stations showing long-term mean monthly values for rainfall, PET and actual evapotranspiration are shown in Appendix C. When the seasonal course of water supply in a rainfed agricultural system is compared with the course of water demand, it is possible to have an insight into the plant-water relationship at a particular place. Quantitative information can be obtained on the many aspects of the soil-plant-atmosphere system such as actual evapotranspiration (AET), differences between actual and potential evapotranspiration, soil water depletion and recharge, and surface

runoff. For example, at San Jose, Costa Rica, the average monthly values of precipitation (P) and potential evapotranspiration (E) are never equal (Figure 2.15). The rainfall distribution pattern shows distinct dry and wet seasons. Precipitation varies through the year from a minimum of about 10 mm in January to a maximum of about 350 mm in September. The potential evapotranspiration, following the seasonal march of available energy, varies from a minimum of 107 mm in November to a maximum of about 130 mm in March. Thus, the seasonal course of both P and PET indicates clearly the periods of water deficit (December through April) and water excess (May through November). Soil moisture storage reaches field capacity by early June and runoff may occur from June through November. There is more water than is needed (A) by the crops during the growing season (April-November).

Figures 2.16 and 2.17 illustrate the case of extremely wet (Chinchina, Colombia) or mostly dry (El Alto, Bolivia) conditions during the entire year.

4. Climate/Crop Condition Models

Considerable effort was made in investigating the nature of agricultural practices and quality of agronomic data in each country prior to the selection of a specific procedure to individually model the selected crops. The determination of the quality of agronomic data, locations and crop calendars for important food crops and subsistence cropping practices were among the many considerations investigated primarily by literature searches, but also from interviews, agroclimatic analysis, and field trips to the countries of interest. For example, U.S. government officials representing various agencies (including US/AID, USDA, DOC, etc.), university officials, and local government officials were among those interviewed for firsthand information concerning local agronomic practices or climatic conditions.

This investigation resulted in the conclusion that agroclimatic/crop

CLIMATIC DIAGRAM

SAN JOSE, COSTA RICA

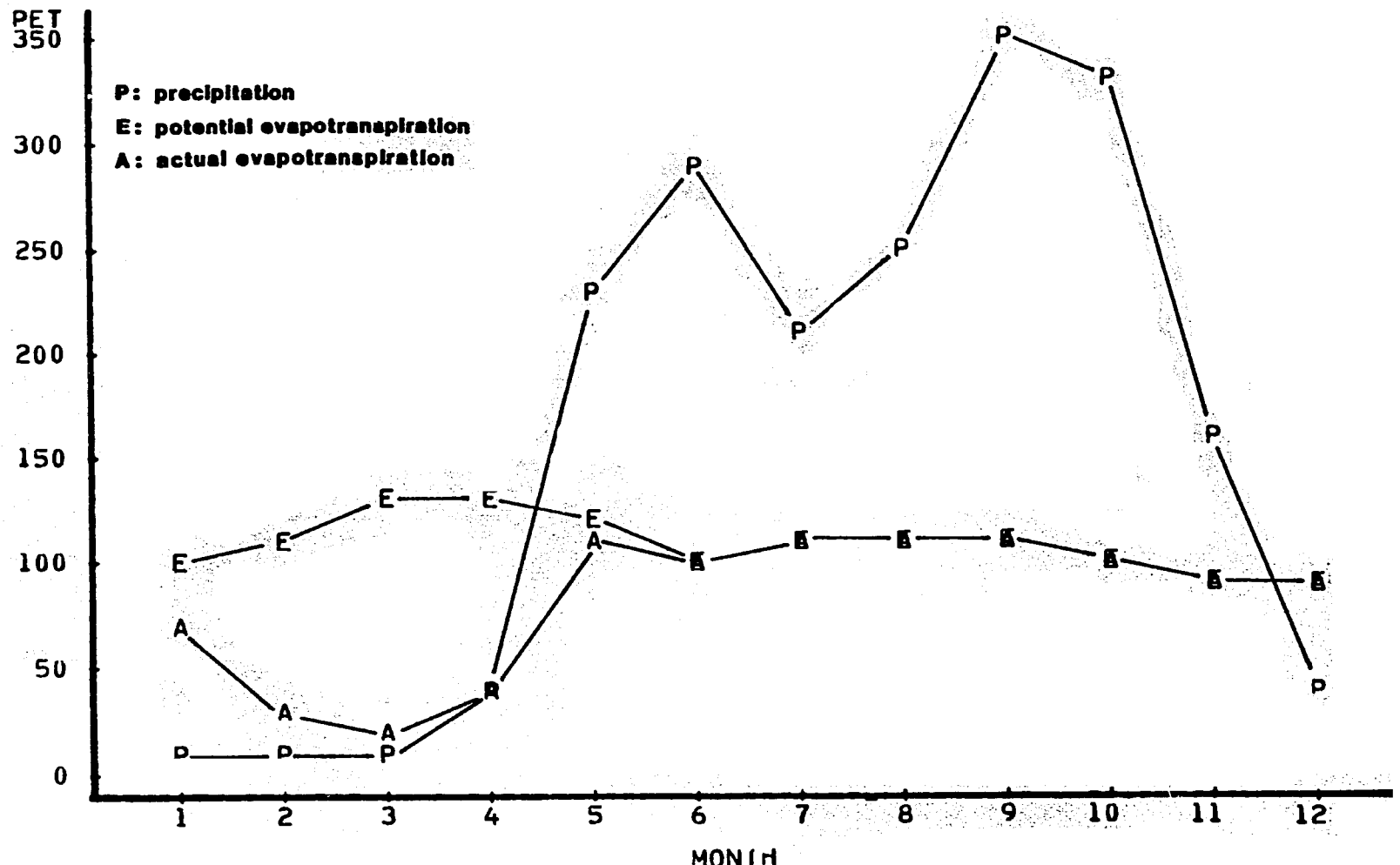


Figure 2.15. Climatic Diagram for San Jose, Costa Rica, Showing Months with Adequate Water Supply (A=E) or Deficient Water Supply (A<E).

CLIMATIC DIAGRAM

CHINCHINA, COLOMBIA

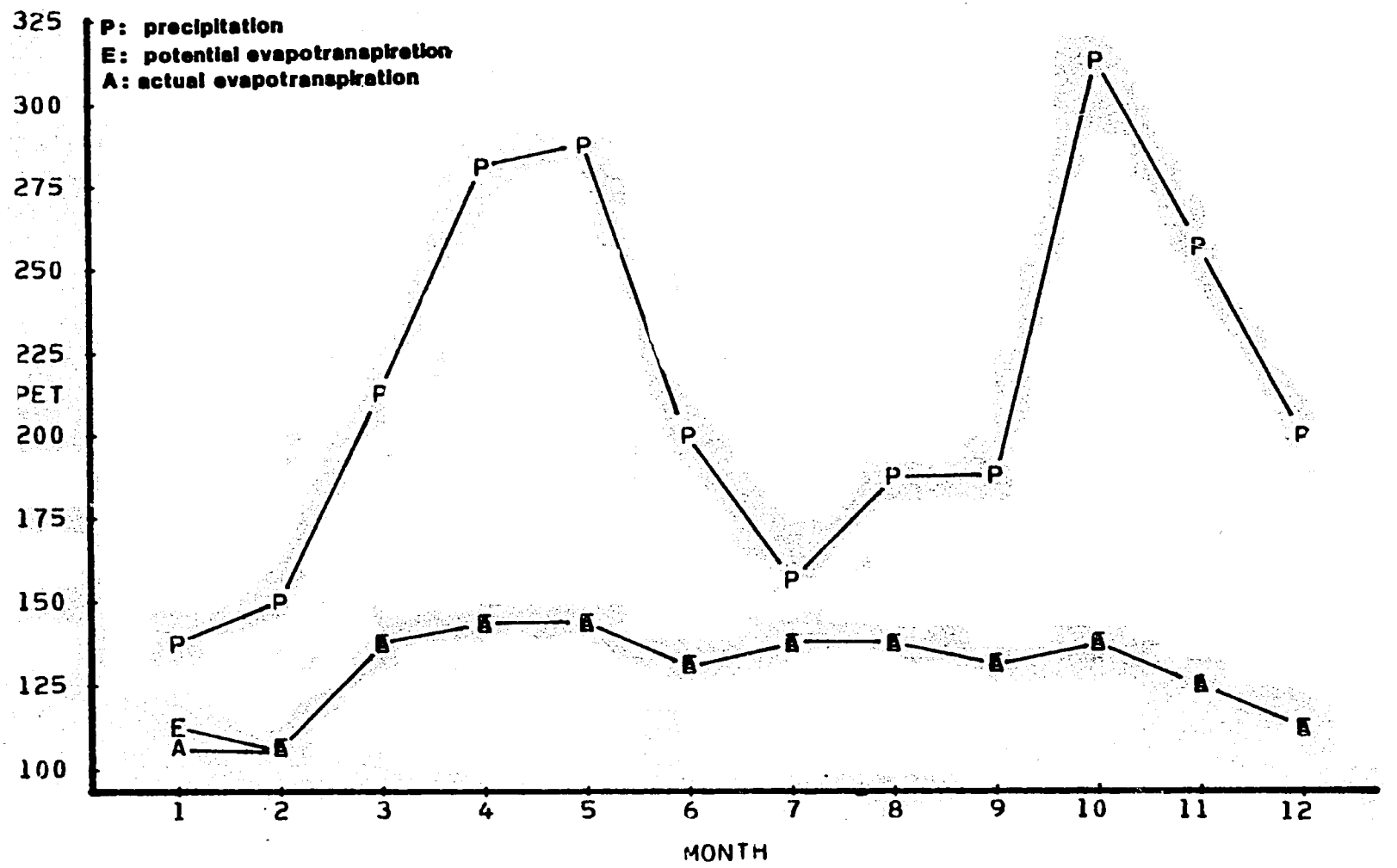


Figure 2.16. Climatic Diagram for Chinchina, Colombia, Showing Months with Adequate Water Supply (A=E) or Deficient Water Supply (A<E).

CLIMATIC DIAGRAM

EL ALTO, BOLIVIA

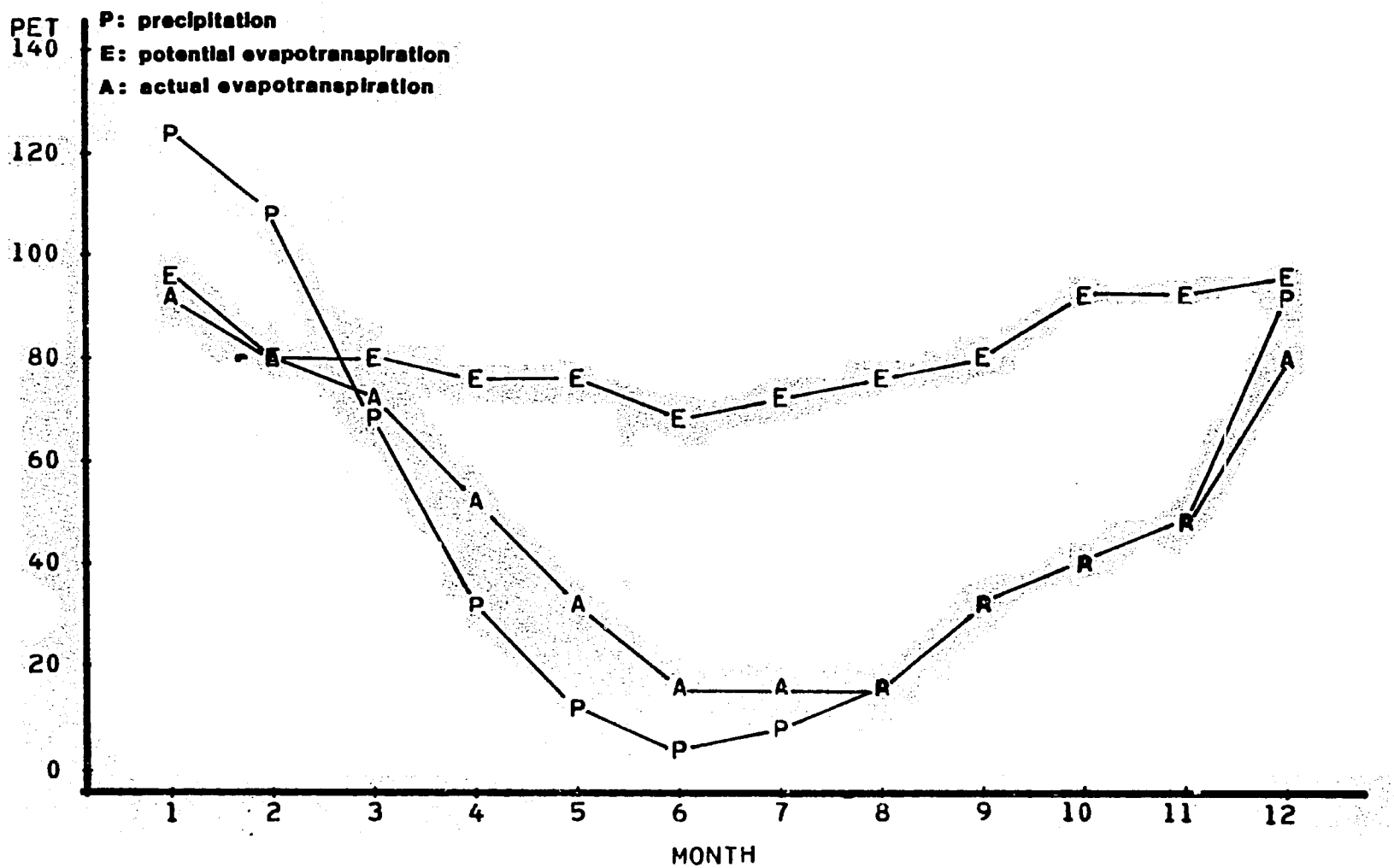


Figure 2.17. Climatic Diagram for El Alto, Bolivia, Showing Months with Adequate Water Supply (A=E) or Deficient Water Supply (A<E).

condition assessment indices, such as the Yield Moisture Index, the Soil Moisture Index, and/or other agroclimatic indices are best suited for developing a reliable, timely subsistence food monitoring system based on climatic data. Although quality crop yield data are generally not available, a traditional linear regression crop yield model for Suriname rice (previously developed by CEAS, 1979a) is included in the country section. Sanchez (1982) demonstrated that district data for the Mantaro Valley in Peru could be used to develop promising statistical models.

a. Agroclimatic/Crop Condition Assessment Indices

The objective of the agroclimatic/crop condition indices is to provide relative information on the impact of weather on crop production. Indices are related to the crop water demand and based on monthly precipitation data. These indices can be expressed in meteorological units (e.g., mm) or in non-dimensional form (e.g., percentiles or percent of long-term mean depending on the available historical data). Information from the following indices may be used to provide monthly crop condition assessments.

<u>Yield Moisture Index (CEAS, 1979a)</u>

The Yield Moisture Index (YMI) is defined as:

$$YMI_j = \sum_{i=1}^{n} P_i \, KC_{ij}$$

where:

YMI_j = Yield Moisture Index for the jth crop (corn, potatoes and wheat).

P_i = precipitation during the ith crop stage (1 = planting, 2 = vegetative, 3 = flowering/reproductive, etc.), and

KC_{ij} = appropriate crop coefficient for the ith crop stage and jth crop (Doorenbos and Pruitt, 1977).

The YMI is a drought index and represents an improvement over cumulative rainfall because the weights (KC_{ij}) are a function of the crop water requirement at each crop stage of the individual crops. For example, the water requirement at the reproductive stage is much higher than at earlier crop stages. The index is computed for 20-30 years and calibrated from episodic data. Assessments during the current year are interpreted according to the historic index values.

Soil Moisture Index (Ravelo and Decker, 1979)

This index is based on the assumption that the seasonal distribution of soil moisture characterizes the effects of climate and weather variability on plant growth better than any single climate parameter. The ratio between plant available water (PAW) and the maximum plant available water (PAW_{max}) is defined as the soil moisture index (SMI). This ratio normalizes the soil moisture according to variations in the type of plant and soil.

The SMI is defined as:

$$SMI = PAW/(PAW_{max})$$

where $0 \leq SMI \leq 1$, and

FC = the field capacity on the maximum moisture that can be retained by the soil after excess gravitational water has drained away.

As in the case of the YMI, the historic time-series of the SMI may be used to assess current conditions relative to conditions that have existed in the past. Relative yield information may be determined from the percentile ranking of the SMI.

Palmer Drought Index (Palmer, 1965)

The Palmer Drought Index (PDI) provides information on the duration and intensity of drought. The index is based on monthly fluctuations of soil

moisture conditions which are estimated from a hydrological accounting system (Palmer, 1965). The required input data include the water holding capacity of the soil, monthly precipitation and monthly potential evapotranspiration.

The PDI is designed to monitor both dry and wet periods. The index values are scaled such that negative values indicate drought and positive values indicate wet conditions; an index value of zero indicates normal conditions. Table 2.1 shows the index categories for the dry and wet periods.

Crop Condition Index

Rainfall, potential evapotranspiration and crop calendar information can be used to assess abnormal crop moisture deficiencies. Moisture deficiencies may result from below normal water supply, above normal crop water requirements or both. The sources of water supply are primarily rainfall and soil available water. The crop water requirement is a function of the atmospheric demand, the type of crop and crop growth stages. It is assumed that by monitoring the water supply and crop water demand it is possible to assess the crop condition. Because in rainfed agriculture the variability of water supply is usually much larger than the crop water requirement, "normal" crop water requirement can be used instead of real-time water demand.

As described by Doorenbos and Pruitt (1977), the crop water requirement may be estimated as follows:

$$CWR_{ij} = PET_i * KC_{ij}$$

where:

CWR_{ij} = Crop Water Requirement for the jth crop and the ith crop growth stage,

PET_i = average Potential Evapotranspiration for the ith crop growth stage, and

KC_{ij} = appropriate Crop Coefficient for the jth crop and the ith crop growth stage.

TABLE 2.1

PALMER DROUGHT INDEX (PDI)

CLASSES FOR WET AND DRY PERIODS

PDI			CLASS
	≥	4.00	Extremely wet
3.00	to	3.99	Very wet
2.00	to	2.99	Moderately wet
1.00	to	1.99	Slightly wet
0.50	to	0.99	Incipient wet spell
0.49	to	-0.49	Near normal
-0.50	to	-0.99	Incipient drought
-1.00	to	-1.99	Mild drought
-2.00	to	-2.99	Moderate drought
-3.00	to	-3.99	Severe drought
	≤	-4.00	Extreme drought

The carry over effect of the previous month's rainfall on this month's water supply may be accounted for as follows:

$$APC_i = P_{i-1} - CWR_{ij-1}$$

for $P_{i-1} > CWR_{ij-1}$, otherwise $APC_i = 0$

where:

APC_i = Antecedent Precipitation Conditions for the ith crop growth stage,

P_{i-1} = precipitation during the previous crop growth stage, and

CWR_{ij-1} = crop water requirement for the previous crop growth stage.

During the planting period, APC_i is estimated as follows:

$$APC_i = P_{i-1} - PET_{i-1}$$

for $P_{i-1} > PET_{i-1}$, otherwise $APC_i = 0$

Where:

PET_{i-1} = potential evapotranspiration during the month prior to planting.

P_{i-1} = precipitation during the month prior to planting.

Finally, the Crop Condition Index (CCI) is defined as:

$$CCI_{ij} = \sum_{i=1}^{n}(APC_i + P_i)/CWR_{ij}$$

where:

CCI_{ij} = Crop Condition Index for the jth crop and the ith crop growth stage, and

P_i = rainfall during the ith crop growth stage.

Rainfall is censored to 200 mm which is approximately the field capacity for medium textured soils. APC_i and CWR_{ij} have been previously defined.

Figures 2.18, 2.19 and 2.20 show the historical CCI for the early vegetative, late vegetative and reproductive stages of a corn crop grown at Huayao/Huancayo (Peru).

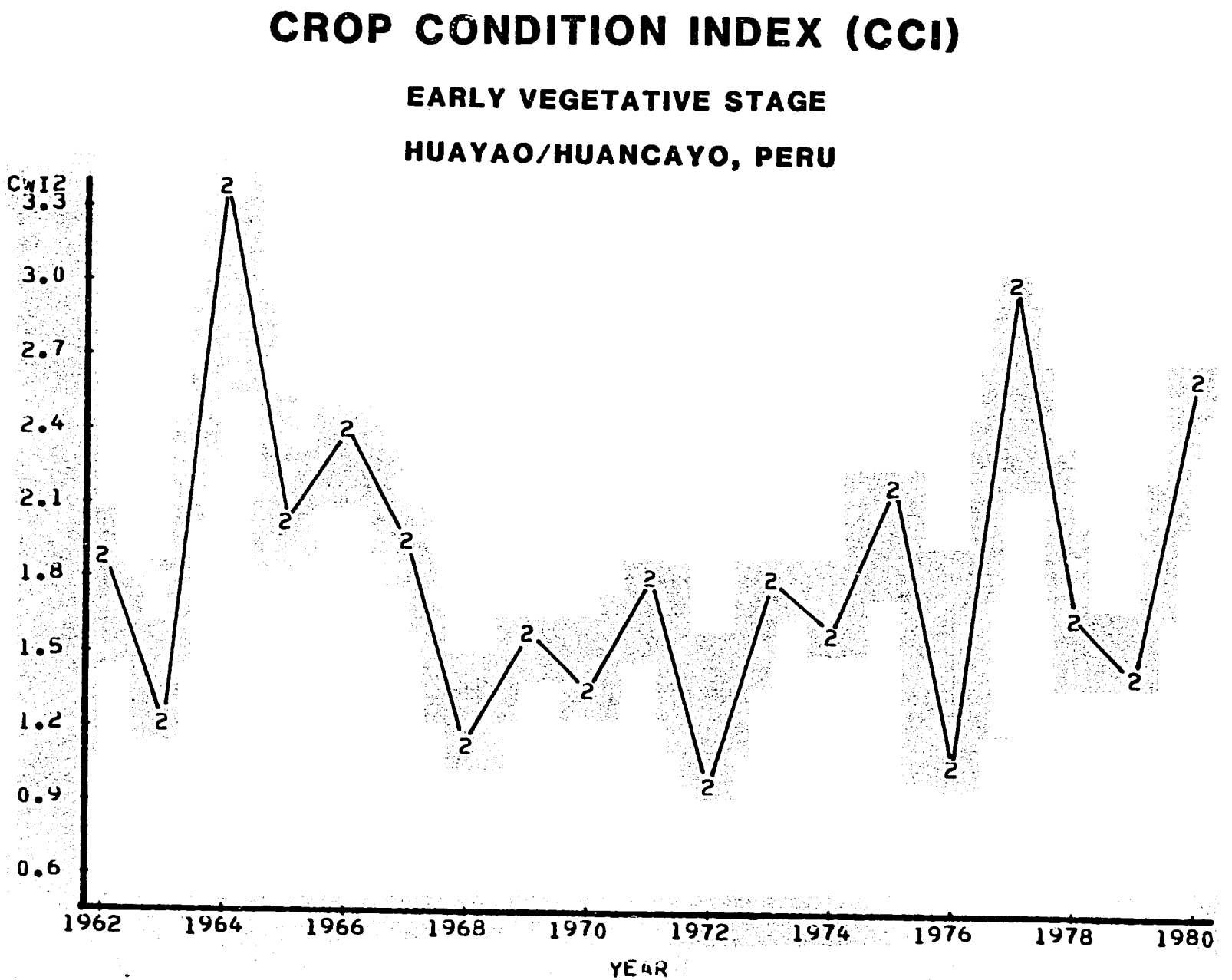


Figure 2.18. Crop Condition Index for Early Vegetative Growth Stage of Corn Grown at Huayao/Huancayo, Peru.

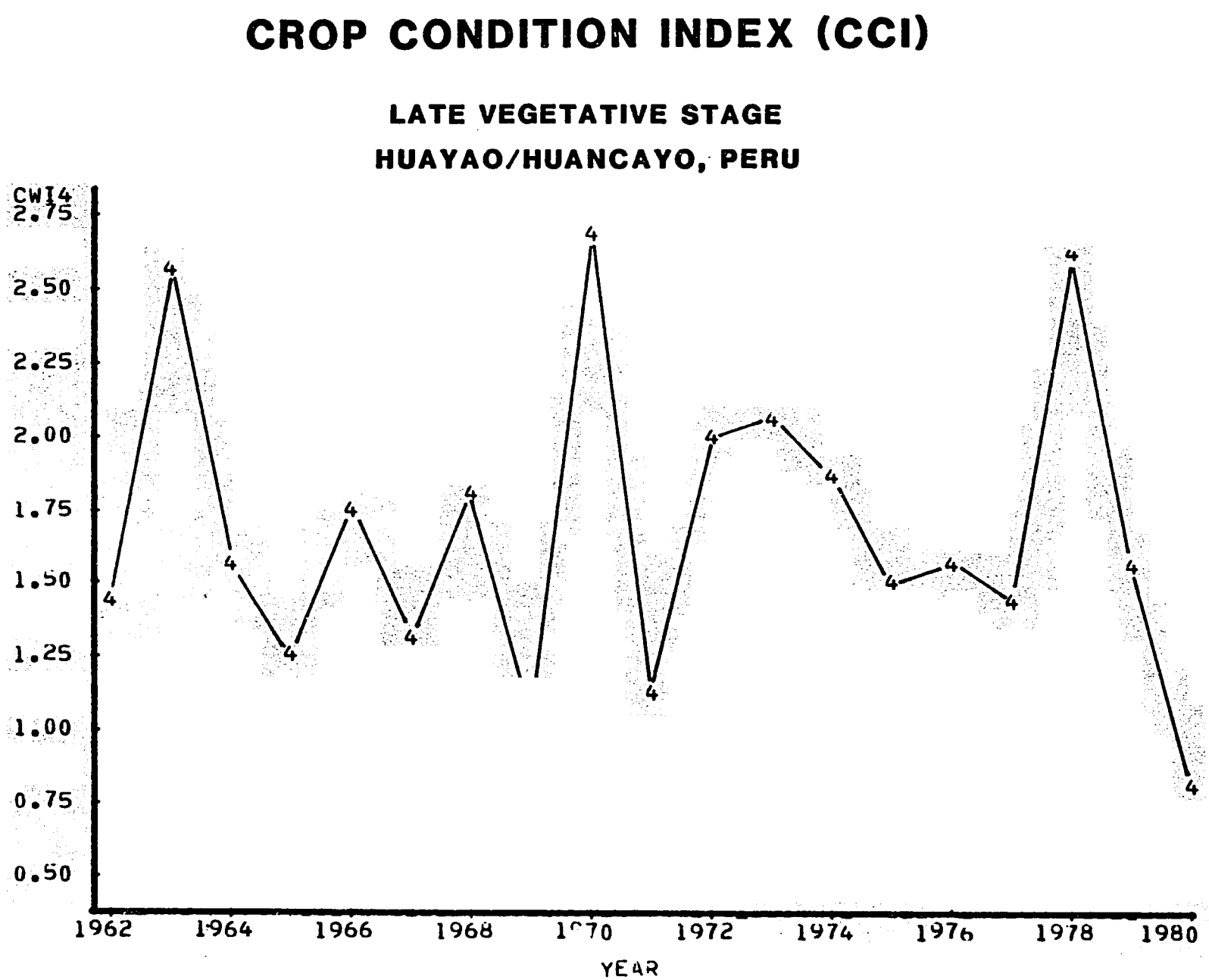


Figure 2.19. Crop Condition Index for Late Vegetative Growth Stage of Corn Grown at Huayao/Huancayo, Peru.

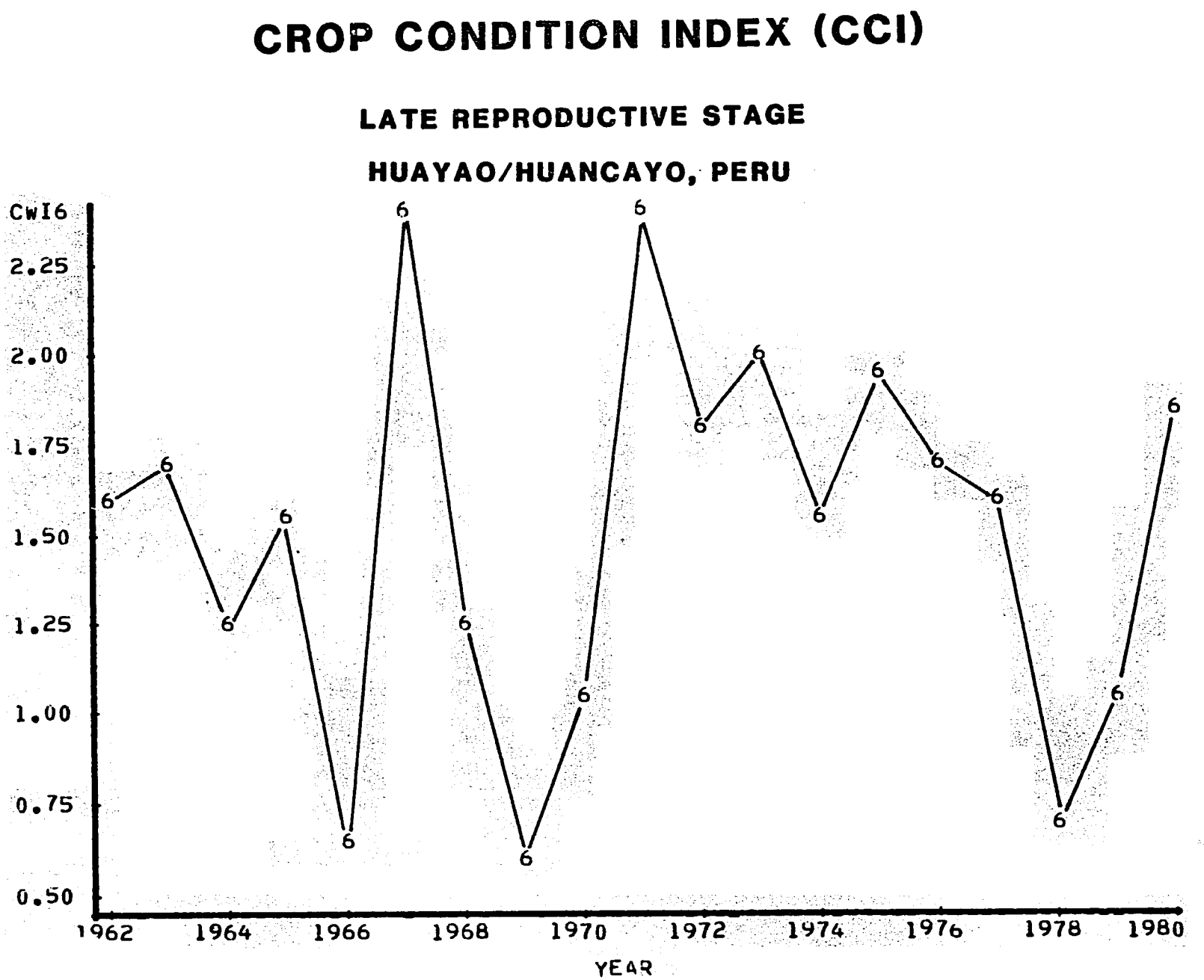


Figure 2.20. Crop Condition Index for Late Reproductive Growth Stage of Corn Grown at Huayao/ Huancayo, Peru.

Episodic and crop yield data can be used to establish threshold values for the index that are associated with normal crops, drought impacted crops, etc. After the relationship between the CCI and crop conditions has been established, the index can be used for assessments.

The proposed CCI should be thoroughly tested and evaluated before operational use.

b. Drought Occurrence as Indicated by the PDI and the SMI

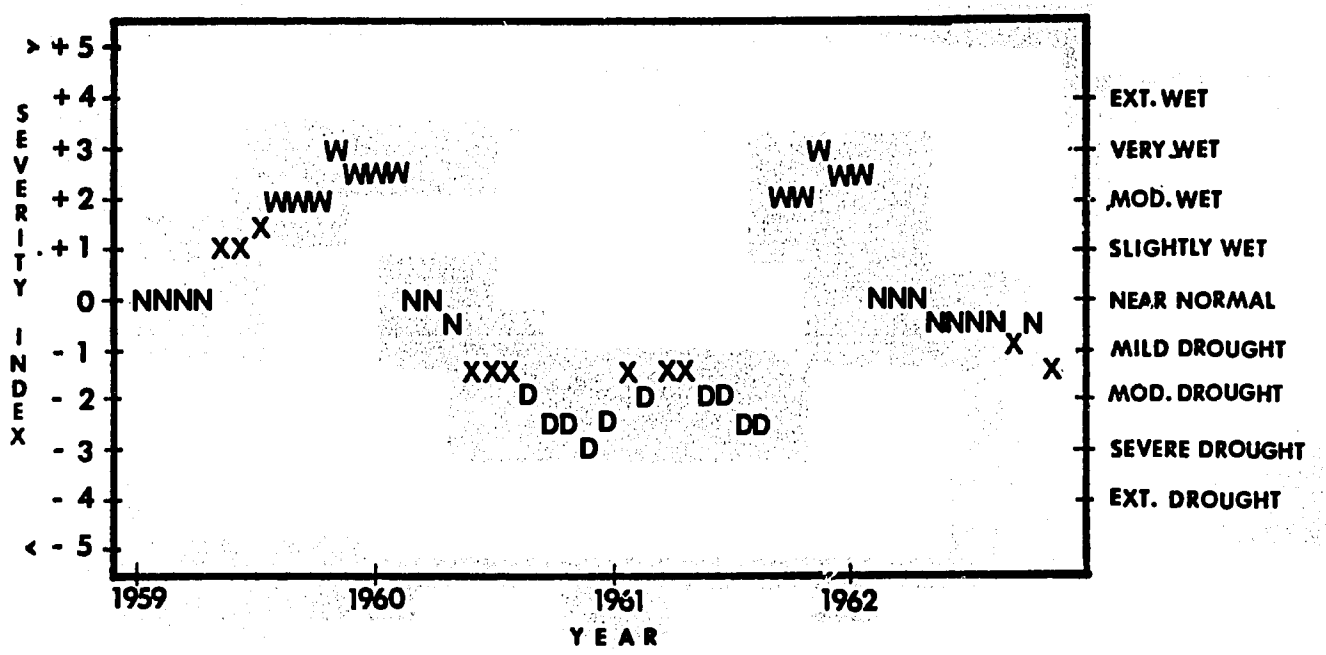
Figure 2.21 shows the Palmer Index on June 1960, suggesting the onset of a mild drought at Pichilingue (Ecuador). The June SMI is in the lower 10th percentile (Figure 2.22). Lack of significant rainfall from June through December intensified the drought as indicated by the PDI severe drought level and a SMI in the 5 to 20th percentile range. The rainy season began in January 1961 with 471 mm (Figure 2.23). February rainfall was 531 mm followed by 328 mm in March and 436 mm in April. Despite the considerable amount of rainfall recorded during the January - April period, the PDI suggests the occurrence of mild to severe drought for this period (Table 2.2). The SMI reflected the impact of the rainfall during the wet season by indicating normal soil moisture conditions (SMI in the 50th percentile).

Similar analysis applies for 1963 and 1964. Figure 2.21 shows the occurrence of drought in 1963 and 1964. While the PDI suggests a 24 month drought, the SMI reflects the soil moisture recharge caused by rainfall in early 1963 and early 1964 which undoubtedly reduced the number of months with drought (Table 2.2).

If SMI values in the range 0 to 20th percentile are indicative of drought, then the PDI and the SMI generally agree on defining the onset of a drought. It also can be noted that under drought conditions, Palmer's technique

PALMER DROUGHT INDEX (PDI)

PICHILINGUE, ECUADOR



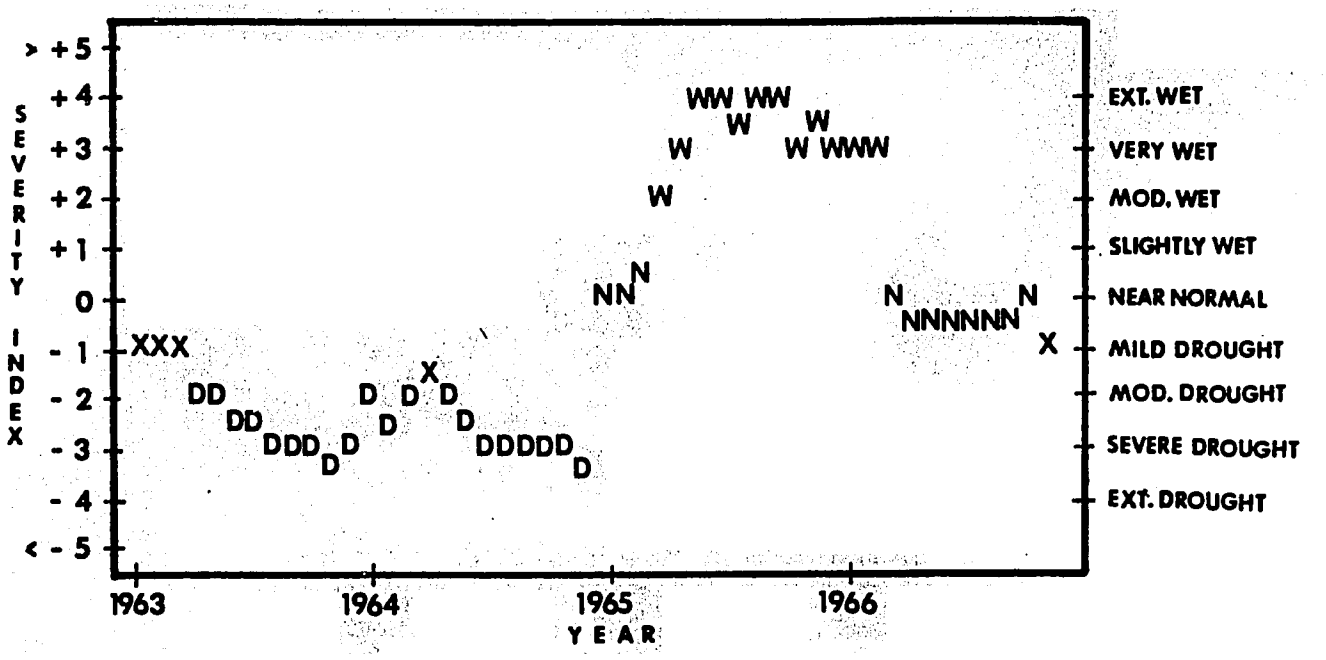


Figure 2.21. Palmer Drought Index for Pichilingue, Ecuador.

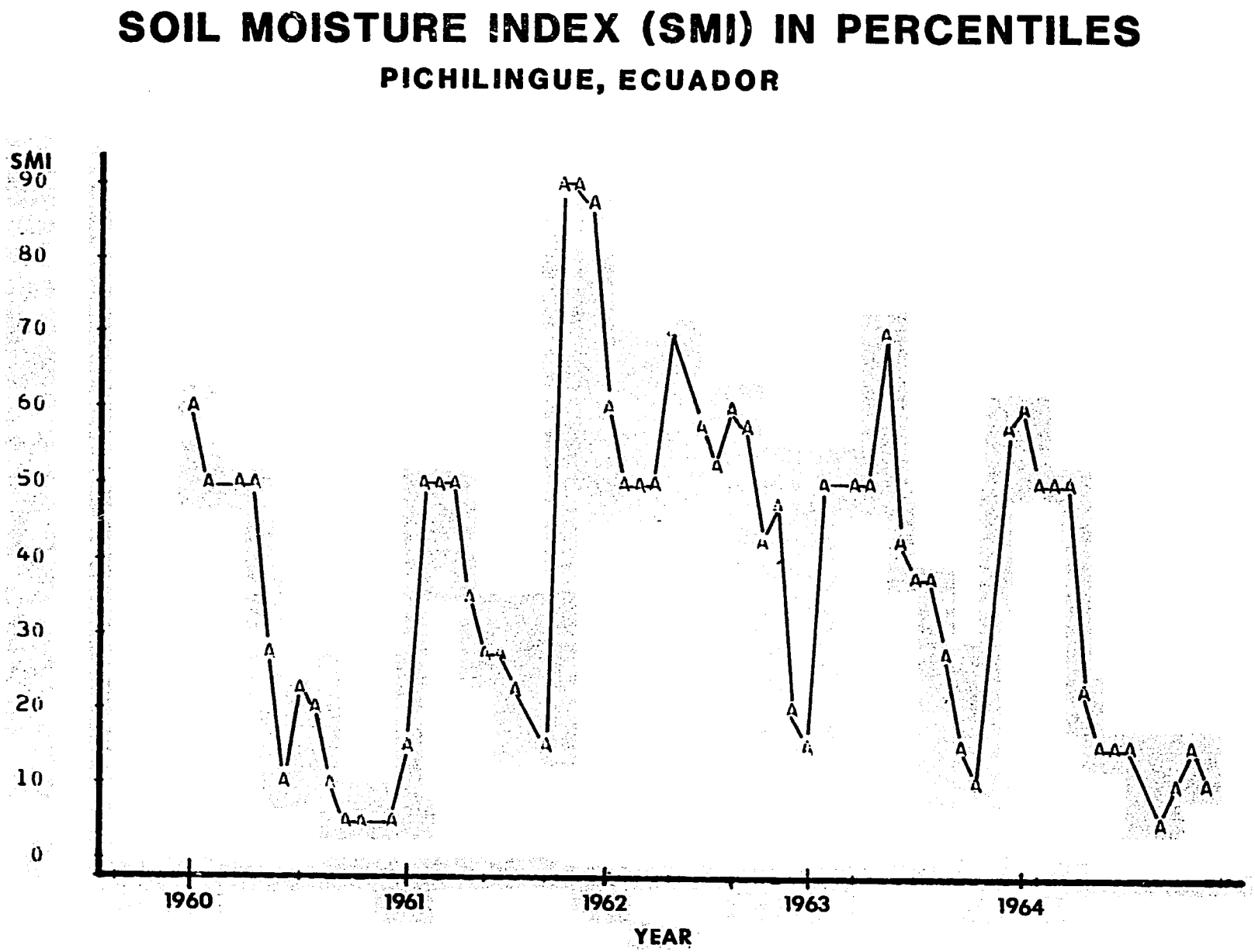


Figure 2.22. Soil Moisture Index (SMI) Expressed in Percentiles for Pichilingue, Ecuador.

MONTHLY RAINFALL (R) IN MILLIMETERS

PICHILINGUE, ECUADOR

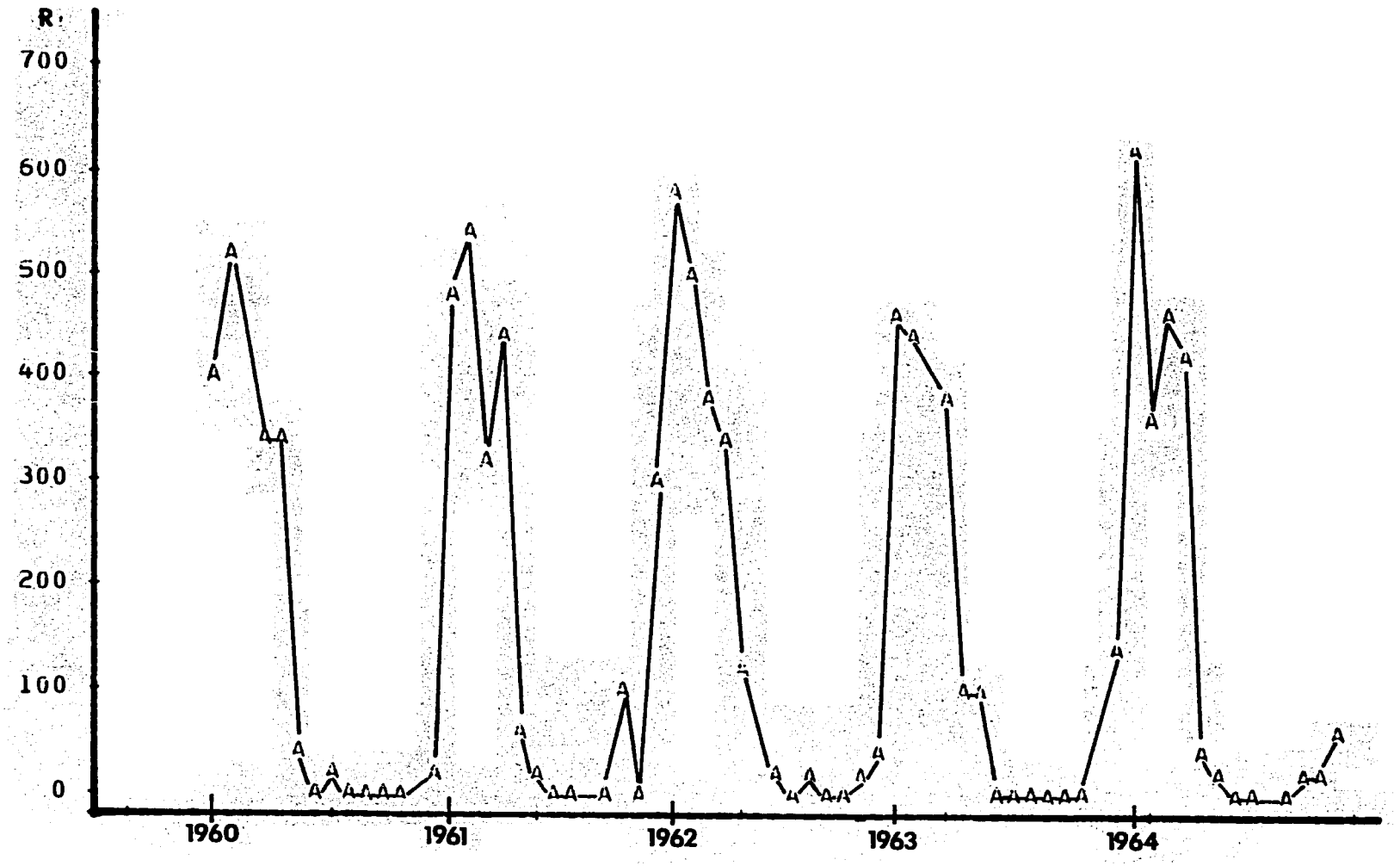


Figure 2.23. Monthly Rainfall for Pichilingue, Ecuador.

TABLE 2.2

Palmer Drought Index, Soil Moisture Index and Rainfall Analysis for Pichilingue, Ecuador

	AGROCLIMATIC INDICES		
DATE	Palmer Drought Index (PDI)	Soil Moisture Index (SMI)	Rainfall
1960/61	Mild to severe drought is indicated from June 1960 through August 1961. Total duration of the drought: 15 months.	SMI values in the 5 to 20th percentile range from June 1960 through January 1961 (8 months)	Approximately 1910 mm fell between June 1960 and August 1961
1963/64	Mild to severe drought is suggested from January 1963 through December 1964 (24 months duration).	SMI in the lower 20th percentile for 10 months during the period January 1963/December 1964.	About 3585 mm of rain were recorded during 1963 and 1964.

shows a large inertia as indicated by the slow response of the PDI to considerable amounts of rainfall.

From the previous analysis it may be concluded that the PDI may be used for drought condition assessment provided rainfall and soil moisture information are considered in the analysis.

CHAPTER III

CLIMATE AND AGRICULTURE IN CENTRAL AND SOUTH AMERICA

The purpose of this chapter is to provide background information and results of regional agroclimatic analysis related to the physical environment, climate and agricultural practices in Central and South America. Regional analysis of these important factors supports discussion in Chapters IV-VI on climate/crop condition indices and development of drought/food shortage assessment procedures for individual countries.

A. Physical Environment

Latin America is a region of diverse physical environments. The area under study extends from Guatemala (18°N) to the southern islands in the Tierra del Fuego group (55°S). The climates of the region range from tropical to temperate to tundra. The configuration of the land area is such that the greatest part of the region lies within the tropics; however, the tropical climate is modified by altitude in the mountains. Because South America is tapered to the south of the Tropic of Capricorn, the area of temperate lands is not large when compared with the tropical core of the region. This tapering means that oceanic influences are progressively more important toward the south. Unlike North America, there is no higher latitude landmass to sustain continental, climatic influences.

Certain characteristics of the Andean countries (Venezuela, Colombia, Ecuador, Peru, Bolivia and Chile) make them unique among high altitude countries of the world. These include:

1) large changes in altitude which result in a vertical succession of ecozones,

2) a considerable range of latitude,

3) immature and generally undifferentiated soils, and

4) A large number of macro and microclimates along the eastern and western slopes and adjacent lowlands created by the North-South position of the Andes perpendicular to the great atmospheric and oceanic circulation regimes.

All of these factors interact to produce a very complex set of climates and distribution of ecozones. Most important are the effects of latitude, exposure, nature of ground surface, elevation and topography.

In the mountains, the environment ranges from snow-covered peaks to high grazing country to valleys and basins of varying altitude in which various crops can be grown (Figure 3.1). In some of the deeper Andean valleys, it is possible to travel from lush, tropical forest to high grasslands that lie above the practical limit of cultivation.

Even within countries of the region the range of environments is immense. The greatest part of the coastal region in Peru is a desert except for cultivated valleys that are irrigated from streams originating high on the western slopes of the Andes. To the east of the Peruvian Andes lies the Oriente, a predominantly tropical region drained by the Amazon system.

B. Climate

A great variety of climates can be found in Central and South America ranging from steaming tropical rain forest to arid, coastal deserts or from stormy peaks on the earth's longest mountain chain to glaciers at sea level. Van Loon et al (1972) describe the large scale climatic features of Central and South America, the meteorological characteristics of the entire Southern Hemisphere, its circulation, radiation budget, heat and water balance, and peculiar aspects of its synoptic meteorology.

1. Climate Classification

A general climate classification for regions in Central and South America was adapted from analysis by Trewartha, 1970 (Figures 3.2 and 3.3).

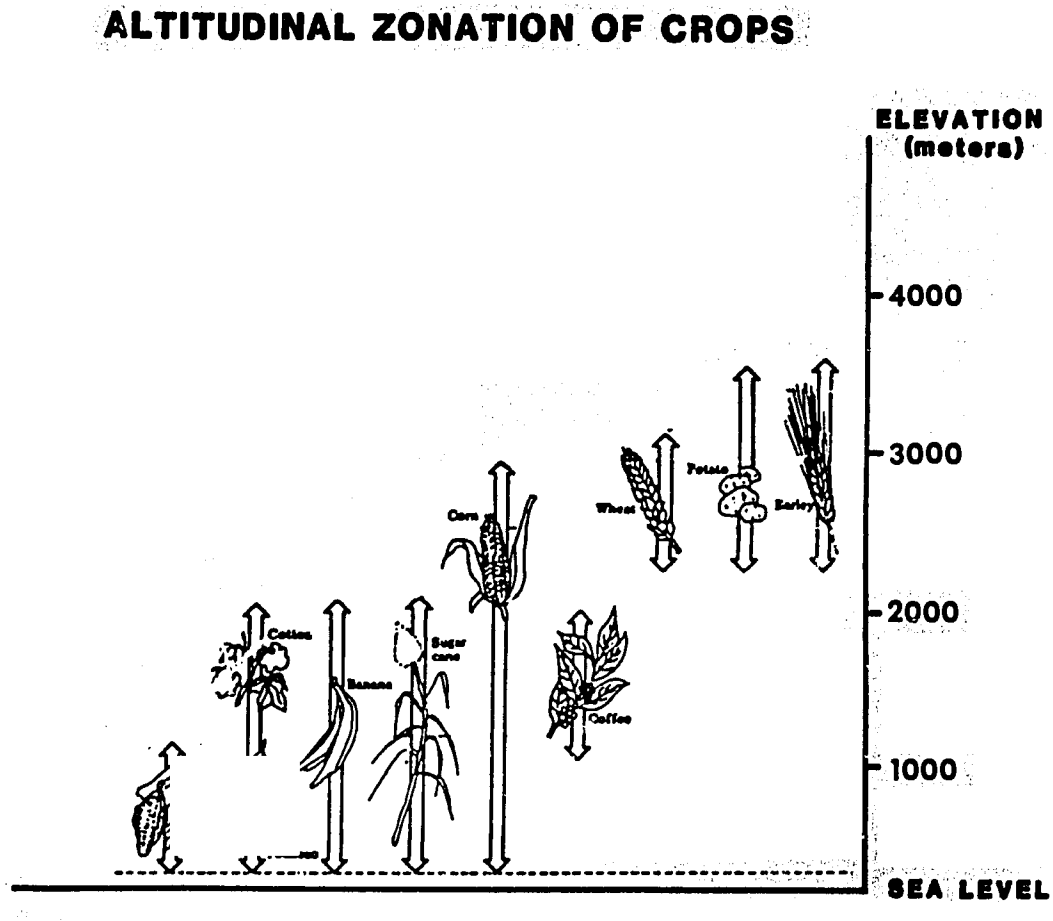


Figure 3.1. Altitudinal Zonation of Major Crops in Tropical Regions.

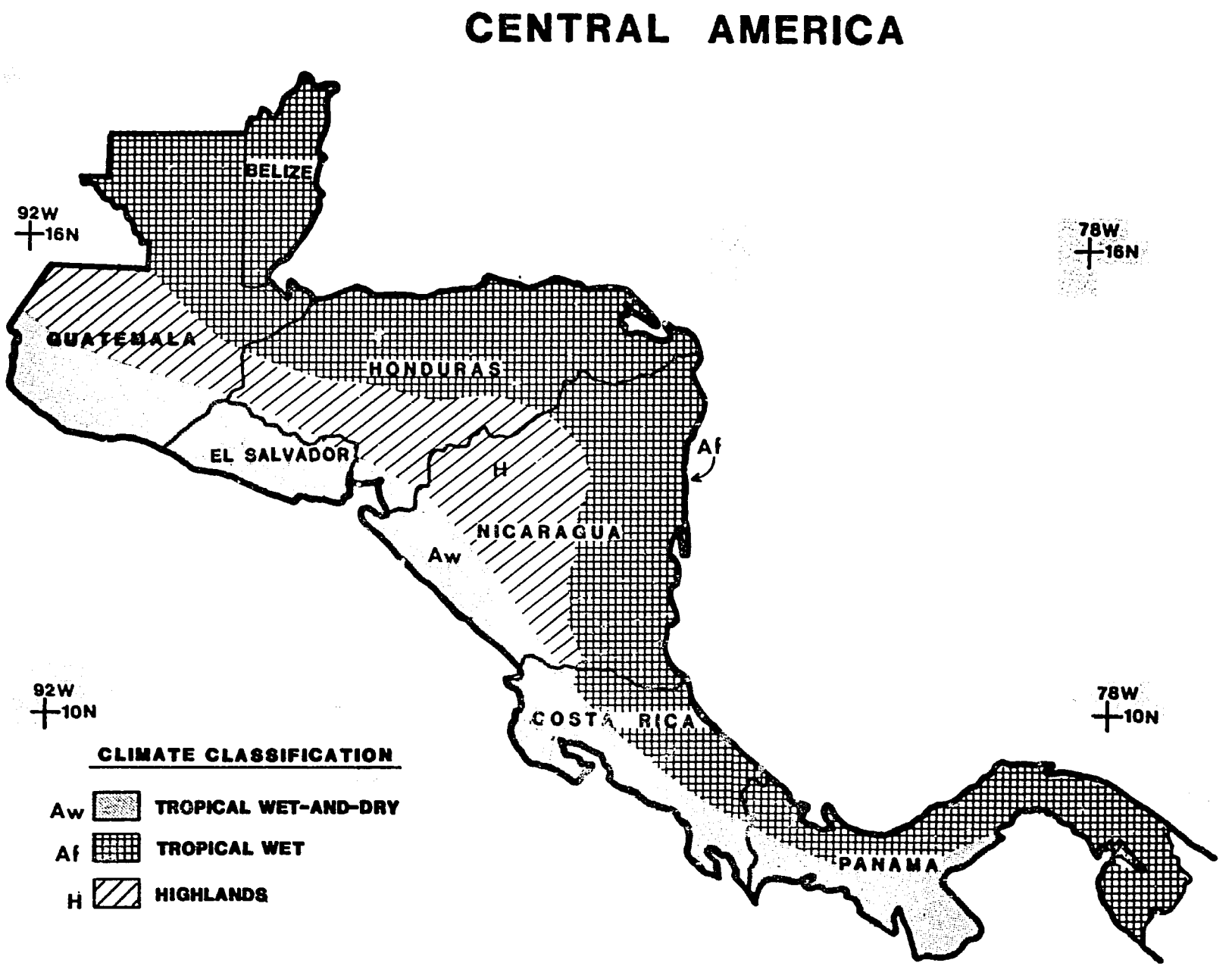


Figure 3.2. Climate Classification of Central America Based on an Adaptation of Analysis by Trewartha (1970). See Table 3.1 for Climate Description.

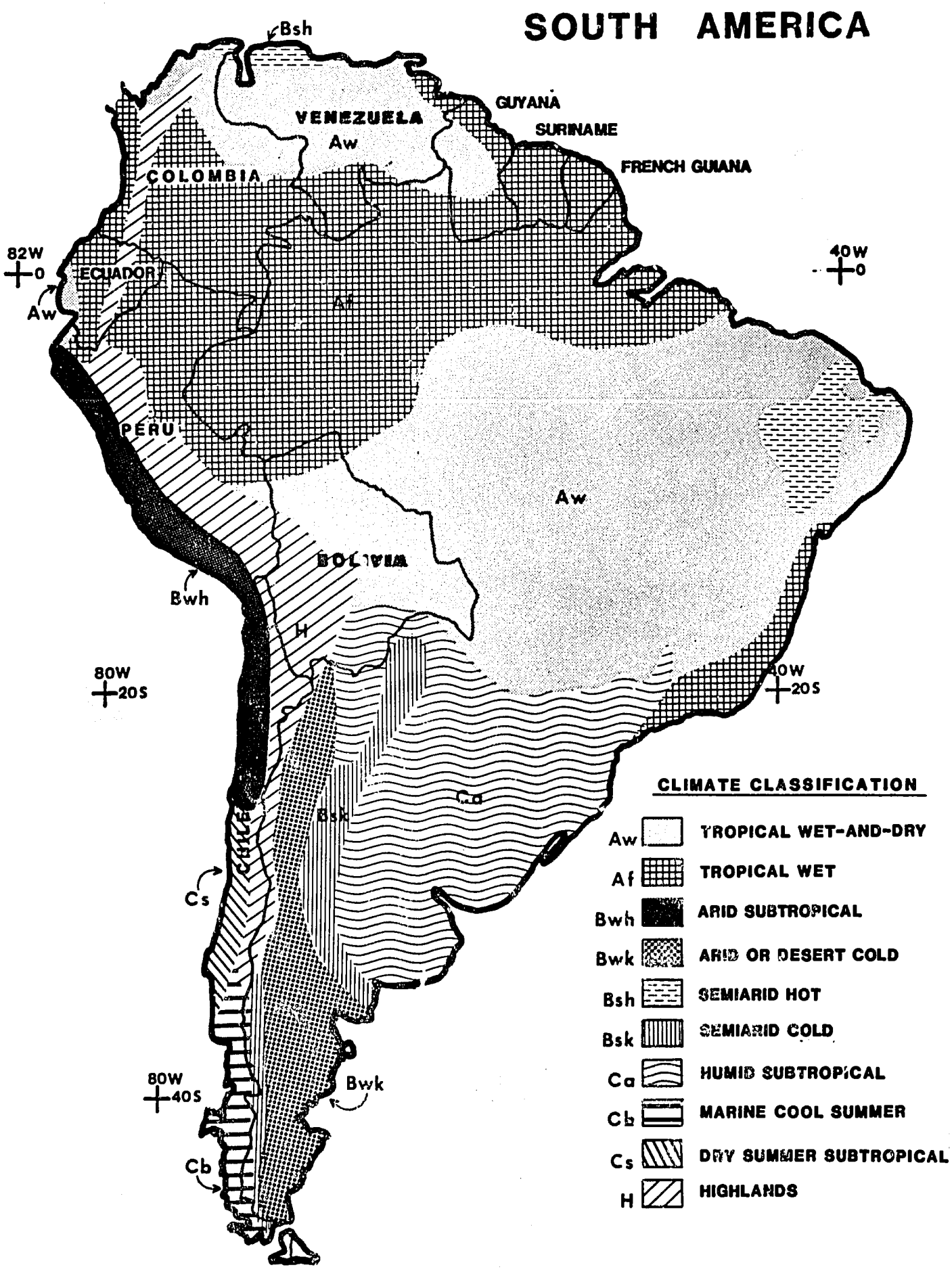


Figure 3.3. Climate Classification of South America Based on an Adaptation of Analysis by Trewartha (1970). See table 3.1 for Climate Description.

This classification is based on temperature and rainfall. It does not consider other climatic components such as solar radiation, wind and air humidity which are integral to a full definition of regional climate.

For a continent that reaches from about 20°N to 55°S, Central and South America exhibits a climatic arrangement which in most respects conforms to that represented on a hypothetical continent. Thus, along the Pacific coast west of the Andes the latitudinal succession of climates is precisely what might be expected from the operation of the great planetary controls. Accordingly, Af climate in western Colombia is replaced by Aw in Ecuador, B climates prevail in Peru and Northern Chile, Cs in Central Chile, and Cf still farther south. East of the Andes as well, there is much in the major climatic arrangement which follows the expected patterns. Accordingly, an extensive Af area in the Amazon Valley is flanked by Aw climates to the north and south while farther poleward to the south Aw merges into Caf.

The climates in Central America are either tropical humid all year around (Af) or tropical humid with dry season (Am) except in the highlands (H) where altitude offsets latitude to produce mesothermal conditions.

Table 3.1 shows the definitions for the climatic types illustrated in Figures 3.2 and 3.3.

The most important departures from the expected patterns are the followings: the winter rainfall maximum in the Caribbean Coast of Honduras, the excessive wetness of the Pacific side of Colombia; the unusual equatorward displacement and intense aridity of the Chilean-Peruvian dry climates; the drought-prone area in northeastern Brazil; and the dry littoral in Northern Venezuela and Colombia.

TABLE 3.1

CLIMATE CLASSIFICATION FOR CENTRAL AND SOUTH AMERICA
BASED ON AN ADAPTATION OF ANALYSIS BY TREWARTHA (1970)

Types of Climate 1/	Pressure and Wind Conditions		Rainfall Pattern
	Summer	Winter	
Af, tropical wet	ITC, doldrums, equatorial westerlies	ITC, doldrums, equatorial westerlies	No dry season
Aw, tropical wet and dry	ITC, doldrums, equatorial westerlies	Trades	High-sun wet (zenithal rains) low sun dry
BS, semiarid (steeped)			
BSh, tropical and subtropical	Subtropical high and dry trades	Subtropical high dry trades	Short moist season
BSk, middle latitude		Continental winter anticyclone	Meager rainfall, most in summer
BW, arid (desert)			
BWh, tropical and Subtropical	Subtropical high and dry trades	Subtropical high dry trades	Constantly dry
BWk, middle latitude		Continental winter anticyclone	Constantly dry
Cs, dry summer subtropical	Subtropical high (stable east side)	Westerlies	Summer drought, winter rain
Ca, humid subtropical	Subtropical high (unstable west side)	Westerlies	Rain in all seasons
Cb, marine climate	Westerlies	Westerlies	Rain in all seasons accent on winter
H, highlands			

1/ A = temperature of coolest month over 18°C.
B = evaporation exceeds precipitation
C = coldest month between 18°C and 0°C.
D = temperature of coldest month under 0°C; warmest month of 10°C.
E = temperature of warmest month under 10°C.
a = warmest month over 22°C.
b = warmest month below 22°C.
c = warmest month below 22°C; less than four months above 10°C.
d = coldest month below - 38°C.

With A climates:
f = no dry season; driest month over 60 mm.
s = dry period at high sun or summer; rare in A climates
w = dry period at low sun or winter; driest month under 60 mm.

With C climates:
f = no dry season; difference between rainest and driest months less than in s and w; driest month of summer over 30 mm.
s = summer dry; at least 3 times as much rain in wettest month of winter as in driest month of summer; driest month less than 30 mm.
w = winter dry; at least 10 times as much rain in wettest month of summer as in driest month of winter.

2. Precipitation

In tropical and temperate regions of Central and South America, the year-to-year variations in agricultural productivity are highly related to variations in rainfall. Figures 3.4 and 3.5 show mean annual precipitation amounts for Central and South America. In general, annual rainfall in South America is less than in Central America, particularly in coastal areas of Belize, Nicaragua, Costa Rica and Panama where annual rainfall exceeds 3,000 mm. Large spatial and temporal variations also exist within each country.

Central America

Coastal areas in the eastern region and particularly the eastern slopes of mountains receive more than 2,000 mm of rain each year. In Greytown (Nicaragua), the annual precipitation is more than 6,500 mm. The Pacific coast receives less rainfall, 750 to 1,000 mm, mostly from thunderstorms. The dry season is December to April; however, on the eastern coast, the season is dry only in comparison with the rest of the year with its excessive rain and moist air. Most of Central America experiences a double maxima of rainfall during the year with peaks about May and October.

South America

The heaviest rains of the continent occur in three main regions. The first region has the largest area which covers most of tropical South America on the east side of the Andes. The rainy season is from October to June and the rainfall occurs in association with the intertropical convergence zone (ITCZ). The second region is located between the Amazon River and 30°S. The rainy season is from October to April and is associated with surges of cold polar air from high southern latitudes interacting with the SE trades of the South Atlantic. The third region, South of 35°S, is dominated by the westerlies. This region is restricted to the mountains and the littoral of Chile. The heaviest rainfall

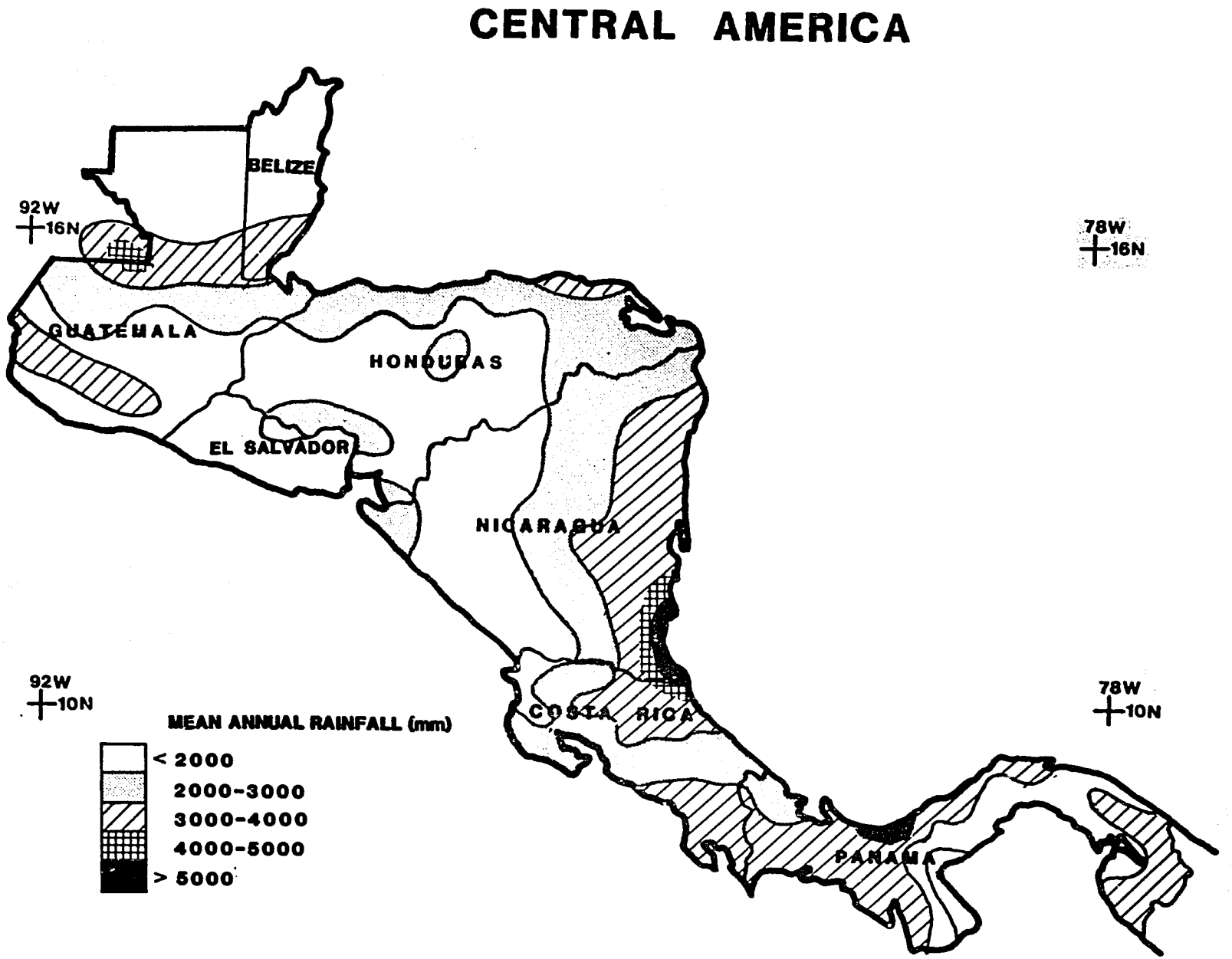


Figure 3.4. Mean Annual Rainfall in Central America.

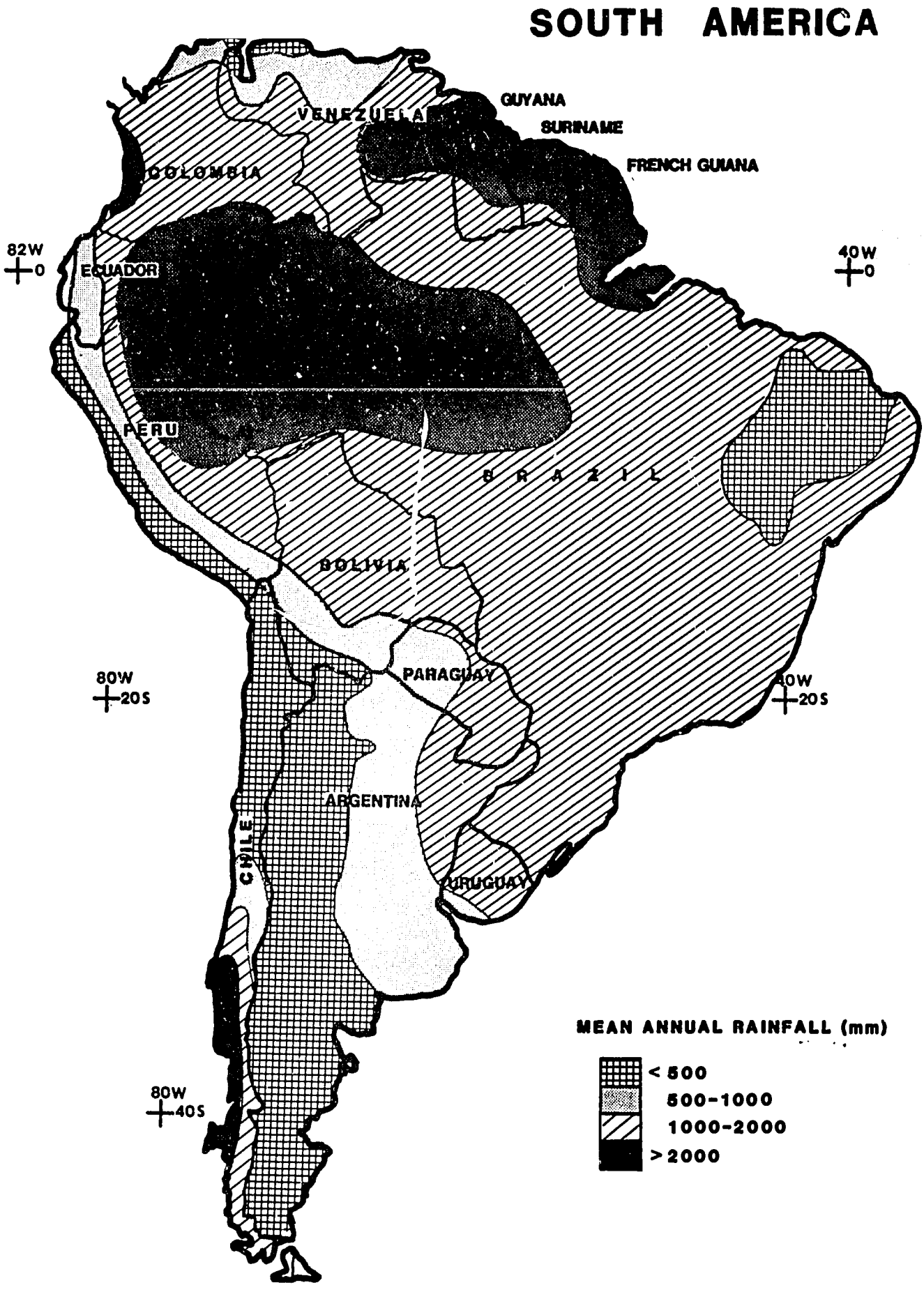


Figure 3.5. Mean Annual Rainfall in South America.

occurs during the winter (April thru October).

In addition to these major regions of heavy rainfall, smaller size regions also receive heavy rainfall, for example, due to local orographic features.

In this study normal monthly rainfall was used to establish agroclimatic regions (Figures 3.6 and 3.7). Appendix A provides rainfall plots showing the seasonal distribution of rainfall for agroclimatic regions in all countries.

3. Solar Radiation, Temperature and Wind

The solar radiation, temperature and wind regimes of Central and South America are greatly affected by the topographic features within the region. The latitudinal span also has a considerable impact on the temporal and spatial variability of these weather elements.

Solar Radiation

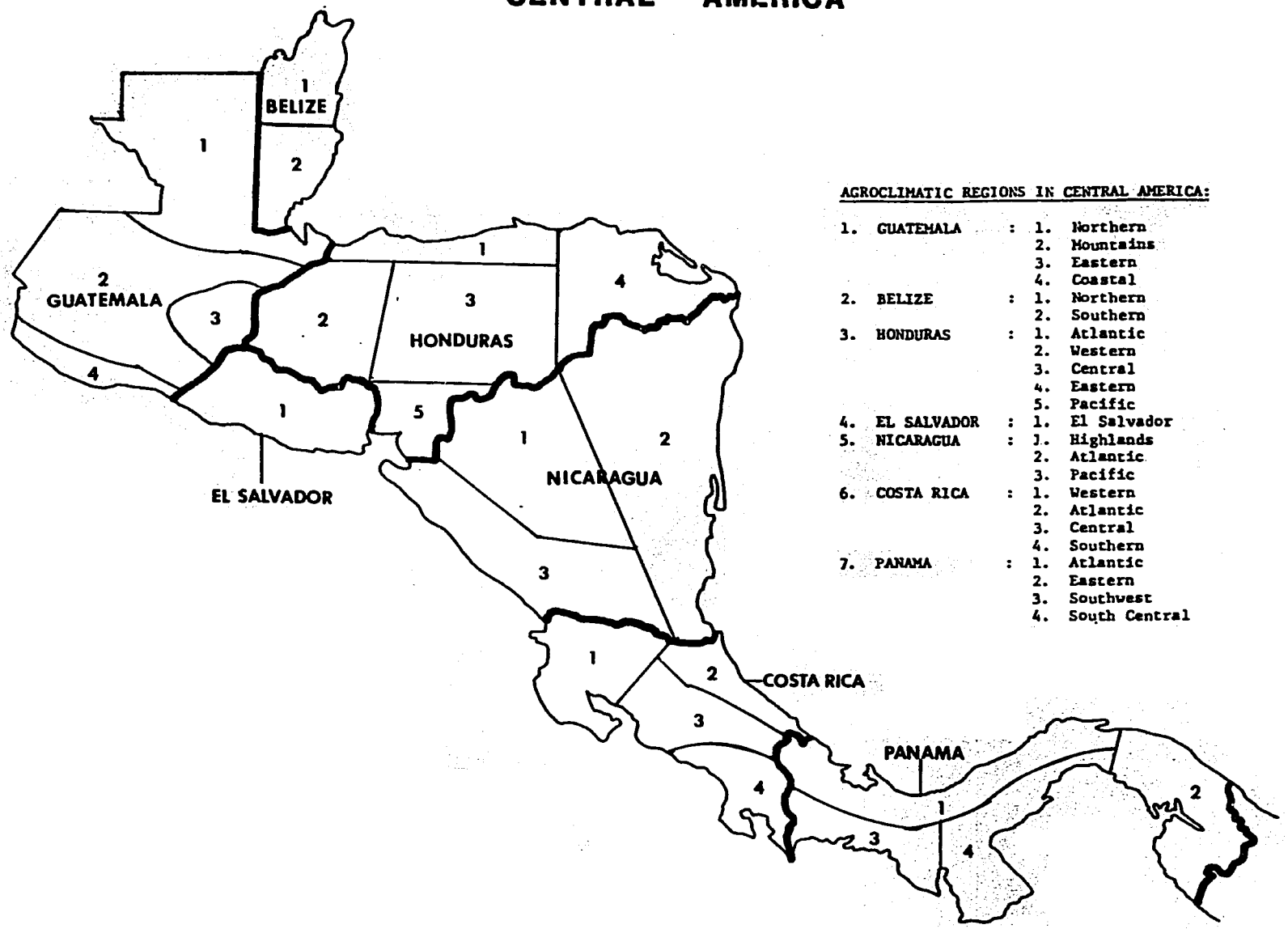
The distribution of annual solar radiation is strongly affected by the cloudiness regime. A general, zonal pattern of distribution is conspicuous in the middle and higher latitudes (i.e., Chile), but this is not the case in the tropics where the amount of clouds is highly variable from region to region (i.e., Colombia). Cloudiness in the tropics and centers of low solar radiation result from strong, large-scale convection. Thus, cloudy western Amazonia (Ecuador, Colombia and Peru) receives less than 400 cal/cm^2 year.

The regions of maximum solar radiation in the subtropics are associated with high-pressure cells and large deserts with relatively little cloud cover (Northern Chile and Southern Peru).

In Central America, the amount of solar radiation during December ranges from 350 cal/cm^2 day in the northern regions (Belize) to over 450 cal/cm^2 day on the Pacific Coastal area of Panama. During June, the pattern is reversed; northern regions receive around 500 cal/cm^2 day while the Pacific Coastal area receives about 350 cal/cm^2 day.

AGROCLIMATIC REGIONS

CENTRAL AMERICA



AGROCLIMATIC REGIONS IN CENTRAL AMERICA:

1. GUATEMALA	:	1. Northern
		2. Mountains
		3. Eastern
		4. Coastal
2. BELIZE	:	1. Northern
		2. Southern
3. HONDURAS	:	1. Atlantic
		2. Western
		3. Central
		4. Eastern
		5. Pacific
4. EL SALVADOR	:	1. El Salvador
5. NICARAGUA	:	1. Highlands
		2. Atlantic
		3. Pacific
6. COSTA RICA	:	1. Western
		2. Atlantic
		3. Central
		4. Southern
7. PANAMA	:	1. Atlantic
		2. Eastern
		3. Southwest
		4. South Central

Figure 3.6. Agroclimatic Regions Used in Early Warning Assessments for Central America.

Figure 3.7. Agroclimatic Regions Used in Early Warning Assessments for South America.

In South America, the annual variation of the solar radiation is quite large except within the equatorial belt. The tropical regions of Western Ecuador and Colombia and Northern Peru receive about 350 cal/cm^2 day throughout the year. In middle and high latitudes, solar radiation ranges from about 50 cal/cm^2 day in June (Chile) to over 700 cal/cm^2 day during December (Bolivia).

Temperature

Tropical and maritime climates with small temperature changes are predominant in Central America. Except for the Atlantic coasts of Honduras and northern Nicaragua where temperatures are moderated by rainfall, the highest temperatures occur just before the onset of the summer rains. The average temperature of the coldest month is higher than 19°C and that of the warmest month is less than 29°C throughout the entire region.

The distribution of the absolute minima shows the effects of cold air invasions during the winter from the North American continent. Low temperatures usually occur after a cold air intrusion from the north has begun to slow down, and radiational cooling during the night adds to the effects of advection. Hoffmann (1960) reports that the highest mountains in Guatemala and Costa Rica have experienced air temperatures slightly below freezing. However, crop damages due to frost are seldom observed in Central America.

In South America, intertropical regions are considerably cooler (with allowance made for elevation) than the corresponding latitudes of Africa and Australia. This is due to extensive cloudiness, large rainfall and dense forests. In July, Venezuela and French Guiana experience the highest temperatures while Southern Brazil and Argentina experience the highest temperatures during January. In the southern winter, the freezing line remains south of Cape Horn (55°S). However, after a cold air intrusion from the south, minimum temperatures can eventually reach -15°C in some areas of Patagonia and the

highlands of the Andes. Frost occurrences in the highlands is a frequent event causing crop damages and shortening the growing season. The narrowness of the land mass and the vastness of the surrounding ocean preclude extremely cold winters in South America. For the same reasons, the summers are remarkably cool. The 10°C isotherm for the warmest month crosses Tierra del Fuego (55°S). In the western regions of South America, the isotherms bend to the north due to the cool Humboldt current which flows to the north. There is a striking temperature contrast between the east and the west coasts of the continent.

Wind

The wind regimes in Central and South America are determined by the large-scale atmospheric general circulation patterns (trade winds associated with the Hadley Cells and the Intertropical Convergence Zone; westerlies in southern Chile) and local winds such as mountain-valley or land-sea breeze circulations. The extensive mountain range has a dominant role in modifying large-scale circulations and determining local patterns. The mean flow conditions for December and September in Central America and for January and July in South America are now described.

Figures 3.8 and 3.9 show the mean streamlines for Central America. The winds are from the northeast during December and from the east during September on the Atlantic Coast. In addition, northerlies can reach as far south as Nicaragua in December and southwesterlies can replace the easterlies in Panama during September. On the Pacific Coast, winds are from the northeast during December but from the southwest in September.

In South America, winds are from the northeast on the eastern side of the Andes during January but are easterlies or southeasterlies in July. During January, on the Pacific side of the Andes and south of the ITCZ, winds are from the west, southwest and southeast but from the north and northwest in the

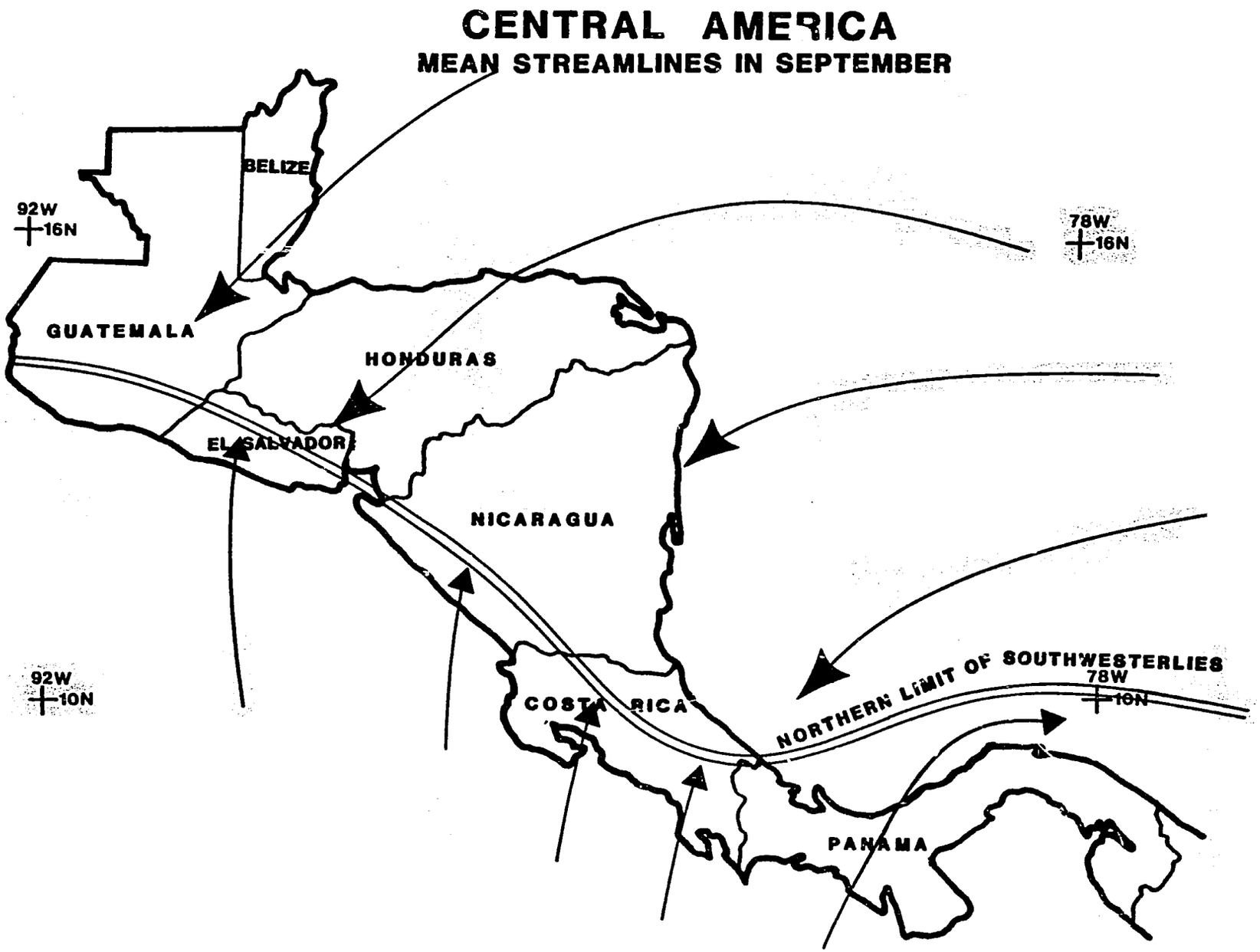


Figure 3.8. Mean Streamlines (September) for Central America.

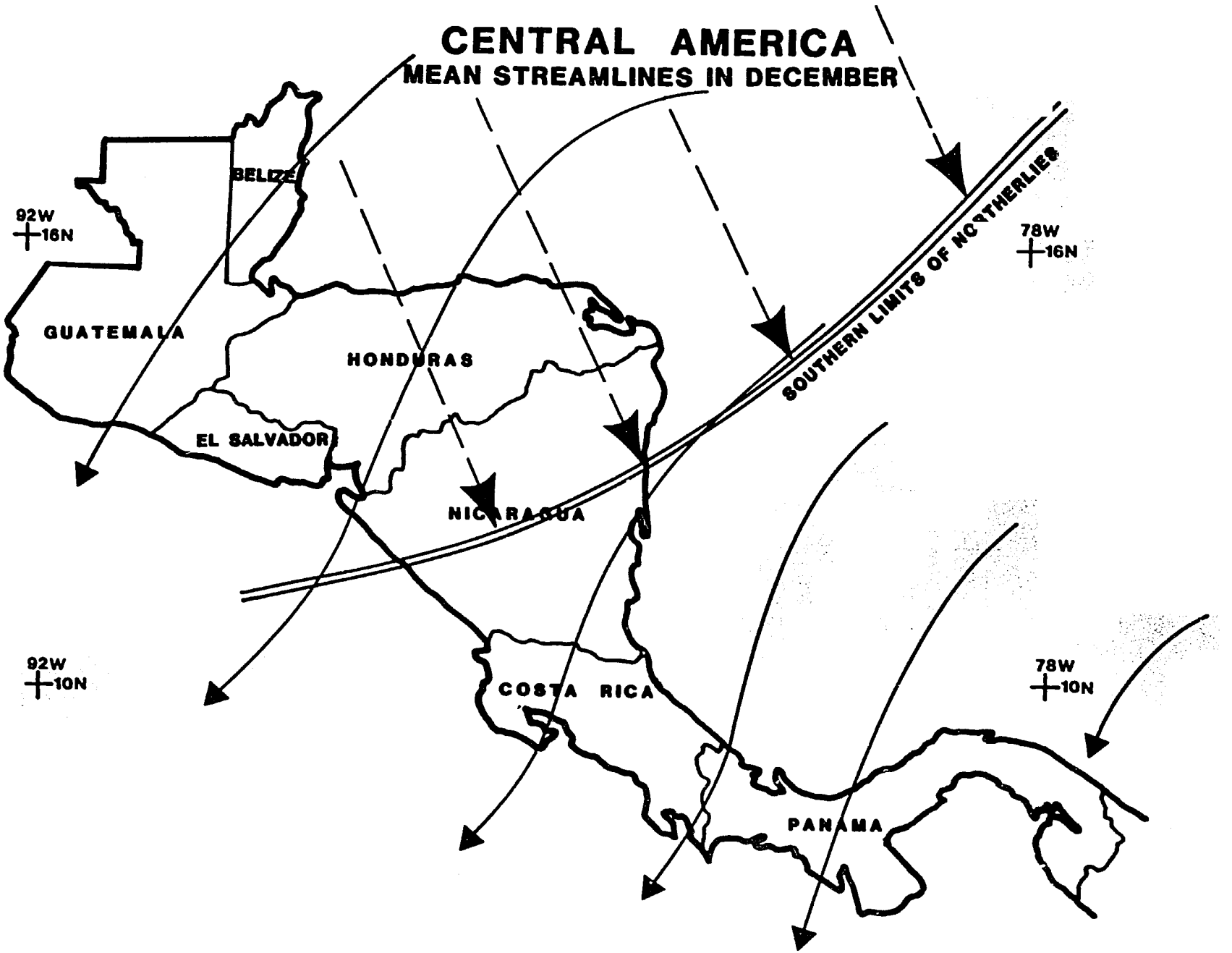


Figure 3.9. Mean Streamlines (December) for Central America.

northern side of the ITCZ. The winds are from the south, southeast and southwest in July (Figures 3.10 and 3.11).

C. Agriculture

This section presents a brief overview of agriculture in Central and South America as related to: 1) current food security issues, particularly vulnerability to climate, and 2) regional background information and analysis used in the development and proposed application of climate/crop condition indices as the basis for providing early-warning assessments of potential climatic impact on food security. The importance of agriculture, regional characteristics, some of the problems, and recent attempts to improve food security through increased production are examined. Because of the paramount importance of corn and beans to tropical Central and South American countries, particular emphasis is placed on the culture of these crops and their agroclimatic requirements. In semiarid regions, corn is usually replaced by sorghum, a drought resistant crop. Wheat, barley and potatoes become major staple food crops in temperate and cold climates (Andean highlands and south of 30° latitude).

1. Regional Overview

In spite of rapid urbanization and the growth of new types of employment, agriculture remains the largest single source of employment throughout Central and South America. Agriculturists live in diverse physical and cultural environments. Some farmers engage in production for subsistence while others produce commercial crops for market.

The agricultural systems can be analyzed from environmental and human perspectives. Environmental factors may have influenced the selection of certain plants and animals and certainly influence the seasonality and intensity of agricultural work. The structure of agricultural systems and the timing of

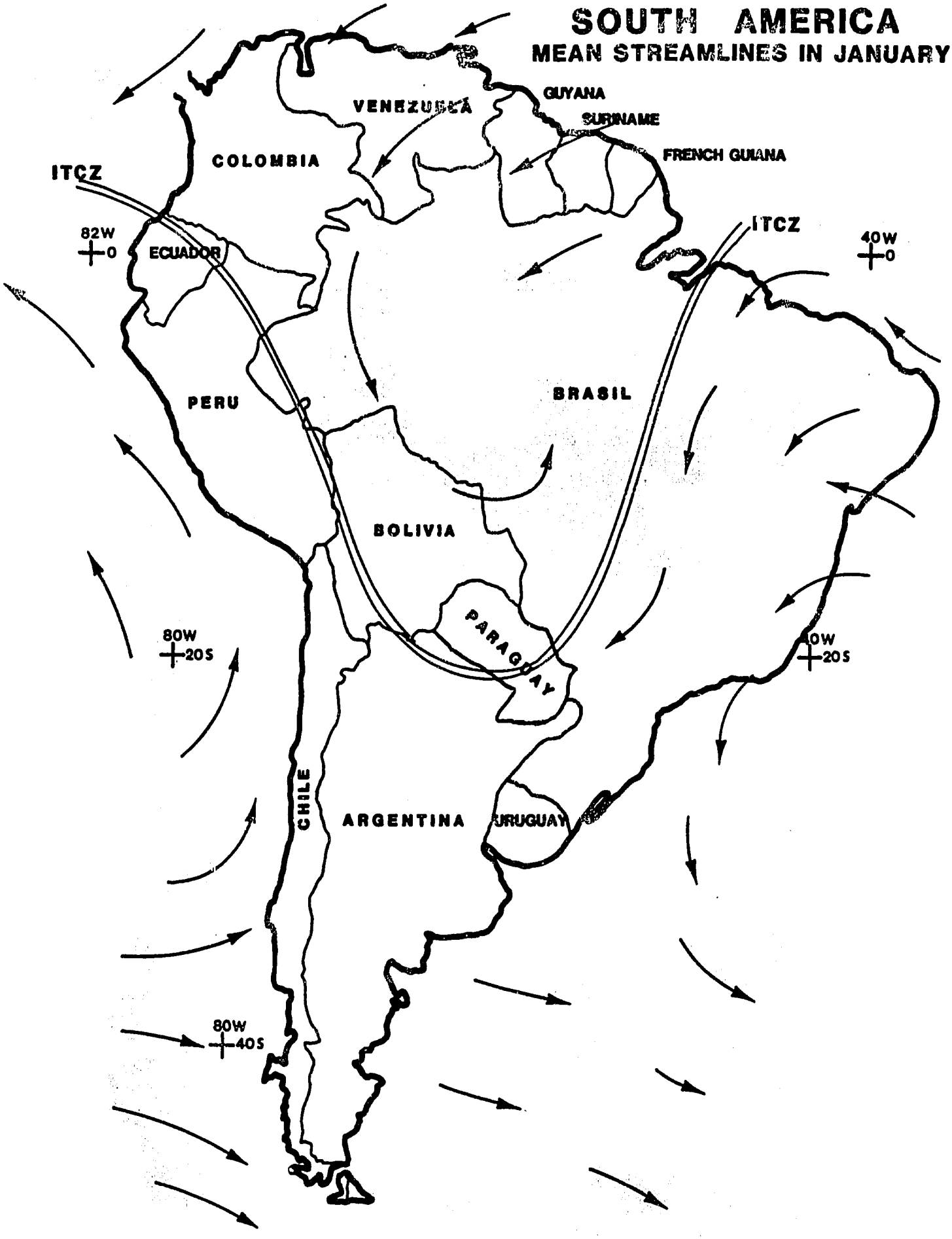


Figure 3.10. Mean Streamlines (January) for South America.

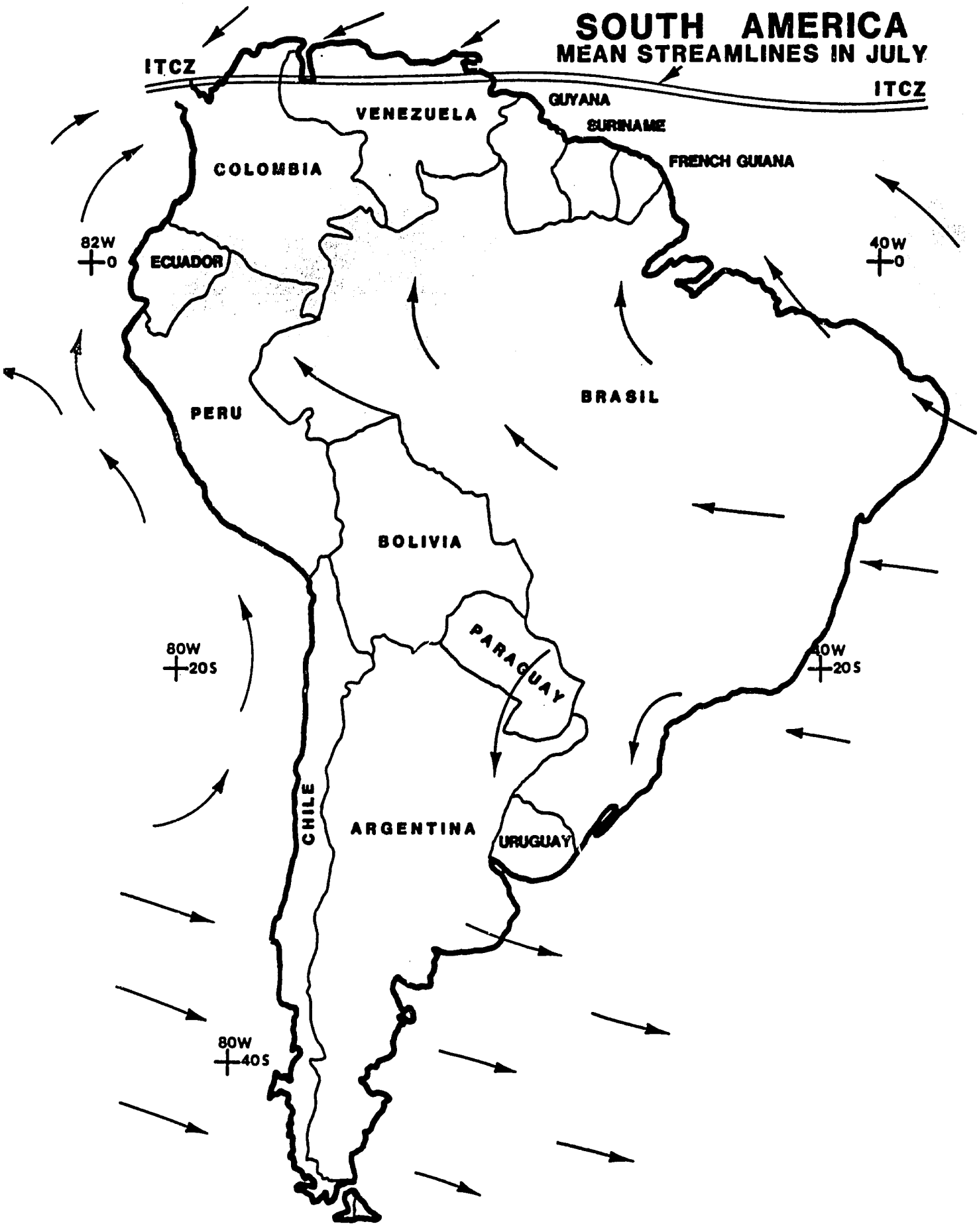


Figure 3.11. Mean Streamlines (July) for South America.

agricultural labor are often related to solar energy, moisture availability, and nutrient resources in the soil. But there is also the human or cultural dimension to be considered in relation to Central and South America. In many traditional societies farming and other productive activities are seen as a part of the social fabric. Some aspects of agriculture may only be explained in terms of cultural traditions instead of the type of input-output accounting procedures used in most advanced farming operations.

In Central and South America, as in other parts of the world, traditional modes of cultivation are being transformed into more commercial types of agriculture as new technologies become available. During the last four decades the pace of technological innovation has accelerated as commercial fertilizers, genetically improved crops, and tractors have become available throughout the area. Transformation in the agricultural sector of the region has been significant. This has been particularly true of countries such as Costa Rica and Colombia, where commercial agriculture is export oriented. Now most states are pursuing policies aimed at applying modern technology to help increase gross agricultural production.

The earliest forms of agriculture in the region employed a very basic technology and were tied closely to locally available environmental resources. Traditional methods are still in use in many regions. The impediments to productivity of the humid tropical environment--plant and animal pests and low levels of soil fertility--are managed in much the same way as they were several hundred years ago (Blouet and Blouet, 1982).

a. Land Use

Land use in Latin America varies considerably among countries. Figure 3.12, shows major land uses: annual and perennial crops, pastures and forests. Annual and perennial crops share a small portion (7.1%) of land area; pastures and forests account for more than 73% of the total. Cultivated land area has expanded in the past 20 years (Table 3.2), but there is considerable potential for further expansion of food crops. Cultivated land in selected countries is shown in Table 3.2.

The area of irrigated land is relatively small in Latin America. Among the countries considered in this project, Chile and Peru have the largest irrigated area (Table 3.3).

b. Agricultural Production and Population

With the exception of a few regions, Latin American agriculture has not been noted for productivity. During the period 1950 through 1980, agricultural production has grown at a compound annual growth rate of 3.1% and the production per capita at only 0.5% (Figure 3.13). In the past three decades, there has been a significant increase the internal demand for agricultural products. Population growth has been the major factor in the increased domestic demand for food. Table 3.4 shows the demographic growth in Latin America for the period 1920-1970; during this period the growth rate almost doubled in most countries from an average of 1.86% in the 1920's to 2.91% in the late 1960's. In 1980 the rural population accounted for 25.6% of the total population in Latin America (Figure 3.14). Although there has been a massive farmer exodus to the cities, the rural population is still considerably large. For example, in Honduras and Guatemala the economically active population engaged in agriculture is about 63 and 56%, respectively (Table 3.5). Population projections for Latin America indicate that by the year 2000 the total population will be near 600 million (Figure 3.15).

TABLE 3.2. CULTIVATED LAND IN SELECTED COUNTRIES OF LATIN AMERICA
(Thousands of Hectares)

Country	1959-1961	1964-1966	1970	1973	1974
Bolivia	613	680	771	771	888
Chile	1,544	1,424	1,425	1,200	1,312
Colombia	3,192	3,546	3,580	3,804	3,997
Costa Rica	321	401	352	351	358
Ecuador	1,024	1,425	1,678	1,662	1,644
El Salvador	585	708	614	709	689
Guatemala	1,257	1,523	1,491	1,759	1,809
Honduras	618	617	599	660	682
Nicaragua	518	819	705	708	715
Panama	371	332	449	458	478
Peru	1,612	1,727	1,894	1,749	1,809
Venezuela	1,250	1,332	1,727	1,534	1,659
LATIN AMERICA	69,257	78,292	84,023	87,677	92,913

Source: Wilkie, W. (Ed.), 1982.

TABLE 3.3. IRRIGATED LAND IN SELECTED COUNTRIES OF LATIN AMERICA
(Thousands of Hectares)

Country	1961-65	1966	1970	1975	1976	1977
Bolivia	74	75	80	120	120	120
Chile	1,084	1,100	1,180	1,260	1,280	1,300
Colombia	231	240	250	280	285	290
Costa Rica	26	26	26	26	26	26
Ecuador	446	463	470	500	510	510
El Salvador	18	20	20	33	33	50
Guatemala	38	45	56	60	62	64
Honduras	60	66	70	80	80	80
Nicaragua	18	18	29	32	70	74
Panama	15	18	20	23	23	25
Peru	1,041	1,078	1,106	1,130	1,150	1,180
Venezuela	218	255	284	314	320	350
LATIN AMERICA	9,255	9,725	10,364	11,439	11,943	12,604

Source: Wilkie, W. (ed.), 1982

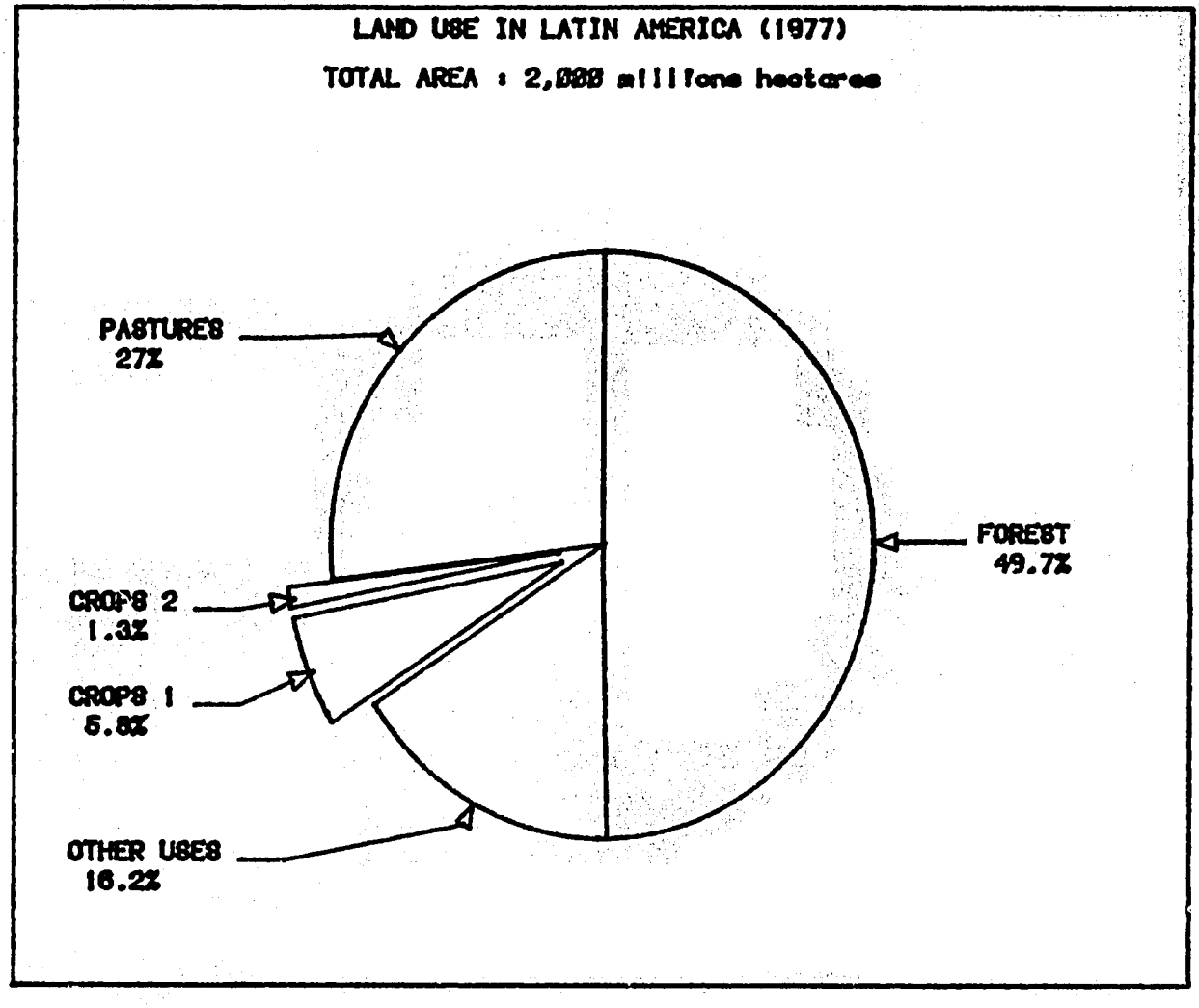


Figure 3.12. Land Use in Latin America (1977).

Source: Wilkie, W. (Ed.), 1982

INDEX OF PRODUCTION IN LATIN AMERICA

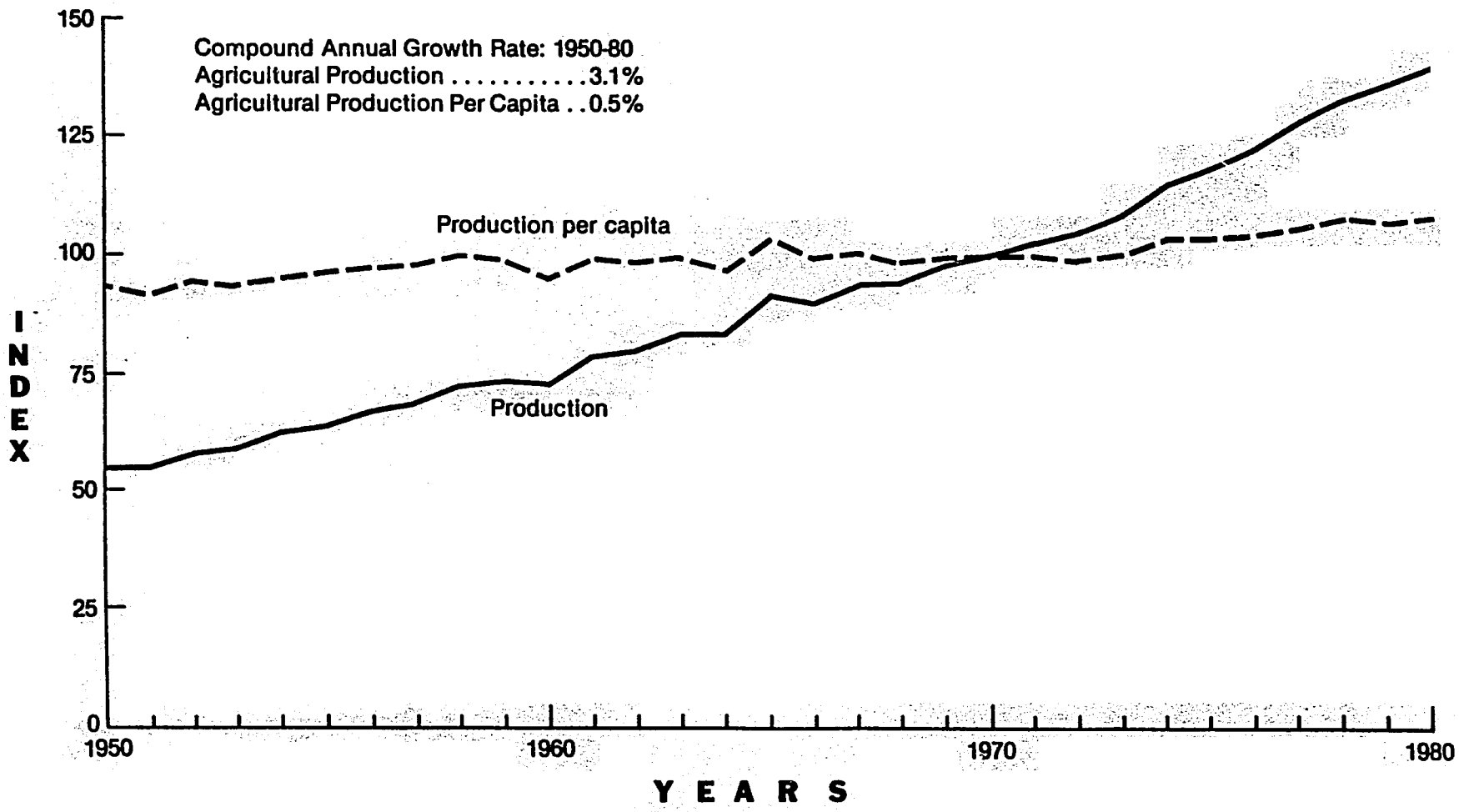


Figure 3.13. Index of Production in Latin America.

SOURCE: USDA, .1981

TABLE 3.4. RATES OF DEMOGRAPHIC GROWTH IN LATIN AMERICA (%)

Country	1920-1925	1925-1930	1930-1935	1935-1940	1940-1945	1945-1950	1950-1955	1955-1960	1960-1965	1965-1970
Bolivia	1.06	1.26	1.45	1.62	1.78	1.92	1.97	2.16	2.29	2.41
Chile	1.54	1.61	1.55	1.50	1.54	1.74	2.41	2.40	2.50	2.26
Colombia	1.94	1.96	2.03	2.19	2.36	2.65	3.05	3.27	3.32	3.46
Costa Rica	1.61	1.82	2.00	2.35	2.98	3.44	3.74	4.13	3.65	3.05
Ecuador	1.14	1.46	1.71	1.91	2.06	2.41	2.83	3.11	3.35	3.41
El Salvador	2.18	2.09	1.19	1.30	1.23	2.05	2.51	2.90	3.04	3.36
Guatemala	1.11	2.94	2.42	1.97	3.36	3.10	2.67	2.82	2.98	2.89
Honduras	1.94	1.92	1.61	1.73	2.01	2.36	2.62	3.18	3.37	3.43
Nicaragua	1.46	1.55	1.74	2.00	2.27	2.55	2.66	3.04	3.06	2.98
Panama	1.58	1.59	.86	2.57	2.55	2.53	2.89	2.97	3.23	3.27
Peru	1.47	1.56	1.65	1.72	1.75	1.81	1.98	2.66	3.05	3.12
Venezuela	1.93	2.17	2.27	2.37	2.84	3.11	3.99	3.92	3.31	3.37
Latin America	1.86	2.03	1.89	1.91	2.22	2.54	2.73	2.85	2.85	2.91

SOURCE: Wilkie, W. (Ed.), 1982.

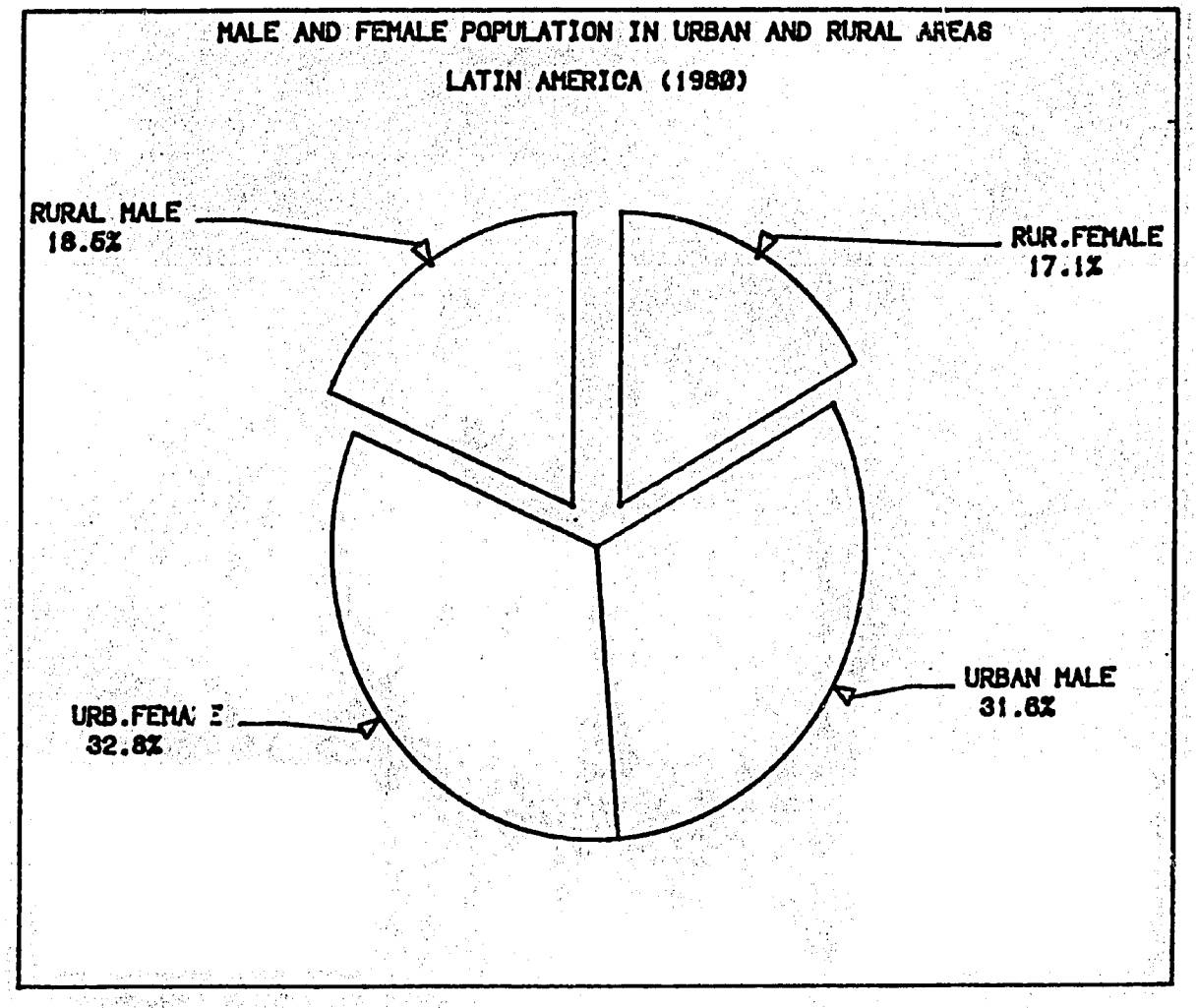


Figure 3.14. Male and Female Population in Urban and Rural Areas Latin America (1980). Estimated population: 358,005,000.

SOURCE: Wilkie, W. (Ed.), 1982

TABLE 3.5. AGRICULTURAL POPULATION AND ECONOMICALLY ACTIVE POPULATION (EAP) IN AGRICULTURE, 1978 (IN THOUSANDS)

Country	Total Population	Agricultural Population	EAP		
			Total	In Agriculture	% Agriculture
Bolivia	4,889	2,498	1,606	820	51.1
Chile	10,830	2,155	3,533	687	19.4
Colombia	26,006	7,597	7,727	2,257	29.2
Costa Rica	2,125	775	703	256	36.5
Ecuador	7,798	6,566	2,473	1,131	45.7
El Salvador	4,516	2,372	1,405	724	51.5
Guatemala	6,021	3,378	1,836	1,030	56.1
Honduras	3,080	1,952	909	576	63.4
Nicaragua	2,559	1,114	761	339	44.5
Panama	1,825	657	614	221	36.0
Peru	16,719	6,868	4,913	1,907	38.8
Venezuela	13,331	2,581	4,024	779	19.4

SOURCE: Wilkie, W. (Ed.), 1982

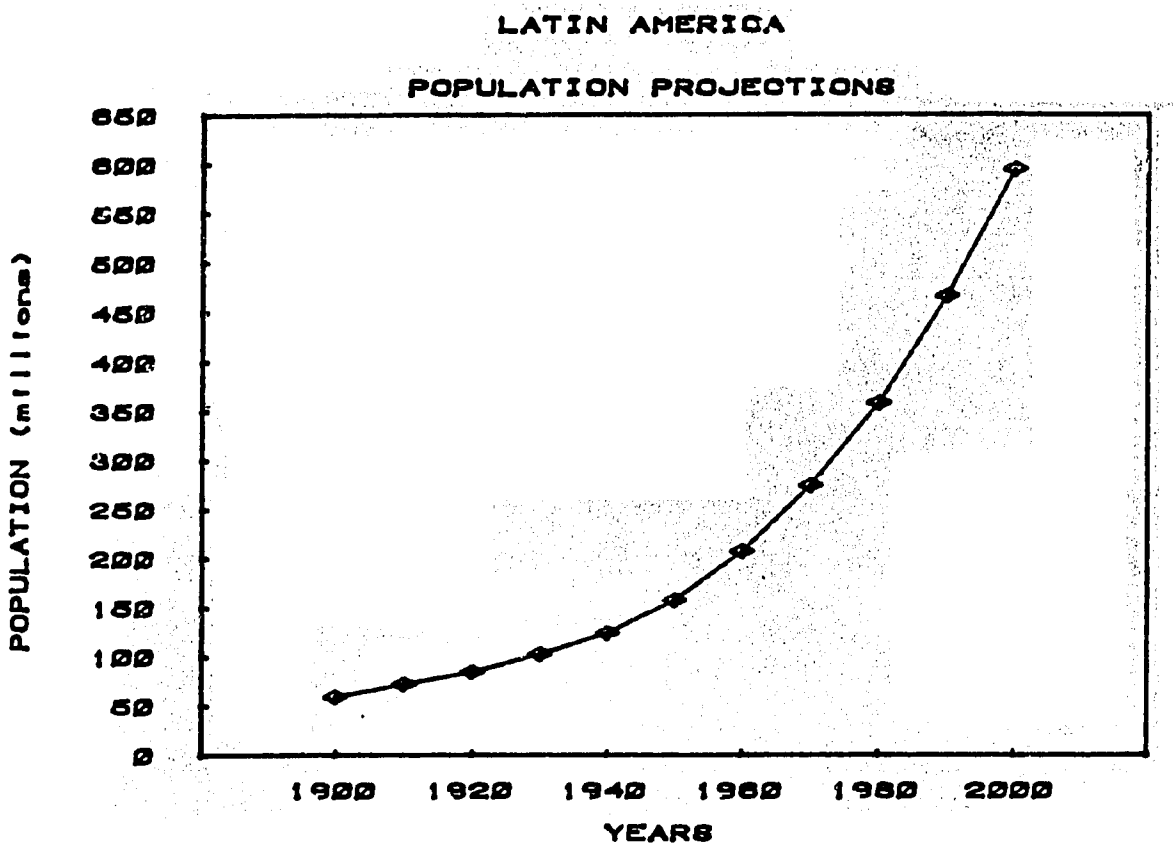


Figure 3.15. Population Projections for Latin America.

SOURCE: Wilkie, W. (Ed.), 1982

2. Corn

a. Climatic Requirements

The bulk of corn is produced between the equator and latitudes not greater than 50°C. Trewartha (1968) provides a climate classification that delineates the corn region as humid and mesothermal. The climatic conditions needed for a corn crop include temperatures over 10°C for 4 to 8 months with a warm summer (warmest month over 22°C). The 10°C isotherm marks the threshold for active growth. Corn is also grown in woodland and grassland climates. The greatest production occurs where the isotherms of the warmest months range between 21° and 27°C and the frost-free season is at least 120 to 180 days in duration. There appears to be no maximum temperature limits for corn production; however, yields usually decrease with higher temperatures and irrigation usually is required to meet the water requirement. There is an upper limit on nocturnal temperatures. In the range of 25-30°C respiration is greatly increased and more energy is used. Under this condition corn plants may actually lose dry matter during the night and the productivity is drastically reduced.

The seasonal water requirement for corn ranges between 350 to 750 mm Haise (1958) reported seasonal consumptive water use for corn of 420 to 540 mm in the Dakotas. Vasquez (1961) found a consumptive water use of 470 mm for corn grown over a 125-day period in Puerto Rico. Yield potential in corn is closely related to soil water availability. In areas with seasonal rainfall less than 750 mm, corn yields are closely tied to rainfall variability.

b. Stages of Growth and Development of Corn

Hanway (1971) proposed a 10 stage plant development system ranging from 0 when the plant tip emerges from the soil to 10 when the plant is physiologically mature. For discussion here, seven different phases will be adapted from Hanway

to establish six crop growth and development periods:

Period 1. Planting to Emergence

Period 2. Emergence to Flower Differentiation

Period 3. Flower Differentiation to Tasseling. Tip of tassel emerged

Period 4. Tasseling to Pollination

Period 5. Pollination to Physiological Maturity

Period 6. Physiological Maturity to Harvesting.

c. Weather Impact on Corn Production

The impact of weather on corn production is closely related to the crop stages. The following discussion will focus on those weather variables that affect the crop performance at each previously defined growth stage.

Period 1. The period from planting to emergence depends on soil moisture, soil temperature and soil aeration. Germination proceeds rapidly at soil temperatures between 25° and 35°C and soil moisture about 80 percent of field capacity (Blacklow, 1972). Corn emergence varies from 5 to 15 days.

Period 2. Corn growth during the vegetative stage has been found to be related to both air temperature and rainfall (Bair, 1942). In the Sierra region of Ecuador, this period can extend for several months due to normally prevailing low temperatures during most of the growing season (Canadas and Salvador, 1982). Correlations between early season weather and yield have generally shown little significance (Thompson, 1963). Micro-effects such as the difference between a poorly drained and a well-drained soil are probably more significant at early stages of growth.

Period 3. In the late vegetative stage, the relationship between weather and yield have been more marked and significant. Temperatures above normal sharply reduce the yield. During this stage, corn plants grow rapidly and water use is greater than in Period 2. The soil moisture may become very

important under low rainfall conditions. Moisture stress during this period will cause yield reductions.

Period 4. This is a very critical stage in corn plant development. The number of ovules that will be fertilized is being determined. Both moisture and fertility stress that occur at this stage can have a serious effect on yield.

Period 5. During the ear-filling stage, significant reduction in yield can occur from moisture stress. Mallet (1972) subjected corn to stress starting at 10, 20, 30 and 40 days after silking and maintained stress for up to 8 days. Four days of stress caused an average yield reduction of 4.3 percent per day of stress. Rainfall becomes the dominant factor on the final crop production. Peters et al (1971) found that high night temperatures (29.4°C) can reduce corn yield almost 40 percent compared with cool temperatures (16.6°C). Early freezes before physiological maturity can cause serious yield losses. Frost damages are quite common in the Mantaro Valley of Peru (Sanchez, 1982) or in the Bolivian Altiplano.

Period 6. After physiological maturity, the grain must dry down to a harvestable moisture level. The rate of drying is affected by weather conditions such as vapor pressure deficit, sunshine hours, evaporation rate and wind.

3. Beans

a. Climatic Requirements

Although beans originated in the subtropical regions of Central America they have been adapted to a wide climatic zone. Beans can be grown in lowlands as well as in mountain environments where frost occurrence is often recorded.

Annual rainfall in the native habitat ranges from 500 to 1800 mm with about 80 percent of this falling from May to October. Flowering and pod filling are controlled by the rainfall regime rather than by day length and temperature. In wetter regions both flowering and maturity are later than in drier regions having the same thermal and photoperiod regimes. Solar radiation is an important factor in bean growth since shading has been observed to stunt growth and reduce yields (Gentry, 1969). Most bean varieties capable of attaining maturity in temperate climates have a dwarf determinate habit. Best growth occurs between 20° and 25°C. Both yield and growth are reduced when the temperature is outside the 15-25°C range.

Beans require a rich, well-drained soil with 500-1000 mm of rainfall during the growing season for optimum germination and growth (Hadas, 1970). Beans are salt-sensitive species.

b. Stages of Growth and Development of Beans

In the native habitat of Central America, beans are sometimes biennial vines but under cultivation they grow as annuals. Habit may be indeterminate as in pole types, determinate as in bush types, or semideterminate as represented by some types grown for the dry seed.

The crop phenological stages are: emergence, bud formation, flowering and maturity. These growth stages delimit the following periods:

Period 1. Planting to Emergence

Period 2. Emergence to Flowering

Period 3. Flowering to Pod Filling

Period 4. Pod Filling to Maturity.

c. Weather Impact on Bean Production

Rainfed bean production is closely related to weather variability, particularly rainfall, temperature and solar radiation conditions during specific phenological periods.

Period 1. Soil temperature and soil moisture are the major factors during this period. Beans germinate most rapidly at 30°C but some varieties germinate equally well over ranges of temperatures from 15° to 30°C. A higher soil moisture is necessary for germination in beans than in corn but excessive soil moisture is unfavorable for germination because of oxygen inhibition. Normally, emergence occurs from 6 to 10 days after planting.

Period 2. This period of vegetative growth is mainly affected by water stress and low temperatures (Stocker, 1974). Cloudiness will stunt growth and reduce yields.

Period 3. This is a critical water period for beans. During the flowering, pod-filling period, significant reduction in yield can occur from moisture stress. Nelson (1962) showed that water stress during flowering and pod development reduced yields by an average of 22 percent. Water stress occurring at anthesis caused reduction in the number of pods, seeds per pod, flower formation and seed protein content (Robins and Domingo, 1956; Dubetz and Mahalle, 1969).

Period 4. Early in this period, soil water content should be relatively high (70 percent or higher) for maximum yield of beans (Maurer et al, 1969). Early frosts in high elevation environments can damage pod development.

4. Wheat

a. Climatic Requirements

The many cultivated varieties of wheat make it adaptable to a wide range of climatic conditions. Wheat is found distributed throughout temperate and high

elevation regions of Central and South America and can tolerate rather high temperature conditions provided the period of high temperature does not coincide with periods of high atmospheric humidity. The combination of high temperatures and high humidity is fatal to wheat. The production of wheat in high elevation regions is subject to frost hazards. For most satisfactory growth and development of grain, a cool, moist growing season, followed by a bright, dry and warm ripening period of 6-8 weeks, with mean daily temperatures between 18 and 22°C is necessary (Percival, 1921). Rainfall requirements during the growing season vary from 300 to 750 mm depending on crop variety and other climatic conditions. The most sensitive stage for water requirement is 15 days before anthesis (Fisher, 1973).

b. Stages of Growth and Development of Wheat

Jensen and Lund (1971) have proposed a phenological scale system for wheat. For discussion here, six crop phenological stages will be adapted from Jensen and Lund to establish five growth and development periods.

Period 1. Planting to Emergence

Period 2. Emergence to Jointing

Period 3. Jointing to Heading

Period 4. Heading to Milk Stage

Period 5. Milk Stage to Total Ripeness

c. Weather Impact on Wheat Production

Weather is a major influence on wheat production in Central and South America. Wheat growth and development, as well as yield, are affected by weather conditions in different ways and at different times during the crop growth cycle.

Period 1. Soil moisture and soil temperature are the controlling factors during this period. Favereau et al (1968) showed that optimum temperatures for wheat germination were approximately 20-25°C and that at 14°C emergence was 43 percent below the optimum. Wheat seed will germinate at temperatures as low as 5°C and up to 35°C. Wheat seedlings have showed some drought resistant characteristics and slight water stress will enhance germination.

Period 2. This period is characterized by vegetative growth. Air temperature, soil moisture and solar radiation have a major impact on wheat growth. Some wheat varieties require vernalization (several days with temperatures between 5 to 8°C). Lack of vernalization will hamper future crop development. The effect of water stress will be most pronounced in those tissues in a rapid stage of development. Primordial initiation and cell enlargement are particularly susceptible to water stress (Slayter, 1969). Low solar radiation intensity tends to increase stem elongation (Kirby and Faris, 1970) while the rate of initiation, emergence and expansion of leaves increases to some extent with an increase in light intensity (Friend, 1965).

Period 3. This period marks the beginning of higher sensitivity to water stress (Figure 3.16) in relation to final crop yields. Water deficit during this period can reduce the rate of appearance of floral primordia (Husseen and Aspinall, 1970).

Period 4. This is the most sensitive period to water stress. Anthesis and fertilization are usually affected by water stress, causing large reductions in final grain yields (Figure 3.16). Frosts and extreme high temperatures can affect flowering and grain filling (Asana and Williams, 1965).

Period 5. Water stress is still important during the early portion of this

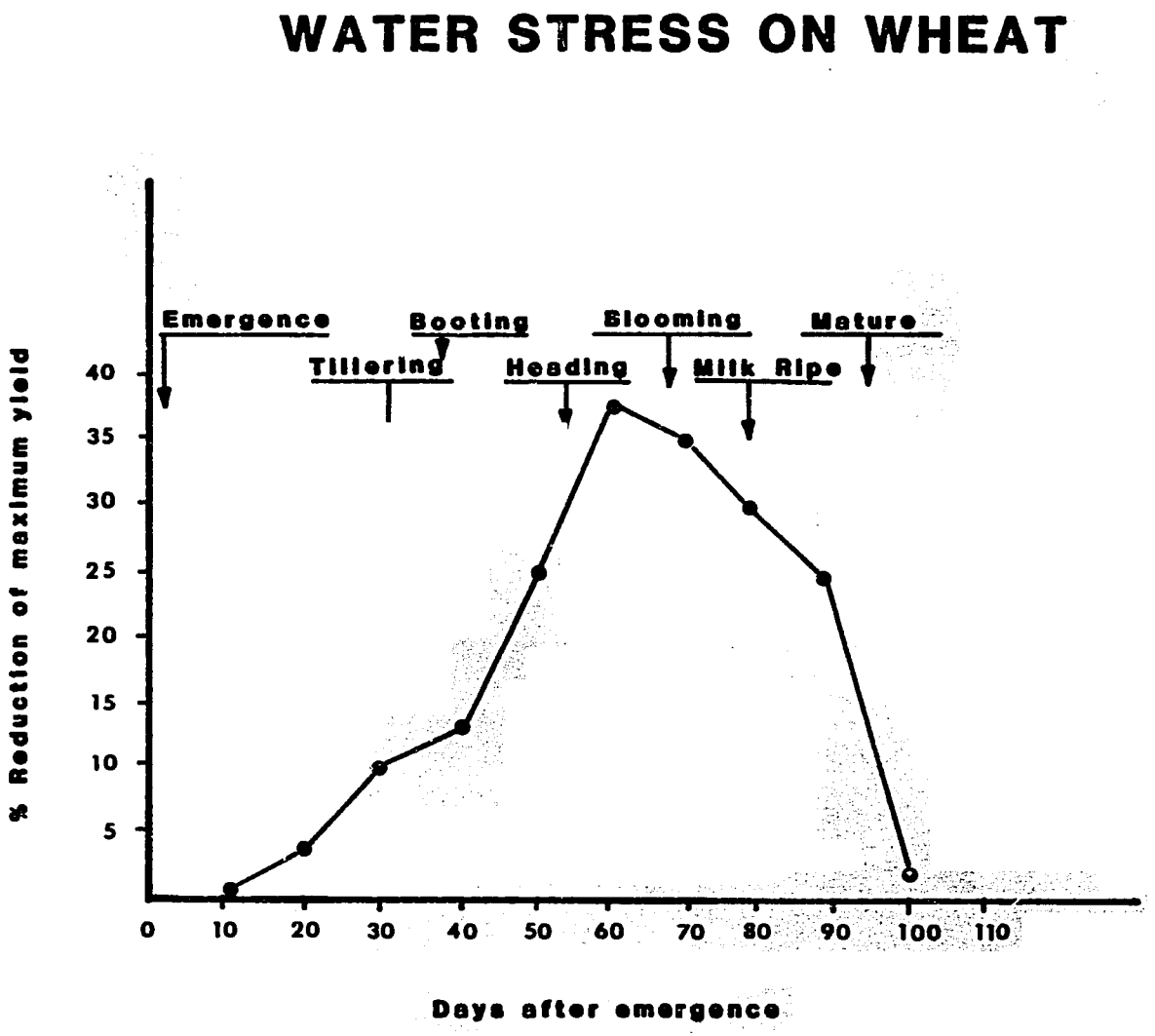


Figure 3.16. Water Stress on Wheat.

period because it results in loss of grain weight. During the ripening process dry weather conditions are beneficial.

In general, excessive moisture and high temperatures during any crop growth period tend to favor wheat diseases.

5. Potatoes

a. Climatic Requirements

The potato originated in South America in the highlands of Peru, Bolivia and Southern Chile. The best environmental conditions for potatoes are related to amount and distribution of rainfall, air and soil temperatures, length of the photoperiod and soil texture. Potatoes are sensitive to soil moisture from the time of planting until the tubers are fully formed. In areas with low rainfall there is a direct correlation between rainfall and yield of potatoes. Conversely, in areas or seasons with excessive rainfall an increase in rainfall may be associated with reduction in yield. Temperature affects tuber formation and yields of potatoes by influencing both the rate of photosynthesis and the rate of respiration. Optimum soil temperatures for tuber formation are from about 16° to 18°C. Usually no tubers are formed when soil temperatures are above 28°C. Potatoes are very sensitive to temperatures below 0°C and a frost-free period of about 4 months is required. Long, warm days are most suitable for the growth of tops in the potato but shorter days are more efficient for tuber formation (Long, 1961). Deep, sandy loams are best suited for the potato crop.

b. Stages of Growth and Development of Potatoes

The potato is normally branched but may be single stemmed. Each seed piece is capable of producing more than one individual stem and stem growth will continue with two or three periods of floral development. The first inflorescense

occurs terminally on the main stem with subsequent inflorescences occurring terminally on secondary branches of the main stem. It is not uncommon for stem growth to exceed 2 meters on vining indeterminant potatoes.

The crop phenological stages are: emergence, tuberization, tuber bulking and maturity. These growth stages delimit the following periods:

Period 1. Planting to Emergence

Period 2. Emergence to Tuberization

Period 3. Tuberization to Tuber Bulking

Period 4. Tuber Bulking to Maturity.

c. Weather Impact on Potato Production

Non-irrigated potato production is particularly affected by extreme temperatures and rainfall variability during specific phenological periods.

Period 1. Soil temperature and soil moisture are the controlling factors during this period. Bud or "eye" sprouting is adversely affected by low soil temperatures and lack of soil moisture.

Period 2. This period of rapid vegetative growth is mainly affected by late frost, and water stress. Periods of moderate water stress can result in decreased tuber yield and tuber quality.

Period 3. From the start of tuber formation, the majority of tubers are initiated over a 2 week period. Maximal penetration and density of roots are reached during this period. Water deficit is the major factor affecting both quantity and quality of tubers.

Period 4. Tuber enlargement is nearly linear for the 30 to 60 days of bulking. High temperatures and water stress cause a decrease in potato yield and potato quality.

6. Crop Calendar

a. Overview

Information on agricultural practices such as planting and harvesting dates is an essential input to crop condition assessment techniques. Weather impact on crop yield is closely related to the crop growth stages. Adverse weather conditions (particularly water stress and frost) during a critical growth stage will adversely affect the final yield more than at late maturity stages of crop development (Salter and Goode, 1967).

Planting and harvesting dates in Latin America at the country level have been published by FAS (1958) and FAO (1978). However, crop seasons vary with ecological conditions existent in the area of the country in which the crop is planted. Therefore, a regional crop calendar which considers the local ecological situation is needed for crop condition assessment. Unfortunately, crop calendar information is available on a regional basis for only a few scattered areas in Latin America (Sanchez, 1982; Canadas and Salvador, 1982).

b. Methodology

A regional crop calendar for corn, beans, wheat and potatoes was estimated using available meteorological and agricultural data. Corn and beans were selected because of their major role as staple food crops in tropical and subtropical American countries. Corn is a major leading indicator of the crop growing season either as a solo crop or intercropped with beans, pigeon peas or manioc. In semiarid regions, corn is replaced by sorghum because of its drought resistance characteristics. In temperate or cold climates (Andean highlands and Central and Southern Chile), wheat and potatoes become the major staple crops.

In estimating the crop calendar, the following steps were established:

1. Analysis of the temperature regime and the rainfall distribution of each agroclimatic region. These agroclimatic regions were developed by Atanas Todorov and verified/adjusted by Andres Ravelo (1982).
2. Analysis of the available agricultural information such as type of crops regionally planted, crop phenology, etc.
3. Statement of a set of assumptions to be used in developing the crop calendar.
4. Adjustment of the estimated crop calendar using available literature on planting and harvesting dates.

The assumptions used in developing the crop calendar are:

- The onset of the rainy season in those agroclimatic regions with a simple maximum rainfall distribution indicates the beginning of the growing season (land plowing and seeding). For instance, the Atlantic region in Colombia shows a regional single maximum rainfall distribution. The planting dates are assumed to be March and April (Figure 3.16).
- The agroclimatic regions with double maximum rainfall distribution can have two growing seasons (main and secondary) in a year. This could be the case for the Cauca region in Colombia, with planting taking place in March-April and September-October (Figure 3.17).
- The length of the growing season is basically a function of two weather parameters: rainfall and air temperature. Irrigation can extend the growing season. According to FAO (1975), in the lowlands of Colombia (i.e., the Pacific region) corn reaches maturity in about 120 days while

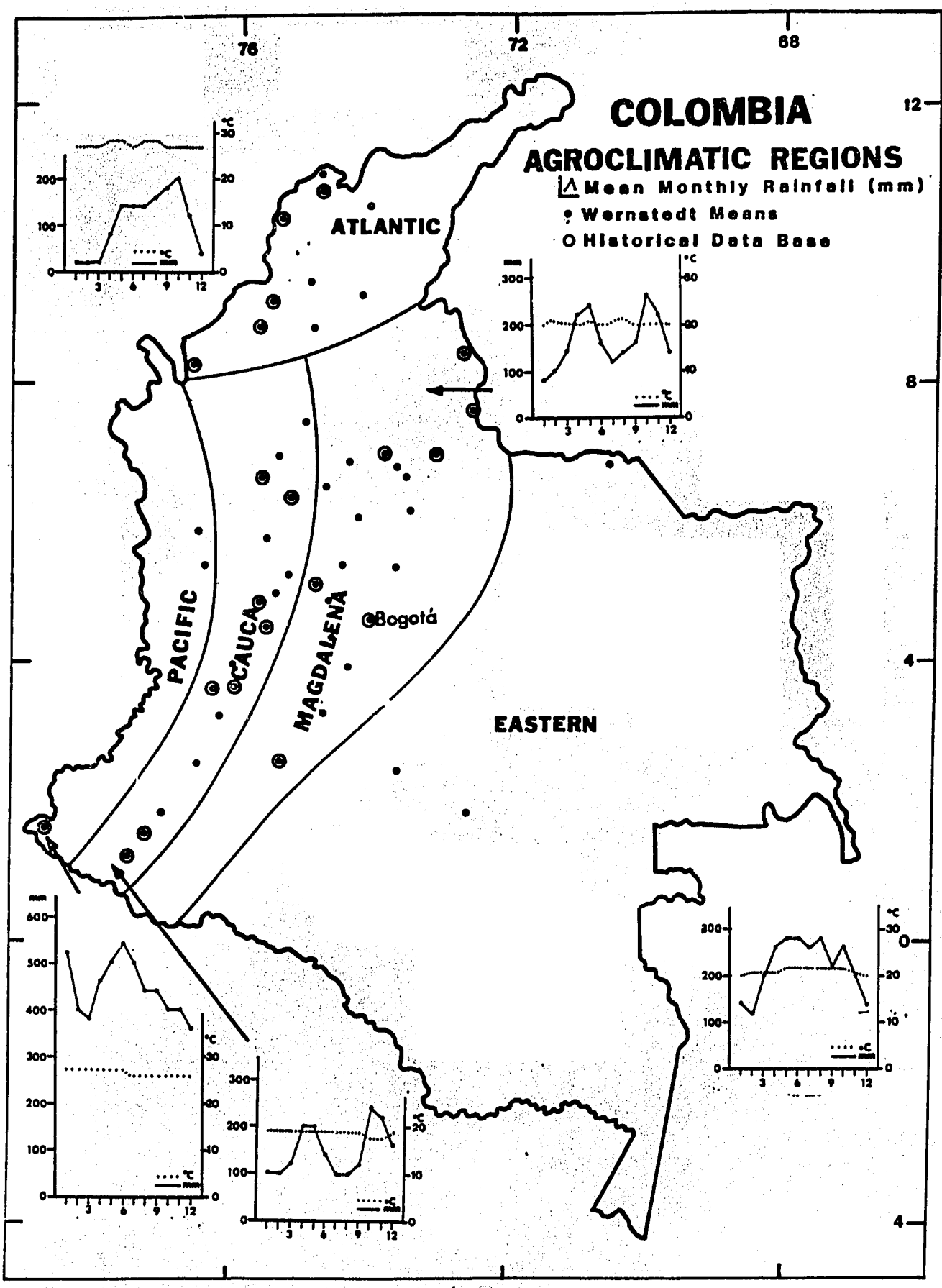


Figure 3.17. Agroclimatic Regions in Colombia Showing the Rainfall Distribution. The Temperature Regime is Indicated for Magdalena and Pacific Regions.

in the Colombian highlands (i.e., the Magdalena region) a corn crop takes over 300 days to mature. Figure 3.17 shows the rainfall and temperature regimes for both regions and Figure 3.18 illustrates the relationship between altitude and corn growth cycle.

c. Results and Discussion

The rainfall distribution and temperature regimes (or location elevation) and the set of assumptions previously stated were used to establish an estimated crop calendar for corn, beans, wheat and potatoes in each agroclimatic region of Central and South America. An example is shown for Peru in Table 3.6.

The estimated dates of planting and harvesting for selected crops were adjusted with available literature information.

Good agreement was found between the estimated and reported crop calendar (see Table 3.7) for some regions in Peru (Sanchez, 1982), Ecuador (Canadas and Salvador, 1982), Bolivia and Colombia (FAO, 1975), El Salvador, Venezuela and Guatemala (FAO, 1978). However, estimated planting and harvesting dates should be used with the qualification that local agricultural practices were not used in determining these dates. Also, rainfall amounts were only qualitatively assessed in affecting the crop growing season. Table 3.6 also shows when excessive rainfall conditions are likely to adversely affect the crop or when irrigation practices are needed for a successful crop.

d. Conclusions

- The estimated regional crop calendar can be used as a tool in developing agroclimatic indices.
- Further verification for other regions and countries is needed in order to validate the proposed crop calendar.

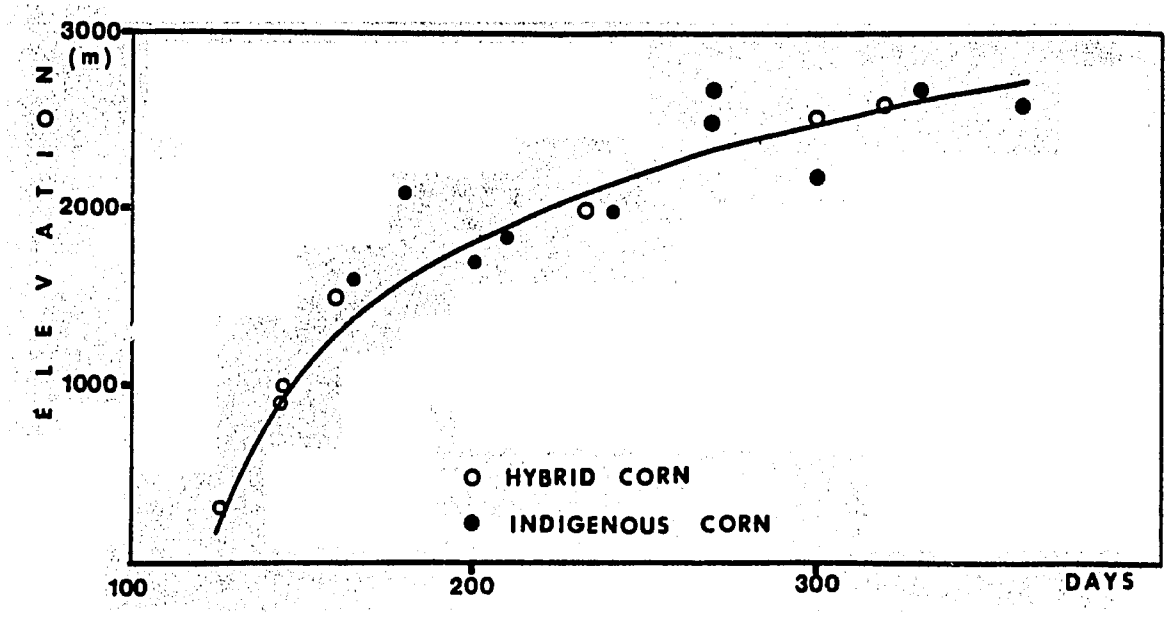


Figure 3.18. Relationship between location elevation and number of days to harvest for corn (hybrid and indigenous) grown in Colombia. (adapted from FAO, 1975)

TABLE 3.6. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN PERU

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn	//	//	//	//	//	OO	OO	OO	OO	OO			Extended crop season due to irrigation.
	Beans			//	//	//	//	OO	OO	OO				Irrigated.
	Rice	//	OO	OO	OO	OO	OO			//	//	//	//	Irrigated.
	Sugarcane	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Irrigated.
Northern Mountains	Corn	—	—	—	OO	OO	OO			//	//	//	//	Usually intercropped with beans and other crops.
	Beans	—	—	OO	OO	OO				//	//	//	//	
	Barley	//	//	—	—	OO	OO	OO				//	//	
	Rice	//	—	—	OO	OO	OO				//	//	//	
	Potatoes	//	—	OO	OO	OO					//	//	//	
Northeast Mountains	Corn	—	—	OO	OO	OO				//	//	//	//	
	Potatoes	—	—	—	OO	OO					//	//	//	
Eastern	Corn	//	—	—	—	OO	OO				//	//	//	
	Beans	—	OO	OO	OO						//	//	//	
Southern Mountains 1/	Corn	—	—	—	OO	OO				//	//	//	—	
	Beans	—	OO	OO						//	//	//	—	
	Wheat	//	—	—	—	OO	OO					//	//	
	Barley	//	—	—	—	OO	OO					//	//	
	Potatoes	—	OO	OO	OO					//	//	//	—	
Southeast	Corn	//	—	—	OO	OO	OO					//	//	
	Beans	//	—	OO	OO							//	//	
	Potatoes	—	—	OO	OO	OO					//	//	//	

1/Source: Sanchez, W.A.,(1982).

Table 3.7 Estimated and observed corn crop calendar for the highland regions of Bolivia, Colombia, Ecuador and Peru.

Country	Agroclimatic Region	Observed Dates		Estimated Dates	
		Planting	Harvesting	Planting	Harvesting
Bolivia	NW Mountains	Oct/Dec	Apr/Jul	Oct/Nov	Apr/May
	S Mountains	Oct/Dec	Apr/Jul	Oct/Dec	Apr/May
Colombia	Cauca	Oct	Mar/Apr	Sept/Oct	Feb/Mar
	Magdalena	Oct/Nov	May	Sept/Oct	May/June
Ecuador	Valleys	Dec	July	Oct/Nov	May
	E Mountains	Nov	July	Oct/Nov	June
Peru	S Mountains	Sept/Oct	May	Oct/Nov	April

CHAPTER IV

CENTRAL AMERICA: AGROCLIMATIC CONDITIONS AND MODELING

A. BELIZE

1. Physical Environment

Belize is located on the eastern side of the Yucatan Peninsula in Central America and has a mainland surface area of 22,966 square kilometers which span about 2.5 degrees latitude (from 16°N - 18.5°N). It is bordered on the north by Mexico, on the west and south by Guatemala and on the east by the Caribbean Sea (Figure 4.1). The Caribbean coastal waters are shallow for up to 70 km from the coast and are dotted with many small islands which form the Barrier Reef that adds an additional 301 square kilometers to Belize.

There are three major regions determined by physical characteristics: the Northern Lowlands, the Maya Mountains in the west-central part of the country and the Coastal Belt.

The soils are mostly infertile, thin, heavily leached or ill drained. There are some soils of high natural fertility; usually found in the south and west-central regions where soils are moderately well drained. Large areas are covered by dense secondary tropical rain forest. The better-drained slopes in the north are covered with pine trees or fairly open savanna. The lower slopes are characterized by low transitional, broadleaf forests. Mangrove swamps are commonly found along the coastal fringe.

The climate varies from wet tropical to dry subtropical and is affected by the extension of the warm equatorial current moving northwards to the Caribbean. Strong winds, notably from hurricanes prevalent from July to October are common. For the remainder of the year, Belize comes under the influence of the trade winds and cold northerly air masses, especially from December to February.

BELIZE

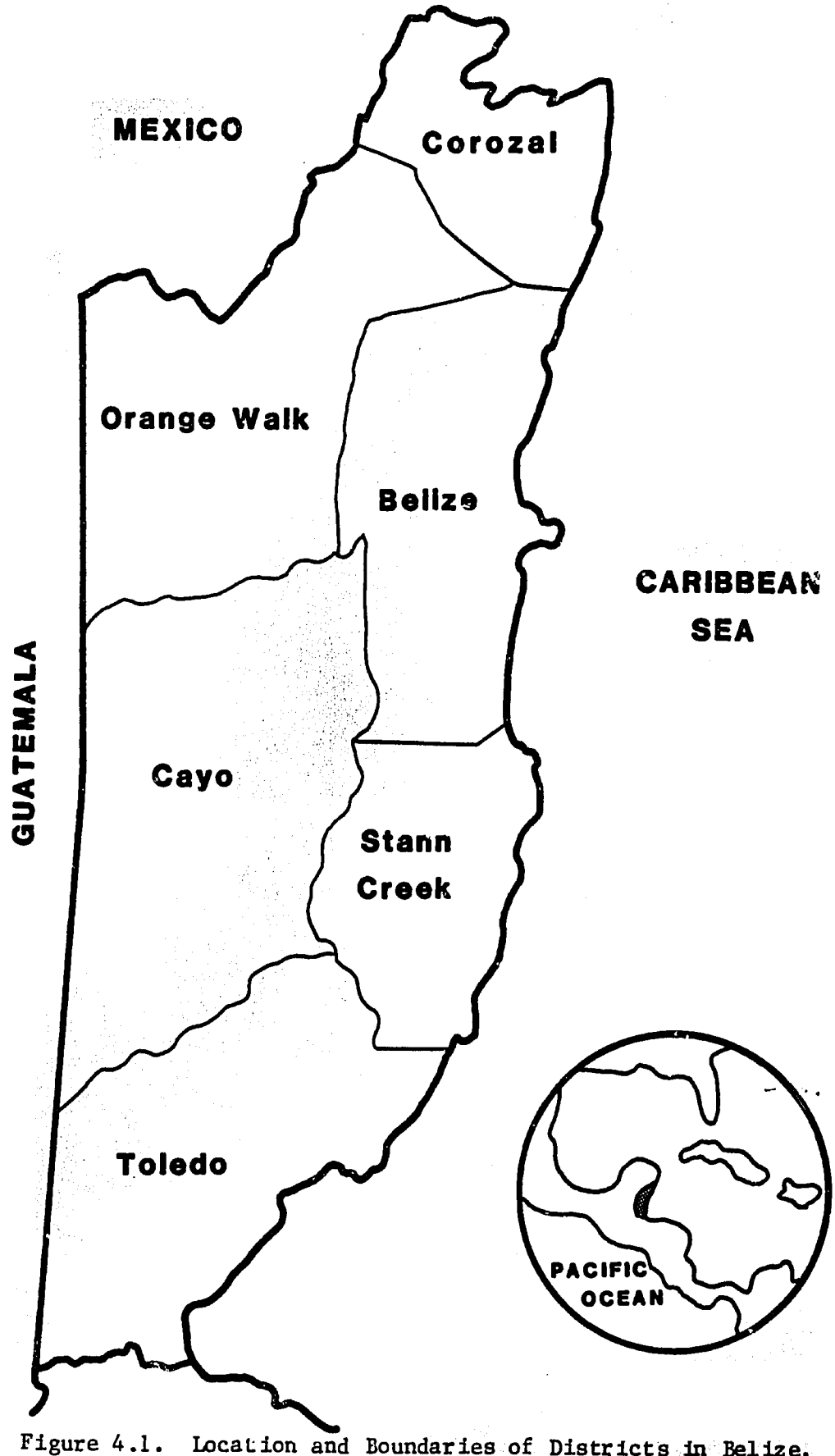


Figure 4.1. Location and Boundaries of Districts in Belize.

In the coastal areas of Belize, the temperatures range from 10°C to 35°C. The seasonal variations are greater inland with extremes ranging from 7.5°C to over 38°C. Upland temperatures average 22°C with temperatures dropping to below 5°C in November and December with the onset of the northerly winds.

The climate is marked by dry and wet seasons with intermittent frontal type precipitation occurring between the transition of the two. The annual wet season occurs at regular cycles and closely follows the periodic march of solar radiation intensity.

In the Northern Lowlands rainfall averages less than 1,500 mm per year; it increases steadily southwards and with altitude to exceed 4,800 mm in the southwest. The western border area lies in a rain shadow and temperatures are less extreme in this area. In the extensive swamp and lagoon areas along the coast, heavy rains frequently cause flooding.

2. Agricultural Practices

In Belize, farming takes place at both subsistence and commercial levels. Most subsistence farming is traditionally done by the Milpa system (Smith, 1980). The Milpa system was introduced by the Mayan civilization and it is based on clearing land by burning, utilizing animal power and timing activities to maximize the use of climatic resources. The system is very effective and has some impressive and favorable aspects; however, it is only appropriate for certain circumstances. Major disadvantages are soil erosion and deforestation. The major land preparation is done in the dry season from February to May and especially in March and April, the two driest months. During this period, most of the country experiences moderately dry, southeasterly winds which originate in the mountains of Honduras. It is by far the safest period for field work.

3. Principal Crops

a. Sugarcane

Most of the sugarcane is produced in Corozal and Orange Walk districts (Figure 4.2). It is grown commercially and production is not fully mechanized, so harvesting is done manually. Planting generally occurs in the spring (May-July); however, some planting also occurs in August, i.e., the fall planting. Harvest is generally during the dry season of April through June (Table 4.1).

b. Bananas

Bananas are major crops in Orange Walk and Stann Creek (Figure 4.2). They are also grown in Corozal and Toledo districts and are produced commercially with high technology including irrigation in Toledo.

Bananas can be planted anytime and generally bear after one year (Table 4.1). This industry is continually expanding and may be largely mechanized in the near future.

c. Rice

Rice is another commercial crop. It is mechanized from seeding to harvest and is intensely managed. It is grown as a major crop in half of the districts: Belize, Cayo and Toledo (Figure 4.2). Planting time for all rice crops is May and June while the harvest is November through January (Table 4.1). In Belize, paddy rice is fully mechanized and flood irrigated except in Cayo where the upland rice is planted by direct seeding, usually after the first rains but before flooding sets in if the area is susceptible to flooding. The upland rice is harvested about 125 days after planting. The paddy rice in Toledo is rain-fed and grown mainly for subsistence. However, production is rapidly increasing; goals are becoming more commercially oriented and improved technology is being introduced.

BELIZE

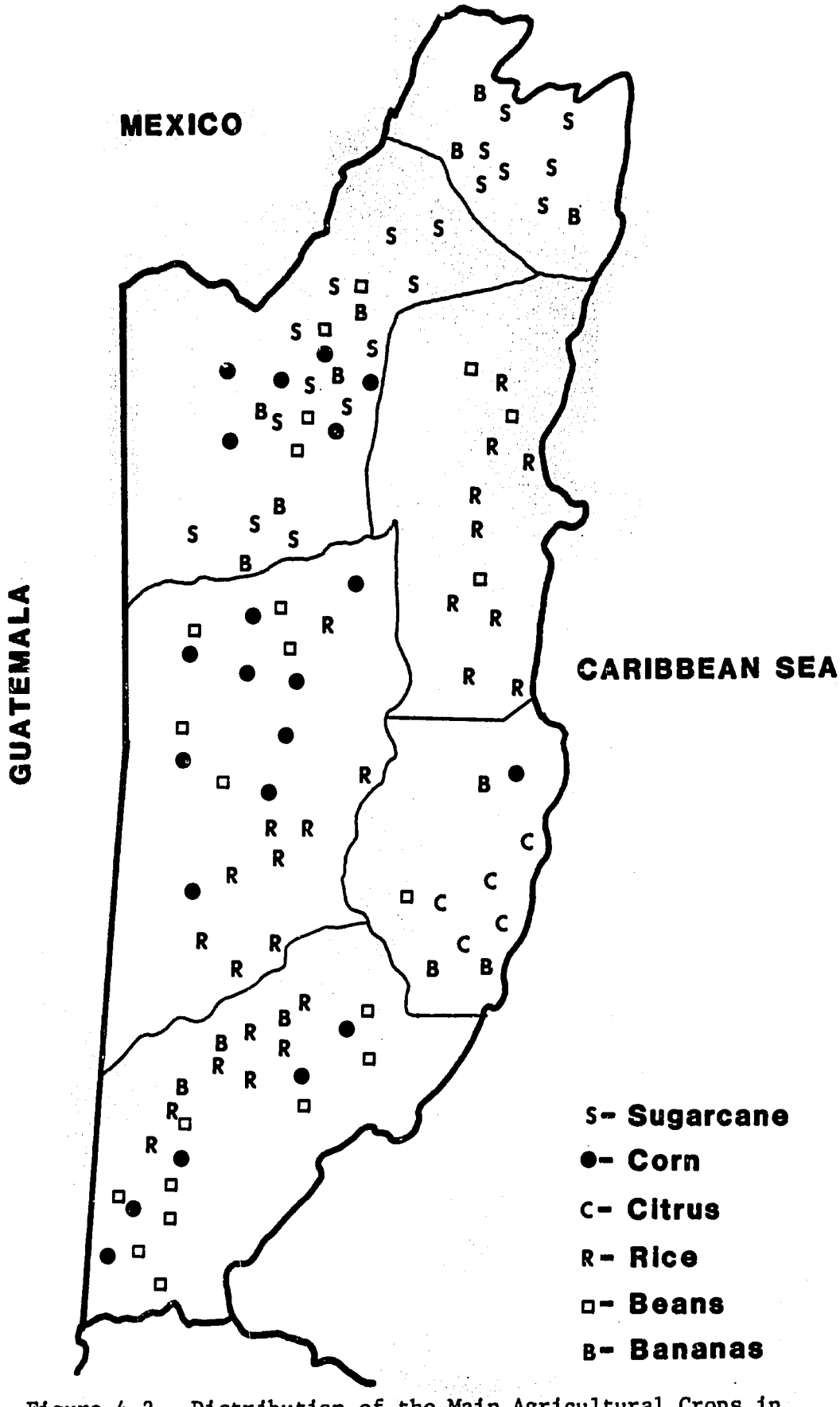


Figure 4.2. Distribution of the Main Agricultural Crops in Belize.

TABLE 4.1. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN BELIZE[1/]

//Planting, --Vegetative/Flowering, 00 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Northern	Corn					//	//	--	--	--	00	00	00	Improved and local varieties. May be intercropped with beans.
	Beans (green)	--	00	0								//	/-	
	Beans (dry)	--	--	00	0							//	/-	Include black-eye, red kidney and pinto beans.
	Sugarcane	--	--	--	00	00	0/	//	/-	--	--	--	--	
	Bananas	00	00	00	00	00	00	00	00	00	00	00	00	Harvested from 10 to 14 months after planting.
Southern	Corn					//	//	--	--	--	00	00	00	Sorghum has a similar crop calendar.
	Beans (green)	--	00	0								//	/-	
	Beans (dry)	--	--	00	0							//	/-	Cowpeas have a similar crop calendar.
	Rice (upland)	00					//	/-	--	--	--	00	00	Direct seedings after first rains.
	Bananas	00	00	00	00	00	00	00	00	00	00	00	00	

1/ Source: Smith, D.T., (1980).

d. Beans

Dry beans, green beans and cowpeas are major crops in Orange Walk, Cayo and Toledo. Planting is in November with harvesting during February through March (Table 4.1). Green beans in the north mature about 60-65 days after planting. All three crops mature earlier in the south. Corn, sorghum, sweet potatoes, yams and cassava are inter-cropped with beans.

e. Citrus

Citrus is a major commercial crop grown in the Stann district and is harvested manually in December through May. Although it is not fully mechanized, it is well managed.

f. Cacao

Cacao is another continuously expanding commercial crop. It is a major crop in Cayo and is harvested in August-March (first crop) and February-April (second crop).

4. Agroclimatic Indices

Figure 4.3 shows the historical Yield Moisture Index (YMI) in percentiles for Belize International Airport (Northern region). The YMI was computed for a corn crop during the main growing season (April-August). YMI values in the 5th to 10th percentile range at the end of the critical flowering period in July-August suggested the possibility of drought impact on corn crops during 1975. The critical YMI value for crop failure may be determined by using episodic data (Table 4.2) and historical crop yield data.

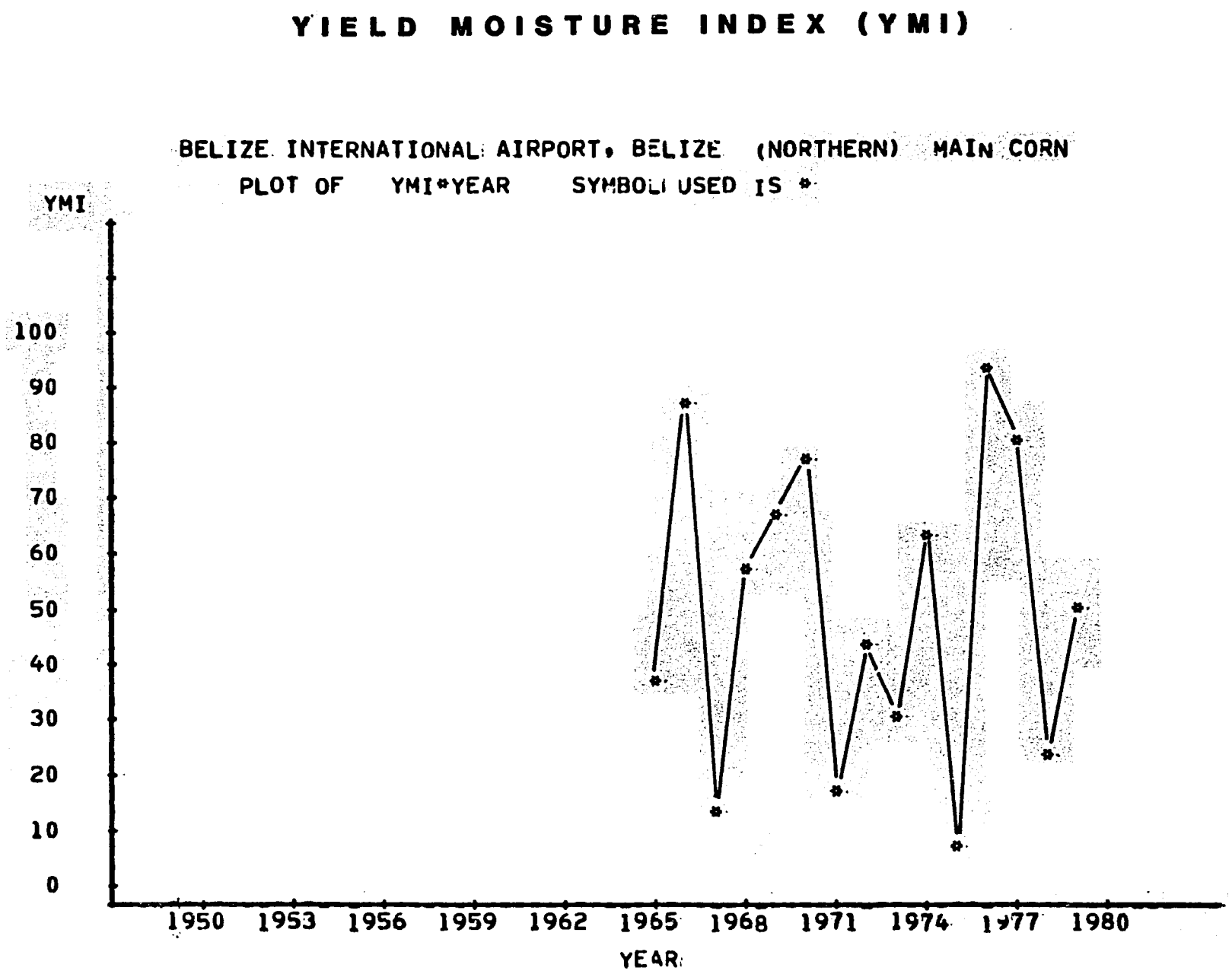


Figure 4.3. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Belize International Airport (Northern Region).

TABLE 4.2

BELIZE

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1961-62		Severe hurricane damage occurred. In 1961, hurricane Hattie damaged banana plantations.
1963-64		Dry weather and insects damaged sugarcane and birds reduced the corn crop.
1966		Excessive rain damaged the corn crop. Weather extremes and plant disease affected bean production.
1970		Panama disease decimated banana production on plantations in Stann Creek. Corn yields cut by blight.
1974		Hurricane Fifi, too little fertilizer and delayed planting cut corn yields.
1975		Countrywide drought.
1977		Drought occurred.
1978		Smut disease threatened sugarcane. Hurricane Greta affected crop yields.
1979	December	Extensive flooding occurred in central and coastal districts damaging the rice crop.

B. COSTA RICA

1. Physical Environment

The Republic of Costa Rica is one of the smallest and least populated of all Latin American countries. In 1980, its population was 2.3 million. The mainland area of 50,900 square kilometers is bordered by Nicaragua on the north and Panama on the southwest. It is divided into 8 provinces (Figure 4.4). There are seacoasts on the Pacific Ocean and the Caribbean Sea. The climate and topography are diverse, ranging from hot coastal lowlands to cold mountain peaks (Figure 4.5). Locally the physical structure is extremely complex but is broadly comprised of three major natural regions, according to Nuhn (1970): the Central Highlands, the Pacific Coastal Lowlands and Mountain Areas, and the Caribbean Lowlands (Figure 4.6).

The Central Highlands lie in a northwest-southwest direction and consist of a northern volcanic range (Cordillera de Guanacaste) of 1,500 to 3,300 m in altitude, and a southern mountain mass (Cordillera de Talamanca) reaching 4,200 m (Figure 4.5). This mass is formed by sediments of Tertiary age and granitic intrusions. These different mountain ranges are separated by a small upland and inter-mountain basin area called the Meseta Central which ranges between 600 and 1,200 m in altitude. From a climatic standpoint, this region is considered as "tierra templada" (temperate land), with mean annual temperatures ranging from 10 to 27°C (Gutierrez Braun, 1959). The capital city of San Jose, located in this region, receives a mean annual rainfall of 1,855 mm with mean relative humidity of 78 percent.

The Costa Rican Pacific coastline is broken by a series of faultline peninsulas and gulfs. Because mean annual temperature is above 22°C, this

COSTA RICA

Figure 4.4. Provinces of Costa Rica.

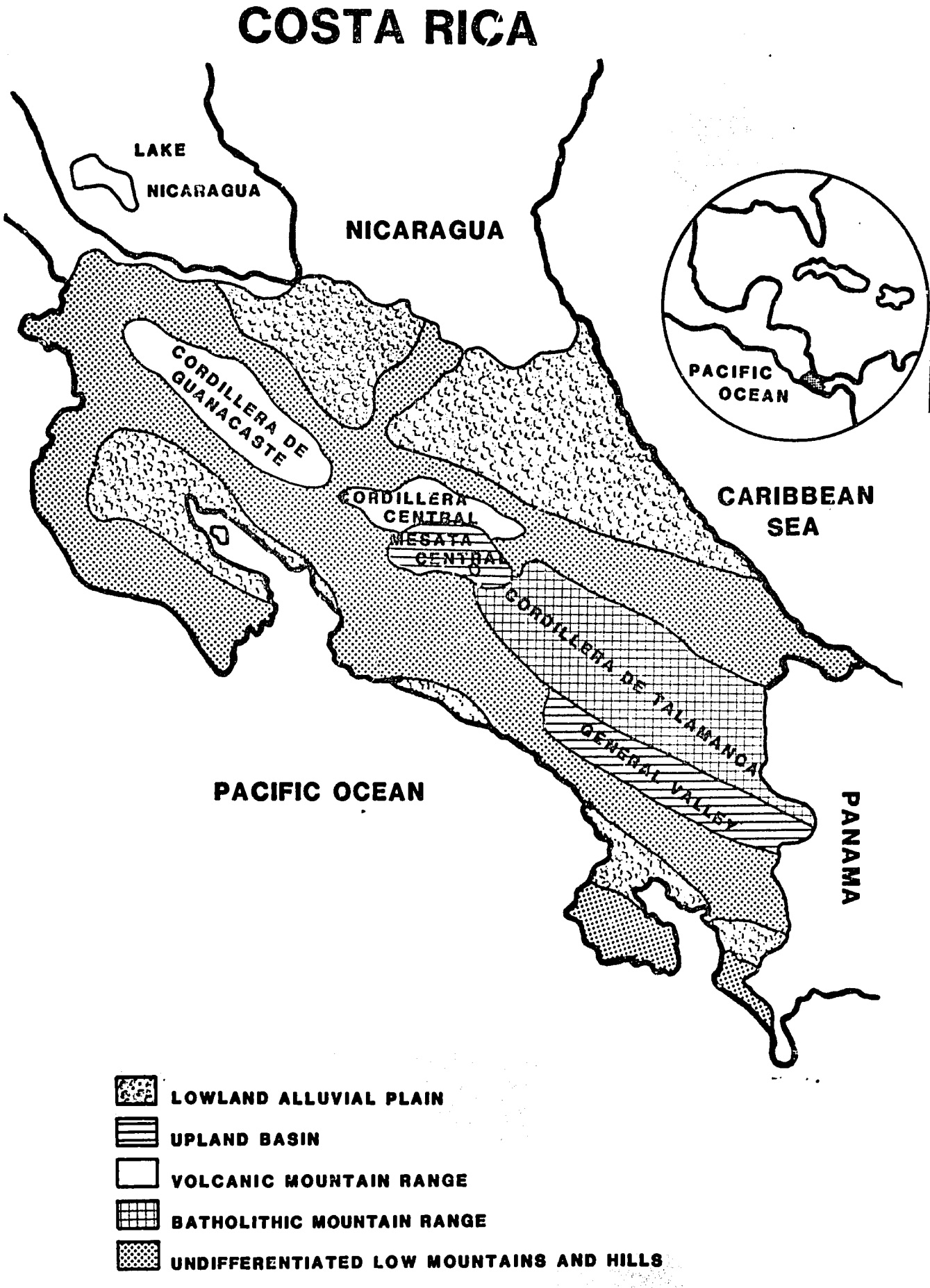


Figure 4.5. Major Physical Features of Costa Rica.

COSTA RICA

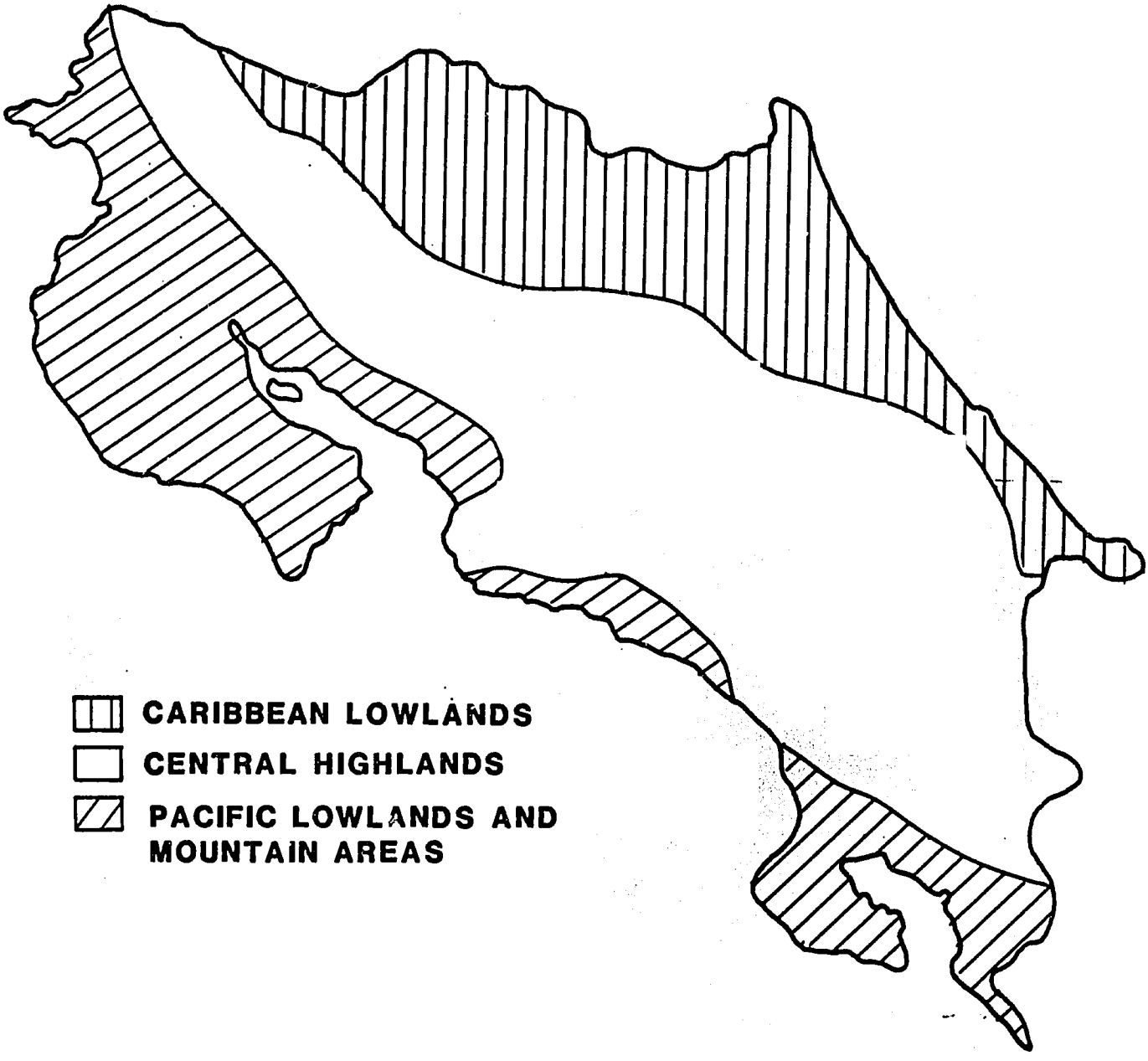


Figure 4.6. Natural Regions of Costa Rica.

region is classified as "tierra caliente" (hot land). Annual rainfall fluctuates from 1,000 to 2,000 mm. The wettest months are June, September, and October while significant reductions occur from January through April (Blutstein et al, 1970).

The Caribbean Lowlands are composed of a number of large alluvial plains separated by low, rolling hills. The largest of these alluvial plains is the San Juan River basin and the Llanos de Santa Clara. Large alluvial flats combine to form a continuous alluvial plain. Also classified as "tierra caliente", the Caribbean Lowlands receive between 3,000 and 4,000 mm of rain per year, with a maximum of 6,000 mm near the Colorado River mouth. December, June, and September, in decreasing order of magnitude, are the months with the highest precipitation (Blutstein, 1970).

The Pacific Coastal Lowlands are small and broken while the Caribbean Lowlands, in contrast, are continuous. They form a wedge which tapers rapidly towards the southeastern border of the country.

2. Agricultural Practices

The economy of Costa Rica is based almost exclusively upon the export of agricultural products. Indeed, agriculture accounts for more than a third of the country's gross domestic product and employs about two-thirds of the Costa Rican labor force. Nuhn (1970) reports that in 1969, 60 percent of the total land area, or 25,450 square kilometers was occupied by farms ("fincas"). In addition, some 13,000 square kilometers of potentially cultivable land offer good opportunities for economic growth.

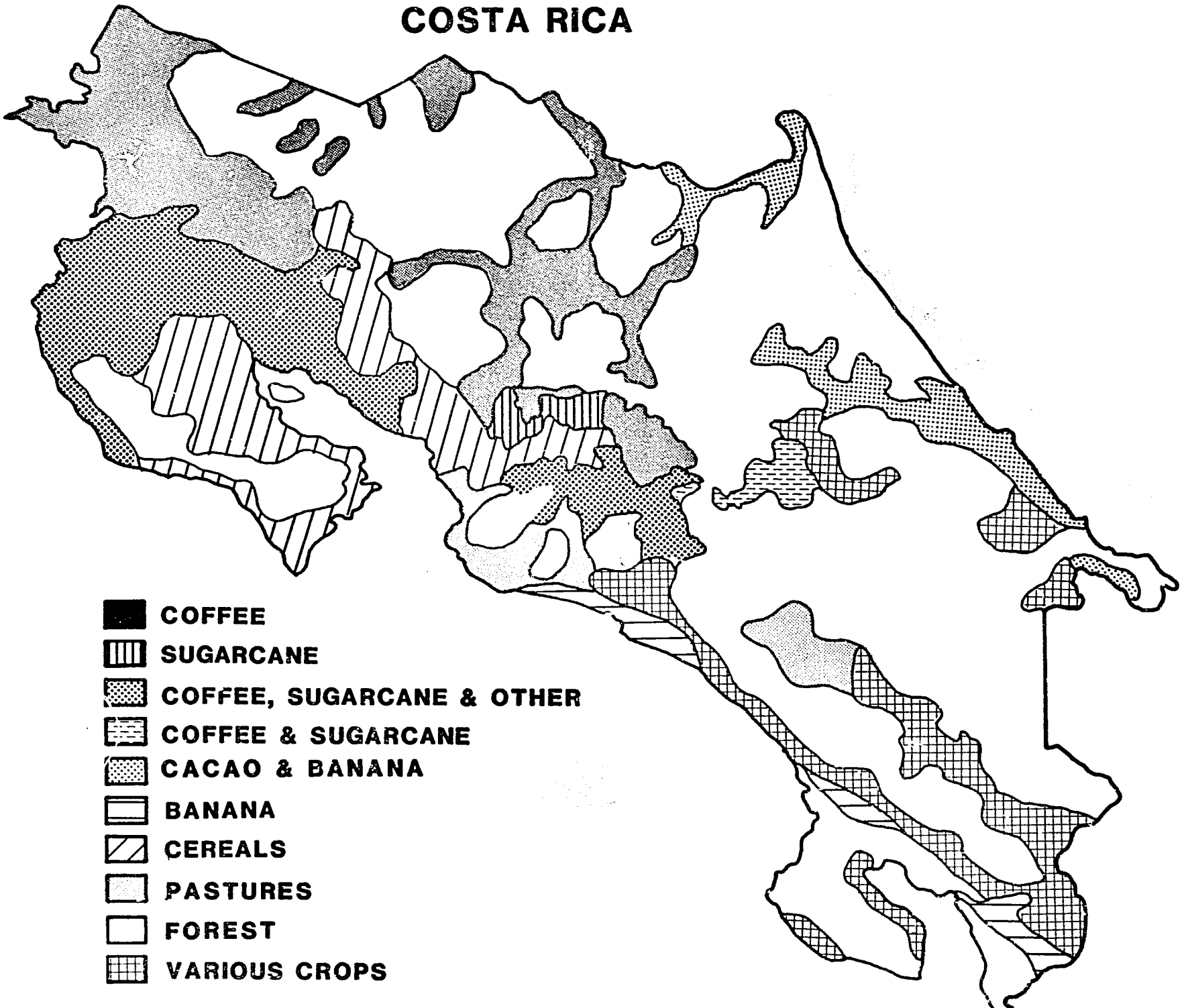
Much of the food grown is directly consumed by the farm families who raise it. Agricultural products are also widely sold for domestic consumption.

May et al, (1952) divide Costa Rica into four agricultural regions: a) the

Central Plateau (Meseta Central), characterized by the production of coffee, sugarcane, dairy products, corn, beans, rice, and potatoes; b) the Atlantic Lowlands with some cacao and abaca operations; c) the Guanacaste Province devoted to the production of beef, corn, beans, and rice; and d) the Southwest, noted mainly for the production of bananas and rice (Figures 4.4 and 4.7). According to the Costa Rican Bureau of Statistics and the Census, the country can also be divided into ten agricultural regions based upon crop production (Figure 4.7).

Most farmers cultivate the land by primitive methods and without organized production plans. However, the technology is fairly modern compared to other Central American countries. About 50 percent of all farmers use bill-hooks, spades, and hoes to cultivate their land while the other 50 percent use animals to pull simple farm tools such as plows or are adequately mechanized. The latter included farms of at least 700 ha whose production was chiefly export oriented.

In 1969, irrigation was still limited to a small number of farms (3 percent), particularly those growing sugarcane (Blutstein, 1970). An even smaller proportion of the farmers used modern chemical weeding and crop spraying techniques. Most agricultural and stockraising activity is conducted on small and medium sized family-owned farms; in 1973, 81% of the farms in Costa Rica were properties of less than 50 hectares. These small farms are the major producers of corn, beans, and milk, staples in the Costa Rican diet. Until 1975, the GOCR promoted the development and production of crops for export. This resulted in a decline in production of crops for domestic consumption, requiring purchases from aboard to supplement the food supply.


COSTA RICA
COFFEE
SUGARCANE
COFFEE, SUGARCANE & OTHER
COFFEE & SUGARCANE
CACAO & BANANA
BANANA
CEREALS
PASTURES
FOREST
VARIOUS CROPS

3. Principal Crops

The principal agricultural crops of Costa Rica are:

1) crops for domestic consumption, including corn, beans, rice, potatoes and sugarcane and

2) export crops, including bananas, coffee, cacao, and abaca.

Other crops grown for food are yucca (used as a substitute for wheat), plantains, pineapples, oranges, tomatoes, peanuts, and sesame.

Table 4.3 shows the estimated regional crop calendar for subsistence farming in Costa Rica.

a. Corn

Corn is the second most important domestic food crop. It is a source of farm income and a contribution to the energy value of the diet. It is grown on small farms over most of the country. Corn yields in Costa Rica are extremely low, less than 37 bushels per ha, because more than half of the corn production is on the Central Plateau where the hilly terrain permits only primitive cultivation methods (Blutstein, 1970). Some government programs make fertilizers available to corn farmers.

In the Atlantic Lowlands and in the Guanacaste Province, there are some areas where corn matures in three months and two crops a year could be grown. These areas are reportedly able to produce yields approximately equivalent to those in the United States -- 100 bushels per acre. In both regions, mechanization of the planting and cultivation is possible, in contrast to the hills. The only obstacle to production is the high year-round rainfall that prevents adequate drying.

Improved corn yields call for shifting to other areas and mechanizing the production. Futhermore, additional research on high-yield varieties suited for the new areas should be carried out.

TABLE 4.3. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN COSTA RICA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Western	Corn			//	//	/-	—	—	OO	OO				Local and improved varieties.
		OO						//	//	/-	—	—	OO	
	Rice			//	//	/-	—	—	OO	OO				
		OO						//	//	/-	—	—	OO	Irrigated and Upland.
	Beans			//	//	/-	-O	OO	O-	//	/-	-O	OO	Matures 65-80 days after planting.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Harvested throughout the year.
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	OO	OO	Harvested from 12 to 18 months after planting/cutting.
	Sorghum			/	//	—	—	—	OO	OO				
Central	Corn			//	//	/-	—	—	OO	OO				
		OO						//	//	/-	—	—	OO	
	Beans			//	//	/-	-O	OO	O					Growing season for dry beans is 30 to 45 days longer.
		OO							//	//	/-	—	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Atlantic	Corn				//	/-	—	—	OO	O				
									/	//	—	—	OO	
	Rice				//	//	—	—	—	OO	OO			
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Southern	Corn			//	/-	—	—	OO	OO					
									//	/-	—	OO	OO	
	Beans			//	//	—	OO	OO						
	Rice			//	/-	—	—	—	OO	OO				
	Sorghum			//	/-	—	—	—	-O	OO	O			
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

b. Beans

Beans are third among the domestic crops in terms of income to farmers. They are mostly grown on small lots scattered throughout the country, but one-third of the total production comes from the Central Plateau. Fertilizer and insecticides are used in some areas. Costa Rica is close to self-sufficiency in the production of beans (Nuhn, 1970).

c. Rice

Rice is grown on small plots in all parts of the country, but the heaviest production is in the Southwest. The cultivation of rice in this region demands very little care and no irrigation to produce two crops a year of a quality grain. However, production does not satisfy domestic needs and foreign rice has to be imported to fill the deficit.

Some rice producers utilize fertilizers and insecticides. The owners of large farms have modern machinery and irrigate their rice fields, particularly those in the Guanacaste Province, where the expansion of rice production appears to offer good possibilities (Nuhn, 1970). The Costa Rican Ministry of Agriculture has been conducting some research directed towards finding a disease-resistant variety.

d. Bananas

The economy of Costa Rica is heavily dependent upon the production of bananas and coffee. In fact, Costa Rica is one of the largest exporters of bananas in the world; in the Western hemisphere, its production is exceeded only by Brazil, Ecuador, and Honduras (FAO, 1977).

Although bananas grow naturally in Costa Rica, they were not an important export crop in the past and went into absolute waste for many years (Villafranca, 1895). Even at the present time, some peasants use the fruit to

feed pigs while many others keep a few plants in their back yards and use the green fruit, boiled with salt or roasted on hot coals, as a substitute for bread. Banana trees are also planted in some small coffee plantations to shade the young trees and to protect the coffee berries against the wind before ripening.

Bananas are cultivated on tropical, coastal lowlands where the climate is uniformly hot and humid. The soils chosen for the production of bananas on a commercial scale are those containing extensive alluvial deposits consisting chiefly of blue clay and rich in decomposed litter. Bananas grow best in places with abundant rainfall or where the soil is damp (Bureau of American Republics, 1892).

On the large plantations, banana trees are planted 4 to 6 m apart in "cuadros" or square areas of varying size. The plants mature in 9 months and after that time the fruit can be gathered every week during the year. Planters usually cut the tree in order to gather the fruit; otherwise, the tree is felled after the bunch (consisting of 32 to 144 bananas each) has been cut (May et al, 1952).

The manner in which bananas are cultivated requires very little skill or labor, nature doing almost all of the work. However, clearing of new land, burning, weeding, and spraying require large capital investments, some of them a year and a half before any crop can be harvested.

Large banana plantations were in operation on the Atlantic coast of Costa Rica until the mid-1930's. At this point they were shifted to the Pacific coast due to the ravages of a fungus known as "Panama disease" (May et al, 1952). In addition, the plantations are often attacked by the "Sigatoka disease." This is a leaf blight that can be controlled only through continuous treatment. The large companies pay special attention to disease control as well as to soil preparation, use of fertilizer, and modern cultivation techniques.

e. Other Crops

Sugarcane

Sugarcane is the most important food crop grown for domestic consumption. It furnishes more income to farmers and at the same time more energy to the diet than any other domestic food product. The production of sugarcane is concentrated in a small area of the Central Plateau at elevations between 700 and 1,400 m, where it requires 18 to 22 months to reach full maturity (May et al, 1952). Other regions, however, can produce a 12-month cane if adequate irrigation is applied.

Most of the cane plantations are small. Sixty percent of them are less than 2 manzanas, or 1.4 ha in size and the largest ones (over 100 manzanas) account for only 0.3 percent of the total number of plantations (Nuhn, 1970). Large farms utilize irrigation, fertilizers, and more efficient machinery, and often have their own sugar refineries called "ingenios."

Sugar production in Costa Rica could be increased through seed selection, more extensive use of fertilizers and improved cultivation practices or shifting production to the zones where cane will mature within a year.

Coffee

Coffee has traditionally been Costa Rica's most important export crop. It furnishes employment, at least part of the year, to one out of every six persons in the entire country and uses 50 percent more land than any other crop (Nuhn, 1970).

Coffee plantations are concentrated in the heart of the Central Plateau, at elevations of 800 to 1,400 m above sea level. This region has a relatively flat terrain, with mean annual temperatures varying from 10 to 27°C and a mean annual rainfall of about 1,900 mm.

As other export crops, coffee is grown with the most mechanization. There is an increasing use of fertilizers, irrigation, pesticides, and soil conservation techniques.

Cacao

Cacao is important to Costa Rica's economy, although the country's crop is small compared to total world output. Cacao is one of the permanent crops that follows the production of bananas when diseases force abandonment. Therefore, it is grown by the large banana companies although its production is also feasible for small operators. However, the small producer provides little care to his cacao trees and inadequately cares for the pods and beans.

A fungus disease known as "pod rot" has made progressive inroads on the cacao plantations of Costa Rica. Apparently the fungus can be controlled by spraying with copper compounds. Moreover, the development of disease-resistant, high-producing stock by the Costa Rican Ministry of Agriculture has helped solve the problem and allowed expansion in the production of this traditional export crop.

4. Agroclimatic Indices

Figure 4.8 shows the historical Yield Moisture Index (YMI) in percentiles for San Jose (Central Region). The YMI was computed for a corn crop during the main growing season (August-December). Drought impact to crops during the 1953, 1959 and 1972 growing seasons is suggested by YMI values in the 5th to 10th percentile range. The critical YMI value for crop failure may be determined by using episodic data (Table 4.4) and historical crop yield data.

YIELD MOISTURE INDEX (YMI)

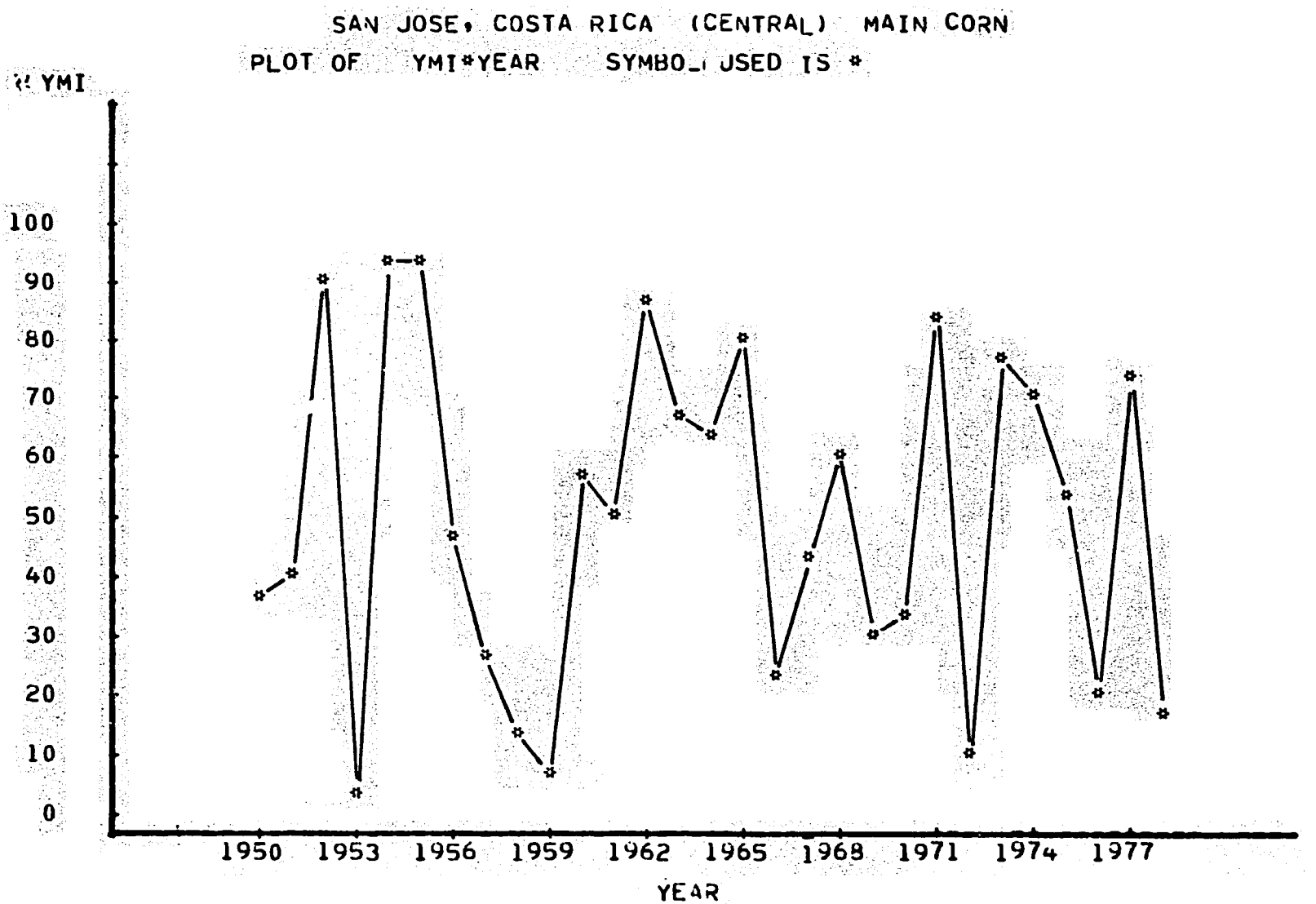


Figure 4.8. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at San Jose (Central Region).

TABLE 4.4

COSTA RICA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1955		Water and wind destroyed crops.
1957		Drought affected crops.
1960-61		Severe blowdowns lowered banana output.
1962-63		Decreased rice production resulted from decreased acreage, late planting and reduced yields.
1963		Volcanic eruptions heavily damaged crops on the central plateau. Early rains reduced the cacao crop. Dry weather reduced rice production.
1964		Drought, insects and volcanic activity sharply cut crop production. Drought in Guanacaste Province damaged corn and rice.
1968		Mt. Arenal's eruption disrupted agricultural growth.
1970		Floods caused considerable damage.
1974		Lack of moisture affected rice production.
1975		Floods reduced rice and bean output.
1976		Severe drought and disease affected rice in the major growing areas, especially the southern zone.
1977		The Guanacaste region was affected by drought in July. Continuing dry weather centered in the Pacific lowlands, caused agricultural decline.
1978		Dry weather reduced the late 1978 corn and bean harvests.

TABLE 4.4

COSTA RICA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1979		Bad weather and plant disease affected agricultural output.
1980		Adverse weather, plant disease, labor problems and high cost of inputs resulted in decline of food production.
1982	September	Drought continued in Guanacaste province causing huge losses in rice, corn, and other crops.

C. EL SALVADOR

1. Physical Environment

The Republic of El Salvador, located on the Pacific Coast of Central America, is the smallest mainland nation of the Western Hemisphere with a total area of 20,935 square kilometers. It is bounded by Guatemala on the west, Honduras on the north and east, and the Pacific Ocean on the South (Figure 4.9). Thus, El Salvador is the only Central American country without a coastline on the Caribbean Sea. Its varied terrain ranges from tropical lowlands on the Pacific coastal plain to arid semi-desert in the mountainous region of the north (Blutstein, et al, 1971).

El Salvador lies entirely within the Central American volcanic axis. Two parallel chains of dormant and active volcanoes extend east-west through the country. The southern range (Cadena Costera or Coastal Range) contains the highest peak (Volcan Santa Ana, 2,340 m) while the northern range (Sierra Madre) is generally lower and less continuous. Low, flat alluvial basins (the Central Lowlands and the valley of the Rio Lempa) are found between the ranges of single peaks and extensive plains existing along the south coast.

The mountain ranges divide the country into three distinct physical zones, based primarily on elevation. The southern coastal plain is called the "tierra caliente" (torrid land). It consists of a narrow, relatively flat belt which extends from the Guatemalan border to the Gulf of Fonseca. The Cadena Costera (Coastal Range) forms the northern demarcation of the torrid zone, which is bounded by the Pacific Ocean on the South. The northernmost latitudinal zone is known as the "tierra fria" (cold land). It comprises the northern lowlands formed by the valley of the Rio Lempa and the Sierra Madre. The term "tierra

Figure 4.9. Location and Boundaries of El Salvador.

fria" is not appropriate, as the area is predominantly warm. Between the two mountain-demarcated zones lie the central highlands called the "tierra templada" (temperate land). This plateau, some 600 m in elevation, includes most of the national territory.

Because of the country's small size and compact physical structure, climatic conditions are relatively uniform in its three zones, with no pronounced extremes distinguishing one from another. Temperatures vary generally with altitude with maximum temperature and humidity along the coastal lowlands, while the central plateau has a temperate, almost semi-tropical climate. Coolest temperatures are found in the northern mountains. In general, the climate is warm (rather than hot) with mean annual temperatures ranging from 23°C in the "tierra fria" to 27°C in the "tierra caliente."

There are two distinct and well-defined seasons: the dry, called the "verano," and the wet, or "invierno." The rainy season lasts from May to October and sometimes extends into early December. The mean annual rainfall for the country is 1,830 mm. In June and September, however, "temporales," or heavy rains, bring persistent overcast and torrential downpours for several days or even weeks, and precipitation then averages about 254 mm monthly, causing floods that render large tracts of rich land uncultivable.

The country is fortunate with respect to the weather hazards of winds and hurricanes that beset surrounding countries. El Salvador is infrequently subjected to gales of high-pressure polar air that drive down from the north in strong, gusty storms, causing minor damage to crops.

Five major natural regions can be distinguished in El Salvador (Figure 4.10). The Coastal Lowlands (A1) are characterized by mangrove swamps, humid forests and semi-humid savannas. In the Central Depression (A2) and the Lempa Valley (A3),

EL SALVADOR

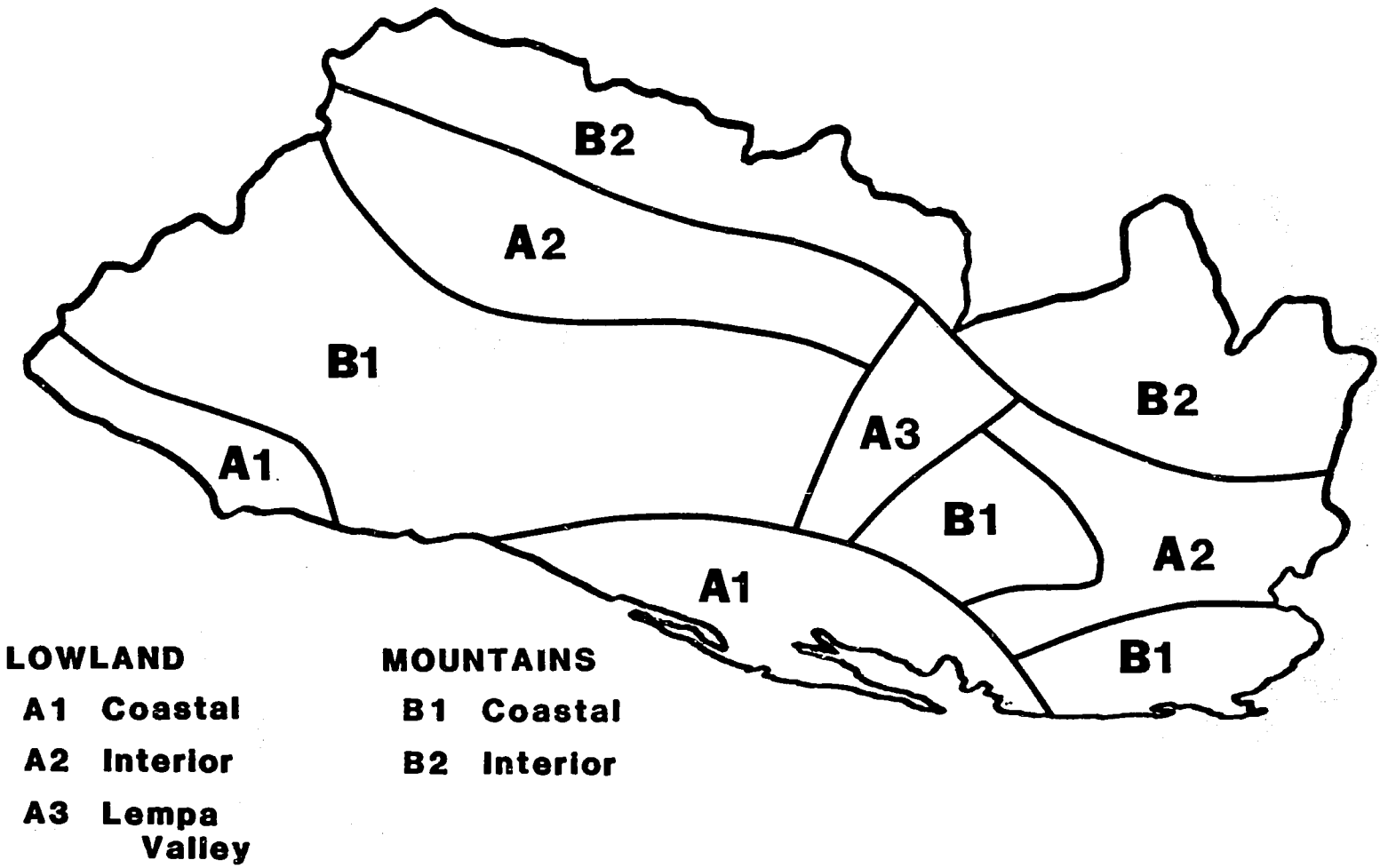


Figure 4.10. Natural Regions of El Salvador.

evergreen forests and chaparral are commonly found, although most of the forests have been cleared and replaced by arable land or permanent pasture. The Coastal Highlands (B1) and the Interior Highlands (B2) are characterized by a marked altitudinal zonation of the natural vegetation. Semi-humid forest covers most of the land below 800 m. Between 800 and 1,800 m temperate forests of oak and pine can be found, but most of this land is used for coffee plantations and livestock ranching. Average temperatures rarely exceed 17°C above 1,800 m elevations and needleleaf evergreen forests are dominant.

2. Agricultural Practices

Although El Salvador is the most industrialized of the Central American republics, over 70 percent of the economically active population is engaged in agriculture. In 1970 agriculture provided one-fourth of the gross national product and generated 90 percent of the nation's foreign exchange (Menendez, 1970).

Land is in short supply, and most of the better acreage is intensively cultivated. Yields of some market crops, notably coffee and cotton, are among the highest in the world, partly because of the unusual amount of fertile land with rich volcanic soils. Overall, some 40 percent of the country's land area is in crops, with coffee taking about 25 percent. Most farms are extremely small. In 1970, 91 percent of them were under 10 ha (22 percent of total farmland) while only 0.1 percent were over 500 ha in size (24 percent of total farmland). The highest proportion of land under cultivation is found along the Pacific coast.

The agricultural system is dualistic. Commercial farming is practiced on the best lands by the upper classes, producing crops chiefly for export. It is concentrated in large continuous tracts of the Coastal Range and the Coastal

Lowlands and in a few patches in the interior lowlands. Subsistence cultivation of small hillside plots by the bulk of the rural population produces most of the food crops. These subsistence farms are found in great numbers on the less desirable steeper slopes. Cultivation practices vary widely from one crop to another. Coffee growers, for example, depend heavily on semi-skilled agricultural labor, since growing coffee on slopes under the shade of other trees makes the use of machinery difficult. In contrast, machinery is extensively used in cotton farming which is also characterized by the use of fertilizer as well as insect and disease control measures. Some areas have been improved through irrigation systems, flood control, land drainage, and soil conservation techniques.

In 1980, the beginning of the first phase of implementation of the Agrarian Reform Law substantially affected the structure of the agricultural sector. During the year, the Salvadorean Agrarian Transformation Institute (ISTA) expropriated 270 farms of more than 500 hectares each, covering a total area of approximately 216,000 hectares. These farms were devoted principally to traditional export crops and stockraising, and accounted for about 15% of the arable land, including some of the most fertile land in the country.

Another important reform was the establishment of government monopolies for sugar and coffee exports. The National Sugar Institute also assumed responsibility for the management of some large sugar mills.

These institutional changes, coupled with financing, labor, weather, and input supply problems, affected the normal development of agricultural activities. Real GDP of the sector declined 6.5 percent in 1980 after rising 1.5 percent in 1979 and at an annual rate of 1.7 percent in 1976-78. Coffee production fell by 5.3 percent due to the above-mentioned problems as well as the presence of rust. The 43 percent decrease in cotton output was due to the cutback in the

area planted and to smaller yields caused by lack of fertilizer and other inputs. Sugarcane production fell by 25 percent as a result of the sharp reduction in the area cultivated and of cane burning on plantations. The output of basic grains was more favorable than that of export crops, reflecting the predominance of small holdings not subject to the agrarian reform.

3. Principal Crops

The basic food crops, which occupy most of the cropland, are corn, beans, rice, and grain sorghum. The most important export crops are coffee, cotton and sugar.

Most staple crops, such as corn, beans, rice and sorghum are grown on small subsistence farms. On steep slopes, the "dibble" or planting stick is used after the vegetation has been cleared by the "slash and burn" technique. On gentler slopes the ox-drawn wooden plow replaces the "dibble". Soils are rarely fertilized or fallowed and become infertile very quickly.

Table 4.5 shows the regional crop calendar for subsistence farming in El Salvador.

a. Corn and Beans

Corn and beans are the basic foods in El Salvador and are frequently grown together with beans planted between rows of corn. Corn, in particular, is grown virtually everywhere, but the heaviest concentrations are found in the coastal plains. Beans, on the other hand, thrive best in the Central Highlands (Figure 4.11).

b. Rice

Rice production, unlike the other major staples, is not only sufficient to meet national demand but also creates a substantial exportable surplus. Nearly all of the crop is raised on nonirrigated fields which are widely dispersed throughout the country.

TABLE 4.5. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN EL SALVADOR

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
El Salvador	Corn	O				//	/-	—	OO	OO				"Winter Crop."
	Beans					//	/-	-O	OO	//	/-	—	OO	"Summer Crop." Matures in 65-85 days.
	Rice					//	//	—	—	—	OO	OO		
	Wheat				//	/-	—	—	OO	O				
	Sorghum				//	//	—	—	—	—	—	OO	OO	Cultivated in coastal areas.
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	OO	OO	Cultivated in highlands.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Potatoes	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

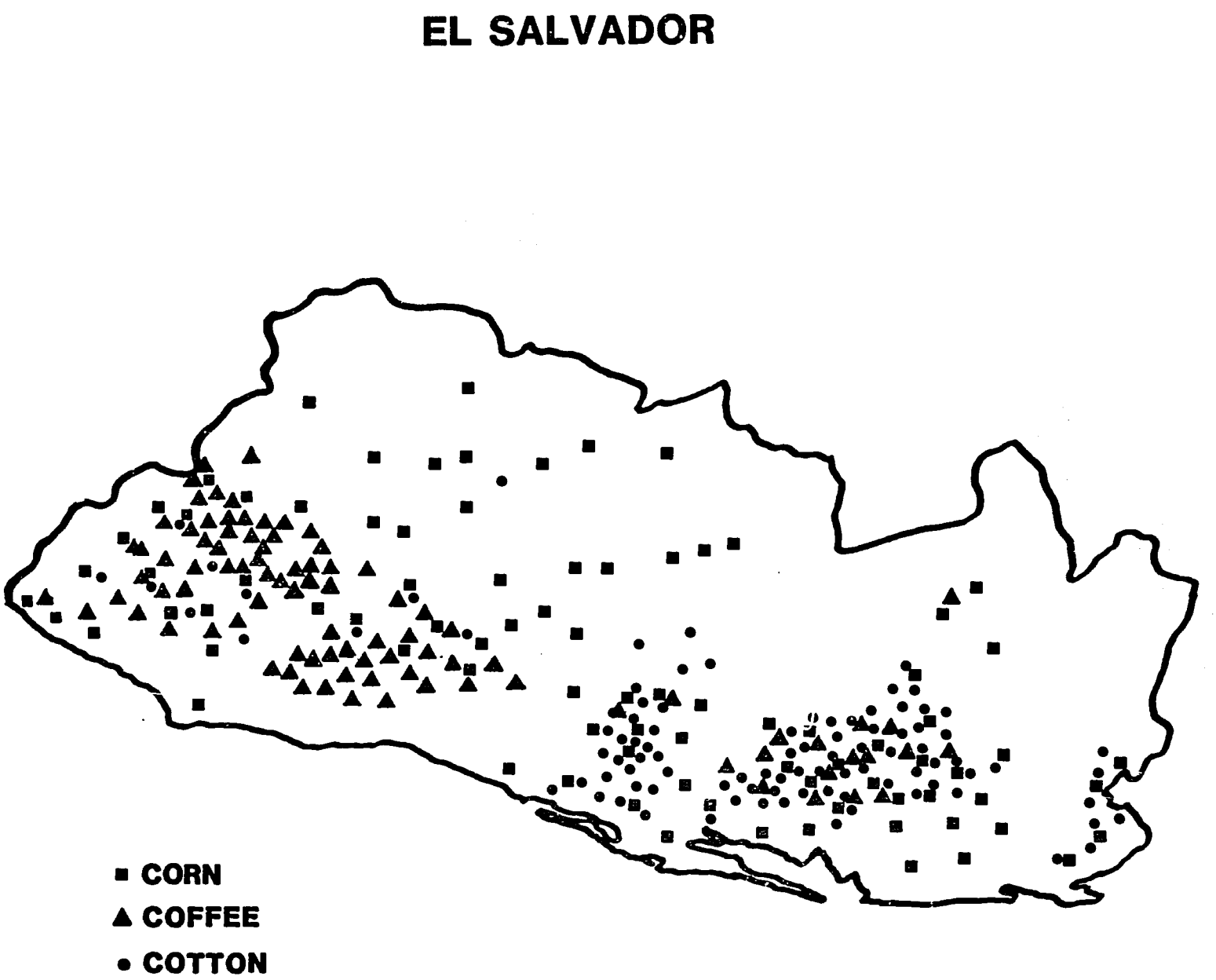


Figure 4.11. Distribution of Selected Agricultural Crops in El Salvador.

c. Sorghum

Sorghum is another crop that is often mingled into cornfields. Used primarily as food for livestock and domestic fowl, it is raised in sufficient abundance to satisfy local demand. Yields of most of the staple crops have fallen steadily over the past 30 years as the best lands are converted to commerical farming.

d. Other Crops

Coffee

Coffee has been the key to the national economy for over a century. Most coffee plantations are located in the Coastal Highlands (B1), at altitudes between 600 and 900 m. The cultivated hill slopes are too steep for mechanization, and the preparation and harvesting of coffee shrubs also require many permanent and seasonal workers so that the estates are largely run by manual labor. Nevertheless, extensive use is made of the best techniques, shelter belts, fertilizers, pesticides, and other modern aids. Most coffee farms are small, about 3 ha on the average, but about 3 percent of them have more than 50 ha and produce three-fifths of the total crop. The harvest season is between November and March, depending upon location and altitude.

During the 1960s El Salvador led all countries except Brazil, Colombia and Mexico in coffee production. Yields were the highest in the world, averaging 860 kg/ha compared with 335 to 450 kg/ha in other principal producing countries. However, much higher yields (up to 2,745 kg/ha) have been achieved with young, densely planted trees grown in unshaded areas with large amounts of fertilizer and careful pruning.

Cotton

Cotton plantations are located mainly in the Coastal Lowlands. They are generally large and highly mechanized but depend on large inputs of manual labor at harvest time. Thinning and late weeding operations are also done by hand.

Insects are the major problem during the growing period; hence a large number of insecticide applications per season are made either by means of aircraft or hand spraying equipment. Utilization of chemical fertilizers is also common. Average cotton yields have been the highest in Central America and are among the highest in the world for nonirrigated cotton.

Sugarcane

Sugarcane is commercially grown in large and highly mechanized plantations located in the central valleys and the western coastal zone. Fertilization is widely practiced and irrigation is fairly common. Disease-resistant strains of cane are now being cultivated with great success.

4. Agroclimatic Indices

Figure 4.12 shows the historical Yield Moisture Index (YMI) in percentiles for Acajutla (El Salvador Region). The YMI was computed for a corn crop during the main growing season (March-September). The agroclimatic index below the 10th percentile suggests poor crop conditions during the 1956 and 1975 crop growing seasons. The critical YMI value for crop failure may be determined by using episodic data (Table 4.6) and historical crop yield data.

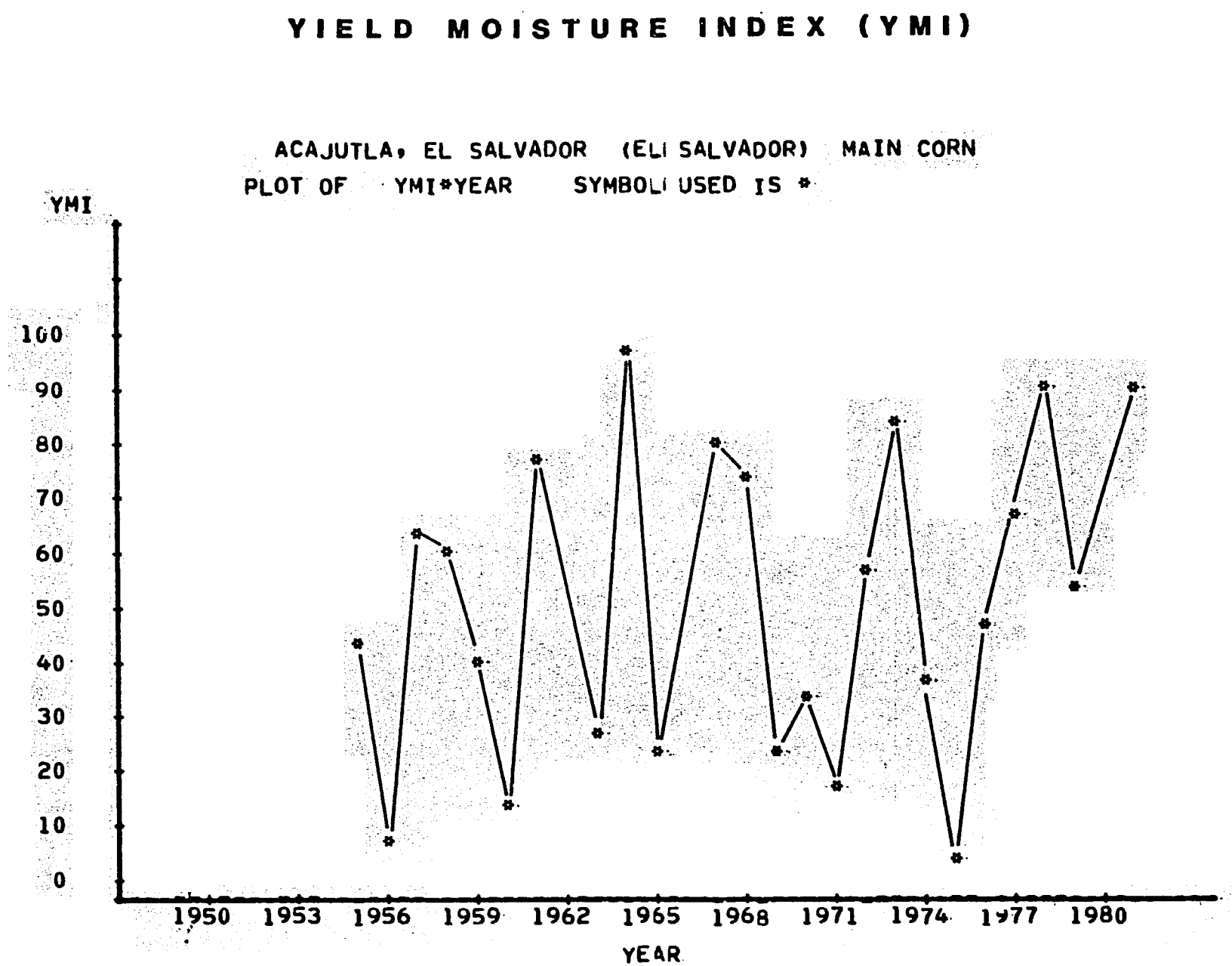


Figure 4.12. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Acajutla (El Salvador Region).

TABLE 4.6

EL SALVADOR

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1957		Drought affected crops.
1963-64		Limited land resources, urban population movement and shifts to export crop production continued.
1964-65		Disease affected rice and beans.
1967		A slow start of the summer rainy season adversely affected crop production in some Pacific coastal areas.
1968		Hot, dry weather adversely affected some food crops in the eastern area of the country.
1972		June and July were very dry and there were great losses to agriculture.
1974		Drought during July and August in the south and flooding in June at Pasaquina reduced corn, bean and rice production.
1975		Drought cut sugarcane yields and floods affected cereals when hurricane Fifi struck in January.
1976		A one-month drought occurring in mid-rainy season lowered yields of grain and other basic food crops.
1977		Severe June storms affected foodcrops in San Vincente, La Paz and Usultan and a midyear drought caused sharp drops in coffee and rice harvests, but other crops did well.
1978		Dry conditions continued in the Pacific coastal area. The persistent dry weather and serious drought cut back production.

TABLE 4.6

EL SALVADOR (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1979		Capital and labor shortages affected agricultural production, especially cotton, coffee and sugar. Coffee rust occurred near Usultan. Floods during September on the Caribbean coast destroyed crops.
1979-80		Sugarcane rust caused serious production problems.
1980		Poor farming practices and civil disturbances affected crop production.
1981		Civil disturbances, shortages of fertilizer and lower world prices affected agricultural production.
1981	October	Area sown to corn and sorghum was reduced because of civil disturbances. Emergency food assistance for 4 months was in operation.
1982	April	Emergency food assistance was extended for another 4 months.
1982	September	Mid-month floods occurred around El Salvador and coastal departments damaging agriculture severely. Aid was given.

D. GUATEMALA

1. Physical Environment

A tropical country with a land area of 108,890 square kilometers and an estimated population of seven million in 1980, Guatemala shares borders with Mexico, Honduras, El Salvador and Belize and has seaports on both the Pacific Ocean and the Caribbean (Figure 4.13). It has a great variety in climate and landforms, allowing a diversity of agricultural crops to be grown.

Much of the country is comprised of highlands, with altitudes varying from sea level to over 4,200 m (Volcan Tajumulco). The mountain systems are related to those of the West Indies and run NW and SE.

The climate and associated vegetation depend upon altitude and upon proximity to either the Caribbean or the Pacific coast. The difference between the average temperatures of the coldest and warmest months in any given place is usually not more than 8°C. The "tierra caliente" (hot land) extends from sea level to 750 m; it has an average daytime temperature of 30.5°C and a nighttime average of 22.5°C. The "tierra templada" (temperate land) extends from 750 to 1,650 m with temperatures ranging from 18° to 25°C. Finally, the "tierra fria" (cold land) extends above 1,650 m with temperatures between 11° and 25°C. Frosts are common in the "tierra fria" between December and February. The dry season from November through April is called "verano" (summer), and the wet season "invierno" (winter).

Four major natural regions are distinguished in Guatemala: 1) the Pacific Coastal Lands, 2) the Highlands, 3) the Caribbean Coast, and 4) El Peten (Figure 4.14). The Highlands contain most of the country's population, occupying 35 percent of the land area, (Dombrowski, et al., 1970).

GUATEMALA

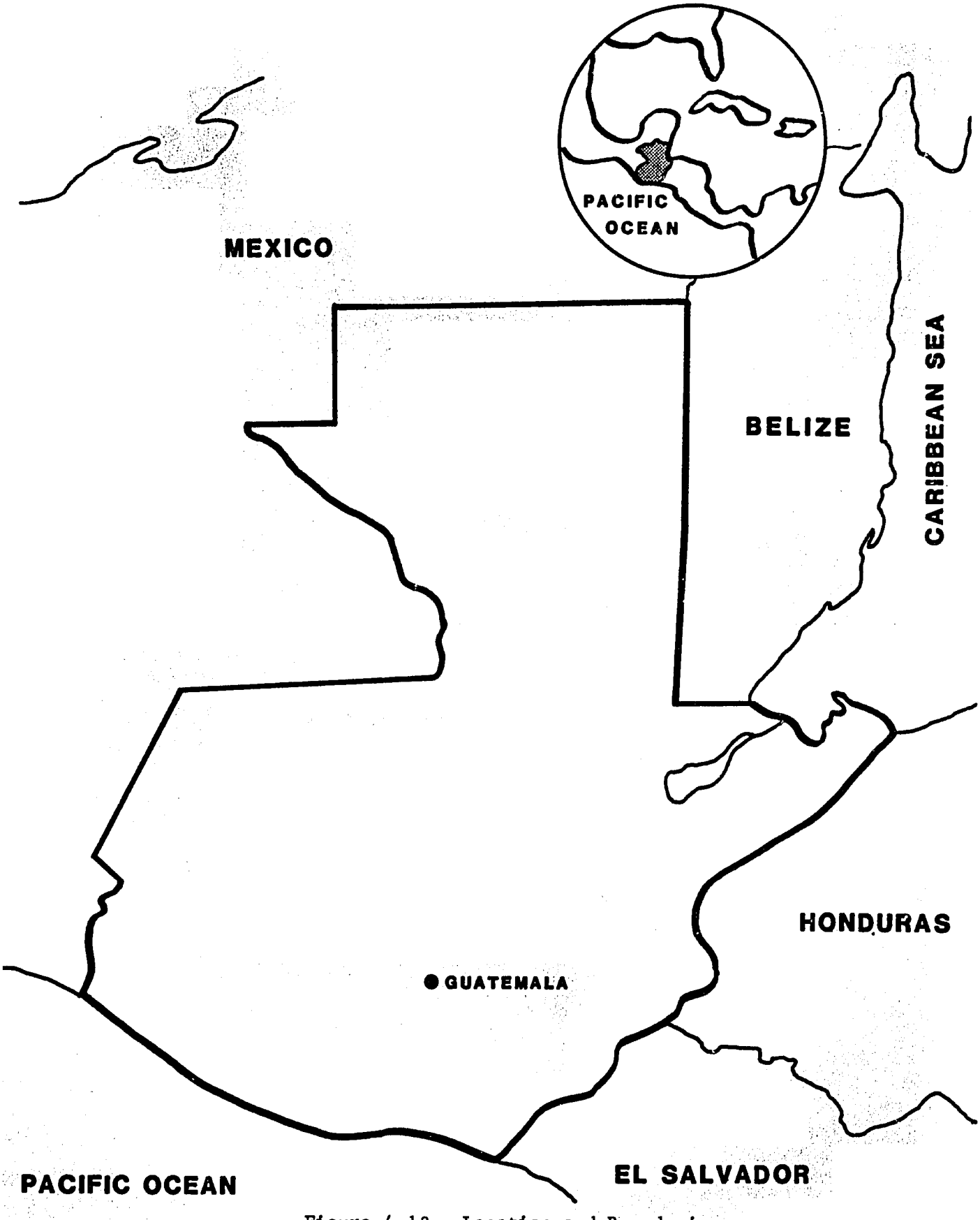
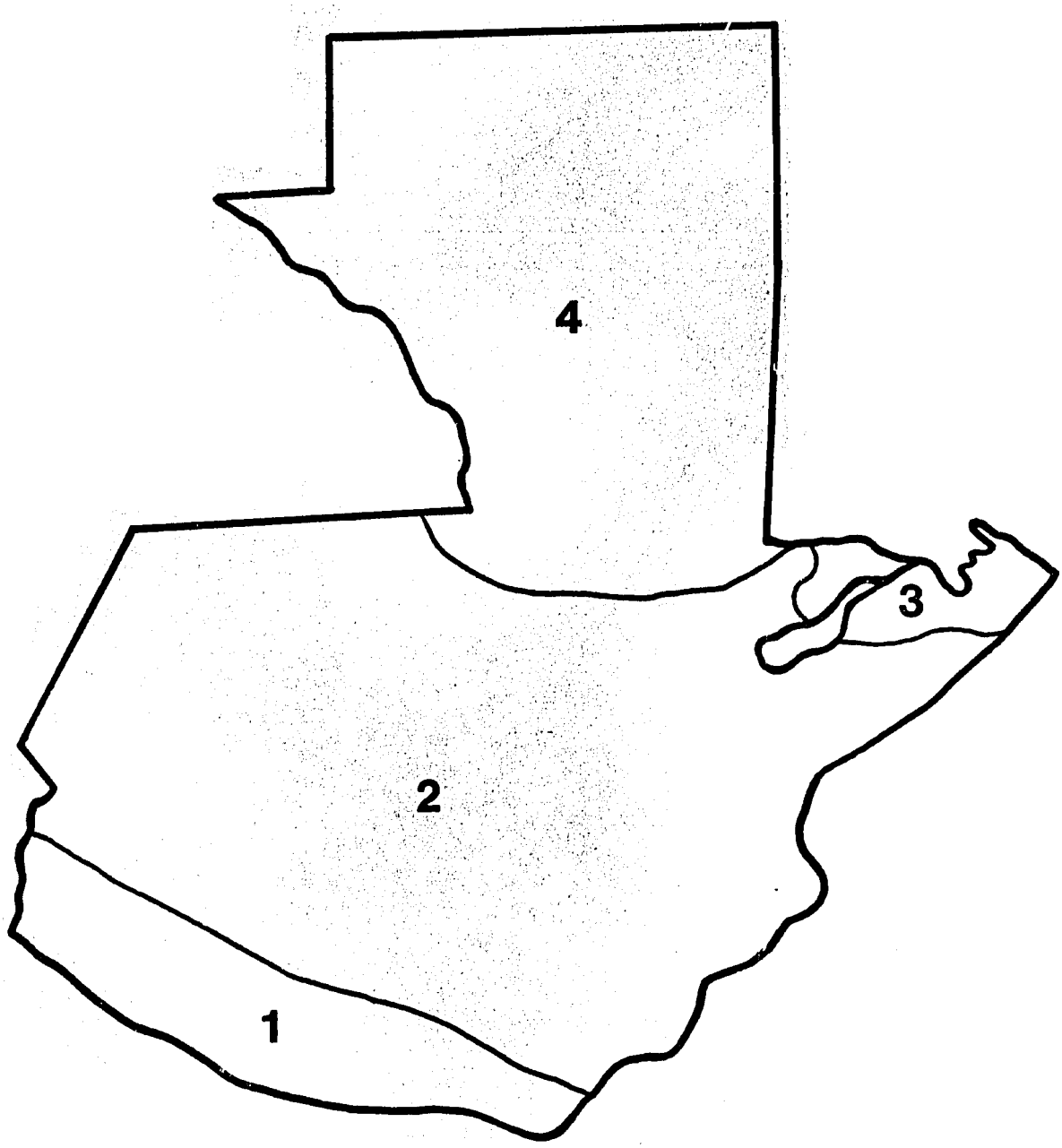


Figure 4.13. Location and Boundaries.

GUATEMALA



1. PACIFIC COASTAL LANDS
2. HIGHLANDS
3. CARIBBEAN COAST
4. EL PETEN

Figure 4.14. Natural Regions.

The Pacific coast is straight and open, with shallow offshore waters. Wet lagoons filled with mangrove lie inland from the sandy shore. Savanna, interspersed with tropical semi-deciduous forest, is the predominant vegetation in this region. The soils are well drained and very fertile, being composed of volcanic ash and alluvium. Temperatures are typical of the "tierra caliente." Slopes are gentle and not too steep for the extensive use of agricultural machinery. Monsoonal winds bring rain but are often destructive to crops. The average rainfall from May through October is about 2,100 mm, whereas from November through April it is only 20 mm. Farther inland, however, rainfall is heavier (over 2,500 mm annually), the dry season is shorter and temperatures are lower than in the coastal plain. Altitudes in this upper piedmont vary from 600 to 1,500 m.

The Highlands above 1,500 m are covered by the remnants of a once extensive pine and oak forest. This forest cover disappears above 3,000 m, and high altitude bunch grass called "paramo" predominates. There are more than 30 volcanoes, some still active. Earthquakes are frequent and sometimes destructive in this area. Guatemala City, located in a highland valley, has temperatures ranging from 16°C in December to 20°C in April. Mean annual rainfall is between 1,000 and 1,500 mm, with a distinct 6 month dry season. Figure 4.15 shows the mountain system ("sierras") of this region.

The coast along the Gulf of Honduras is flat and vulnerable to Caribbean storms. The climate in the coastal area is humid-tropical, with over 3,000 mm per year and no distinct dry season. The mean monthly temperature ranges from 23°C in December to 28°C in May. In February, the month of the lowest rainfall, this region receives about 76 mm. Tropical rain forest of broadleaf evergreen trees covers much of the area.

GUATEMALA

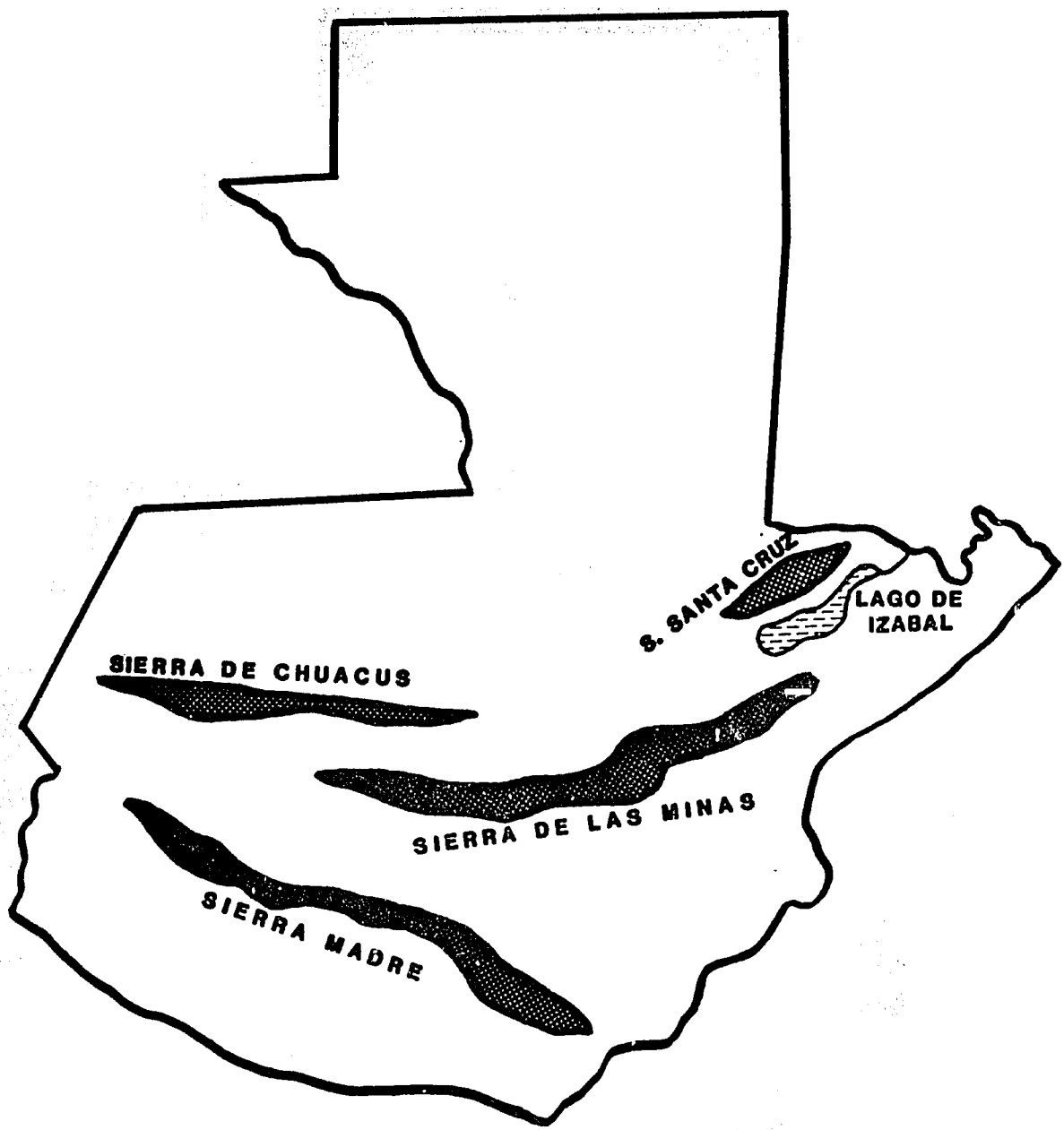


Figure 4.15. Major Physical Features of Guatemala.

The vast region of El Peten, comprising about one-third of the national territory, is a rolling limestone plateau with altitudes varying from 150 to 210 m. It is covered with dense tropical rain forest, occasionally interspersed with open savannas. The soils are relatively poor for agriculture. The annual rainfall is heavy, averaging 2,000 mm in the north and 3,800 mm in the south. Humid conditions prevail year round, with less rain from November through April.

2. Agricultural Practices

Guatemala experiences such different climatic conditions and has so many soil types, that it is the best suited of all Central American countries for varied agricultural production (Dombrowski, 1970). Indeed, agriculture is the dominant sector of the economy, contributing about 25 percent of the GDP and employing 65 percent of the economically active population.

Nearly 87 percent of the land area of Guatemala is potentially productive for agricultural purposes. Only 15 percent, however, appears to be covered with agricultural crops (Sheck, 1970). The level of technology varies from primitive to modern. The small corn farmer, working an unfertilized plot with hand tools, contrasts with large plantations utilizing machinery and scientific farming principles. As of 1968, a total of about 50,000 ha were under irrigation (Dombrowski, 1970) while less than 5 percent of the agricultural investment was in machinery.

Three major agricultural systems can be identified: 1) commercial (or plantation) agriculture, which is concerned chiefly with the production of coffee, sugarcane, cotton and bananas on vast estates; 2) subsistence (or "milpa") agriculture, related to the cultivation of corn and subsidiary staples on small plots; and 3) mixed farming which involves medium-sized farms producing crops

and livestock for both subsistence and commercial purposes. While commercial farms use mechanization, fertilizers, irrigation and modern techniques, "milpa" farmers (mostly Indians) cultivate their land with the most primitive tools and practice a "slash and burn" shifting farming. Mixed farming is performed by non-Indians or Ladinos, who use more advanced tools and techniques such as crop rotation and improved seed varieties and produce slightly higher yields than the "milpa" farmers. In general, at highest altitudes a single grain crop (usually wheat) is planted in April and May and harvested in December and January. At lower elevations, however, it is possible to secure two crops of grains (usually corn) and vegetables.

Land tenure, land use, and the government's role in agriculture were dominant themes of the 1970s. Land distribution is highly skewed as land ownership is concentrated in the hands of a privileged few. In the Western Highlands, 60 percent of the population is on 26 percent of the land area. Half of the farms are less than one hectare (3 acres) and often are fragmented into noncontiguous plots. The average family does not have enough land to provide for basic needs and in recent years, the problem has been exacerbated by increased population pressure. Erosion and reduced productivity are the consequences of overuse of mountain terrain. In contrast, coastal and Peten lands, more suited to farming, are under-used. Recent high prices for exported crops, combined with the government of Guatemala marketing policy of providing imported grain below cost in urban areas, resulted in a shift from grains and beans to sugar and cotton by Pacific Coast growers.

3. Principal Crops

The major food staple is corn, followed by beans, wheat, and rice. The most important exports are coffee, cotton, sugar, bananas, and beef. Because the major domestic food crops do not always meet requirements, imports are sometimes necessary. Table 4.7 shows an estimated regional crop calendar for subsistence farming in Guatemala.

TABLE 4.7. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN GUATEMALA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Northern	Corn				//	//	—	—	OO	OO				
		OO								//	/-	—	OO	Second crop up to 1500m.
	Beans					//	/-	—	OO	O				Dry beans have 2 to 3 months longer period.
	Rice				//	//	—	—	OO	OO				
	Wheat					//	//	—	—	—	OO	OO		
	Sorghum					//	//	—	—	OO	OO			
Mountains	Corn				//	//	—	—	OO	OO				
	Beans					//	/-	—	OO	O				
	Wheat					//	//	—	—	—	OO	OO		At high elevations, harvest is delayed by 1 to 2 months.
Eastern	Corn						//	/-	—	—	OO	OO		
	Beans					//	/-	—	—	OO	O			
Coastal	Corn				//	//	—	—	OO	OO				
	Beans				//	/-	—	OO	O					
	Sorghum				//	//	—	—	—	OO	OO			
	Sugarcane	OO	OO	OO	OO	—	—	—	—	—	—	—	OO	Harvested 12 to 18 months after planting/cutting.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

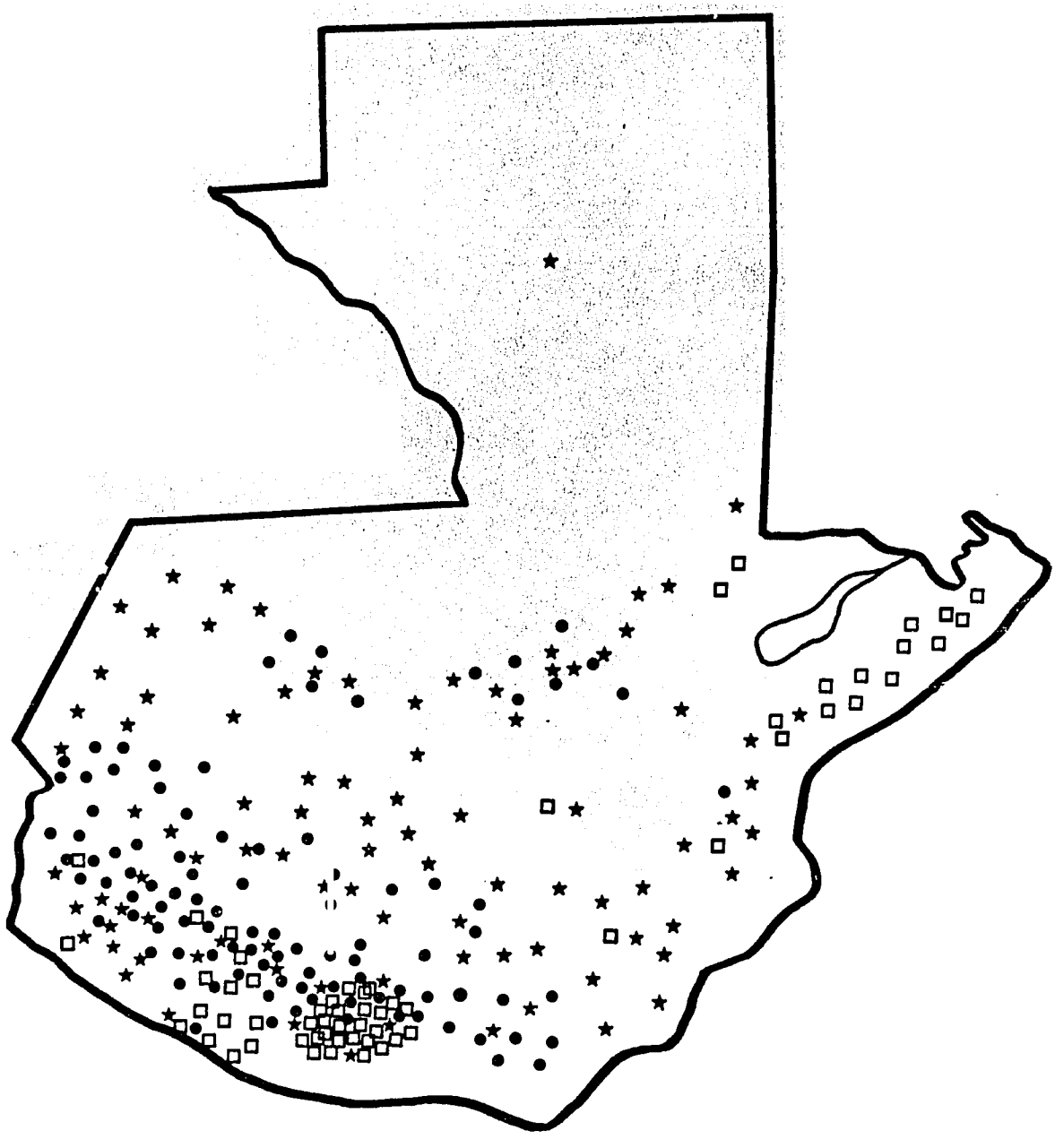
a. Corn

Corn (maize) is the major Indian crop and main food staple. Virtually every rural family grows it on small plots called "milpas." An estimated 800,000 ha are planted in corn throughout the country (Figure 4.16). Corn can be grown in Guatemala up to 2,850 m altitude. Each 300 m adds about 3 to 4 weeks to the time needed for crop maturation, and as much as 9 months is normal near the frostline. In the lower altitudes the growing season is shorter and two crops a year can be harvested, although the extreme drought (November - April) is a problem in areas inland from the Caribbean coast. In addition, the farmer is faced with insect damage. Most of the corn is grown in the central Highlands, characterized by a dry season between December and June. However, mists and dews moisten the soil enough to permit planting before the beginning of the rainy season. The best land for corn is in the Pacific coastal region, but many of the highland varieties of corn do not grow well at the lower elevations. Guatemala has more corn varieties than any other country in the world. Many of these varieties do not grow well outside their particular locale (site), and corn from other countries does not grow well in Guatemala. Corn yields are relatively low and sometimes the production does not satisfy local needs, making imports necessary. Nevertheless, corn yield has increased significantly due to the use of fertilizer.

b. Beans

Black beans constitute the chief source of protein for the rural population and provide about one-third of their diet. Bean production is concentrated in the Highlands, but extends throughout the country. Generally the annual production of beans is insufficient for domestic consumption, and imports are necessary. Most farmers plant beans in their cornfields between rows of corn.

GUATEMALA



• COFFEE

★ CORN

□ BANANAS

Figure 4.16. Distribution of Selected Agricultural Crops in Guatemala.

c. Wheat

Soft varieties of wheat are grown in very high altitude areas between 1,600 and 2,700 m. Most wheat is produced by small farmers in the Departments of Quezaltenango and San Marcos. The production satisifies only 33 to 50 percent of domestic demand; the balance is imported.

d. Rice

The Departments of Jutiapa, Santa Rosa, San Marcos, Quezaltenango, and Retalhuleu are the major rice producers in Guatemala. In recent years, rice production has been increasing to the point where frequent surpluses occur.

e. Other crops

Coffee

Coffee is the principal crop of Guatemala in terms of foreign exchange earnings. A total of 140,000 ha, located in every department except El Peten (too hot) and Totonicapan (too cold), are planted to coffee. Guatemala has been the major coffee producer of Central America and the fourth or fifth producer and exporter in the Western Hemisphere since 1880. More than 80 percent of the coffee is grown at altitudes between 300 and 1,500 m, although some is also grown in the lowlands where farmers use banana trees as shade for young coffee bushes.

The young tree matures in five years. Harvesting begins in late September or early October and lasts as long as two months. Another two months are required before the coffee is ready for export.

Cotton

Cotton is the second most important export crop for earning foreign exchange in Guatemala. Most of the cotton is grown on the Pacific coastal lands at an elevation of 180 m, where some of the world's highest yields per hectare for nonirrigated cotton are obtained.

Planting begins in July and harvesting in November, lasting through March. The major problem for growers is pest control.

Sugarcane

Sugarcane is grown in all departments except Totonicapan, which is too cold. About one-third of all sugar produced is exported, half to the United States. Sugarcane is harvested from late November to February.

Bananas

Bananas are grown commercially in two areas: the Pacific coast and the lower Motagua Valley near the Caribbean Sea. The greatest hazard to bananas is Panama disease, a fungus which attacks the roots of the plants. A second major hazard is wind blowdowns, usually on the Pacific side, during May. Another disease is Sigatoka, a leaf blight which can be controlled by spraying. There is no effective remedy for Panama disease except flooding the land for several years and letting it remain fallow in this condition. Because of disease and blowdowns, banana production has decreased steadily over the years.

Minor Crops

There are numerous minor crops raised in Guatemala, mostly for domestic consumption but some for export. Essential oils (citronella and lemon grass oil), tobacco, and honey are the three most important minor exports, while rubber, cacao, fruits and vegetables, millet, sorghum, potatoes, sesame, cassava and hard fibers are raised exclusively for local consumption.

4. Agroclimatic Indices

Figure 4.17 shows the historical Yield Moisture Index (YMI) in percentiles for Guatemala City (Mountain region). The YMI was computed for a corn crop during the main growing season (April-August). The YMI in the lower 10th percentile indicates the occurrence of drought impacted crops in 1967 and 1977. The critical YMI value for crop failure may be determined by using episodic data (Table 4.8) and historical crop yield data.

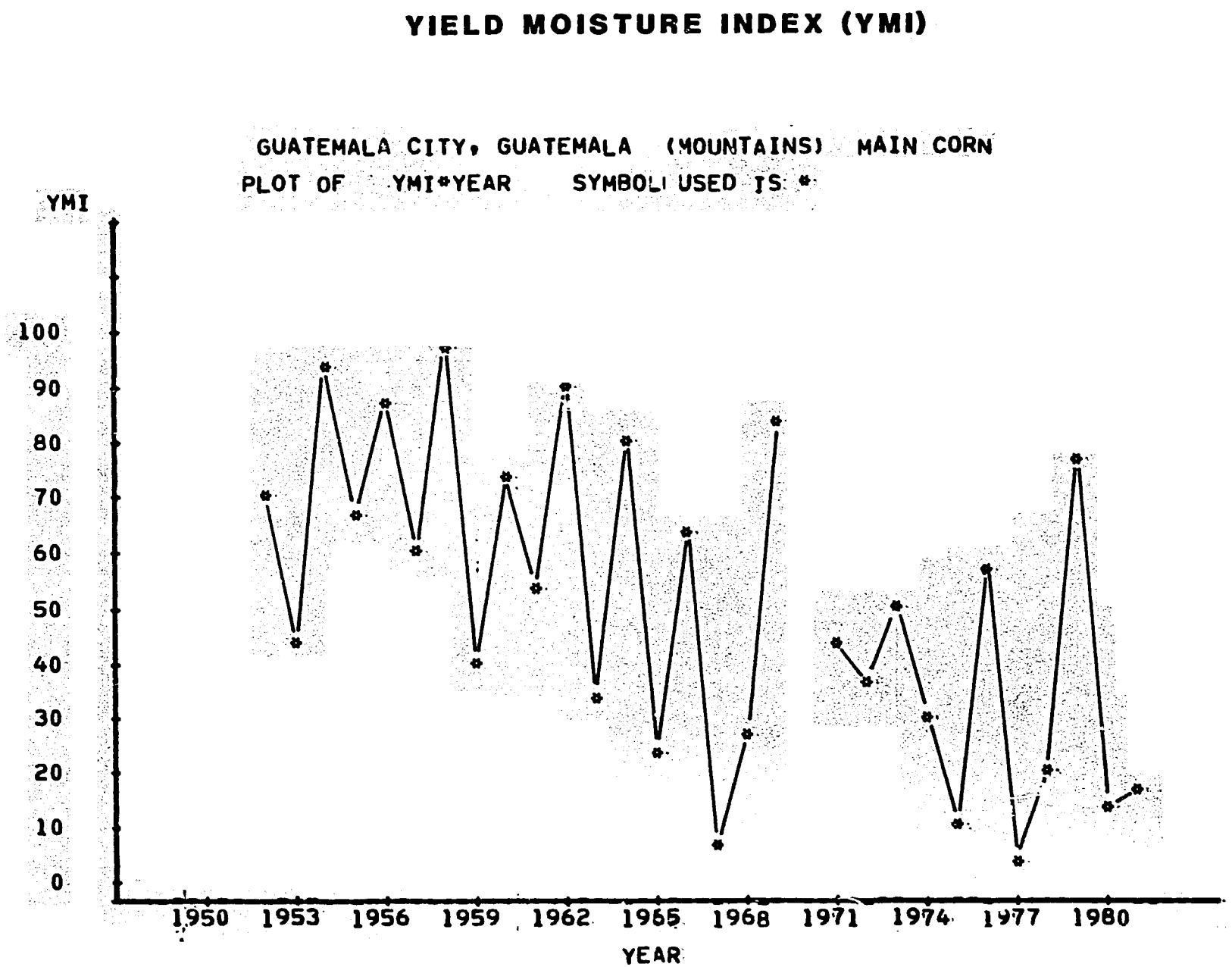


Figure 4.17. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Guatemala City (Mountains Region).

TABLE 4.8

GUATEMALA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1950-54		Land area rented for corn declined.
1950-82		Heavy use of insecticides on the cotton crop increased pest resistance and yields were falling.
1954-55		Below average corn production resulted in a food shortage.
1957		Drought affected crops.
1963-64		An unusually late rainy season in 1963 affected early 1963-64 harvested crops.
1969		A hurricane devastated the southern coast.
1974		Intensive rain, lack of seed and fertilizer and a volcanic eruption slowed agricultural growth.
1974-75		Heavy rainfall, volcanic activity and hurricanes adversely affected cereal output.
1975-76		Adverse weather, insect infestations and an earthquake affected agriculture.
1976		The rainy season started slowly and was interrupted by a month-long midyear dry spell. After the dry spell, there was rain that continued late into the season.
1977		Drought affected rice and heavy rains in March damaged maize and bean crops in the Ixcan region. Needed rainfall for basic grains was delayed in Oriente and Altiplano areas in August. In September the corn crop in the southwest was affected by drought. The cereals crop was reduced by drought.

TABLE 4.8

GUATEMALA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1979		Prolonged rains in September-October affected crops.
1980		Excessive and untimely rains reduced wheat and sorghum production.
1981		Rust threatened coffee crops.
1982	September	A storm struck the southern coastal area and several departments in the central and eastern areas just prior to harvest time and caused lowered production. Civil disturbances resulted in serious food shortages in the north and northwest districts.

E. HONDURAS

1. Physical Environment

Honduras is the second largest Central American country, having an area of 112,090 square kilometers. Centrally located, it extends from the Guatemalan border on the west to the Coco River which separates it from Nicaragua on the East. El Salvador, Nicaragua and the Pacific Ocean form the southern boundaries and the Caribbean Sea the northern. The seaboard on the Caribbean is over 650 km in length and stretches eastward from the Gulf of Honduras. On the Pacific, the Gulf of Fonseca provides an outlet approximately 80 km long (Figure 4.18). Over 80 percent of the land is mountainous but some lowland areas are found along the Caribbean and Pacific coasts.

Two major mountain ranges divide the country into two sections, the north and the south. In the north, extensions of the Central American Cordillera run from the Guatemalan border to the Platano River (Figure 4.19). These mountain chains lie east-northeast and west-southwest and run largely parallel to the coast and to each other. In the southern half of the country, the Volcanic Highlands extend from the border with El Salvador in the southwest to the border with Nicaragua in the east (Figure 4.19), but do not have a recognizable trend. These southern ranges are higher than the northern Central American Cordillera chains and include the highest peak in the country (2,900 m) located in the Department of Lempira.

In the areas between the mountain ranges, in both the Central American Cordillera and the Volcanic Highlands, are plateaus, river valleys, and savannas. These constitute the only arable level land in the country (20 percent) except for the north coastal areas which are planted to bananas (Blutstein, et al, 1971).

Figure 4.18. Location and Boundaries of Honduras.

HONDURAS

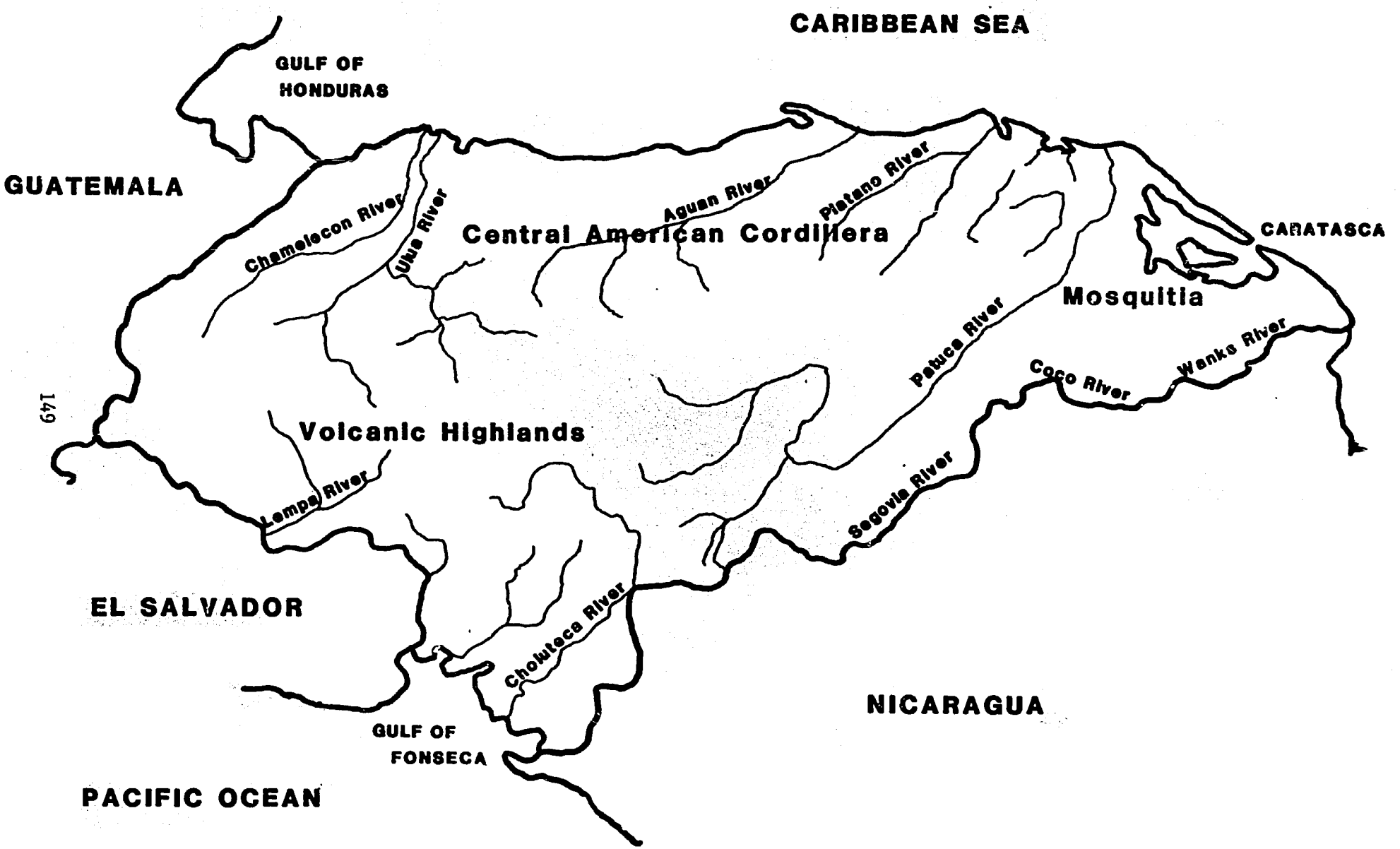


Figure 4.19. Major Rivers in Honduras.

Four major natural regions can be recognized in Honduras (Figure 4.20): (A) Northern Coastal Lowlands, (B) Northeastern Coastal Plains, (C) Interior Highlands, and (D) Pacific Lowlands. This division is based on climate, topography, and vegetation.

On the humid lowlands of the Caribbean (A), the soils are suited to a wide range of crops. This is one of the most important farming areas, particularly the Rio Ullua Basin. Drainage and control of seasonal flooding, however, are critical problems in this region.

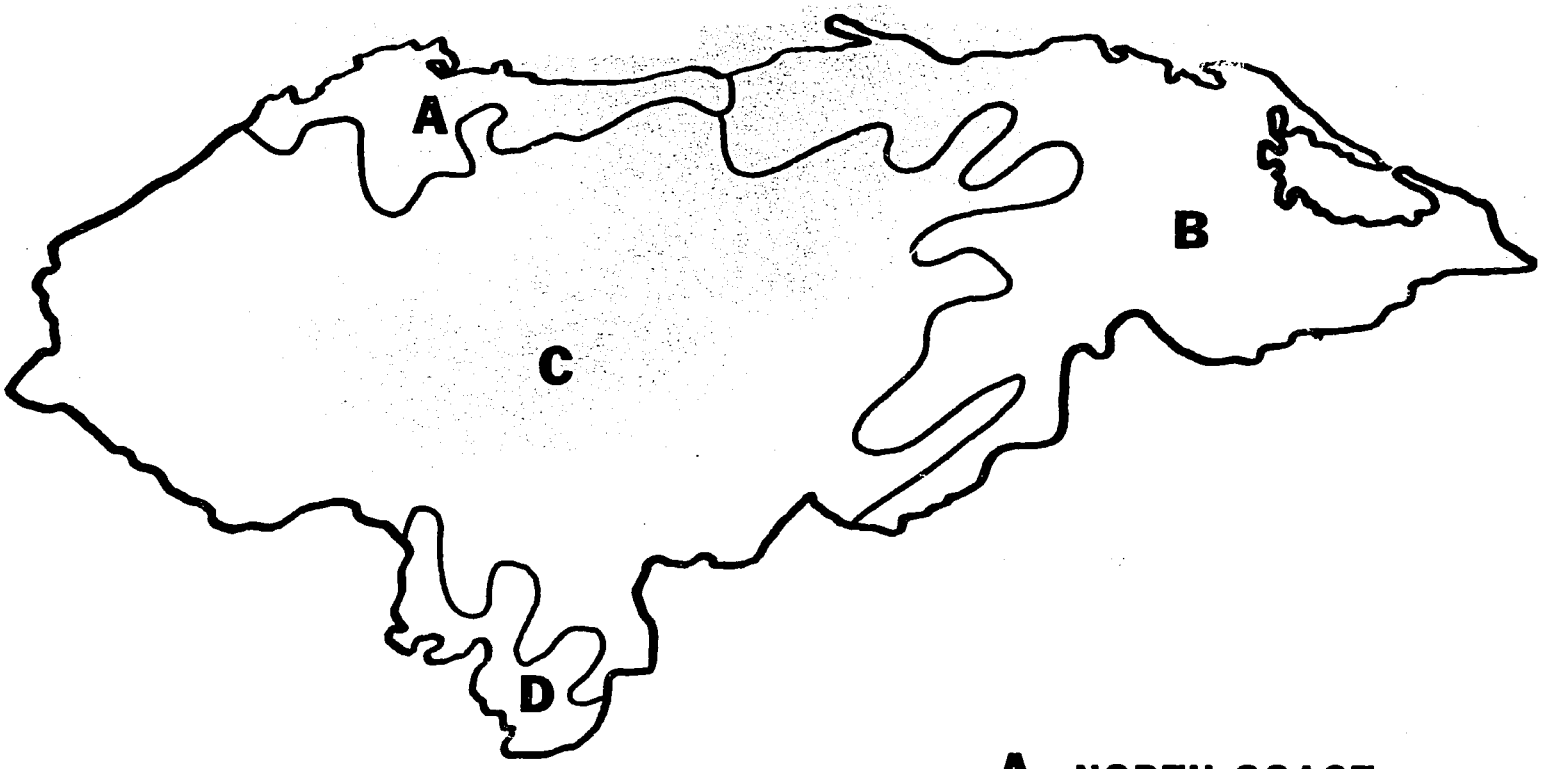
The Northeastern Coastal Plains (B) include a lowland pine savanna with coastal marshes and mangrove fringe called "La Mosquitia," the Caratasca lagoon, and the foothills forming the hinterland of "La Mosquitia." This region constitutes about 40 percent of the country's total area.

The Interior Highlands (C), with 3 sub-regions, cover 10 departments. The soils here are immature and relatively infertile and their use depends upon water availability. The practice of hillside farming, combined with slash-burn cultivation, has resulted in widespread deforestation and serious soil erosion.

The Pacific Lowlands (D), occupying only 2 percent of the total area of Honduras, are located behind a mangrove-fringed shoreline. A well defined dry season has created a semideciduous forest and patches of savanna in this region.

The climate as well as the vegetation is dominated by the prevailing northeast trade winds, modified to varying degrees by the topography. Rainfall produces distinct seasonal variations in the climate. The wet season, "invierno," extends from May to November, while the dry season or "verano" lasts from November to April. A minor but agriculturally significant short dry

HONDURAS



A NORTH COAST

B NORTH-EAST COAST

C INTERIOR HIGHLANDS

D PACIFIC LOWLANDS

Figure 4.20. Natural Regions of Honduras.

season, the "veranillo," usually occurs for a two-week period in July or August. The fundamental patterns of climate and vegetation are determined by altitude, which creates zones whose combined rainfall and temperature regimes are associated with specific crop distributions. The Northern Coastal Lowlands (A and B), for example, represent the tierra caliente which extends up to altitudes of 750 m with annual rainfall ranging from 2,000 to 3,000 mm and temperatures consistently around 30°C. On the Pacific Lowlands (D), the tierra caliente is less pronounced due to a greater seasonal differentiation.

The tierra templada extends up to 2,000 m, with a mean annual temperature of 21°C and annual precipitation varying between 750 and 1,500 mm. The Interior Highlands (C) are classified as tierra templada and have vegetation including pine, oak and other hardwoods.

Climatic hazards consist of hurricanes from late July to early October, and "nortes," short spells of cold polar air which roll south during the winter from October to April. The character of rainfall is ill-defined in Honduras but two forms may produce severe flooding hazards. The Gulf of Fonseca is one of the two regions of maximum thunderstorm activity in Central America, with a nine year average of 116 storms a year at Amapala (Crosbie, 1970) and with intense, localized rainfall. In contrast, due to weak tropical disturbances during the warmer months, rainfall may occur in the form of temporales, i.e., continuous, steady rain from stratified clouds over an extensive area lasting several days.

2. Agricultural Practices

Honduras is the least economically developed of the five Central American republics. A 1970 agricultural survey revealed that only 7 percent of the total land area was under cultivation (Crosbie, 1970). Nonetheless, agriculture continues to be the largest component of the economy, contributing about 38 percent

to the GDP and employing over 60 percent of the country's economically active population (Blutstein, 1971).

Approximately 90 percent of the farmland is used for the production of subsistence crops, largely for domestic consumption but also for export. Domestic food production is sufficient to meet needs and the country exports whatever surplus production occurs, mainly to El Salvador.

Most farmers use techniques and practices that usually exhaust the fertility of the soil. The small farmer does not practice soil conservation or prevent erosion, although many crops are grown on slopes where erosion occurs. In general, soils are low in phosphorus although high in potassium. Commercial fertilizers are seldom used; the use of animal and human manure is more common. Less than 20,000 metric tons of commercial fertilizers are consumed annually. Crop rotation is not practiced. When the yield of a plot starts to diminish, it is left fallow. Another plot is worked until it too starts to diminish in yield, and then the farmer returns to work the first plot. There is very little mechanization throughout the country. Hand-tools are used on almost all farms. According to Blutstein (1971), 77 percent of the farmers use a machete to dig up the soil and a stick to sow the seed. The same author reports that less than 8 percent of the farm land was under irrigation in the mid-1960's and most of it was on large plantations growing bananas, sugar and cotton.

In 1974 the rural population of about 1.93 million (300,000 families) was distributed over 178,000 farm units, 75,000 of which exceeded 5 hectares. One-third of these rural families had incomes above subsistence level (75,000 who had larger farms and 25,000 banana workers), one-third had insufficient land for subsistence, and one-third were landless. Poverty is greatest in the southwest along the border with El Salvador because of rough terrain, poor soils, and

limited infrastructure. Increasing peasant unrest has recently resulted in a rural development policy emphasizing land redistribution, based on allowable maximum farm sizes and efficiency of use and production. Land under bananas, sugarcane, African palm, coffee, pineapple, citrus, and tobacco (all significant or potential exports) is not subject to expropriation as long as efficient production is maintained.

Redistribution of expropriated land was begun in October 1975 with groups (asentamientos) working larger farms on a cooperative basis the major beneficiaries. By the end of 1978, the National Agrarian Institute (charged with implementation of the Agrarian Reform Program) had distributed 203,833 ha of land to a total of 35,586 families organized into 1,240 groups.

3. Principal Crops

Corn is the principal food crop, followed by sorghum, beans, and rice. Bananas and coffee are in turn the two major export crops and account for about 60 percent of all exports by value, bananas representing almost 50 percent (Blutstein, 1971). Other important staples are wheat, squash, sweet potatoes, cassava and plantains.

Table 4.9 shows an estimated regional crop calendar for subsistence farming in Honduras.

a. Corn

Most of the rural population is engaged in farming in the highlands where corn covers the greatest area (Figure 4.21). About 50 percent is grown on small farms of less than 10 ha. This staple food is cultivated throughout the country from sea level to high elevations, covering about half of all the farm land. The effects of weather are reflected in widely varying annual crop yields. For example, in 1966 and 1967, heavy rains caused a lower yield than in previous years, whereas good weather in 1968 permitted a record crop of over 390,000 metric tons. Again, rain damage in 1969 caused a low yield. Output per acre is

TABLE 4.9. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN HONDURAS

// Planting, — Vegetative/Flowering, 00 Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Atlantic	Corn					//	//	—	—	00	00			Usually intercropped with beans or other crops.
	Beans					//	/-	—	00	0				Matures in 65 to 80 days.
	Rice	00	0		//	/-	—	—	—	00	// 00	/-	—	
	Bananas	00	00	00	00	00	00	00	00	00	00	00	00	Planted anytime. Harvested after one year.
Western	Corn					//	//	—	—	00	00			
	Beans					//	/-	—	00	0				
	Sorghum					//	//	—	—	—	—	00	00	
	Sugarcane	—	00	00	00	00	—	—	—	—	—	—	—	Harvested from 12 to 18 months after planting/cutting.
Central	Corn					//	//	—	—	00	00			
	Beans					//	/-	—	00	0				
	Sorghum					//	//	—	—	—	—	00	00	
	Sugarcane	—	00	00	00	00	—	—	—	—	—	—	—	
Eastern	Corn					//	//	—	—	00	00			
	Beans					//	/-	—	00	0				
Pacific	Corn				//	//	—	—	00	00				
	Beans				//	/-	—	00	0					
	Sugarcane	—	00	00	00	00	—	—	—	—	—	—	—	
	Bananas	00	00	00	00	00	00	00	00	00	00	00	00	

HONDURAS

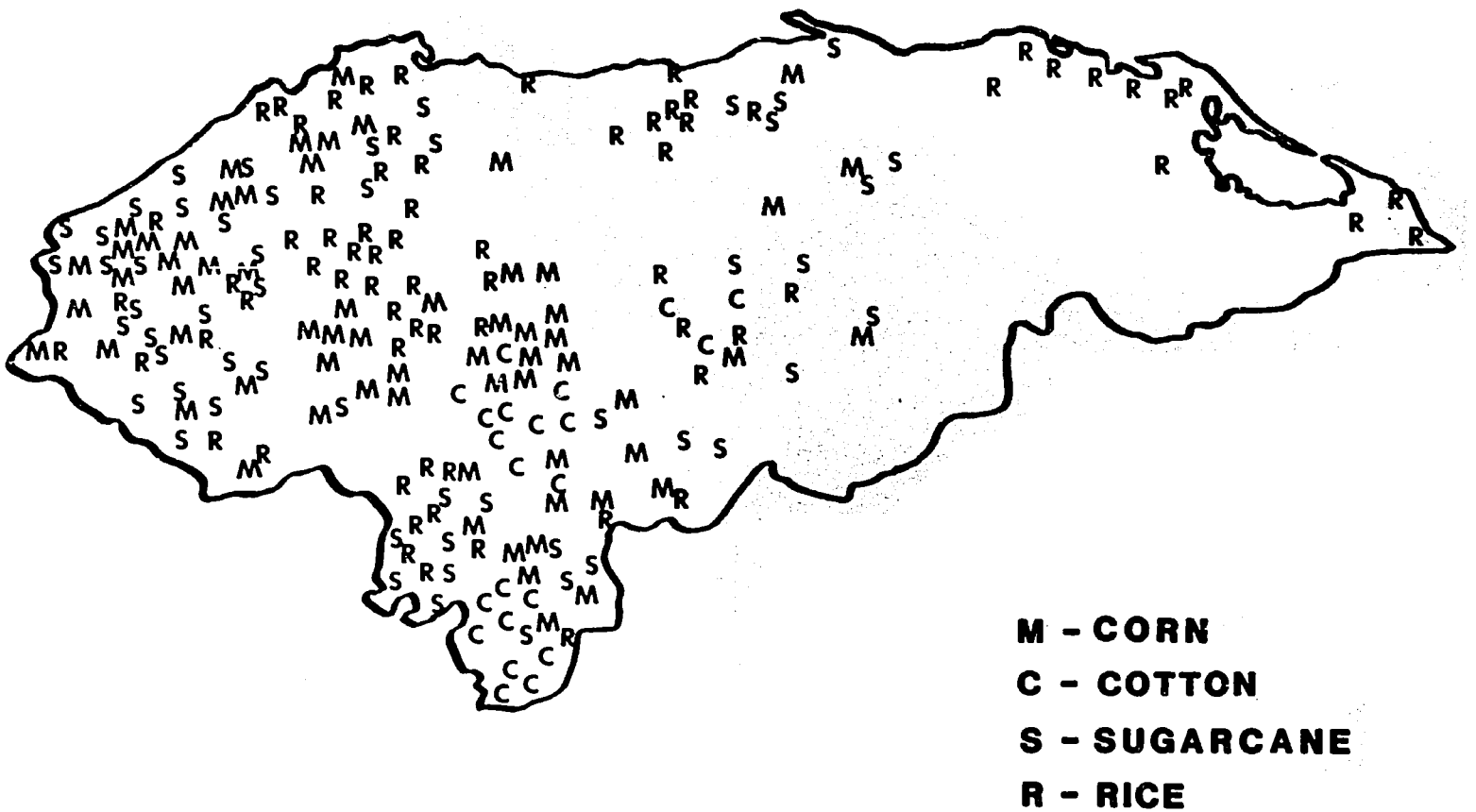


Figure 4.21. Distribution of Agricultural Crops in Honduras.

low compared to other Central American countries. Government assistance in the form of improved seeds, fertilizer, and technical advice reaches only a small percentage of the farmers.

b. Beans

Beans are one of the basic food crops and provide the staple protein in the diet. About 40 percent of the crop is grown by small farmers on small plots without any modern technology. Corn farmers frequently grow beans in the same fields after the corn harvest.

c. Rice

Rice is cultivated mainly on small plantations in the Atlantic Coast departments. Because of good soil and ideal climatic conditions, the yield per hectare is considered to be more than adequate (Blutstein, 1971).

d. Sorghum

Sorghum is raised both as an animal food and for human consumption. Like beans, it is grown on small plots with marginal productivity, mainly in southern Honduras, but total production is higher than that of beans.

e. Other Crops

Sugarcane is grown mainly in the central and southern regions of the country (Figure 4.21). The production of sugar in Honduras satisfies domestic needs and small surpluses are exported to the United States.

Bananas

The banana industry is the leading export industry and the principal area of foreign investment. By 1970, bananas accounted for 50 percent of total exports, and the country was the world's second largest banana producer after Ecuador. Banana plantations are located mainly along the north coast and constitute the most technically advanced sector of the economy. In the large plantations, several disease-resistant varieties have been successfully introduced. Hurricane Francelia caused banana production to drop significantly in 1969.

Coffee

Coffee is grown on small and medium sized farms and is the nation's second most important export. Attempts have been made to improve the quality and yield by providing technical assistance and new trees to the small farmer.

4. Agroclimatic Indices

Figure 4.22 shows the historical Yield Moisture Index (YMI) in percentiles for Tegucigalpa (Central Region). The YMI was computed for a corn crop during the main growing season (April-September). YMI values below the 10th percentile suggest poor crop conditions in 1971 and 1975. The critical YMI value for crop failure may be determined by using episodic data (Table 4.10) and historical crop yield data.

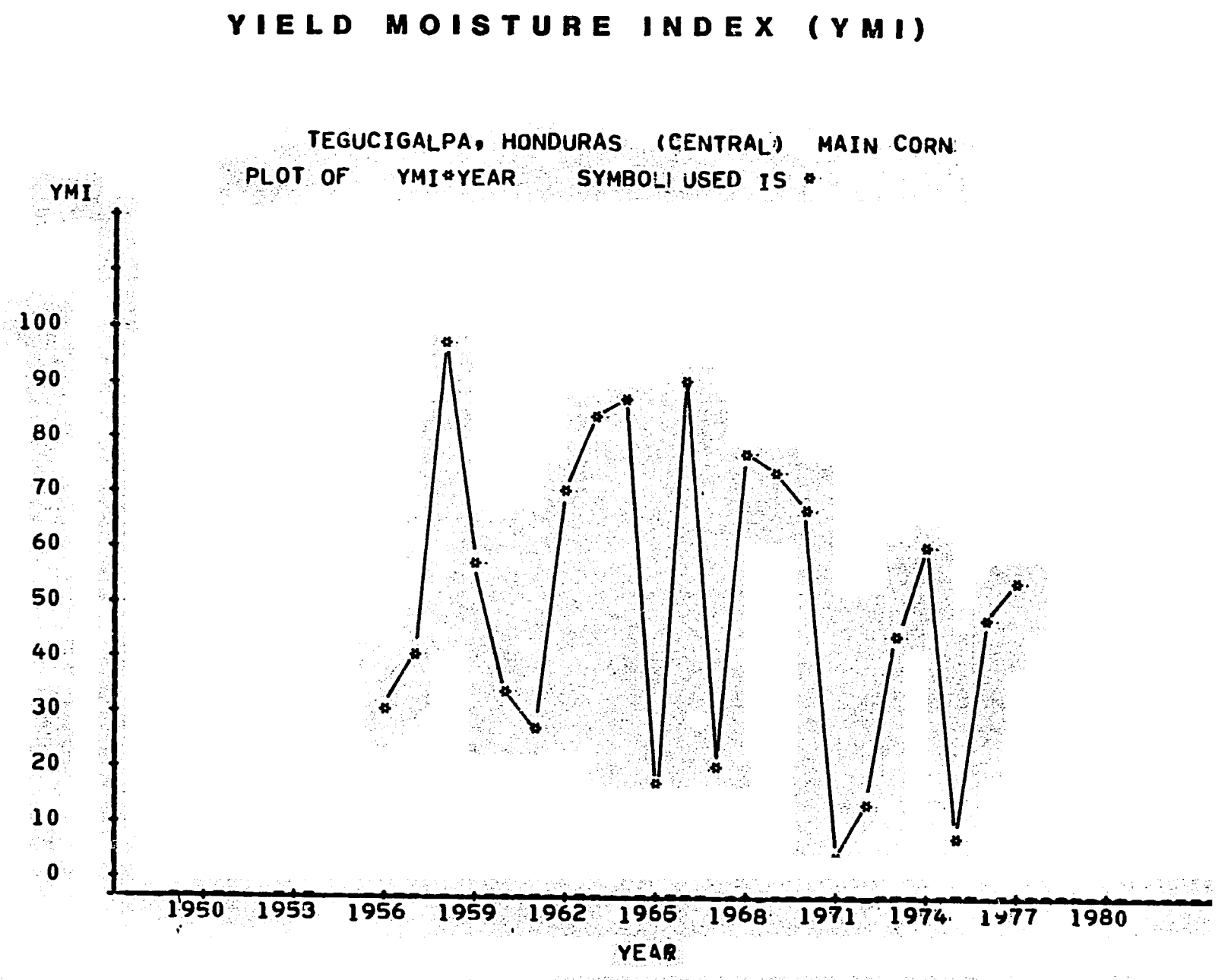


Figure 4.22. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Tegucigalpa (Central Region).

TABLE 4.10

HONDURAS

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC DATA
1957		Drought affected crops.
1961		Hurricane Hattie damaged banana plantations.
1963		Banana production still reflected diseases and blowdowns of previous years.
1965		Drought and floods affected the corn and bean crops.
1966		Heavy rains caused a lower yield in corn production.
1967		A slow start of summer rainy season hurt crop production in some pacific coastal areas.
1969		Hurricane Francelia affected crop production.
1970		Bad weather, insect damage and low prices affected cotton.
1971		A prolonged drought affected crops. In September, a hurricane caused much destruction.
1974		Hurricane Fifi destroyed crops.
1975		A severe drought over most of the country through midyear affected agriculture.
1976		Rice output was hit hard by weather.
1977	March	Pest infestations, floods and drought affected crops.
1978		The corn crop needed rain, especially in the southern states.

TABLE 4.10

HONDURAS (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1979	November	Floods seriously damaged grain crops, banana plantations and fruit trees. Blue mold caused serious losses to tobacco.
1980	September	Corn output was affected by floods in the northern part of the country. Rice, sorghum and cotton output fell below 1979 levels.
1981	October	Floods washed away crops in the north-west areas.
1982	May	A tropical storm destroyed crops.

F. NICARAGUA

1. Physical Environment

Nicaragua is the largest of the Central American countries with an area of 139,700 square kilometers. Included in this area are approximately 9,000 square kilometers of lakes, lagoons, and swamps. The country is bounded by Costa Rica on the south and Honduras on the north and extends from the Caribbean Sea to the Pacific Ocean (Figure 4.23).

A triangular wedge of highlands extends south from Honduras through the center of the country (Figure 4.24). A wide belt of lowlands, fringed by swamps, separates these highlands from the Caribbean Sea. These large lowlands, the Nicaraguan Depression, extend diagonally across the Isthmus from the Gulf of Fonseca (on the Honduran border) to Costa Rica and the Caribbean. The lowland is covered with volcanic detritus. The central and southern portions are dominated by the Managua and Nicaragua Lakes. A narrow, discontinuous belt of dormant and active volcanoes separates the depression from the coastal plains and the Pacific Ocean (Ryan, et al., 1970).

Five major natural regions can be identified in Nicaragua (Figure 4.24). The Pacific Coastal Lowlands (A1) form a relatively continuous strip along the entire western seaboard of the country. The eastward limits of the region reach an altitude of 400 m. The soils are principally of volcanic origin. The rainy and dry seasons are of equal length.

The Pacific Uplands (B1) are relatively low-ranging (between 400 and 1,600 m) and are discontinuous. The region consists of heavily dissected upland plateaus which have dormant and active volcanoes.

The Central Lowland (A2) is a large continuous depression covered with volcanic and alluvial deposits. Although the altitude of the whole area is low,

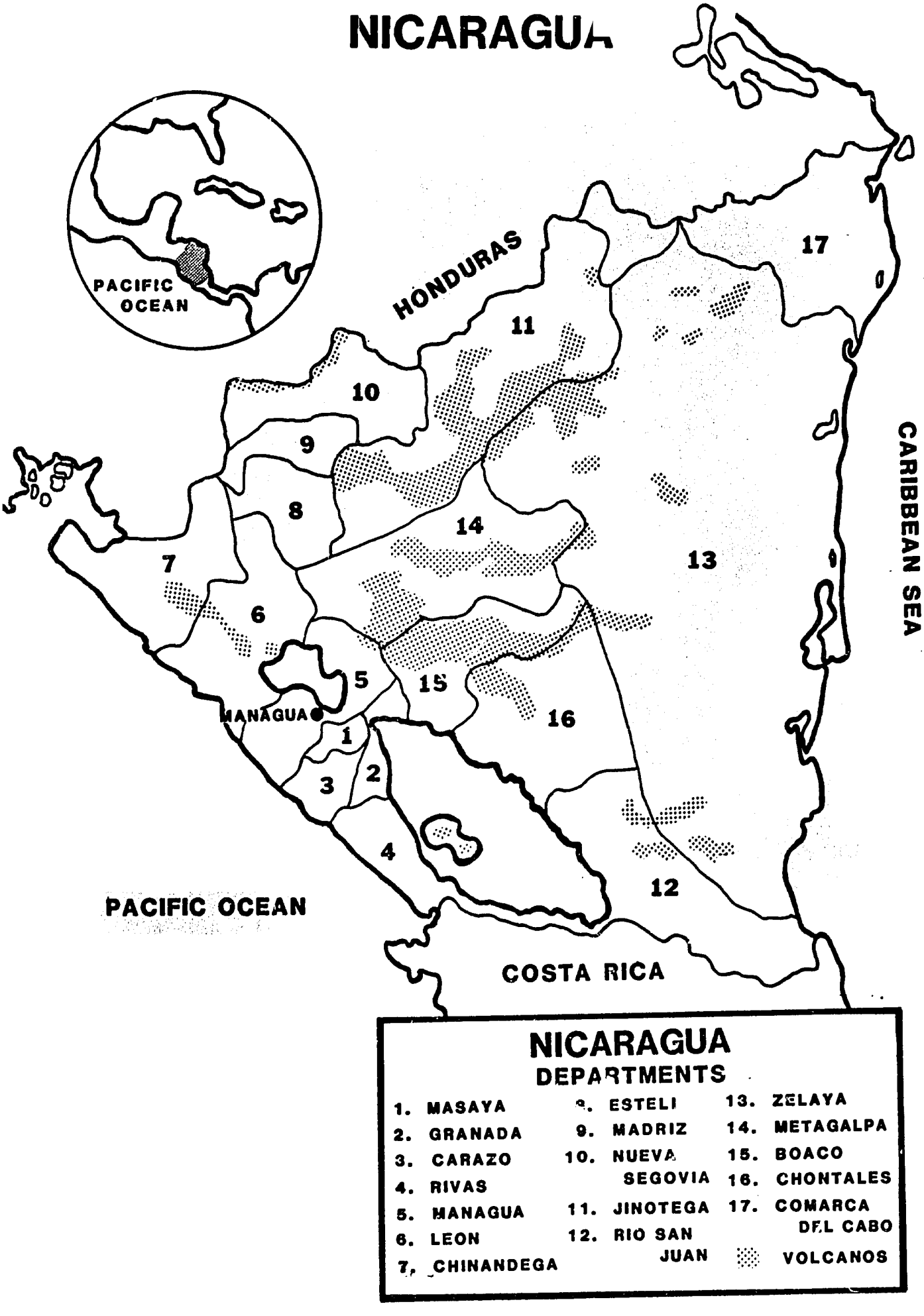


Figure 4.23. Location and Boundaries of Nicaragua.

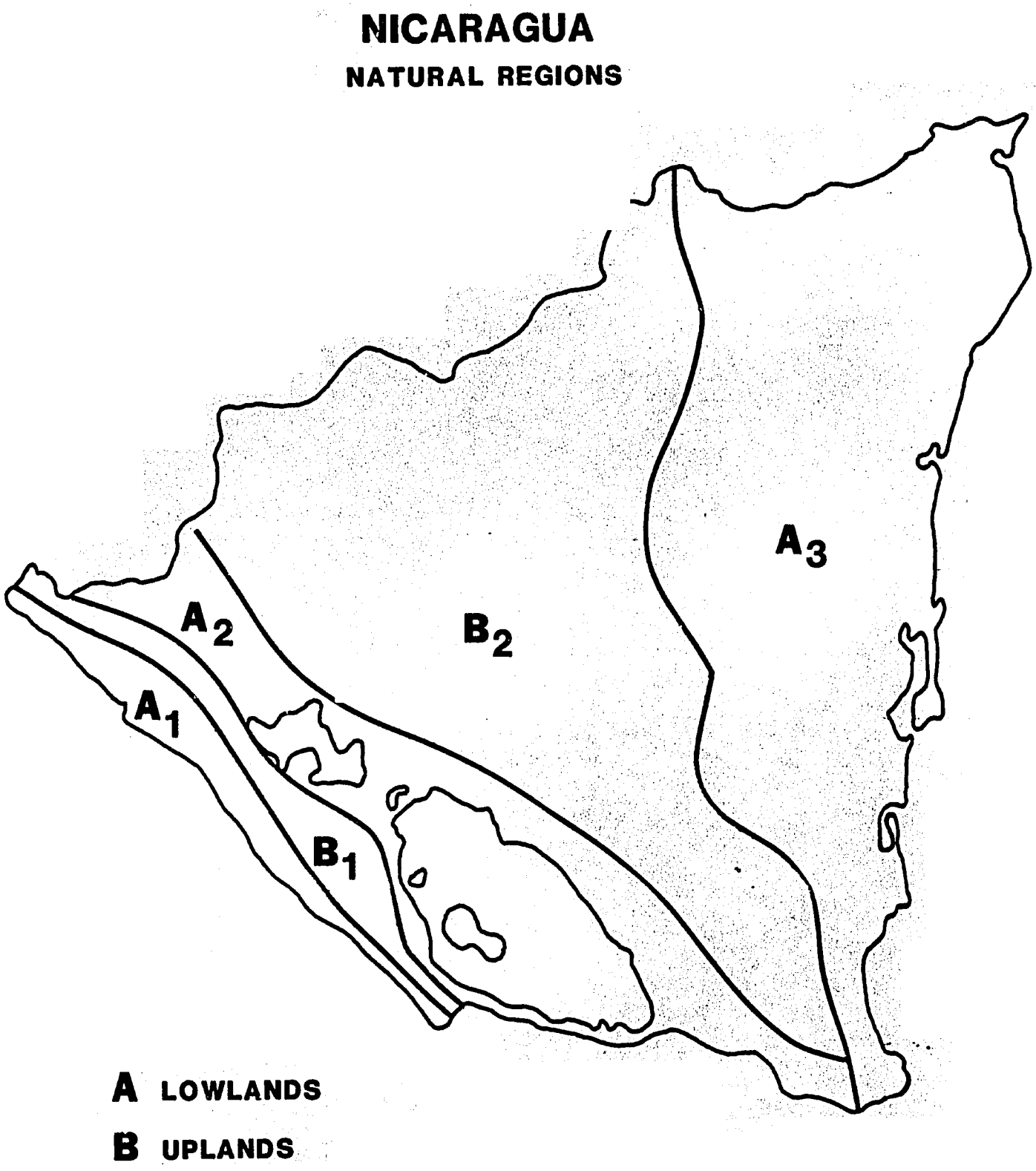


Figure 4.24. Natural Regions of Nicaragua.

there is considerable variation in local relief. Large tracts in the central and southern portions of the depression are covered by lakes, lagoons, and swamps.

The Central Uplands (B2) form a large triangular wedge, extending southeast from Honduras to the San Juan River. The western edge of the region forms a continental divide with altitudes ranging between 500 and 1,000 m. The topography is rugged, with comparatively restricted valleys and plateaus. The eastern slope has been heavily cut by many large rivers. Large, finger-like ridges extend eastwards into the Caribbean Lowlands.

The Caribbean Lowlands (A3), also called the Eastern Plains or the Mosquito Coast, comprise about 40 percent of the total area of the country. Low-lying plains sloping to the Atlantic are made up of a wide variety of soils. The prevailing vegetation in this region is evergreen tropical forest of mixed composition.

The climate of Nicaragua is tropical with a typical rainy season (winter) and a dry season (summer). Wide differences in temperature, precipitation, and the timing and duration in the season result from variations in elevation, proximity to the mountain systems and numerous other local factors.

The Pacific Coastal Lowlands (A1) and the Central Lowlands (A2) are characterized by mean annual temperature ranging between 30°C at sea level and 24°C at 600 m. The mean annual rainfall is only 875 mm in the southern coastal and central plains but rises to 1,875 mm on the Honduran border. The rainy season begins in May and ends in November.

The Pacific Uplands (B1) are cooler and drier than the surrounding lowlands. The rainfall rarely exceeds 1,500 mm and also lasts from May to November. Mean annual temperatures vary from 24°C at 600 m to 16°C at 1,400 m.

The Central Uplands (B2) receive heavy rainfall throughout the year, ranging from 2,000 mm on the western slopes to 3,500 mm on the Atlantic-facing slopes. Mean annual temperatures range from 15°C at high altitudes to 22°C on the humid, east-facing slopes.

The vast Caribbean Lowlands (A3) are typically hot and humid. Mean annual temperatures range between 24 and 26°C throughout the entire region. The rainy season lasts from 10 to 12 months, with annual rainfall totals varying from 3,100 to 5,900 mm.

2. Agricultural Practices

Agriculture is the foundation for Nicaragua's economic growth and development. It contributes about one-third of the gross national product and employs more than half of the country's labor force. In 1980, primary commodities accounted for 77 percent of merchandise exports. The value of merchandise exports in 1980 totaled US $449 million (World Bank). In the same year the total crop land accounted for less than 7 percent of the total land area.

Teran (1970) reports that with the exception of cotton, the yields of all crops are considerably low by international standards. However, as a result of steady improvements in crop yields over the last two decades, Nicaragua is largely self-sufficient in many agricultural commodities. In fact, imported foodstuffs, mainly wheat and rice, represented only 6 percent of the total value of the imported goods in 1980.

Three major types of farms can be recognized in Nicaragua: subsistence, diversified, and specialized. The first two types are usually owner-operated and engaged in general agriculture or stockraising.

Subsistence farms, the dominant form, are generally small and produce only staple food crops (e.g., corn, beans, and rice) for local consumption.

Primitive methods are still utilized. The most widely used farm implements are the Spanish wooden ox-plow and variants of the Indian digging stick. Subsistence farmers use the characteristic Mesoamerican shifting slash-and-burn agriculture. The land is cleared with axe and machete, burned just before the rains begin, then planted with the aid of the wooden ox-plow or the digging stick depending on the terrain. These plots are used for two or three years and then left fallow for several seasons before being cultivated again.

Diversified farms have a subsistence base but grow fruit, vegetables, and other produce for urban markets, together with a few hectares of cotton, coffee, or tobacco. These farms are generally larger than subsistence farms and some application of modern methods and machinery can be found.

Specialized farms are commercial enterprises producing coffee, cotton, bananas, sugarcane, or cattle for internal and overseas markets. These farms are characterized by modern intensive cultivation methods including extensive use of fertilizer and machinery.

Increased mechanization and use of fertilizer, pesticides, and irrigation can be observed only in the large commercial operations where productivity is substantially higher than in the other farm types (Ryan, 1970). Frequently the introduction of mechanical equipment has increased the problem of soil erosion and exhaustion, especially on cotton-producing farms. The extension of irrigation has led to high yields in rice, sugarcane, bananas, and tobacco.

Part of the government's agrarian reform process is the incorporation into public domain of the farm-related holdings, generally large-scale and modern in operation, of the leaders of the former regime: 2,200 farms, 65 agrobusinesses, 25 farm service companies. Public holdings represent only 7 percent of arable lands but 18 percent of total production. A series of reform measures, adopted

with the aim of gradually eliminating the dual agricultural system within a mixed economy, does not include redistribution of government lands in the near future because of the overriding necessity to maintain their present productive contribution to the economy.

3. Principal Crops

a. Corn

Corn, the principal staple of Nicaragua's subsistence agriculture, is widely distributed (Figure 4.25). This wide distribution is also characteristic of other foodgrains. Two-thirds of the output of corn and beans and almost half of that of sorghum are produced in the Central Uplands. The regional crop calendar for corn, beans and other selected crops is shown in Table 4.11.

b. Other Crops

Cotton, the major export crop, is concentrated in the most fertile lowlands of the Pacific region. Coffee, the second export crop of Nicaragua, is cultivated in the Pacific and Central Uplands. The production of cotton and coffee for export has become increasingly mechanized. In addition, the use of fertilizers and pesticides has improved productivity.

Other important crops include beans, rice, sugarcane, bananas, sorghum, sesame, and tobacco. The Caribbean Lowlands have considerable potential for such crops as the African oil palm, cacao, pepper, and abaca (Teran, 1970).

4. Agroclimatic Indices

Figure 4.26 shows the historical Yield Moisture Index (YMI) in percentiles for Lovago (Pacific Region). The YMI was computed for a corn crop during the main growing season (May-October). Poor crop conditions are indicated by the YMI (5th percentile) during the 1972 crop growing season. The critical YMI value for crop failure may be determined by using episodic data (Table 4.12) and historical crop yield data.

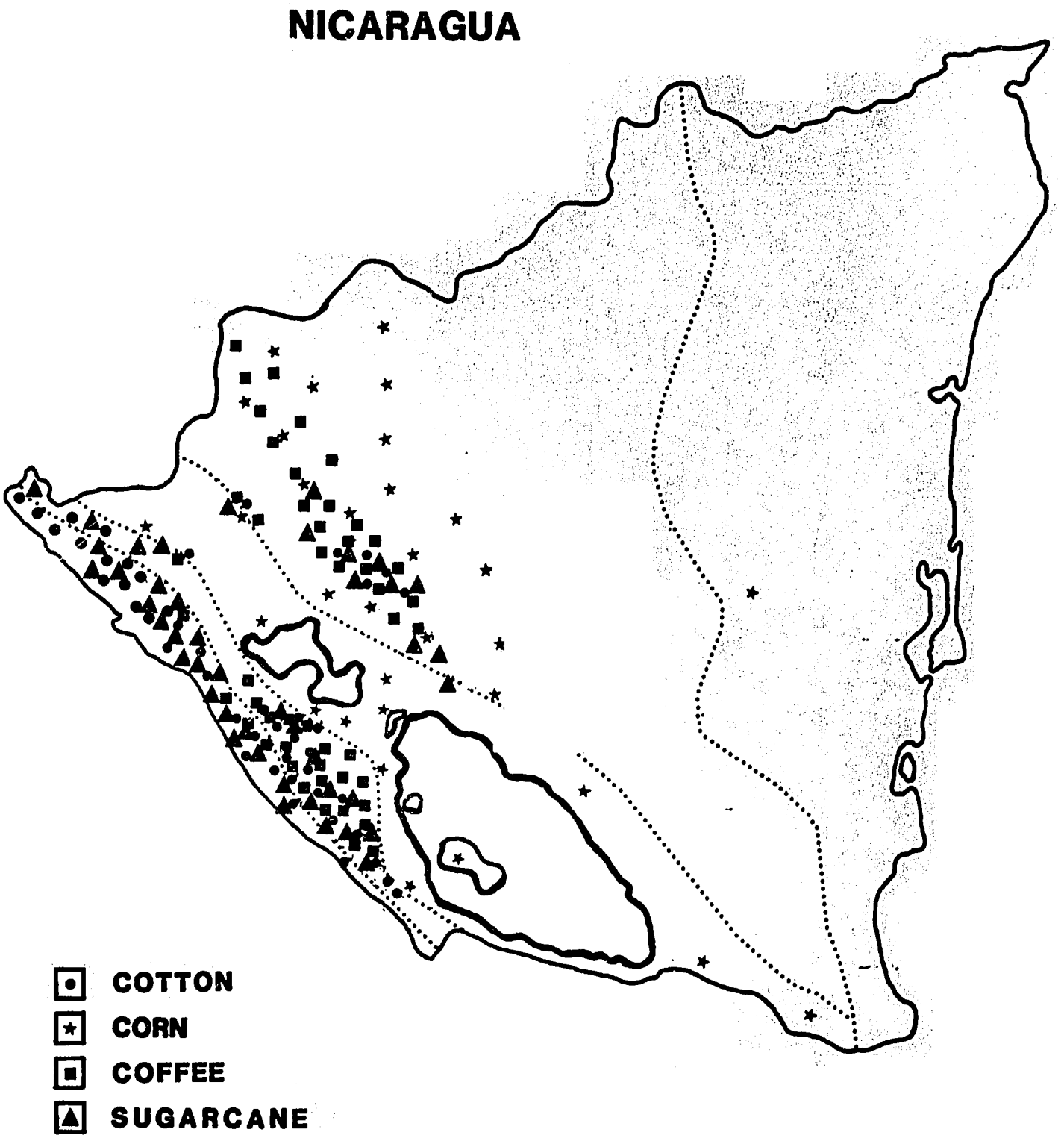


Figure 4.25. Distribution of Selected Agricultural Crops in Nicaragua.

TABLE 4.11. ESTIMATED REGIONAL CROP CALENDAR FOR SUBISTENCE FARMING IN NICARAGUA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Atlantic	Corn					//	//	—	—	OO	OO			Excessive rain.
	Beans					//	/–	—	OO	O				
Highlands	Corn					//	//	—	—	OO	OO			Usually intercropped with beans.
	Beans					//	/–	—	OO	O				Takes 65 to 80 days to reach maturity.
	Potatoes					//	/–	—	–O	OO				A second crop may be growm between November & February.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Harvested from 10 to 14 months after planting.
Pacific	Corn	O				//	/–	—	–O	OO	//	/–	—	Local and improved varieties.
	Beans					//	/–	–O	OO	//	/–	–O	OO	Intercropped with corn.
	Rice						//	/–	—	—	—	OO	OO	Mostly rainfed.
	Sorghum					//	//	—	—	—	OO	OO		
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	—	OO	Harvested from 12 to 18 months after planting/cutting.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

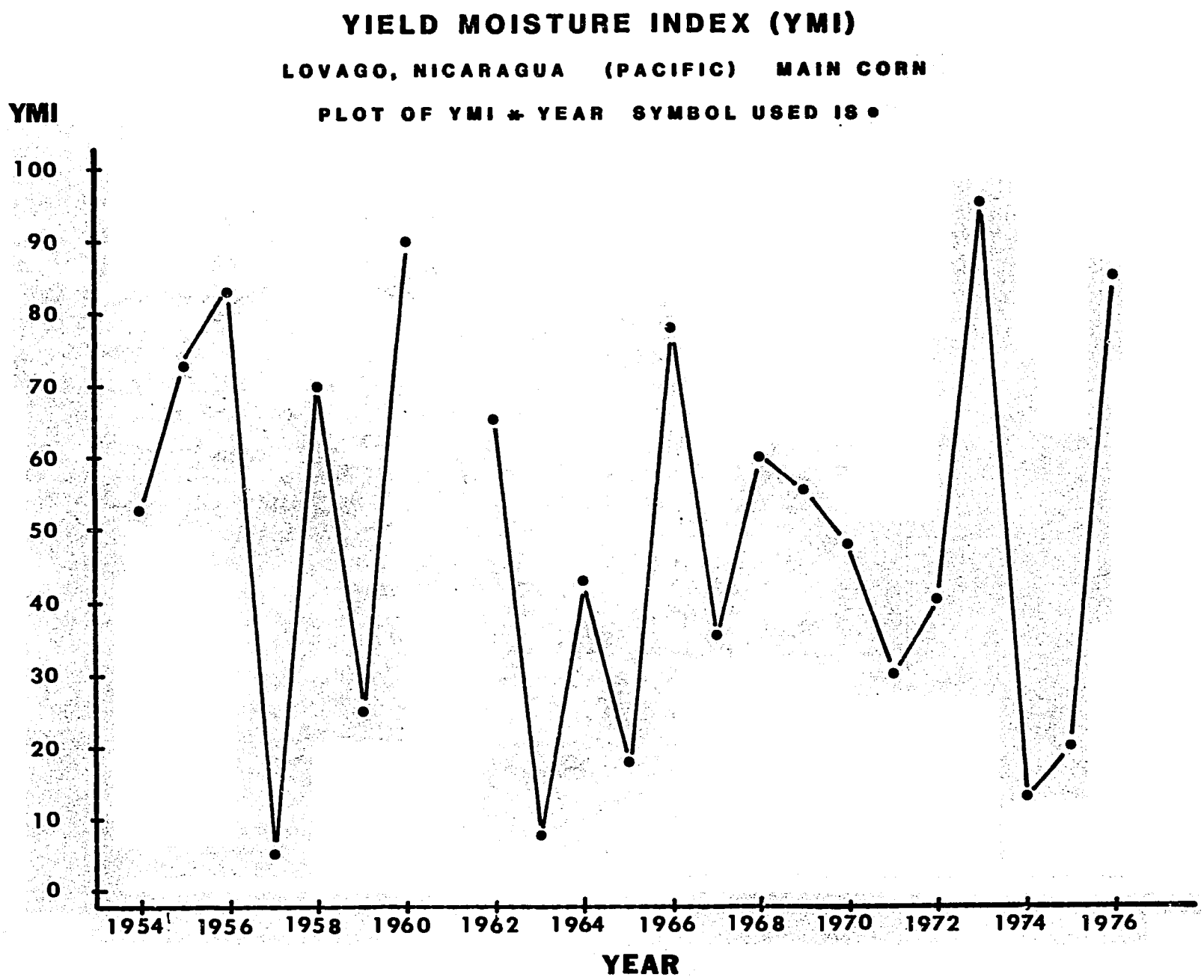


Figure 4.26. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Lovago (Pacific Region).

TABLE 4.12

NICARAGUA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1957		Drought affected crops.
1963-64		Crops were damaged by drought.
1965		Extremely dry weather reduced yields, especially corn.
1966		Agricultural conditions were unusually bad.
1967		A slow start of summer rainy season hurt crop production in some Pacific coastal areas.
1974		Corn and rice production was adversely affected by either excessive rains or drought.
1975		Expanded plantings resulted in a larger crop harvest despite unusually dry weather early in the year.
1976		Dry weather lowered yields. Widespread flooding occurred on the Atlantic coast in July.
1977		Drought occurred in major grain producing regions.
1978		Good crops resulted from favorable weather.
1979		Civil disturbances caused crop production to fall. Floods damaged crops in December.
1979-80		Sugarcane rust caused serious production problems.

TABLE 4.12

NICARAGUA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1980		Continued dry weather prevailed over the entire country since March, 1979. Food shortages still existed in May. In September tropical storm Hermine damaged crops in northern areas.
1981	July	Northern zones suffered from famine caused by floods damaging foodstuffs. Floods also hit the Atlantic coast in June.
1982	May	Tropical storms damaged crops. A two-month dry spell ending in mid-September severely affected maize, sorghum and bean crops.

G. PANAMA

1. Physical Environment

Panama is located at the southwest extremity of Central America, forming the lowest portion of the isthmus that connects North and South America. It runs west to east for about 700 km with a width of 48 to 185 km, covering an area of 77,082 square kilometers. Its boundaries are the Caribbean Sea to the north, the Pacific Ocean to the south, Colombia to the east, and Costa Rica to the west (Figure 4.27).

The dominant feature of the country's landform is the central mountains and hills that form the continental divide (Figure 4.28). The mountain range of the divide is called the Cordillera de Talamanca near the Costa Rican border. It then becomes the Serrania de Tabasara, and the portion close to the Canal Zone is called the Sierra de Veraguas. As a whole, the range between Costa Rica and the Canal is generally referred to as the Cordillera Central. Near the Colombian border there are highlands related to the Andean system of South America -- the Cordillera de San Blas and The Serrania del Darien. The highest point in the country is the Volcan Baru (formerly Volcan de Chiriqui) rising to approximately 3,450 m (Weil, et al., 1972).

Panama has more than 300 long, slow-running rivers with extensive basins emptying into the Pacific. The largest is the Rio Tuira which flows into the Golfo de San Miguel. It is the only navigable river.

The Atlantic coastline, about 1,246 km long, has many good natural harbors but few towns; the only important port facilities are in San Cristobal. There are numerous islands of the Bocas del Toro Archipelago near the Costa Rican border, important because of the shield they provide for the banana port of Almirante.

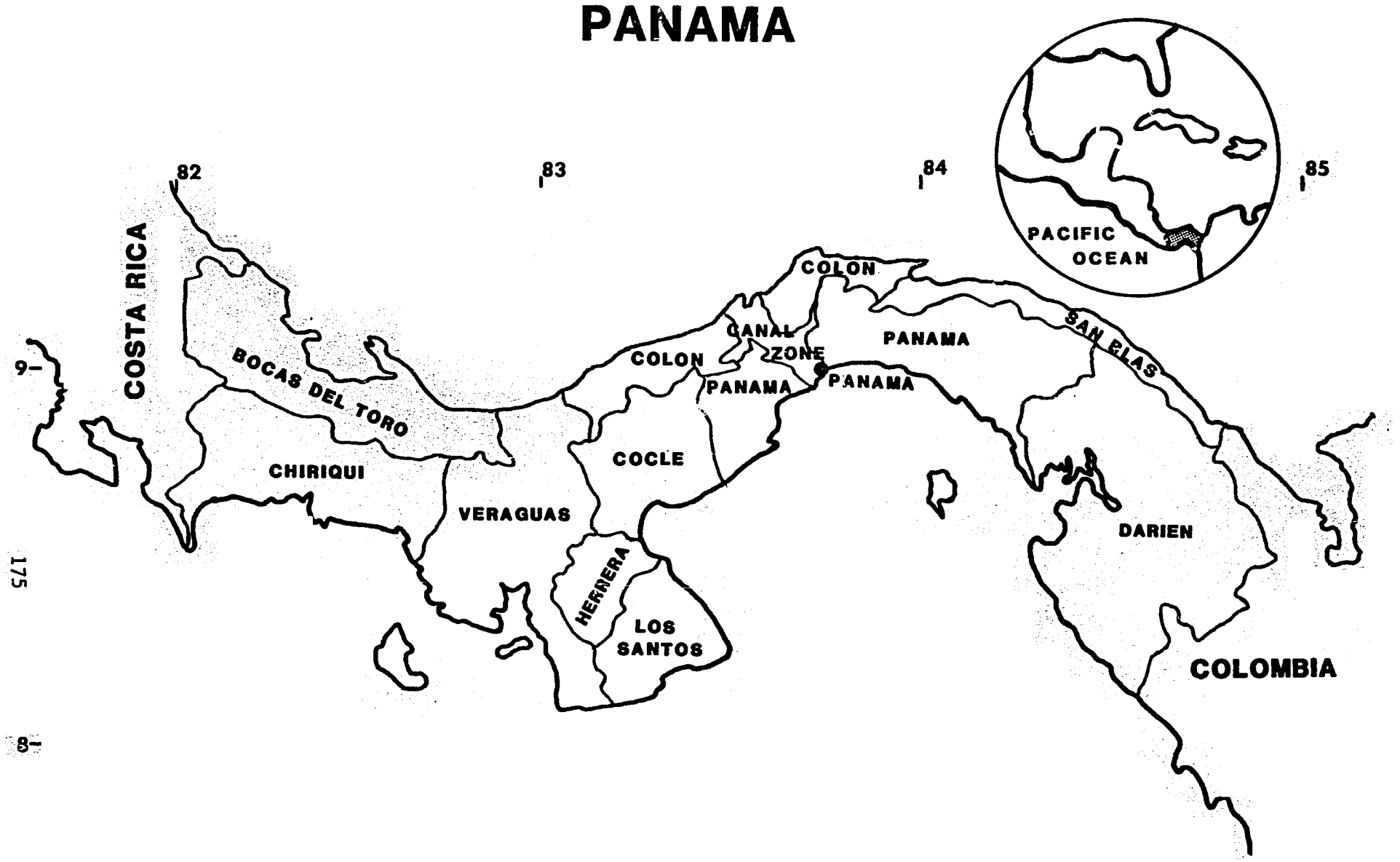


Figure 4.27. Panama: Boundaries and Provinces.

PANAMA

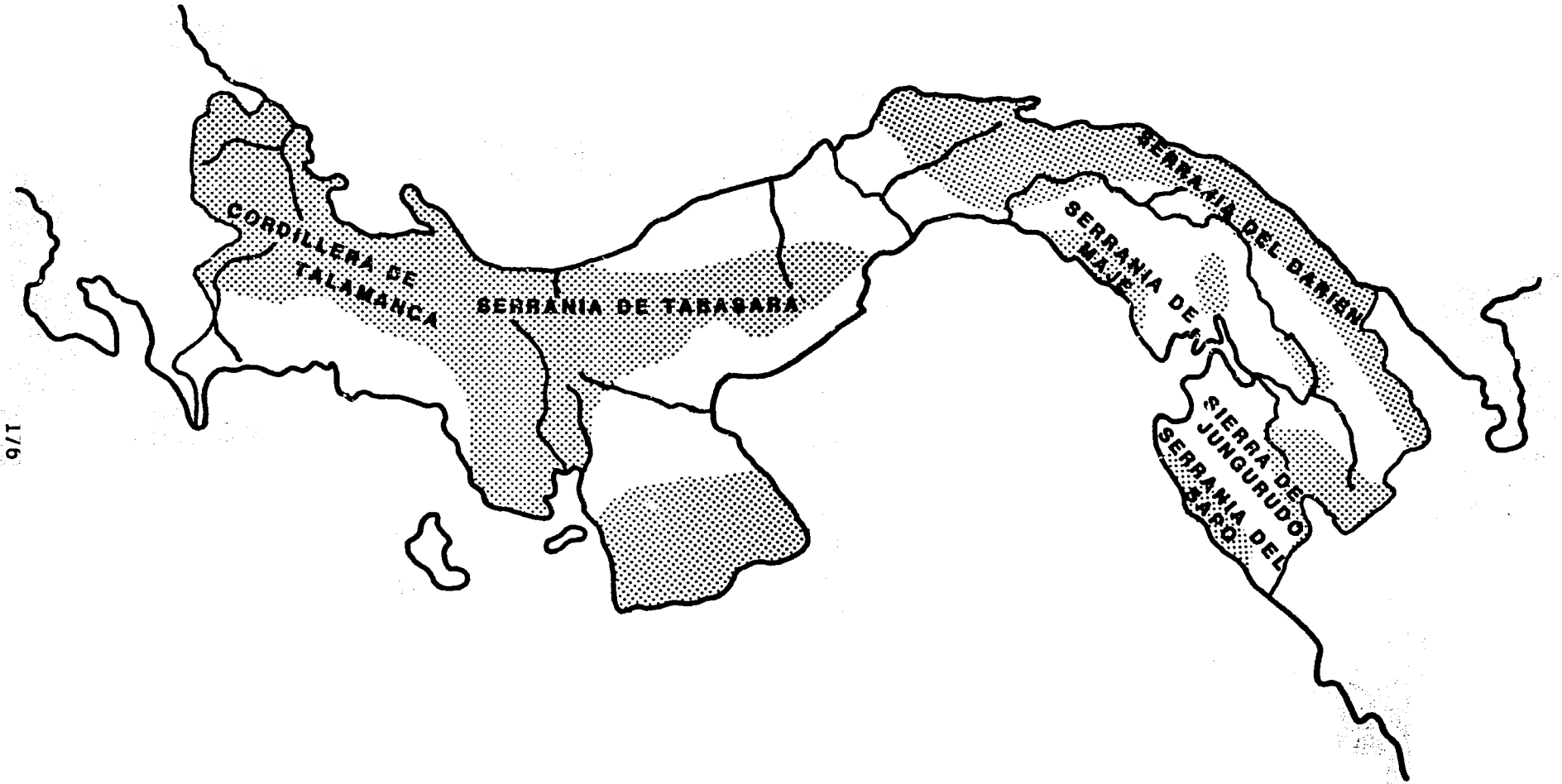


Figure 4.28. Topography and Major Rivers.

The Pacific coastline is about 1,634 km in length with over 1,000 islands off the coast. The coastal waters are very shallow with wide mud flats, causing an extreme tidal range.

Panama lies in the tropical zone, and because of variations in altitude and temperature three climatic types can be distinguished (Calzecchi-Onesti, 1970): (a) caliente or hot climate, peculiar to the lowlands below 700 m, which occupy 87 percent of Panama's total land area; (b) templado or temperate climate, characteristic of lands between 700 and 1,500 m, which occupy only 10 percent of the total area; and (c) frio or cold climate which characterizes the high lands above 1,500 m.

In the lowlands ("tierras calientes") the minimum temperature never falls below 18°C, and the average annual temperature is 26.7°C on the Caribbean coast and 25.9°C on the Pacific coast. In the "tierras templadas" the temperature decreases 1°C for every 200 m above 700 m. The mean annual temperature ranges from 15 to 18°C. In the high lands ("tierras frias") the fall in temperature is strictly related to altitude; the annual average varies between 3 and 15°C.

The climate of Panama is characterized by two seasons: (a) the dry, corresponding to the astronomic winter and lasting from January to April; and (b) the rainy, lasting from May to December. Rainfall varies regionally from less than 1,300 to more than 3,000 mm and falls almost entirely during the wet season (Calzecchi-Onesti, 1970).

The country can be divided into three natural regions: the tropical "selva," the Pacific savanna, and the Central Region with the high Darien and the Chagres areas (Figure 4.29). The tropical "selva" is covered by tropical forest and occupies part of the "tierras calientes." The Pacific savanna region has a dry tropical climate. The mountainous "tierras templadas" of the Cordillera Central and high Darien are heavily forested. The Chagres area occupies the central isthmus of Panama and has low hills and valleys covered by tropical forests.

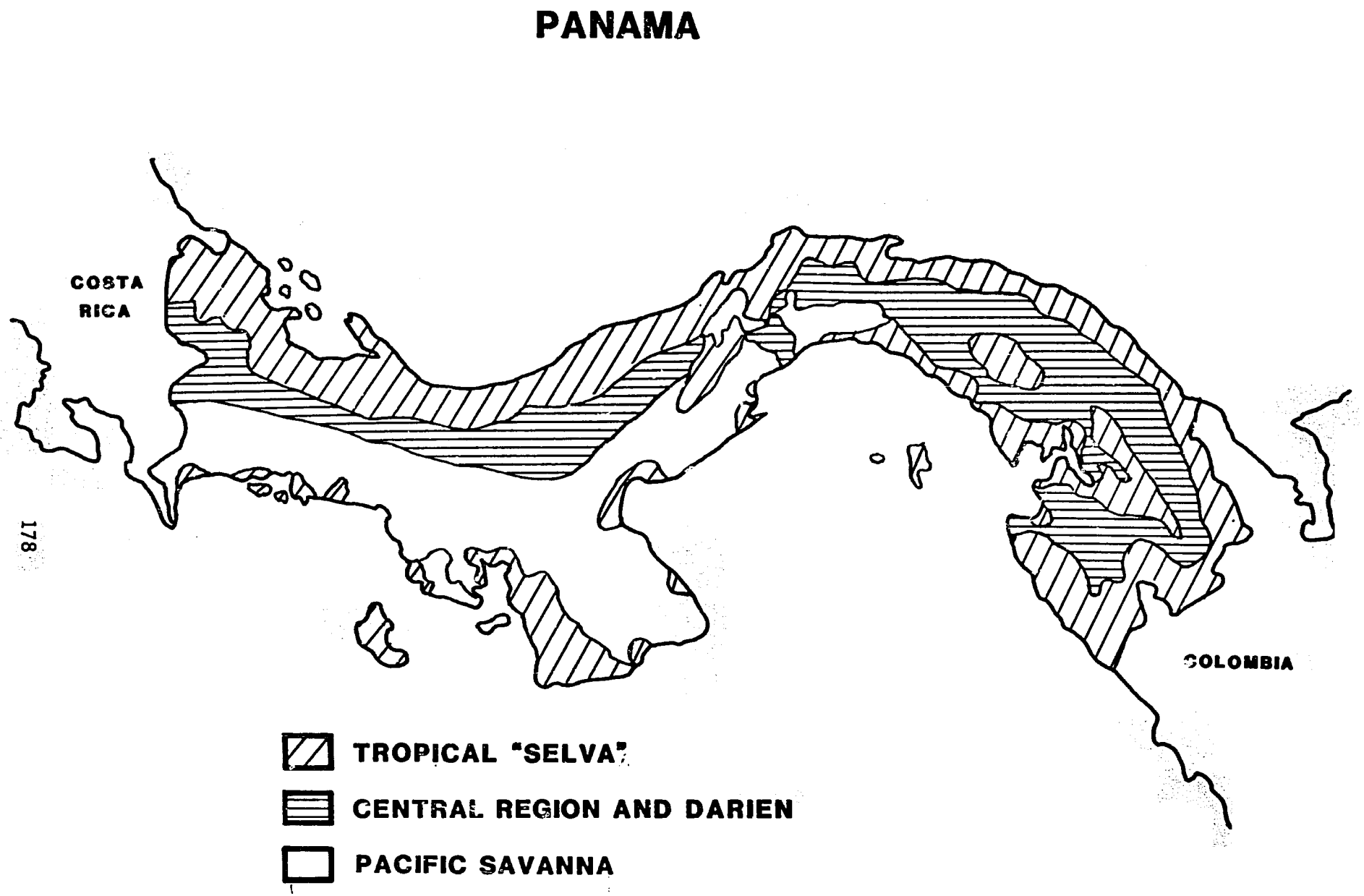


Figure 4.29. Natural Regions.

2. Agricultural Practices

According to a 1970 agricultural survey, about 29 percent of the total land area of Panama was in farmland. By the late 1970's, agriculture accounted for only 15 percent of the country's gross domestic product. Even so, agriculture was the main source of jobs, employing 31 percent of the labor force in 1978 (Eglin, 1981).

Most farmers practice a slash-and-burn type of shifting cultivation, also known as "machete" or "roza" farming. Their basic tools are the "machete" (a large heavy knife used in clearing land and in harvesting) and the "coa" or "chuzo" a digging or planting stick to make holes for seeds. There are, however, a few dozen large holdings with a high degree of mechanization that utilize modern techniques and produce for the market, representing only 2 percent of the total number of farms. These can therefore be classified as commercial farms. Cattle ranches, coffee, rice, sugarcane and banana producers, and vegetable growers are included here.

In this system of shifting cultivation the farmer clears and plants a field and when the productivity of the soil is nearly exhausted, usually after one or two years of use, he moves to clear another patch nearby, leaving the formerly used land to natural regeneration. He may return to the first plot and clear it again after several years (Villegas, 1917). The farmer is virtually forced to do this because of the poor quality and thinness of the top soil. Indeed, most soils are low in phosphorous, nitrogen, and organic matter and high in acidity. Furthermore, erosion is particularly damaging to grazing lands.

According to Weil et al (1972), clearing of virgin forest land or secondary overgrowth is done in the dry season following mid-December. Planting is done immediately after burning and clearing during March and April and, by the time

the rain becomes heavy, most of it is completed. Under the influence of the hot and humid climate, crops mature rapidly and can be harvested toward the middle of the wet season. In many instances a second crop can be planted and harvested toward the end of the wet season or early in the dry months. Usually more than one crop is planted in the same field.

Topography and soil quality limit utilization of land for agricultural purposes. Most farming is carried on at elevations lower than 300 m, on the hills and plains of the lowland that covers half of the country's surface.

Extensive use of fertilizers and mechanization is the exception rather than the rule in Panama. In 1969, for example, only about 13,000 tons of fertilizers were used in the entire country, mostly by the banana and sugarcane growers (Weil et al, 1972). On the other hand, fewer than 2 percent of the farms used wheel and caterpillar tractors. These were used mainly on banana and sugar plantations and secondarily for rice production (Calzecchi-Onesti, 1970). Even plowing is not an accepted practice because of the expenses involved in the purchase and maintenance of draft animals and equipment. However, small farmers can rent machinery for land clearing, plowing, and harvesting from several government-operated machine stations.

To conserve moisture during the dry months, irrigation has been developed and applied chiefly on banana and sugarcane plantations and rice fields. The government also began an irrigation program in 1969 in various dry areas.

Prevailing high temperatures and the high relative humidity promote the rapid spread of weeds, insects, and diseases that retard agricultural development. Much greater use of pesticides is reported, however, even by some of the smallest farms.

3. Principal Crops

The major food crops of Panama are bananas, the leading export, and rice and corn, which are the primary food staples. Other important products are

coffee, beans, cacao, tubers, tobacco, tomatoes, citrus fruits, other fruits and vegetables, eggs, poultry, and fishmeal. Shrimp, sugar, and beef are making growing export contributions. Figure 4.30 illustrates the areas devoted to bananas, coffee, and sugarcane.

Table 4.13 shows the estimated regional crop calendar for subsistence farming in Panama.

a. Rice

Rice is a staple food of the population and is grown on almost every farm. The area planted to rice has been increasing steadily and by the 1976-77 crop year reached a record of 122,400 ha (Eglin, 1981). The development of dry-land rice production has ranked at the top of government programs, and as a result the country has been self-sufficient in this product for several years since 1953. Two crops a year are grown. Eighty percent of the rice is produced by small farmers who seed untilled soil with the "chuzo." The remaining 20 percent of the national output comes from the larger farms, located in the Provinces of Cocle and Chiriqui (Figure 4.27). These farms use machinery, fertilizers, and improved seed varieties. When fertilizers are used in mechanical farming significant yield increases are attained, from 0.95 tons per ha on small, traditional farms to 2.4 tons per ha on large, relatively modern ones.

In spite of the introduction of new and improved varieties, farmers must still contend with a rice-eating wild bird called the "arrocero." This is more of a pest than insects.

b. Corn

Corn, the second most important subsistence crop, is grown on about 68 percent of all farms. It is cultivated by hand on slopes where machinery cannot be utilized. Most farmers use traditional methods and no fertilizers. Chiriqui and Veraguas are the leading corn-producing areas (Figure 4.27). The sowing in these provinces is done only during the rainy season.

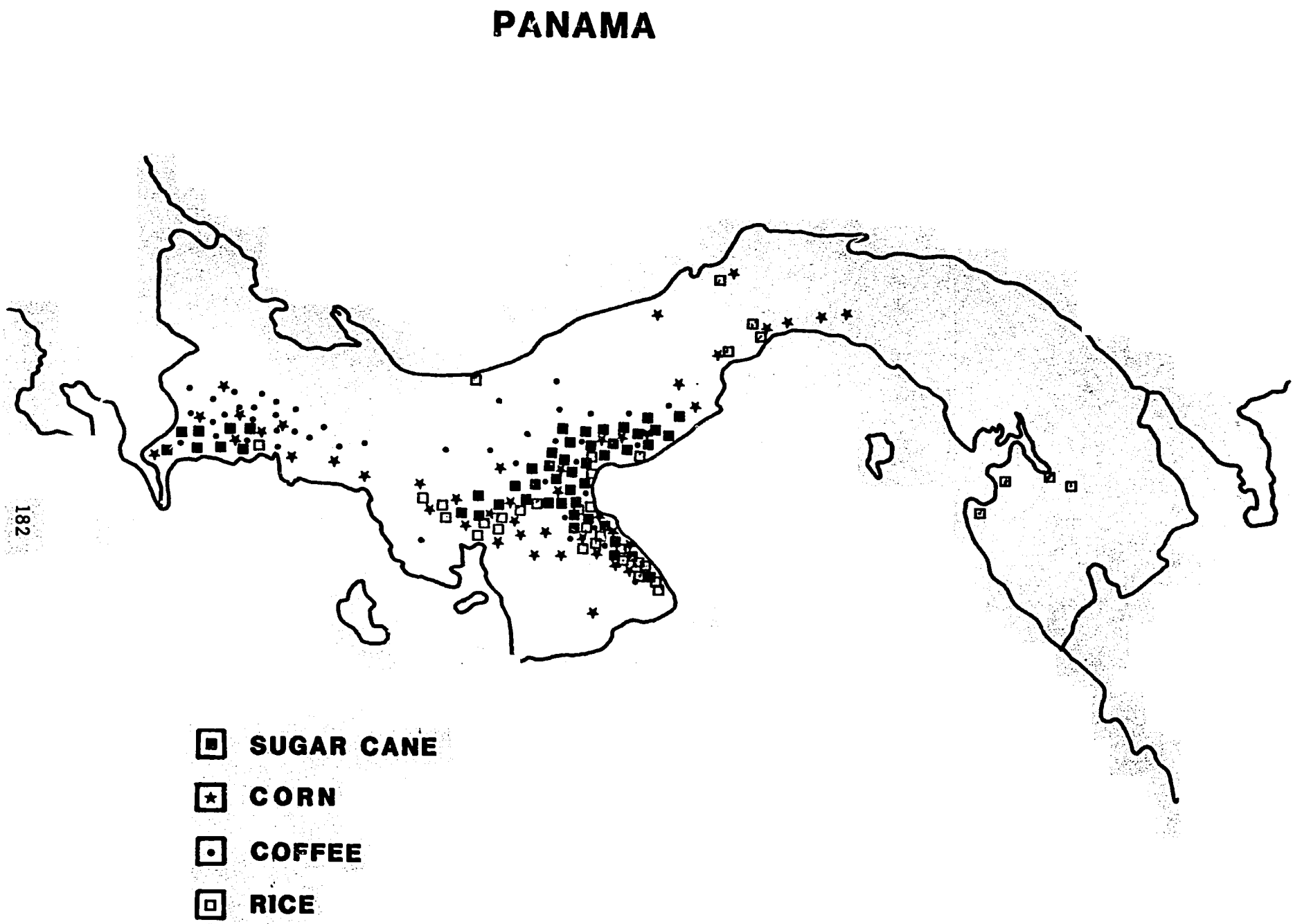


Figure 4.30. Distribution of Selected Agricultural Crops in Panama.

TABLE 4.13. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN PANAMA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Atlantic	Corn					//	//	—	—	OO	OO			Intercropped with beans.
	Beans					//	/-	—	OO	O				
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Harvested from 10 to 14 months after planting.
Southwest	Corn					//	//	—	—	OO	OO			Local and improved varieties.
	Rice					//	//	—	—	—	OO	OO		Rainfed and Irrigated.
	Beans					//	/-	—	OO	O				
	Sugarcane	OO	OO	OO	OO	—	—	—	—	—	—	—	OO	Harvested from 12 to 18 months after planting/cutting.
Southcentral	Corn					//	//	—	—	OO	OO			
	Rice					//	//	—	—	—	OO	OO		
	Beans					//	/-	—	OO	O				
	Sugarcane	OO	OO	OO	OO	—	—	—	—	—	—	—	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Eastern	Corn					//	//	—	—	OO	OO			
	Beans					//	/-	—	OO	O				

Domestic production, 88,000 tons in 1977, does not meet local demand and small imports are required. Better cultivation practices and improved seed qualities may eventually increase the output.

c. Beans

Various kinds of beans are grown in small lots using traditional methods without fertilizer or mechanization. Thirty-five percent of the total production is in Veraguas Province. Most of the annual production is consumed on the farms. Bean yields are low because of lack of storage facilities and insect control. Improved varieties have been introduced lately in an attempt to encourage the cultivation of beans as a rotation crop with rice.

d. Bananas

Bananas are the most important export crop of Panama, contributing nearly one-fifth of agriculture's share of gross domestic product (GDP) in the mid-1970's (Eglin, 1981). The largest plantations are located in the Provinces of Bocas del Toro and Chiriqui while small growers who supply the local market are concentrated in eastern Darien and near the Canal Zone (Figure 4.27). A high degree of technology is utilized in banana production.

Windstorms and rainstorms occasionally destroy millions of plants, as they did in late 1970. Fungus diseases, such as Sikatoga and Panama diseases, make repeated inroads despite preventive measures. A new variety of disease-resistant banana has been introduced with great success. The stems are encased in plastic bags while growing to prevent insect damage, and yield per hectare has thus risen sharply (Eglin, 1981).

e. Other crops

Sugarcane

In 1978, sugarcane was the third most important crop in area cultivated, with about 58,000 ha and an annual production of 2.8 million tons (Eglin, 1981). The value of sugar exports in 1975 was second only to bananas.

Panama's climate is not ideally suited for sugarcane; this results in a low sugar content of the product in spite of the use of irrigation and fertilizer. More than one-half of the production is concentrated in the Cocle Province (Figure 4.27). The subsistence farmers of other provinces also grow sugarcane by interspersing it among the traditional rice, corn, and bean crops.

Coffee

Seven percent of total cropland is planted in coffee. A few large plantations use modern techniques and produce mainly for export. There are also numerous small coffee farms, less than one hectare in size, where the trees are old and the technology low.

4. Agroclimatic Indices

Figure 4.31 shows historical Yield Moisture Index (YMI) in percentiles for Balboa Hieghtsalbroof (South Central Region). The YMI was computed for a corn crop during the main growing season (April-September). Crop conditions during 1979 and 1980 were particularly poor as suggested by YMI values in the lower 5th to 10th percentile range. The critical YMI value for crop failure may be determined by using episodic data (Table 4.14) and historical crop yield data.

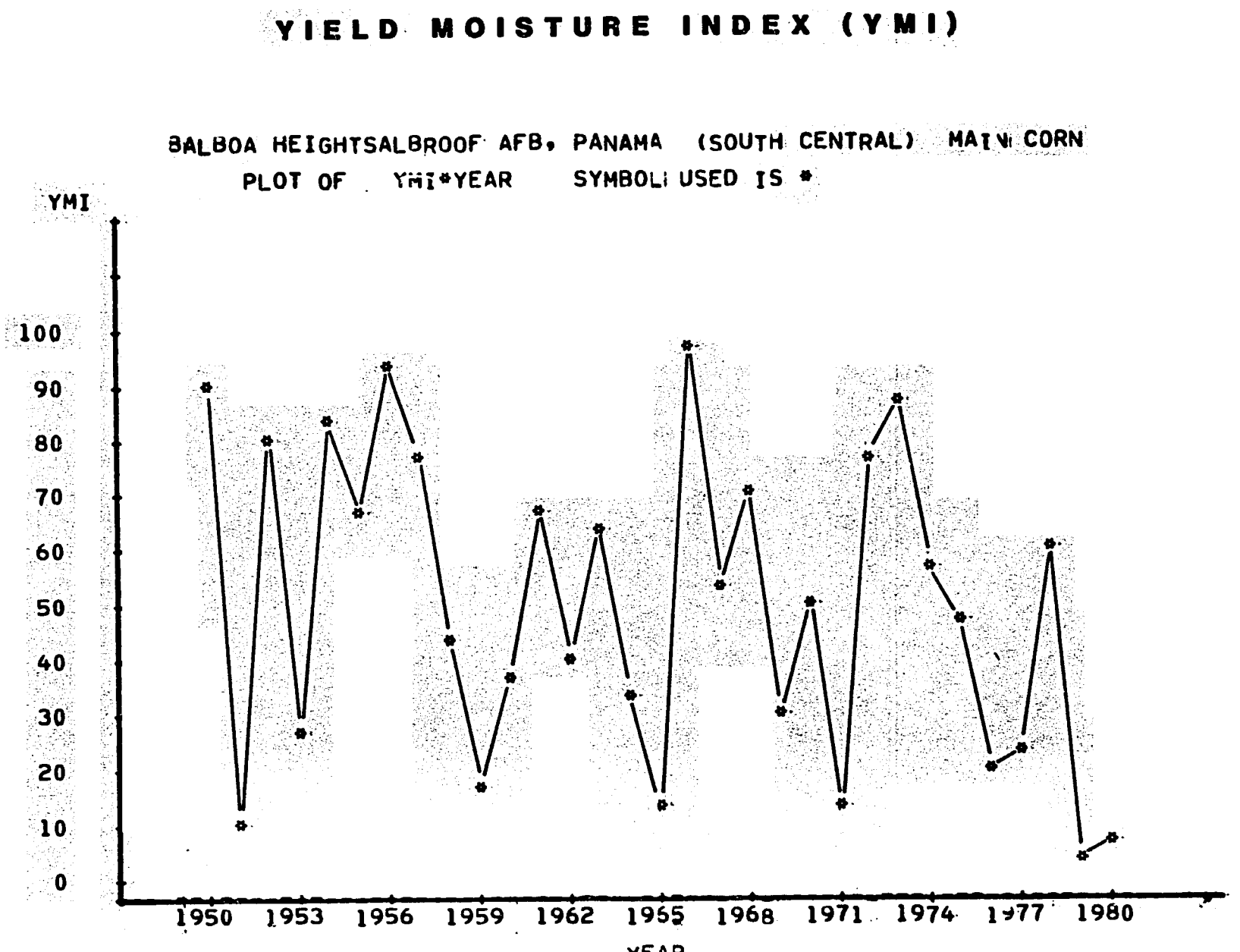


Figure 4.31. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Balboa Heightsalbroof AFB (South Central Region).

TABLE 4.14

PANAMA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1957		Drought affected crops.
1960-61		Severe blowdowns lowered banana output.
1963-64		Heavy rains and winds adversely affected agricultural outputs.
1965		Scattered areas of drought reduced output of main food crops of corn and rice.
1966		Drought reduced food production.
1970		Wind and rainstorms destroyed millions of banana plants.
1974		Rice production fell both from too much rain and drought.
1975		The year began abnoramlly dry and ended too wet, but agriculture output increased.
1976		Drought caused both abandonment and reduced yields of rice, corn and beans in major production areas. First maize and rice crops were affected in December.
1977		Better weather increased agricultural output.
1978		Growing conditions were good.
1979		Bananas were damaged by a tropical storm. Corn and beans were affected by bad weather.
1980		Excessive moisture reduced corn production. Cane smut and rust affected sugar output.

CHAPTER V

SOUTH AMERICA: AGROCLIMATIC CONDITIONS AND MODELING

A. BOLIVIA

1. Physical Environment

Bolivia, one of the two land-locked countries in South America, is surrounded by Peru, Brazil, Paraguay, Argentina, and Chile, and covers an area of 1,098,581 square kilometers (Figure 5.1). Its population is sparse (slightly over 5 million) and very unevenly distributed.

Although Bolivia lies entirely within the tropics, its climate varies greatly due to the extreme differences in elevation -- 100 m along the Brazilian border to more than 6,500 m on the highest mountain peaks. This, along with a wide diversity in soils, results in many kinds of vegetation ranging from sparse scrub cover in the semiarid highlands to lush rain forests in the eastern plains.

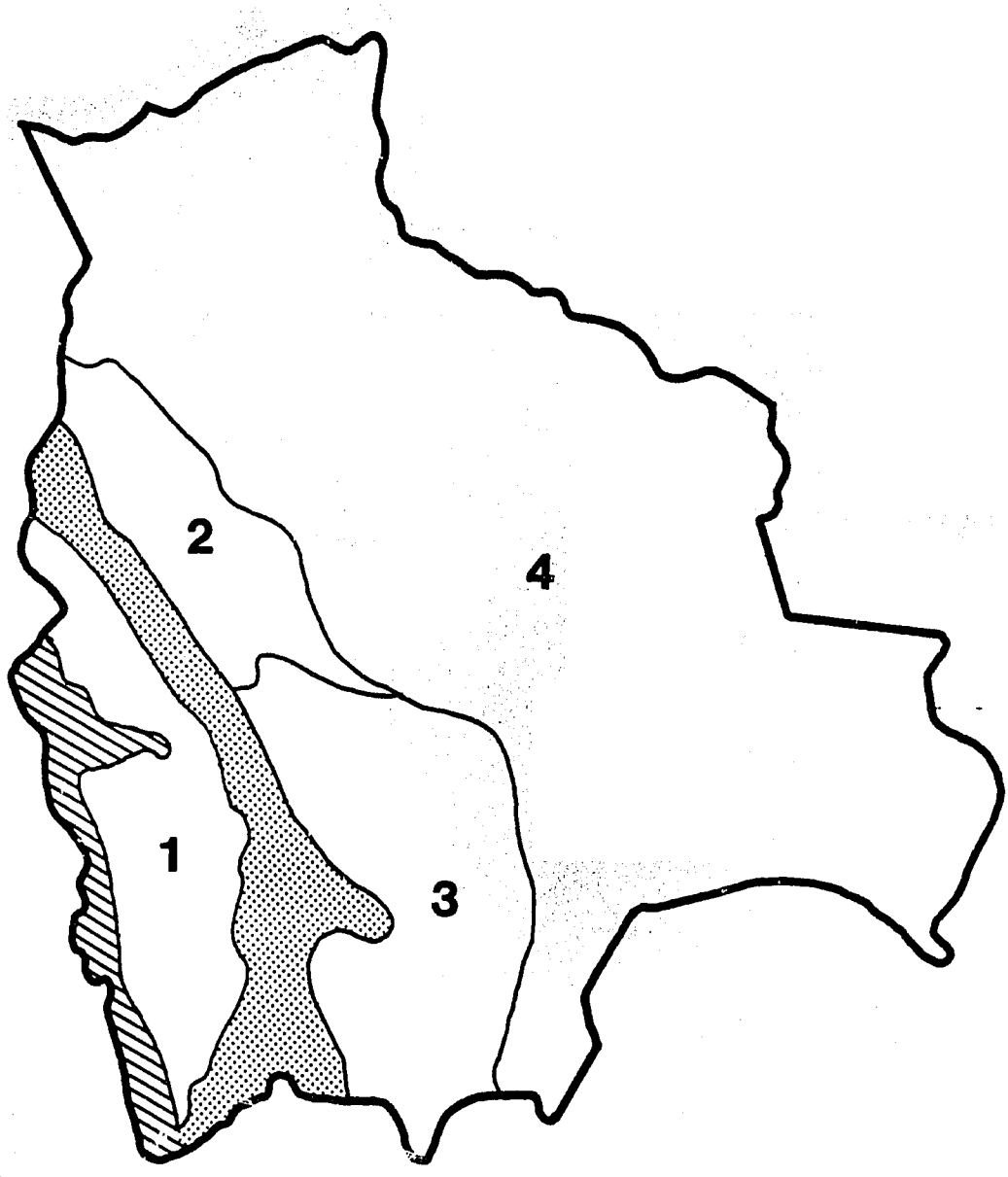
Bolivia can be divided into four natural regions: 1) the Altiplano, 2) the Yungas, 3) the Valles, and 4) the Oriente (Figure 5.2).

The Altiplano, between the Cordillera Occidental and the Cordillera Oriental, extends southward from Peru to the Argentine frontier for 800 km with altitudes varying between 3,600 and 4,200 m. It is the largest basin of inland drainage in South America. Lake Titicaca, South America's largest lake and the world's highest body of water, exerts a strong influence on the climate in the surrounding areas; they are the most heavily populated and the most agriculturally productive areas of the Altiplano.

The Yungas, the most fertile region in Bolivia, consists of sharply tilted mountain valleys that descend eastward from the crests of the Cordillera Real. The zone lying between 900 and 2,700 m is the semitropical Yungas -- a series of narrow river valleys with rich soils, heavy rains, and lush vegetation.

Figure 5.1. Location and Boundaries of Departments in Bolivia.

BOLIVIA



Western Cordillera

Eastern Cordillera

1. Altiplano
2. Yungas
3. Valles
4. Oriente

Figure 5.2. Natural Regions of Bolivia.

The Valles lie south of the Yungas and represent the descent from the Andean heights to the lowlands. The valleys and basins here are broader and more extensive than in the Yungas. The soils of the Valles support the country's most intensive agriculture. However, the high ridges and plateaus of this region, known as the Puna, are sparsely populated and unproductive.

The Oriente, covering about two-thirds of the national territory, includes all of the country east of the Andes. The flat northern part of the region consists of tropical rain forests and the Llanos de Moxos, which covers most of the Mamore River basin. Much of this area seasonally turns to swamp because of poor drainage. In the plains of northern Santa Cruz, the terrain becomes gently rolling and better drained. Savannas alternate with forests, and some cultivated areas are also found. In the southern part, a low line of hills marks the beginning of the Bolivian part of the Gran Chaco that continues southward into Paraguay.

Climatic conditions vary quite sharply, both between and within the regions due to topographic factors. From west to east, mean annual temperatures increase progressively from the chill of the Altiplano to the tropical warmth of the Oriente. Precipitation is lightest in the Altiplano and heaviest in the Oriente; in all regions, it tends to decrease from north to south. Most of the rainfall occurs between October and April (summer) but it varies considerably from year to year as well as seasonally, and both floods and droughts are common. In 1956 and 1957 a sustained drought destroyed the Altiplano crops; in 1968 heavy flooding caused serious damage in five of the country's nine departments.

2. Agricultural Practices

In the early 1970's agriculture provided employment for about two-thirds of the economically active population but accounted for only 20 percent of the GDP

and 10 percent of Bolivia's exports. The production of food crops does not satisfy the demand, and large quantities of food, especially wheat, dairy products and edible oilseeds, have to be imported. The acreage planted and the yield per acre have shown a declining trend in the last decade, particularly for barley, corn and potatoes.

Cultivation tools are varied in Bolivia although the primitive Indian methods and implements still prevail. The pointed digging stick is the principal tool used for cultivation of potatoes, and a wooden club called a Lampa is used to break up earth clods. The principal instrument used in planting cereals is a wooden plow, which sometimes has a steel tip. A foot plow, similar to a fork, is a common tool on the Altiplano. Shovels, picks, steel poles, and axes are also used.

Few large agricultural implements are used, except on the larger farms in the Oriente. About 90 percent of all farm work is done manually.

Little fertilizer is applied, crop residues and animal manure being used instead. Crop rotation is the only soil conservation method practiced by most farmers. Potatoes are usually planted first. The field is then planted with legumes or quinoa and then with barley. Finally it is left fallow. The length of the rotation cycle is generally four to five years.

About 10 percent of the cultivated land is under some form of irrigation. The various systems are mainly small-scale projects bringing water by gravity to lands in the valleys and near Lakes Titicaca and Poopo.

Arable land per rural inhabitant is low, about 0.34 ha per capita in the Sierra. The situation is somewhat better in the Costa at 0.51 ha per capita. However, continued rural population growth will severely limit land resource availability in the future.

The distribution of land ownership in Ecuador is highly skewed. Sixty-eight percent of farms are smaller than 5 ha and 5 percent are larger than 50 ha. An agrarian reform program that is to include the redistribution of about 2.25 million acres has been incorporated into the current Five Year Development Plan.

3. Principal Crops

a. Potatoes

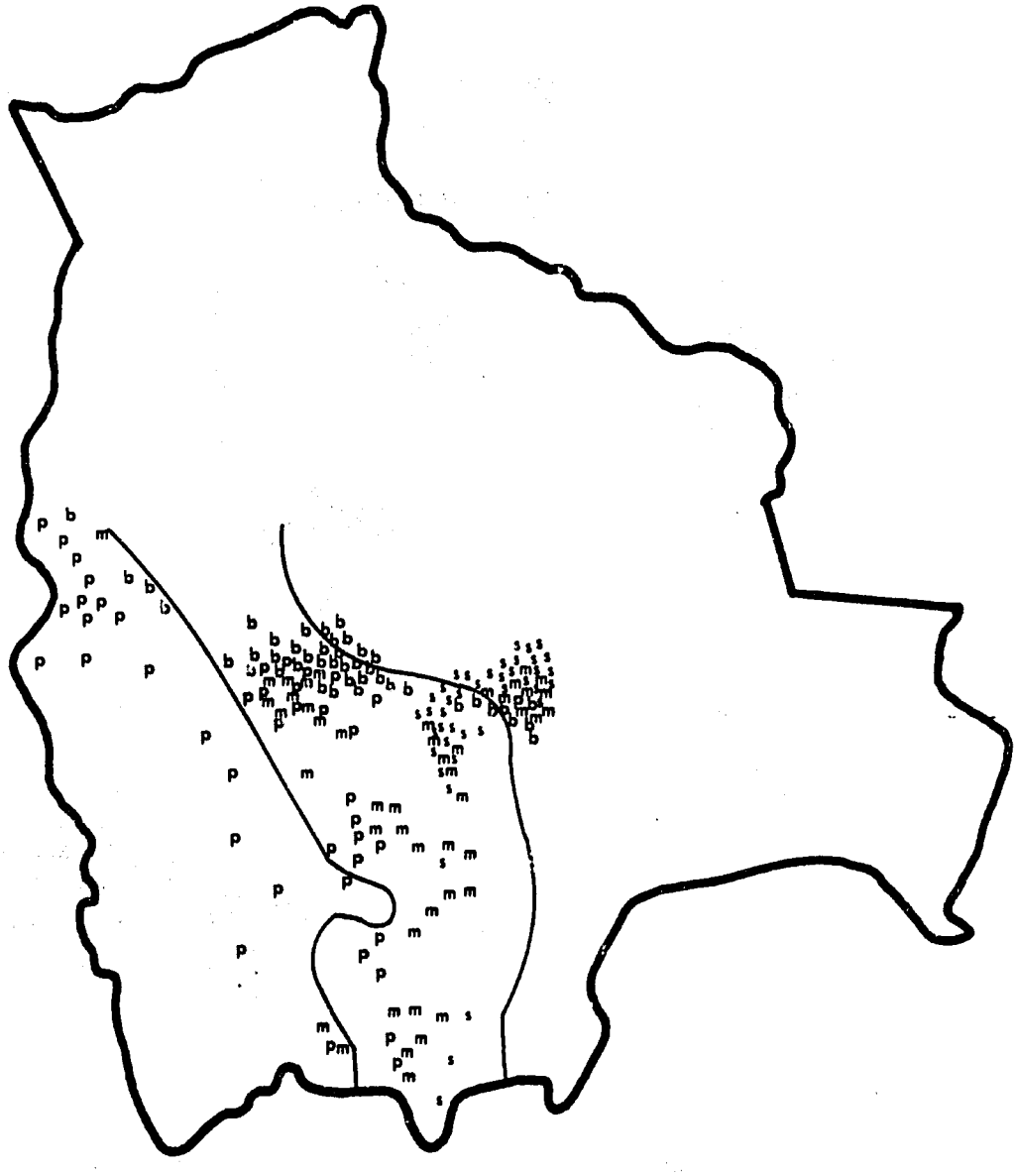
Potatoes are the most important food crop and constitute the basic diet of the highland population. Potatoes are planted mostly on the Altiplano but also in the Valles and in the Oriente. Production tends to fluctuate, but the country is, in general, self-sufficient (Figure 5.3).

The environmental conditions of the Altiplano, with large differences in temperature between night and day, intense radiation and low humidity, are very helpful for keeping potatoes in storage. The most widely known variety has a 140-day cycle and yields around 15 ton/ha, provided it receives 300 mm of rain during the growing season. These yields were obtained at altitudes between 3,500 and 4,000 m.

Sowing is done in September-November when soils are still dry, before the rains of December-March. On the average potatoes reach maturity by April, although this depends on several factors. Table 5.1 shows an estimated regional calendar for potatoes.

Potatoes are grown from 320 m (growing season = 90-200 days) up to 4,000 m (growing season = 150 days) of altitude, and the optimum conditions seem to be 12°C temperature at approximately 3,000 m. The use of N and P fertilizers has doubled yields. However, Bolivian potatoes are very susceptible to diseases, as well as frosts and droughts. For this reason, Andean varieties have been introduced in low areas. These winter crops are irrigated.

BOLIVIA



m - Corn

p - Potatoes

s - Sugarcane

b - Bananas

Figure 5.3. Distribution of Selected Agricultural Crops in Bolivia.

TABLE 5.1. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN BOLIVIA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Eastern Lowlands	Corn	—	—	—	OO	OO				//	//	//	—	
	Beans	OO	OO							//	//	—	—	
	Rice	—	—	OO	OO	OO					//	//	—	Major producing area.
	Sugarcane	—	—	—	—	OO	OO	OO	OO	OO	—	—	—	Harvested from 12 to 18 months after planting/cutting.
NW Mountains	Corn	—	—	—	OO	OO				//	//	//	—	Planting/harvesting date varies with elevation.
	Potatoes	—	—	OO	OO	OO	OO		//	//	//	//	—	Local varieties.
Southern Mountains	Corn	—	—	—	OO	OO				//	//	//	—	Planting/harvesting date varies with elevation.
	Potatoes	—	—	OO	OO	OO			//	//	//	//	—	Local varieties.
	Wheat	—	—	—	—	OO	OO					//	//	
Desert	Corn	—	—	—	OO	OO				//	//	//	//	Irrigated.
	Potatoes	—	—	OO	OO	OO			//	//	//	//	//	Irrigated.

b. Corn

Corn is the second most important food crop in the country and is grown mainly in the valley and lowlands. It is mostly cultivated by small farmers (90 percent), at altitudes between 100 and 3,500 m.

Forty-five corn types (with more than 140 varieties) are cultivated in Bolivia, 36 of them above 1,000 m and the balance in low soils. However, many can be found at 3,500 m and some of them (forage-type) up to 4,000 m.

Sowing is carried out between September and December (rainy season) and the harvest between April and July. Late varieties, by contrast, can be sown in August and September but irrigation is required. The growing season ranges from 115 to 270 days. Table 5.1 shows an estimated regional calendar for corn.

Both acreage and production of corn have been increasing steadily in Bolivia. Corn is consumed as a vegetable, in the form of flour and meal, and as a fermented beverage called chicha. Only 11 percent is used as forage.

c. Wheat

Wheat is the food crop with the largest production deficit. It is raised in small plots, with traditional methods, in the departments of Cochabamba, Potosi, Tarija, and La Paz.

Wheat is cultivated from 1,800 to 2,400 m, in areas with more rainfall and more stable temperatures than the Altiplano. Eight early varieties, resistant to wheat rust, are used in the country and relatively good yields per acre are obtained. At high altitudes, sowing is done from November to December and the harvest takes place in May-June. Early varieties are sown later. In the plains of Santa Cruz, sowing is performed in the winter (April-May), coinciding with the rains, while harvesting occurs in August-September. Table 5.1 shows an estimated regional calendar for wheat.

At elevations between 2,400 and 3,400 m wheat has a cycle of 130-180 days. Altitude affects the blooming period and the shape of the kernels. Harvest usually takes place at the end of March.

Local production of wheat satisfies only 20 percent of the domestic demand. As a result large quantities of wheat and wheat flour are imported annually despite the government's attempt to encourage increased production.

d. Barley

Barley is an important highland crop with 120,000 ha planted annually. Optimum altitude seems to be between 3,000 and 3,900 m. In the Altiplano, barley is rotated with quinoa or potatoes.

In most places barley is eaten roasted or milled and is used for beer-making. In some localities however, it is utilized as animal feed. Yields are generally low except on farms where fertilizers are applied.

e. Rice

Rice has become a standard item in the diet of lowland and valley people, and production has been increasing for the last three decades. Annual production has reached very high levels, and surpluses are sometimes available for export. Otherwise, the stocks are retained as a buffer supply to substitute for potatoes in years of lower potato production. Most of the rice is grown in the Santa Cruz area. Table 5.1 shows an estimated regional calendar for rice.

f. Other Crops

Quinoa and canahua are small, hardy cereals which require little attention and grow well at altitudes between 2,250 and 3,600 m. They have protein and vitamin content. The former is prepared and eaten like rice while the latter is used in the form of toasted flour.

Cotton is the most important export crop. Although almost no fertilizer or irrigation is utilized on cotton plantations, the yield per acre is among the highest in the world because of excellent climatic conditions and a minimal amount of pest damage.

Other crops of Bolivia include sugarcane, coffee, tea, cacao, coca, oilseeds (sesame, castor beans, soybeans, sunflowers, peanuts, and cottonseeds), fruits and vegetables, rye, oats, alfalfa, tobacco and pyrethrum.

4. Agroclimatic Indices

Figure 5.4 shows the historical Yield Moisture Index (YMI) in percentiles for Santa Cruz (Eastern Lowlands Region). The YMI was computed for a corn crop during the main growing season (October-March). Corn crops may have been adversely affected by dry weather conditions during the 1954, 1956 and 1972 growing seasons as indicated by YMI values in the lower 10th percentile. The critical YMI value for crop failure may be determined by using episodic data (Table 5.2) and historical crop yield data.

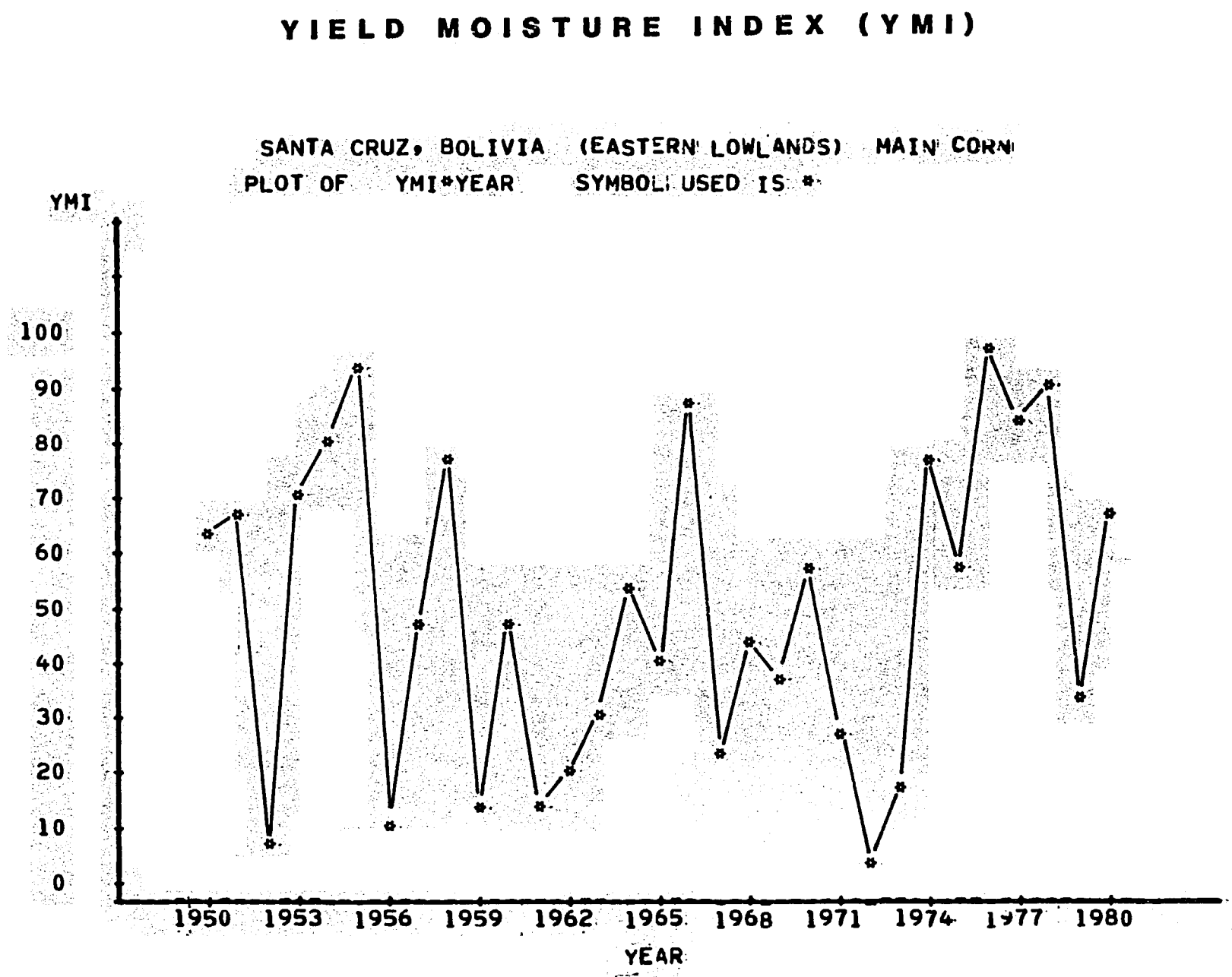


Figure 5.4. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Santa Cruz (Eastern Lowlands Region).

TABLE 5.2

BOLIVIA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1956		Food scarcity. Crops damaged by frost and drought in the Altiplano.
1956-57		Drought virtually destroyed Altiplano crops.
1966		Adverse weather reduced agricultural production in the Altiplano.
1967		Adverse growing conditions reduced basic food crops in the Bolivian highlands.
1968		Floods.
1971		Drought occurred in the Altiplano highlands.
1971-72		Sugar production declined from shift to other crops.
1974	May	Floods damaged crops.
1975		Since November 1974, dry weather persisted and delayed crop plantings, developments and harvests. Aid was given to Chilean refugees.
1976		End of the year floods affected the subtropical farm area of Santa Cruz.
1977	March	Areas affected most by drought were north, central and south Altiplano and the upper-end of the valley region. The food situation was critical.
1978		Rice area was reduced. Agriculture was relatively good.
1979	January	Floods washed away crops in Oruru, Santa Cruz, Beni, Pando, Cochabamba and La Paz. Pests plagued Bolivia also.

TABLE 5.2

BOLIVIA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1980		Extremes in weather continued to damage crops. Heavy hailstorms hit Tarija in January and drought occurred there in May.
1981	May	Torrential rains hit Santa Cruz region during cereal and oilseed harvests.
1982	March	Floods destroyed crops in Beni, Santa Cruz, Cochabamba and northern La Paz.

B. CHILE

1. Physical Environment

Chile occupies a total area of 741,767 square kilometers, extending more than 4,000 km from north to south and less than 200 km in width. The national territory extends along the west coast of South America, from the deserts in the north to the cold waters washing the shores of Cape Horn, and is compressed between the Andes an the South Pacific. Bordering countries are Peru, Bolivia, and Argentina (Figure 5.5).

There are three outstanding parallel natural features, the coastal range of mountains, the great Cordillera de los Andes, and the Central Valley which lies between the two mountain systems. The coastal range consists of a plateau-like series of rounded hills, broken occasionally by gorges and rivers. Its peaks reach 2,100 m in the northern part of the country but the system plunges into the sea in the far south.

The spine of the Andes extends almost the full length of the country. In the northern sector of the range is Ojos del Salado, Chile's loftiest peak at 6,750 m. South of Santiago, the nation's capital, the peaks become progressively lower. In the far south, the Andes continue to deteriorate and become lost in the lowlands of the Chilean Patagonia on both sides of the Strait of Magellan. The system makes a final appearance at Cape Horn, the crest of a submerged mountain.

Between the Andes and the coastal range, the long Central Valley is poorly defined in the far north where it takes the form of almost rainless and barren plateau basins. This Central Valley becomes well defined in the midland sector, the country's prosperous agricultural and industrial heartland. South

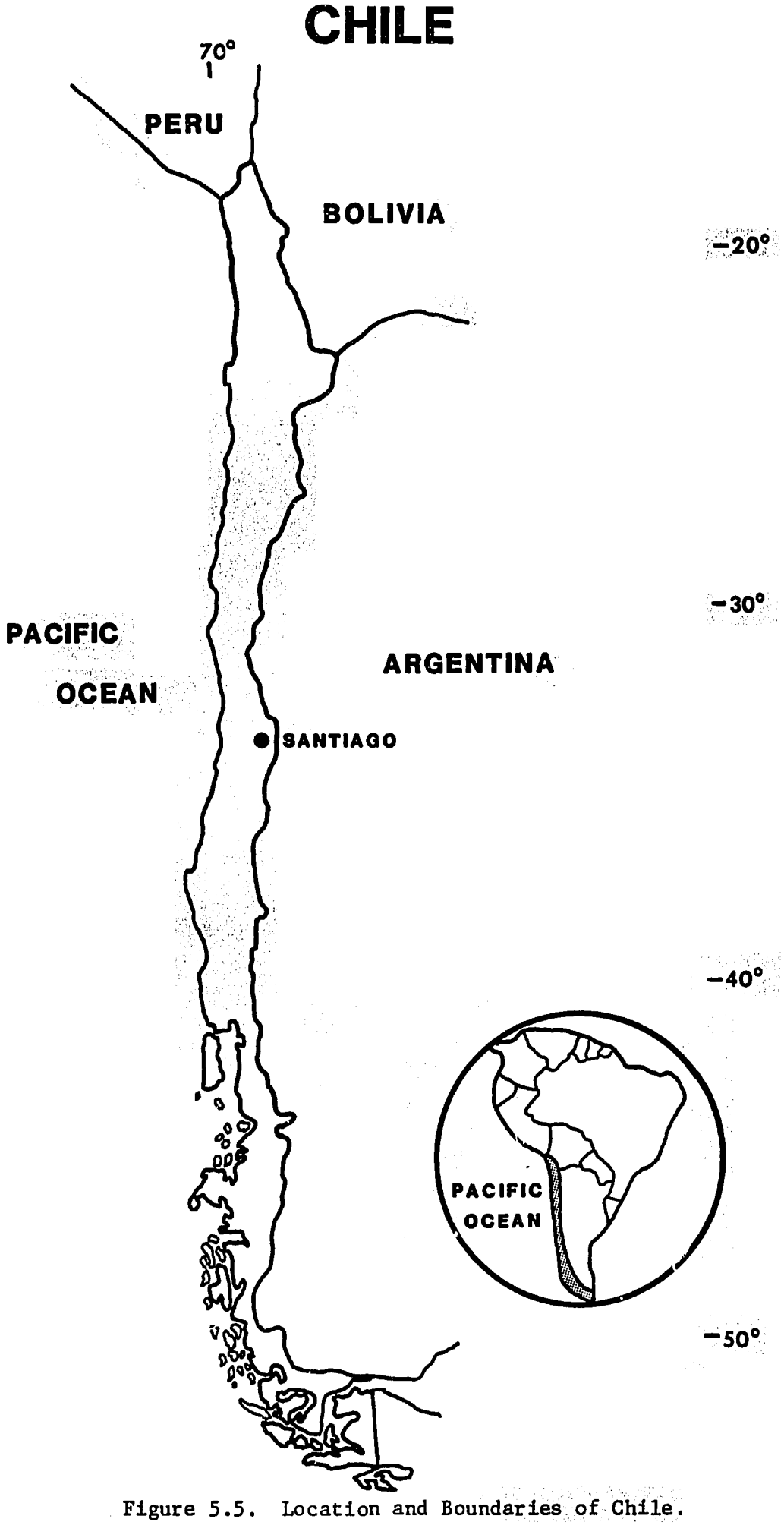


Figure 5.5. Location and Boundaries of Chile.

of the Bio-Bio River it becomes a land of heavy rain and dense forest, which abruptly terminates at about 31°S. Farther south, there are countless uninhabited islands, channels, fjords, heavily forested cordilleras (and continuous wind and rain), until the foot of the continent is reached. At the foot there is a low grassy plain and, across the Strait of Magellan, the archipelago of Tierra del Fuego.

The northern desert is customarily referred to as the Norte Grande and the transitional region immediately to its south as the Norte Chico. The fertile and heavily populated provinces of the midlands may be referred to as Central Chile, and the land of forests and lakes to their south as South Central Chile. Finally, there are the remote achipelagoes, fjords, and channels of the Far South.

In the Norte Grande the Central Valley is made up of a series of high plateau basins with sand, clay, and salt deposits. The coastal range is usually between 600 and 900 m above sea level and drops abruptly to the ocean in the cliffs. This region includes most of the Puna de Atacama (Atacama Desert). Numerous Andean streams drain toward the Pacific, but with only one exception (the Loa River) all are absorbed by the desert providing limited amounts of water to oasis farm villages. The cool Humboldt Current has a moderating effect on the temperature of the Puna. Thus, in Arica, at the Peruvian border, the mean annual temperature is 19°C and the rainfall 0.7 mm. Temperatures are lower and rainfall, however scanty, is greater along the northern coast than in the desert interior, although occasional rains fall at 2,400 m and higher in the Andes. The average relative humidity in the interior town of Calama is 48 percent, and in some portions of the Atacama Desert, the coefficient of evaporation is greater than that in the Sahara. In contrast in the coastal town of Iquique, the average relative humidity is 81 percent. A weather phenomenon of the northern coast is a heavy winter mist known as the Camanchaca.

The Norte Chico is a transitional zone made up of short transverse valleys formed between spurs from the Andes. The average temperatures (14°C in La Serena) are considerably lower. The rainfall remains extremely scanty, most falling in winter.

Central Chile is an extraordinarily fertile area known as the Valle de Chile. This is the country's heartland, consisting of a 65 km wide sloping plain made up of alluvial fans of soil of vast thickness built up by the region's principal rivers, the Mapocho, Maule and Maipo. The soil is heavily mineralized and produces fruits and vegetables of great size and excellent quality grown under irrigation. South of the Bio-Bio River, the Valle de Chile, less continuous in this region, is crossed by numerous small rivers which serrate the residual coastal range. This is a land of forests and lakes.

In both Central and South-Central Chile, the temperatures remain much the same as those in the Norte Chico and, although rainfall is somewhat heavier, irrigation of crops is necessary. Santiago, for example, has a mean annual temperature of 14°C and annual rainfall of 355 mm. Most of the precipitation occurs between May and August. Average temperatures remain about the same southward to the Bio-Bio River, but rainfall increases, reaching 1,270 mm at Concepcion. Farther to the south, average temperatures gradually become slightly lower and the rainfall much heavier. In Valdivia the mean temperature is 12°C and the rainfall over 2,500 mm.

South of Puerto Montt the Central Valley drops into the sea and the coastal range continues only as a great number of offshore islands in an area known as the Far South or Archipelagic Chile. This region has very little arable land, and the thick forest changes from deciduous to evergreen. At the tip of the

continent there is a lowland zone called the Chilean Patagonia or Atlantic Chile, which is an undulating plain of glacial-morainic formation used largely for pasture (Figure 5.5a).

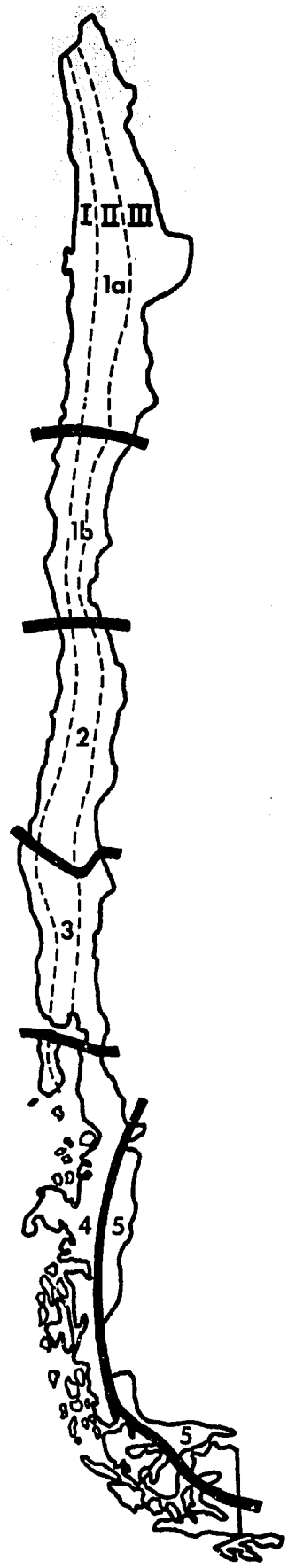
2. Agricultural Practices

Agriculture is the principal Chilean economic activity. In 1979, it contributed about 10 percent of GDP and employed 18 percent of the labor force. Twenty-one percent of land area is classed as agricultural including natural and improved pastures; of this, 13.7 million acres are capable of crop production, but only 3.2 to 3.7 million acres are cultivated annually; the remaining land is left fallow or is used as pasturage. (Twenty-seven percent of total area of Chile is natural forest, much of it suitable for commerical exploitation.)

Crop types and land use vary markedly from one region to another. In the north, agriculture is possible only in river valleys and along lower slopes of the Andes on alluvial fans of mountain streams. Fruits and vegetables are grown in river valleys; at higher elevations, corn, beans and alfalfa are raised on small plots. Above 2,500 mm of elevation, moisture allows grazing of sheep, goats, llamas, and alpacas. In Atacama and Coquimbo provinces, winter fog fosters grazing sheep and goats on western slopes of the coastal range.

The central region, comprising Aconcagua through Nuble provinces, has climate, terrain, and potential like those of the central valley of California. Rice, tobacco, hemp, sunflower, barley, beans, corn, wheat and potatoes are grown here. The south-central region including Concepcion through Cautin provinces, has 31 percent of arable land. It is the principal beef producing area. Major cereals such as oats and wheat are grown here. Non-irrigated vineyards and major apple orchards are located here. In Valdivia, Osorono, and Llanquihue provinces, agriculture is limited to cold-climate crops but good farming practices have resulted in high yields. The region produces potatoes, oats, wheat, and lumber (Figure 5.5b). An estimated regional crop calendar for subsistence farming in Chile is shown in Table 5.3.

CHILE



1. DESERT
   a) DESERT (Norte Grande)
   b) SEMI - DESERT (Norte Chico)

2. CENTRAL CHILE

3. FOREST

4. ARCHIPELAGO

5. ATLANTIC

SUBREGIONS
   I. COASTAL RANGE
   II. CENTRAL VALLEY
   III. ANDEAN CORDILLERA

Figure 5.5a. Natural Regions of Chile.

CHILE

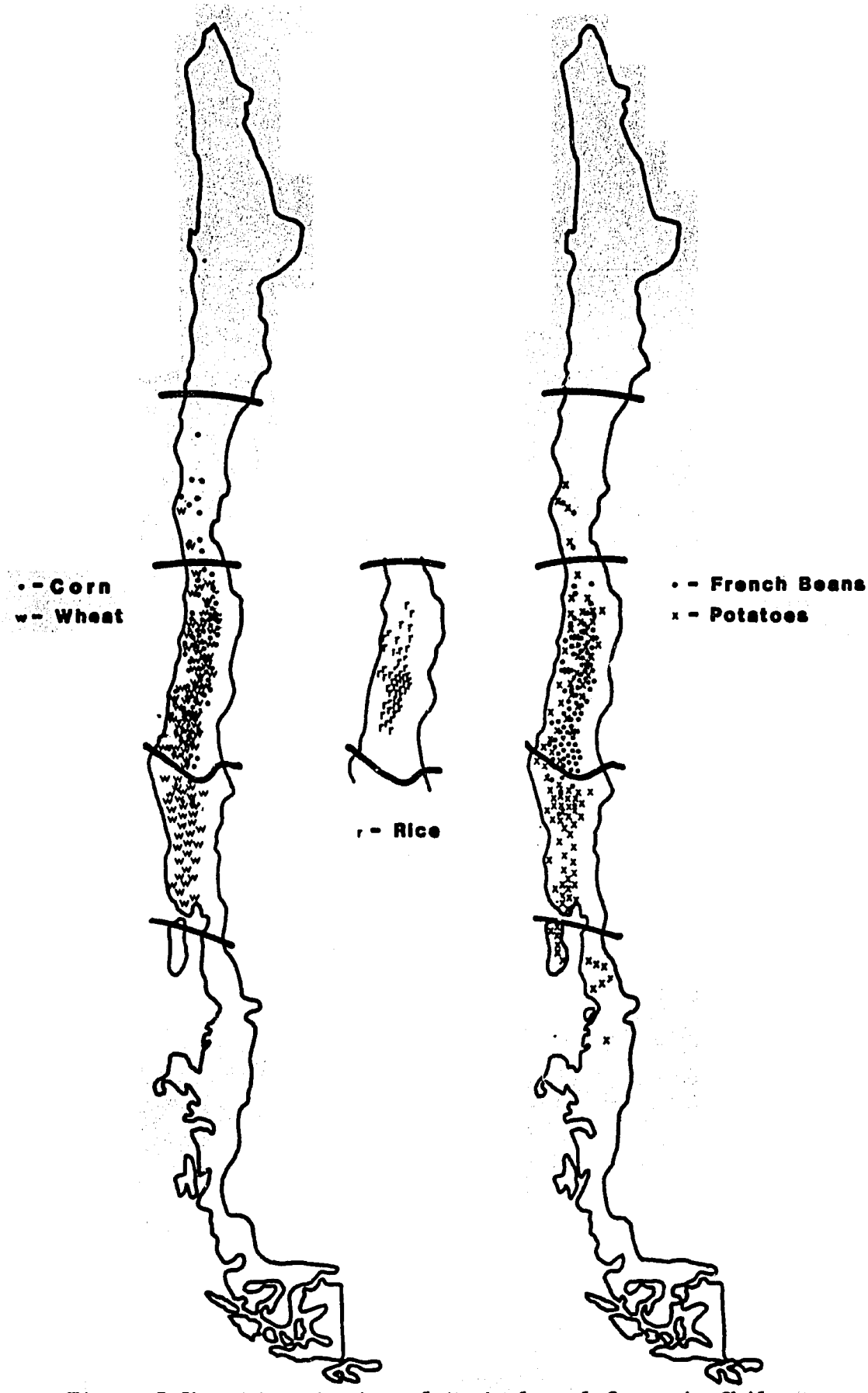


Figure 5.5b. Distribution of Agricultural Crops in Chile.

TABLE 5.3. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN CHILE

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Arid	Corn	—	OO	OO	OO					//	//	//	—	Irrigated.
	Beans	—	OO	OO							//	//	—	Irrigated.
Semiarid	Corn	—	—	OO	OO						//	//	—	Irrigated.
	Beans	—	OO	O								//	/-	Irrigated.
Temperate	Rice	—	—	—	OO	OO					//	//	—	
	Wheat				//	//	—	—	—	—	OO	OO		
	Potatoes	—	—	OO	OO					//	//	—	—	
Humid	Wheat	OO				//	//	—	—	—	—	--	OO	
	Beans	—	OO	OO							//	/-	—	
	Potatoes	—	—	OO	OO						//	//	—	
Southern	Potatoes	—	—	—	OO	O						//	/-	

In Chiloe, Aisen, and Magallanes provinces, the major agriculture activity is sheep raising with an emphasis on high quality wool production. Fifty percent of the sheep in this country are raised here. The region is an important beef producer.

A number of factors, among them the government's failure to provide adequate agricultural inputs while holding product prices unrealistically low in relation to the international market, lack of vocational education among agricultural workers, poor management, and inefficient distribution of farmland, have led to underutilization of agricultural lands and resources. Since World War II, per capita agricultural indices have declined, though national indices continued to increase during the 1950's and 1960's. Redistribution of farmland under Allende government, though necessary, increased production deficits by increasing uncertainty in the more efficient private sector and failed to provide adequate technical and managerial assistance to asentamientos (recipients of expropriated land). The present government has moved to stabilize land reform by restoring 20 percent of expropriated holdings to individual producers while leaving 80 percent under jurisdiction of Agrarian Reform Corporation (CORA). The government of Chile hopes, through reorganization of the Ministry of Agriculture, to increase effectiveness of technical assistance and availability of credits/inputs.

3. Agroclimatic Indices

Figure 5.6 shows the historical Yield Moisture Index (YMI) in percentiles for Puerto Montt/El Tepual (Southern Region). The YMI was computed for a potato crop during the main growing season (November-March). YMI values in the lower 10th percentile suggest poor corn crop conditions during 1954, 1958 and 1970. The critical YMI value for crop failure may be determined by using episodic data (Table 5.4) and historical crop yield data.

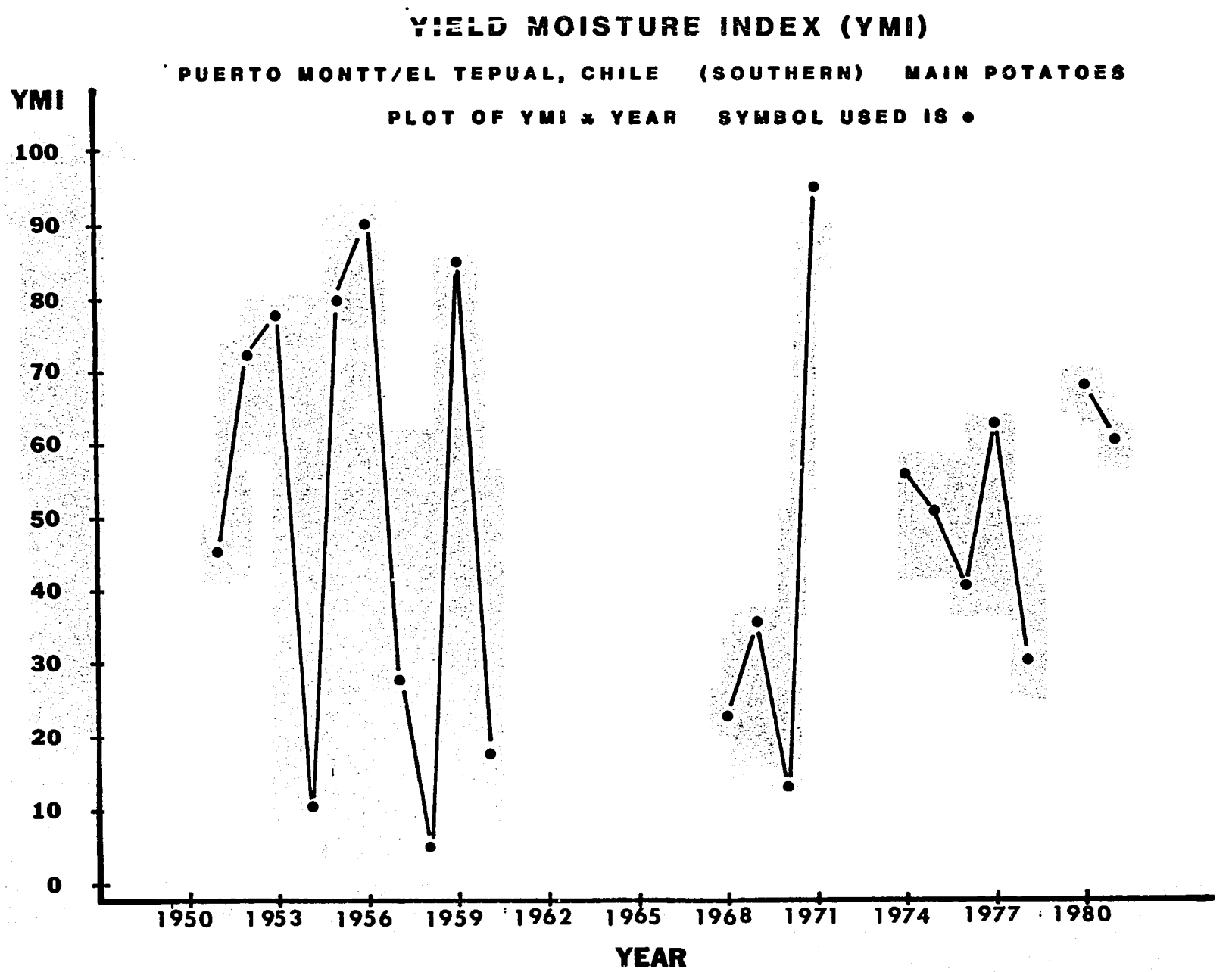


Figure 5.6. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Potatoes at Puerto Montt/El Tepual (Southern Region).

TABLE 5.4

CHILE

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1955		Severe winter weather affected fruit production.
1956		Adverse weather affected crops.
1957		Drought reduced vegetable production.
1960		Many disasters hit the country. Drought damaged crops in central Chile.
1961		Valdivia Valley experienced an earthquake and flood.
1962		Southcentral Chile experienced a severe drought.
1964		Severe drought, particularly in north-central regions, reduced spring plantings and delayed growth of winter crops.
1965		Adverse weather damaged winter crops.
1966		Floods and fungus diseases occurred in the important southcentral zone damaging crops and delaying planting of the 1967 wheat crop.
1967		Unusually cold weather and drought affected crops.
1968		Drought and cold weather damaged crops in the central valley.
1969		Drought continued to affect yields for rice, corn, oats and barley.
1971		Production was down. In June, high winds and heavy snowfall affected the central area and the Andes. In July, a severe earthquake hit the same area followed soon by a heavy rain and windstorm. At Aysen, Coyhaique, Balmaceda and Chile Chico falls of volcanic ash and dust, avalanches of snow and torrents of water due to the melting of glaciers in the intense heat, followed by heavy rain and high winds, caused widespread damage to crops.

TABLE 5.4

CHILE (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

AR	MONTH	EPISODIC EVENT
1972-7		Adverse weather affected the country.
1973		Harvests were poor. It was dry over most of the country, especially the coastal areas of extreme northern provinces.
1974		Wet weather damaged crops in June. Wheat production was down 60 percent below the 1966-70 average.
1975		Unfavorable weather, insects, and lack of fertilizer and improved seeds cut the wheat harvest.
1976	September	Dry weather affected crops in northern and central regions. Insects and disease damaged the wheat in January. There was poor planting weather. In June there was localized heavy thunderstorms except in the central regions.
1977	June	Coquimbo experienced severe drought for the second consecutive year. Flooding affected the greater part of the country.
1978		Adverse weather cut production of grains. In November, wind and heavy rain caused damage to 70 percent of the crops in the central area of the country.
1979		Agricultural production recovered.
1979-80		Wet harvest weather significantly reduced the wheat harvest.
1980	May	Normal rainfall interrupted the dry spell which for several months had affected the southern area.
1981		Less fertilizer and poor land management affected wheat yield. Drought affected the Santiago area in June. Precipitation was above normal in central areas and below normal in the extreme south. Floods occurred in May.

C. COLOMBIA

1. Physical Environment

Colombia is the fifth largest republic of Latin America, covering an area of 1,138,338 square kilometers. Located in the northwest corner of the South American continent, it is the only country of South America with both Atlantic and Pacific coastlines (Figure 5.7).

The country is dominated by three parallel ranges of the Andes Mountains -- the Cordillera Occidental in the West, the Cordillera Central, and the Cordillera Oriental in the east. These "cordilleras" cross the country on a northwesterly axis in the form of a trident. The population is concentrated in plateaus and basins scattered among these ranges and the valleys of the two great rivers that separate them -- the Cauca and the Magdalena. West of the Andes are two coastal lowlands. The Atlantic Lowlands consist largely of open, swampy land, with extensive cattle raising and plantation agriculture, while the Pacific Lowlands are narrower, swampy, and heavily forested. East of the Andes lies a great interior plain crossed from east to west by many large rivers. It consists principally of open land in the north and tropical jungle in the south and remains largely undeveloped.

Although Colombia lies within the torrid equatorial zone, there is an unusual variety of climate zones due to altitude and topography. The climatic areas can be grouped into five clearly discernable broad zones. They are: 1) tierra caliente (hot lands), ranging from sea level to 800 m with mean annual temperatures of over 23°C and abundant rainfall; 2) tierra templada (temperate lands), from 800 to 1,800 m where the temperature ranges from 17° to 23°C, with two or three rainy seasons a year; 3) tierra fria (cold lands), from 1,800

COLOMBIA

Figure 5.7. Location and Boundaries of Colombia.

to 3,000 m, with temperatures between 12° and 17°C and less frequent rainfall; 4) the paramo located on high treeless mountain slopes between 3,000 and 4,200 m, with temperatures below 12°C and little precipitation; and 5) nevado, the glacial zone of permanent snow on the slopes and peaks over 4,200 m.

Based on topographic, climatic, and vegetative characteristics, five major natural regions are recognized in Colombia. These are: the Andes Mountains, the Atlantic Lowlands, the Pacific Lowlands, the Eastern Plains or Llanos, and the Amazon Tropical Rain Forest (Figure 5.8).

The Andean Region (A) occupies 25 percent of the national territory, including the fertile, densely populated inter-Andean valleys and the sparsely inhabited, cold paramo. Altitudes reach more than 5,700 m and mountain peaks are permanently covered with snow.

The Atlantic Lowlands (B1) cover about 10 percent of the national territory and have a hot and dry climate and a herbaceous vegetation. Two rainy seasons alternate over six-month periods with two dry seasons.

The Pacific Lowlands (B2) extend from the Gulf of Uraba to the Ecuadorean border and from the Pacific Ocean to the Cordillera Occidental, covering about 5 percent of the total area of Colombia. This region, covered by tropical rain forest, has a hot and wet climate, abundant rainfall and numerous rivers.

The Llanos Region (B3) is a grassy plain which extends from the Venezuelan border to the Guaviare River, east of the Cordillera Oriental. It covers about 20 percent of Colombia's territory and has a hot and dry climate. Cattle raising is practiced in piedmont areas.

The Tropical Rain Forest (B4) extends from the Guaviare River to the Amazon, and from the Eastern Cordillera to the frontier with Brazil. Covering approximately 330,000 square kilometers, this region represents 40 percent of the total land area of the country. It is a low plain, covered by virgin tropical rain forest and traversed by wide swift rivers.

COLOMBIA

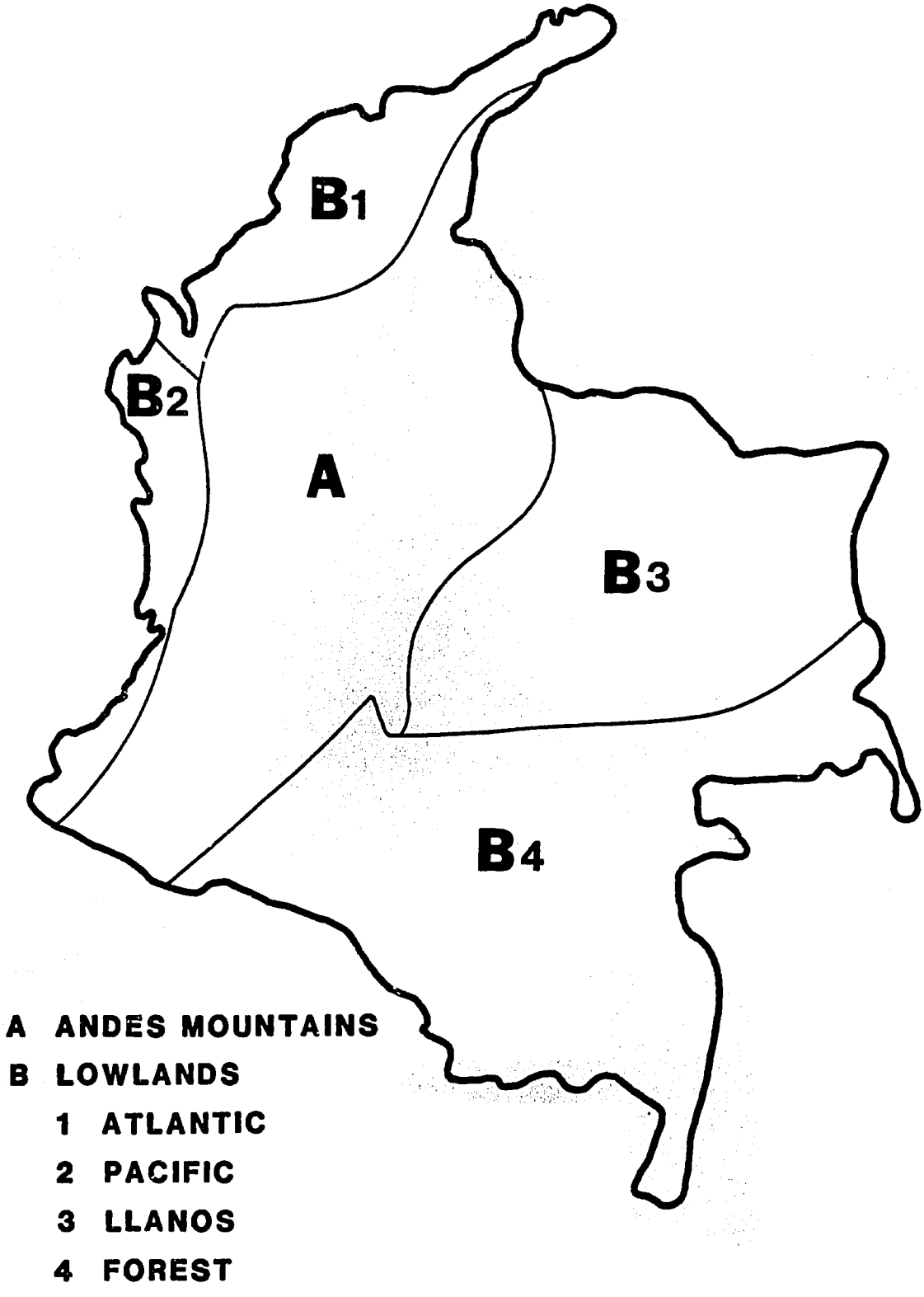


Figure 5.8. Natural Regions of Colombia.

2. Agricultural Practices

Of the total land area of the country, about 5.4 million ha (4.9 percent) are devoted to crops. The actual amount of cropland used, however, is only 3.6 million ha with the balance being kept fallow as a conservation measure.

Preparation of the soil, planting and cultivation are done mainly with handtools, particularly hoes, sometimes supplemented by plowing with oxen and a crude plow or with tractors. The traditional method of preparing the land consists of clearing at the beginning of the dry season and burning of the cut brush once it is dry. Seeds are generally planted by hand, using a digging stick or a shovel.

Very few farms have agricultural machinery despite the credit made available by the government to purchase it. The use of fertilizers is not widespread, although some crops (sugarcane, potatoes, wheat, rice, and barley) do receive small applications. Lack of irrigation and flood control systems during lengthy droughts and periods of excessive rainfall result in considerable crop losses, such as those in 1971. Some private farmers, however, have their own irrigation and drainage systems. Farmers growing wheat, barley and potatoes use herbicides and pesticides. The use of improved seeds is becoming more widespread.

3. Principal Crops

a. Corn

The crop grown most widely throughout the country is corn; about 560,000 ha were planted in 1975 (Figure 5.9). It is grown by many small-scale farmers and on some relatively modern farms. One-third of the corn is planted to high-yield, disease-resistant varieties. Used for both human and animal consumption, the supply is usually sufficient to meet domestic needs and permit some export.

COLOMBIA

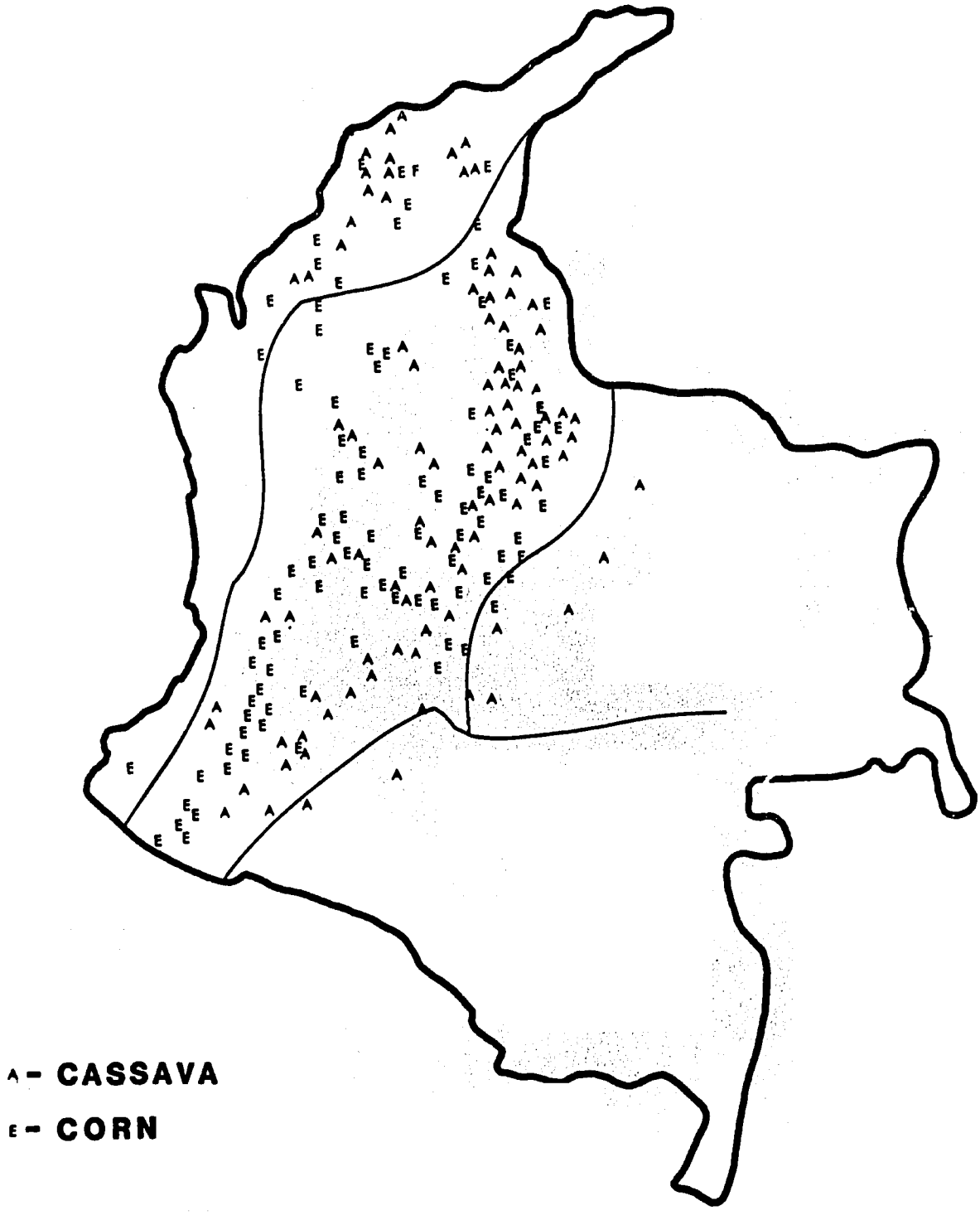


Figure 5.9. Distribution of Corn and Cassava in Colombia.

Corn is planted with beans, especially at high altitudes. The corn-beans combination constitutes a balanced diet for low-income people.

Corn yields are very high (about 4,300 kg/ha, in those farms growing improved varieties, but the overall national yield is low, less than 850 kg/ha. Table 5.5 shows an estimated regional calendar for corn and bean crops grown in Colombia.

b. Rice

Rice is a staple of the national diet, and its production has been steadily rising. Production has increased as a result of increased area, greater mechanization, improved seeds, and irrigation. Most of the rice is paddy grown, but large amounts are raised on dry land in upland areas and along river banks in swampy areas. Yields per hectare rank among the highest in the world, and two crops a year are grown. An estimated crop calendar for rice grown in the Pacific region is shown in Table 5.5.

c. Wheat and Barley

These are two highland crops usually grown in Colombia at over 2,000 m in altitude. Farmers often shift from one to the other depending on price. About 70 percent of the production comes from small farms consisting of less than 10 hectares in size.

d. Other Crops

Coffee

Coffee is the most important crop in the country, providing a livelihood for an estimated 2 million people (Figure 5.10). Coffee production contributes about 10 percent to the GDP and coffee is the major export. The country ranks second in the world, after Brazil, in both coffee production and coffee exports.

Two harvests per year are reaped from the nearly 2 billion coffee trees estimated to be growing. Generally it takes 2-3 years for a coffee tree to produce its first crop, but it can continue to produce for as long as 20 years with the maximum yield between the seventh and twelfth years.

TABLE 5.5. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN COLOMBIA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Atlantic	Corn			//	//	—	—	—	OO	OO				Usually intercropped with beans or other crops.
	Beans			//	/-	—	OO	O						Dry beans have 2 to 3 months longer period.
	Sugarcane	OO	OO	OO	OO	—	—	—	—	—	—	OO	OO	Harvested from 12 to 18 months after planting/cutting.
Pacific	Corn			//	//	—	—	OO	OO					
	Beans			//	/-	—	OO	O						
	Rice				//	//	—	—	—	OO	OO			Rainfed varieties.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Planted anytime. Harvested after one year.
Cauca	Corn	OO	OO							//	//	—	—	
	Beans									//	—	—	OO	
	Potatoes			//	/-	—	—	—	—	OO	OO			
	Sugarcane	OO	OO	OO	OO	—	—	—	—	—	—	OO	OO	
Magdalena	Corn			//	//	—	—	OO	OO					
	Beans			//	/-	—	OO	O						
	Sugarcane	OO	OO	OO	OO	OO	—	—	—	—	—	OO	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Eastern	Corn				//	//	—	—	OO	OO				
	Beans				//	/-	—	OO	O					

COLOMBIA

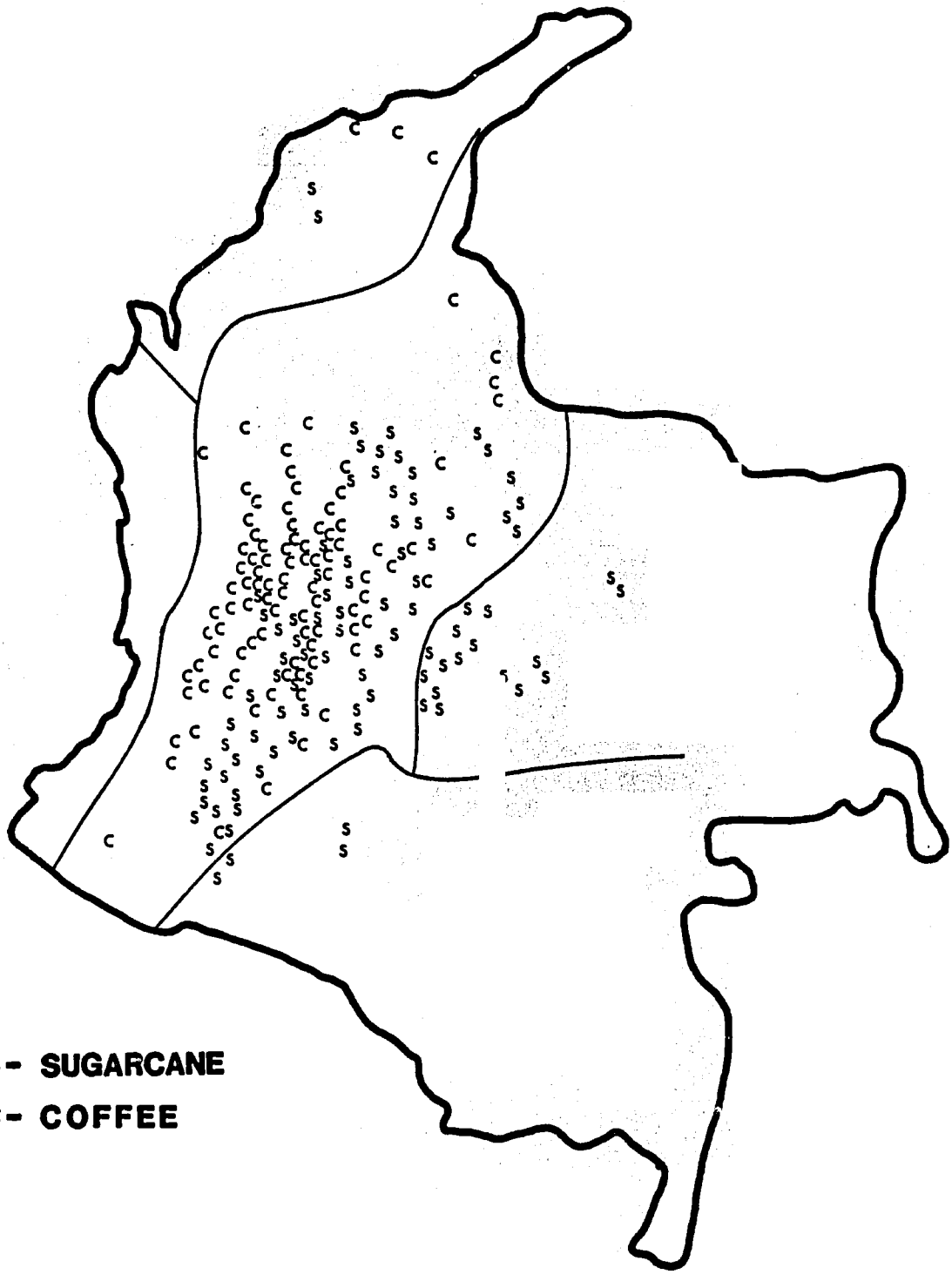


Figure 5.10. Distribution of Sugarcane and Coffee in Colombia.

Although coffee grows all over the country, Antioquia Department ranks first in number of coffee farms, total production, and area planted in coffee, while Quindio Department has the highest yield per hectare.

Sugarcane

This is also an important export crop of Colombia. The main feature of this crop is that the harvest takes place almost year-round, providing permanent employment for cane cutters (Table 5.5).

Bananas

Bananas are grown on small plots primarily for home use and domestic sales and on plantations for export. As much as 40 percent of the total production is consumed domestically. Bananas bring the farmer the highest gross return per hectare. Plantains are also widely grown; Colombians are the highest per capita consumers of plantains in the world.

Potatoes

Potatoes are raised in many highland areas, mainly on small farms. Most potato farmers use fertilizers, and two harvests a year are possible: one in January-February and the other in September-October (Table 5.5).

Other crops grown for local consumption include cassava, arracacha, beans, pineapples, citrus, papayas, avocados, cacao, and many other fruits and vegetables. A number of oilseeds, such as cottonseed, African oil palm, sesame, coconut, soybean, and peanut are also grown.

4. Agroclimatic Indices

Figure 5.11 shows the historical Yield Moisture Index (YMI) in percentiles for Cali (Cauca Region). The YMI was computed for a corn crop during the main growing season (September-March). Dry weather conditions during 1958, 1963 and 1970 adversely affected corn crops as suggested by YMI values in the 0-10th percentile range. The critical YMI values for crop failure may be determined by using episodic data (Table 5.6) and historical crop yield data.

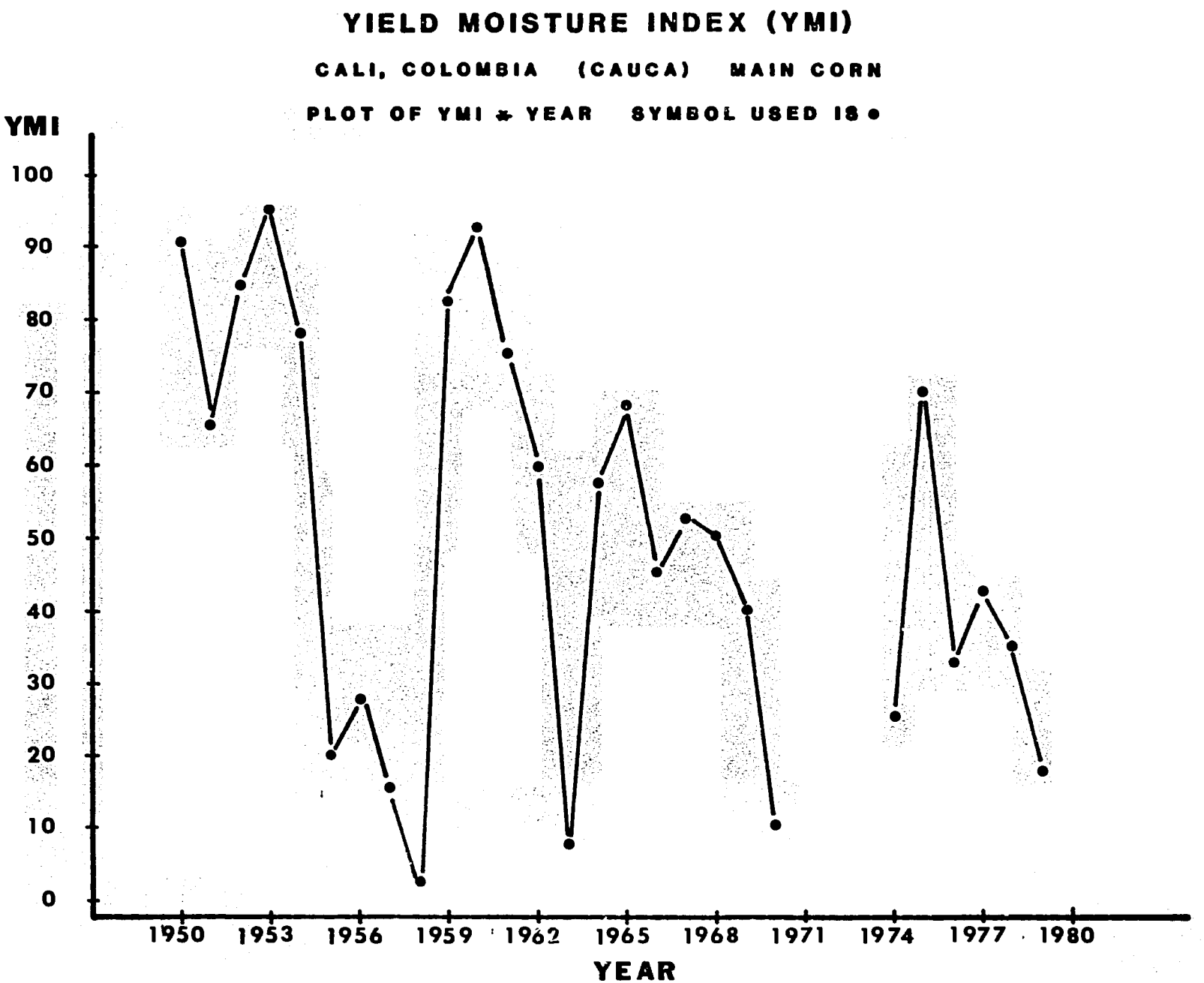


Figure 5.11. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Cali (Cauca Region).

TABLE 5.6

COLOMBIA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1957		Drought reduced corn and bean output. Hurricane winds damaged the banana crop.
1958		Drought reduced banana yields.
1960		Disease problems occurred in Santa Marta plantations in the early 60's.
1960-61		Low precipitation reduced output of coffee and pulses.
1962		Panama and sigatoka diseases attacked the banana crop.
1963-64		Production for many crops dropped because of a shift to seasame and soybeans. Unfavorable weather decreased wheat and corn crops.
1966		Early drought hit some areas. Insects affected rice.
1967		Heavy rains reduced coffee yields. Insects damaged rice and frost damaged barley.
1968		A shift to other crops cut corn and rice production. Rice was also shifted from dryland to irrigated.
1971		Floods and drought caused loss of crops.
1972-73		Adverse weather affected the country.
1974		Wheat and barley production declined. Rice, feed grains and other crops made gains.
1975	December	Wheat disease was reported. Frosts in central and southeastern areas resulted in losses to wheat, potato, corn and barley crops. Floods in north, middle and lower Magdelena made the food situation serious. An October hailstorm damaged the coffee crop in the central areas.

TABLE 5.6

COLOMBIA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1976		Summer droughts, heavy winter rains and insects cut production. Aid was given to flood victims. Damaging heavy rains fell in Cali, Valle during May. Rivers in eastern areas of the country flooded.
1977		Drought over the whole country the first three months damaged crops. End of September rains relieved, somewhat, crops damaged by early-September drought. Heavy rains and frosts in November damaged crops in the Bogota agricultural area.
1978		Crop conditions improved, but frosts in the early months adversely affected cereals and potato crops around Bogota.
1979	November	Extensive floods damaged crops, especially rice, most seriously in Bogota and Santander areas. Strong earth tremors also hit the central region in December. Frosts in January and February in the savanna of Bogota caused a great loss to agriculture.
1980		Severe drought at the beginning of the year affected lowland crops. There were hailstorms in July and August. Widespread floods hit the northern and western regions in October. More drought and frosts affected upland production at the end of the year.
1981	August	A large southeastern area was flooded, damaging coffee, sugarcane and banana plantations. January and September frosts in the savanna around Bogota and in the central and southwestern areas inflicted damage to cereal crops.
1982	March	Eight weeks of severe dryness in the central regions.

D. ECUADOR

1. Physical Environment

Ecuador, an Andean country of South America, is bordered on the North by Colombia, on the South and East by Peru, and on the West by the Pacific Ocean (Figure 5.12). The total land area of 280,277 square kilometers can be divided into four distinct natural regions: the Costa, the Sierra, the Oriente, and the Galapagos Islands (Figure 5.13),(Weil, et al, 1973).

The Andes Mountains, with altitudes of up to 6,300 m, form the backbone of Ecuador extending north and south through the center of the country in approximately two parallel mountain ranges. Intermountain basins lie between the ranges. The altitude of these basins or valleys varies between 2,000 and 3,000 m. Immediately to the west of the high Sierra lies the coastal plain or Costa, which consists of mangroves, lowlands, and gentle rolling hills. The Oriente region, to the East of the Sierra, is quite remote and consists of tropical rain forest in the upper Amazon River basin.

Soil, vegetation, and climatic types are extremely diverse and the transitions from one region to another are very rapid. At the northern end of the Costa there are two rainy seasons with an annual average exceeding 4,000 mm. Farther south the rainy seasons merge into one, lasting less than two months in some places, and the annual rainfall seldom exceeds 350 mm. Only xerophytic vegetation is found in these drier areas.

Although Ecuador is close to the equator, the relief is such that a marked vertical zonation of climate and vegetation exists on both sides of the Sierra. With increasing altitude, average temperatures fall steadily and rainfall

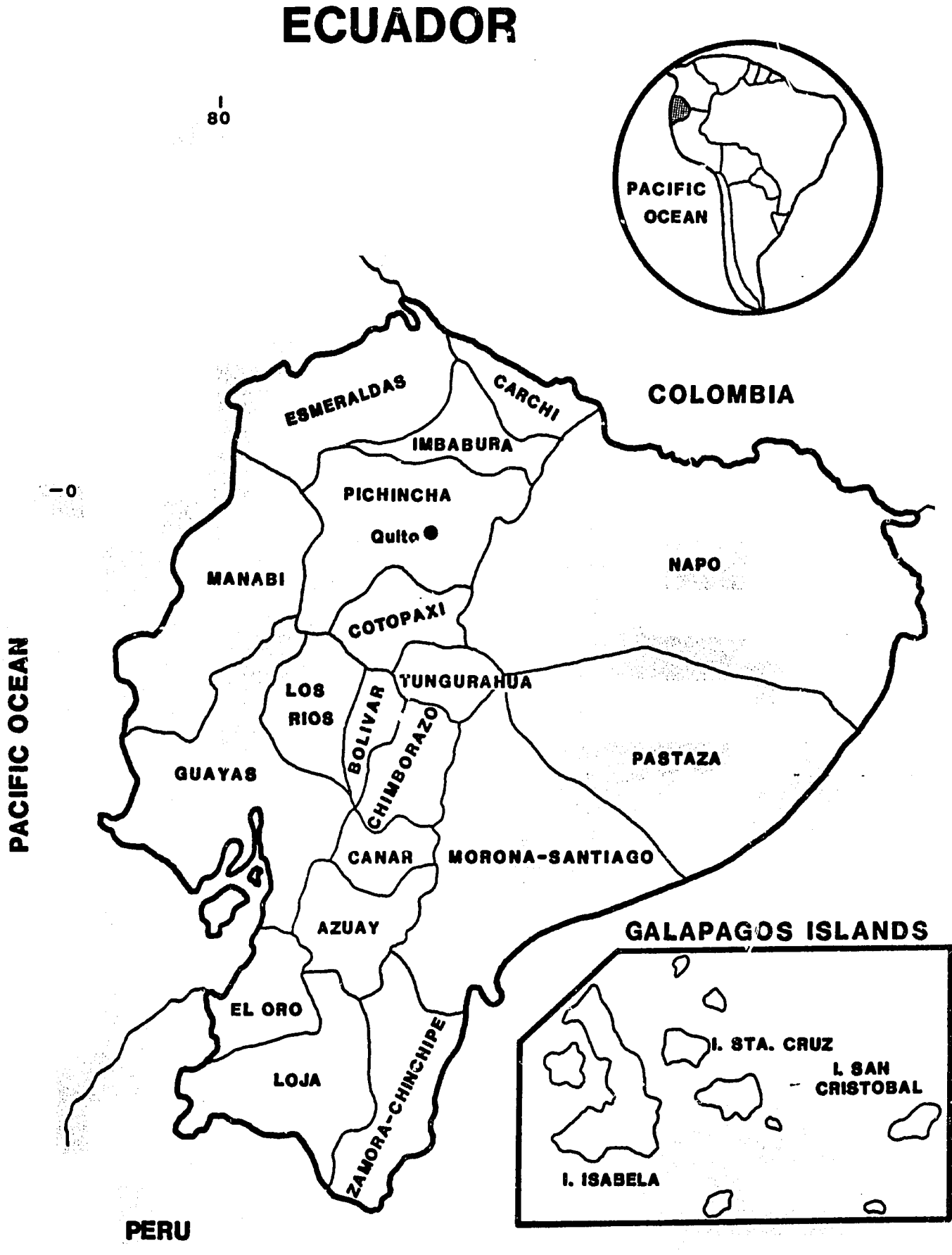


Figure 5.12. Location and Boundaries of Ecuador.

ECUADOR

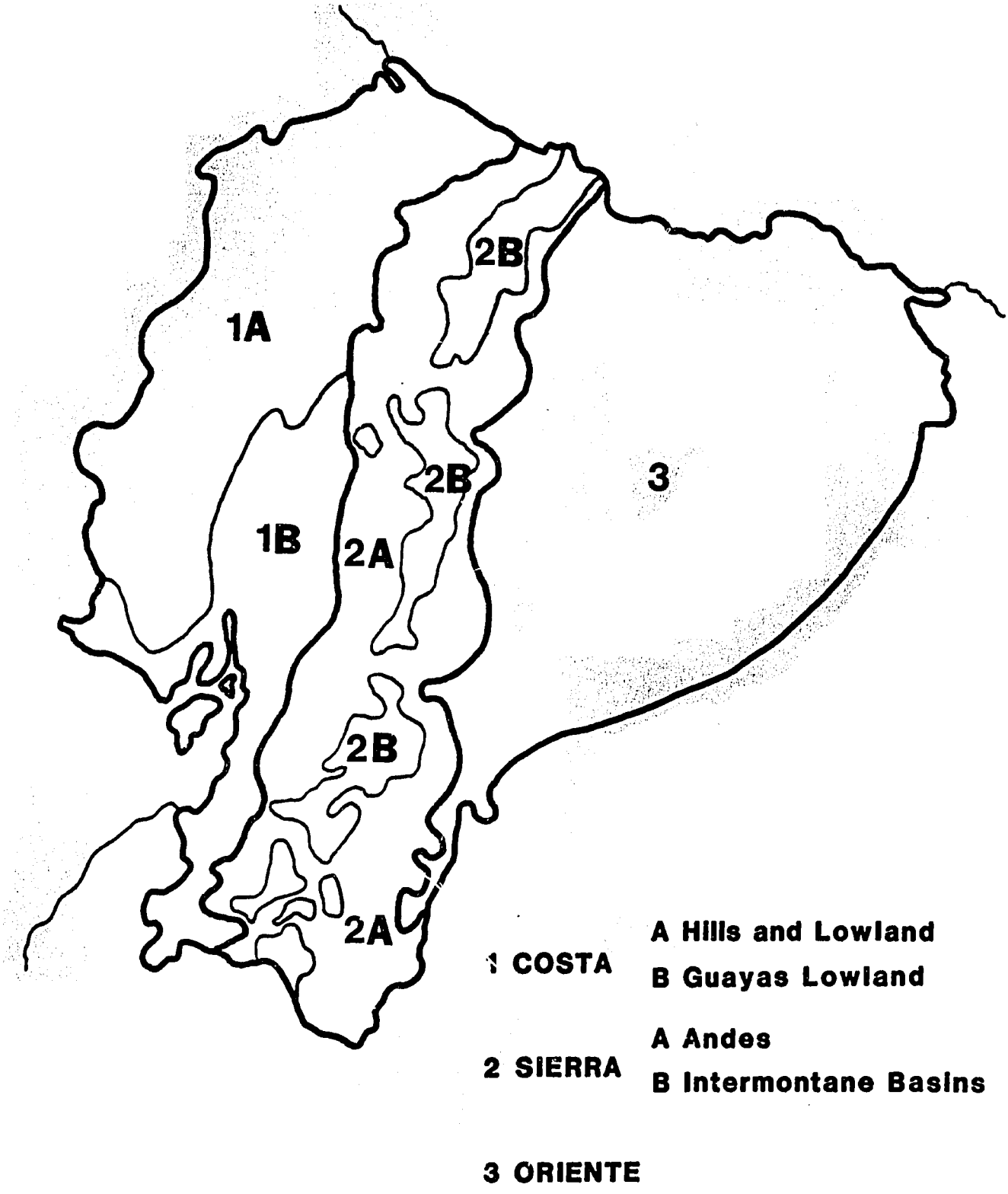


Figure 5.13. Natural Regions of Ecuador.

generally increases. There is a parallel transition from tropical lowland forests through cool Andean rain forests and humid sierran bush to "paramo" savanna grasslands and scrub at the highest elevations. Over half the Sierra is now a grassy "paramo." The intermountain basins are slightly warmer, experiencing an annual temperature range of 7° to 20°C and an average rainfall of 1,500 mm.

The Oriente experiences an equatorial climatic regime, with over 3,000 mm of rainfall a year and a mean annual temperature exceeding 20°C. The region is drained by the tributaries of the Amazon.

2. Agricultural Practices

Agriculture contributes about 42 percent of Ecuador's GDP, provides employment for 56 percent of the country's labor force, and generates over 90 percent of export earnings. Yet only 5 percent of the land is under cultivation.

Of the 2.1 million ha of land cultivated with annual or permanent crops, 61 percent is located on the Costa, 34 percent in the Sierra, 4 percent in the Oriente, and 1 percent on the Galapagos Islands. Land on the Costa is generally fertile and highly productive. In the Sierra, land use is determined by altitude, rainfall, and soil composition.

Patterns of cultivation range from primitive to modern, with the more modern methods generally used on the Costa where much of the production is geared for export. Very little mechanization can be found in any of the regions, most implements are hand tools, particularly machetes. In the Sierra, the most common agricultural instrument is the "azadon," a hoe with a large blade and an ax-like handle. Ox-drawn plows are used on some farms, but a digging stick suffices for cultivation on slopes.

The use of chemical fertilizer is confined to the larger enterprises in the Costa. In the Sierra, by contrast, animal manure is the only type of fertilizer used. The use of irrigation and pesticides is increasing, even on smaller farms (Pons, 1970).

3. Principal Crops

The basic food crops of the country, corn, potatoes, barley, beans and wheat are grown mainly in the intermountain basins of the Sierra. The Costa produces a large exportable surplus of bananas, coffee, sugarcane, cacao, rice and cotton. Table 5.7 shows an estimated regional calendar for selected crops grown in Ecuador.

a. Corn

Corn is grown widely throughout the country and accounts for the largest amount of planted cropland (Figure 5.14). It can be found growing from sea level to altitudes of 3,200 m. The main producing areas are in the Sierra, where eight to ten months are required to bring a crop to maturity. Corn is sown between November and December, while harvest is carried out in March-April for "green corn" and May-July for the dry grain.

Corn production in Ecuador shows an increasing trend due to improved varieties and a more extensive use of fertilizer. The use of herbicides has resulted in greater yields per ha.

b. Potatoes

Potatoes are a very important crop of the Sierra, their production being concentrated in the high (2,500-3,500 m) cool areas of the Provinces of Cotopaxi, Chimborazo, Pichincha, and Tungurahua.

There is one major sowing season for potatoes in Ecuador which takes place in October-December. In some areas, the sowing season can be extended because there are no frosts. The growing season at the optimum altitude of 3,000 m is about six months. At 3,500 m, however, it extends to nine months.

TABLE 5.7. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN ECUADOR

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn	//	—	—	—	OO	OO						//	Local and improved varieties.
	Beans	//	/-	—	OO	O								
	Rice	//	—	—	OO	OO							//	A "summer" crop is planted in June and harvested in Sept/Dec.
	Sugarcane	OO	OO	—	—	—	—	—	OO	OO	OO	OO	OO	Harvested from 12 to 18 months after planting/cutting.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Western Mountains	Corn	—	—	—	—	—	OO	OO				//	//	
	Potatoes	—	—	—	—	—	OO	OO			//	//	—	
	Wheat	—	—	—	—	—	OO	OO			//	//	—	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Harvested from 10 to 14 months after planting.
Valleys[1]	Corn	//	—	—	—	—	OO	OO					//	
	Beans	/-	—	—	OO	O							//	
	Wheat	//	—	—	—	—	OO	OO					//	
	Potatoes	//	—	—	—	—	OO	OO					//	
Eastern Mountains	Corn	—	—	—	—	OO	OO					//	//	
	Beans	—	—	OO	O							//	/-	
	Potatoes	—	—	—	—	OO	OO					//	//	
	Wheat	—	—	—	—	—	OO	OO				//	//	

1/Source: Canadas L. and Salvador, H.(1982).

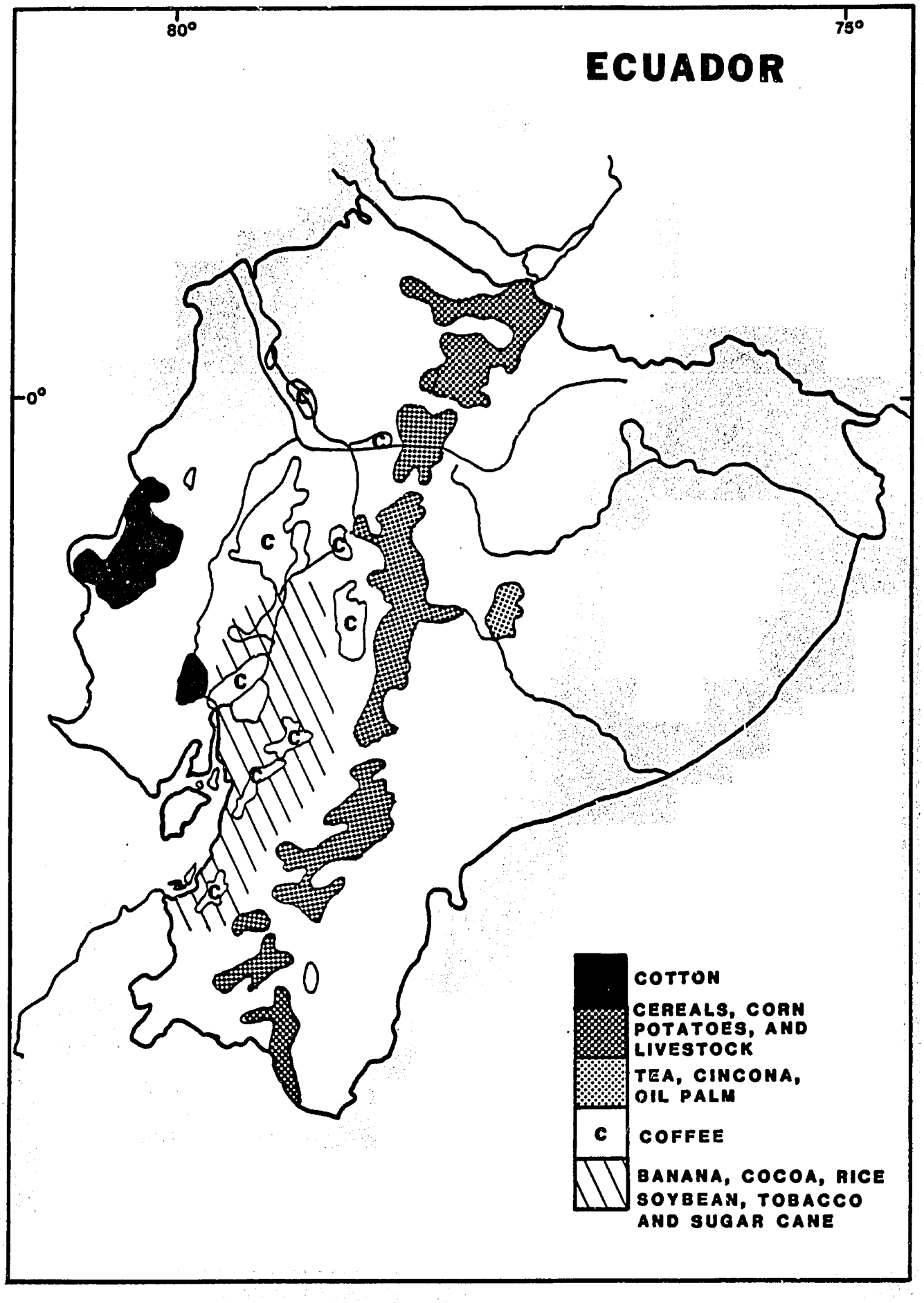


Figure 5.14.- Distribution of Agricultural Crops in Ecuador.

Increased yields have resulted from better methods of cultivation, improved seed strains, and use of fertilizers.

c. Barley

Barley is grown both as a food grain and as malt for the brewing industry. It is cultivated on most highland farms, where production has been increasing by the use of improved seeds. The optimum altitude is 2,800-3,000 m, while the optimum temperature seems to be 12-15°C.

The growing season lasts 5½ to 6 months. Mechanical sowing and harvesting is practiced on the larger farms, resulting in higher yields.

d. Wheat

Wheat is the third crop in terms of cultivated area after corn and barley. It is also grown in the intermountain basins of the Sierra, the largest quantities being produced in the Province of Pichincha.

Wheat is grown without irrigation at altitudes varying from 1,000 to 4,000 m, and the growing season varies accordingly from 130 to 210 days. In contrast, an early variety grown on the Costa with irrigation has a cycle of only 100 days. The optimum altitude seems to be between 2,700 and 3,000 m, where yields are reported to be about 7 tons/ha with fertilizer.

Wheat production and yield are low in Ecuador, and considerable amounts have to be imported in order to satisfy domestic demand.

e. Rice

Rice is one of the basic food staples of the country. It is cultivated mainly on the flood plains of the Guayas River basin. Two annual crops are harvested; a large winter crop, planted in December and January and harvested from April to May (Table 5.7), and a smaller crop, planted in early summer and harvested from September to October. Rice production is sufficient to meet local demand, and in some years an export surplus is available.

f. Other Crops

Beans

The area planted in beans in Ecuador is the largest of the Andean countries but yields are lower than those of Peru and Colombia. Beans are usually planted with corn, and constitute an important part of the diet for low-income workers and farmers of the Sierra.

Bananas

Bananas have been the leading export crop of Ecuador for the last 25 years. The coastal provinces are the main producing areas, but some production comes from the lower western slopes of the Sierra. A large number of families are dependent upon banana cultivation.

Over 50 percent of the total area devoted to bananas is planted with the Cavendish variety, the remainder being the Gros Michel and the Lacatan varieties. Banana yields have been increasing steadily.

Coffee

Grown mostly on small landholdings, coffee has usually been the second most valuable crop in the country. About 86 percent of total coffee acreage is in the coastal provinces.

Because of the small size of the farms, production techniques have not been improved and yields are low, particularly in years of drought. Irrigation is rarely used, and less than one percent of the farmers use fertilizer or pesticides.

Cacao

The third most valuable crop is cacao, which has been an export commodity for over two centuries. It is most profitably cultivated in the Costa provinces, particularly in Guayos and Los Rios.

Sugarcane

Another widely grown crop, sugarcane is produced both in the Sierra and on the Costa. The coastal farmers plant improved varieties, irrigate their fields, and use better cultivation practices than the sugarcane farmers of the Sierra.

Numerous minor crops are grown in Ecuador. These include cotton, royal and African oil palms, sesame, peanuts, soybeans, coconuts, castor beans, abaca, tobacco, pyrethrum, tea, ramie, rubber, oats, rye, and several fruits (pears, peaches, plums, avocados, citrus, pineapples, melons, guavas, and mangoes). Ecuador is one of the world's major castor bean producers and exporters.

4. Agroclimatic Indices

Figure 5.15 shows the historical Yield Moisture Index (YMI) in percentiles for Izobamba (Valleys Region). The YMI was computed for a corn crop during the main growing season (October-May). Particularly dry years (1963 and 1976 to 1978) adversely affected corn yield, verified by YMI values in the 8th to 20th percentile range. The critical YMI value for crop failure may be determined by using episodic data (Table 5.8) and historical crop yield data.

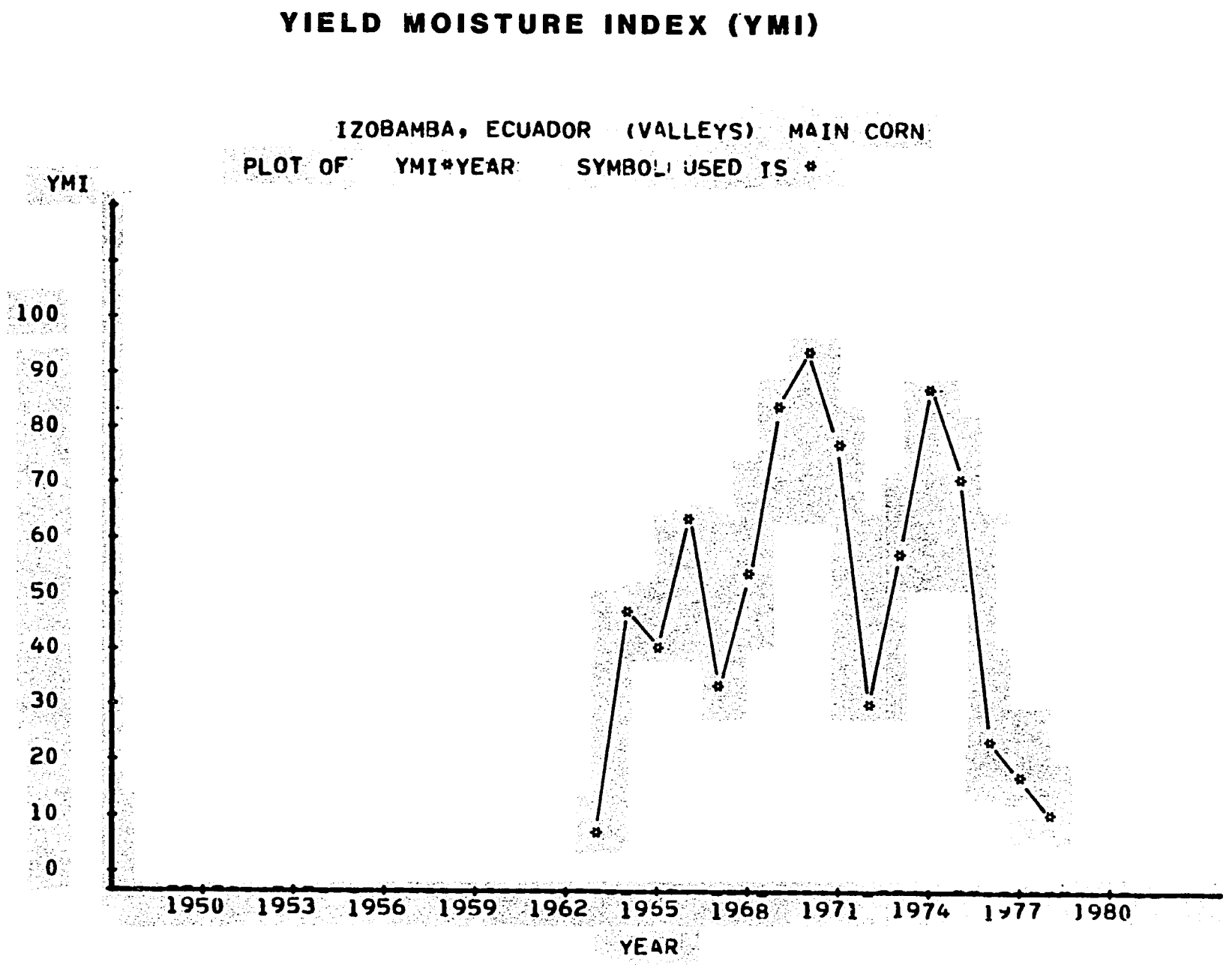


Figure 5.15. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Izobamba (Valleys Region).

TABLE 5.8

ECUADOR

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1960's		Plant diseases, insect damage and poor production practices limited wheat output.
1963-65		Three-year drought in the coastal region.
1966		Adverse weather affected crop production.
1967		Coastal agriculture, especially rice, was reduced by flooding and later drought.
1968		Severe drought covering the important coastal and southern provinces affected production, especially rice.
1971		Agricultural production decreased.
1972-73		Adverse weather affected the country.
1974		Food crops showed little growth.
1975		Excessive rains affected wheat, cotton, barley and coffee. Cool temperatures affected cacao and coffee growth.
1976		Heavy rains eased the drought in October, but shortages of credit limited agricultural growth.
1977	February	Deficient rains and pests affected cereals in the Sierra region. In April, there were floods in Littoral states. Frosts affected grains and soya crops in the northern and central areas of Sierra in August. In December there was frost and lack of rain in the south of the Sierra.
1978		Serious drought damaged food crops. Yellow rust affected wheat.

TABLE 5.8

ECUADOR (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1979	December	A dry spell affected coastal and Sierra regions. In several provinces of the Sierra, severe frosts seriously damaged crops, especially soft corn.
1980		Drought restricted production of food crops, particularly rice. Frosts occurred in Tungurahua and Bolivar provinces in July and November.
1981		Dry weather delayed food crop growth. Heavy rains in March in large areas of the Sierra and frosts and heavy rains in some provinces occurred in May.
1982	May	A severe drought hit Manabi and Guayas provinces causing loss of staple crops.

E. FRENCH GUIANA

1. Physical Environment

French Guiana, an overseas department of France since 1946, is located on the northeast coast of South America. It is bounded by the Atlantic Ocean on the north, Brazil on the east and south, and Suriname on the west, and has a land area of 91,000 square kilometers.

The physiography of the country consists of low hills rising from the Coastal Plain and an inland plateau area stretching into the outlines of the Guiana Highlands. The Coastal Plain is 25-30 km wide and has a coastal fringe of mangrove swamp.

The climate of French Guiana is strongly affected by the fluctuations of the intertropical front, which brings a very irregular rainfall regime. A range of 2,500 to 4,000 mm has been recorded for the same location in two consecutive years. There are two wet and two dry seasons during the year. The short wet season extends from mid-December to mid-February, and is followed by a short dry season until mid-April. The main wet season lasts from mid-April to mid-August and the main dry season then lasts until mid-December.

Temperatures remain fairly constant throughout the year. The warmest month is October with 27°C while the coldest is January with an average of 25°C. Relative humidity is high throughout the year, rising to over 90 percent in the wet season and falling to about 80 percent in October. Mean annual rainfall varies from 4,000 mm on the coast to 2,000 mm inland, and great variations occur from year to year.

The climate is favorable to the agricultural production of many tropical plants but cultivation is limited by several factors which, in turn, limit agricultural productivity.

2. Agricultural Practices

Less than 3,000 people (10 percent of the population) are engaged in agriculture and the majority of them work within a subsistence economy. Only 3,000 ha are devoted to agriculture (Service Departemental d' Agronomic de la Guyane, 1970).

The staple crop of French Guiana is manioc, which occupies 33 percent of all cultivated land. Sugarcane and corn each account for 400 ha while various tuber crops cover a further 600 ha. Most crops, with the exception of sugarcane, are grown by shifting cultivation.

An estimated regional crop calendar for subsistence agriculture in French Guiana is shown in Table 5.9.

3. Agroclimatic Indices

Figure 5.16 shows the historical Yield Moisture Index (YMI) in percentiles for Cayenne/Rochambeau (Coastal Region). The YMI was computed for a corn crop during the main growing season (October-March). Poor crop conditions may be associated with YMI values below the 10th percentile in the 1963, 1965 and 1972 crop growing season). The critical YMI value for crop failure may be determined by using episodic data (Table 5.10) and historical crop yield data.

TABLE 5.9. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN FRENCH GUIANA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn			//	//	—	—	OO	OO					Usually intercropped with other crops. Second crop planted in August-September.
	Beans			//	/-	—	OO	O						
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Planted throughout the year.
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	OO	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Inland	Corn			//	//	—	—	OO	OO					
	Beans			//	/-	—	OO	O						
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Sugarcane	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

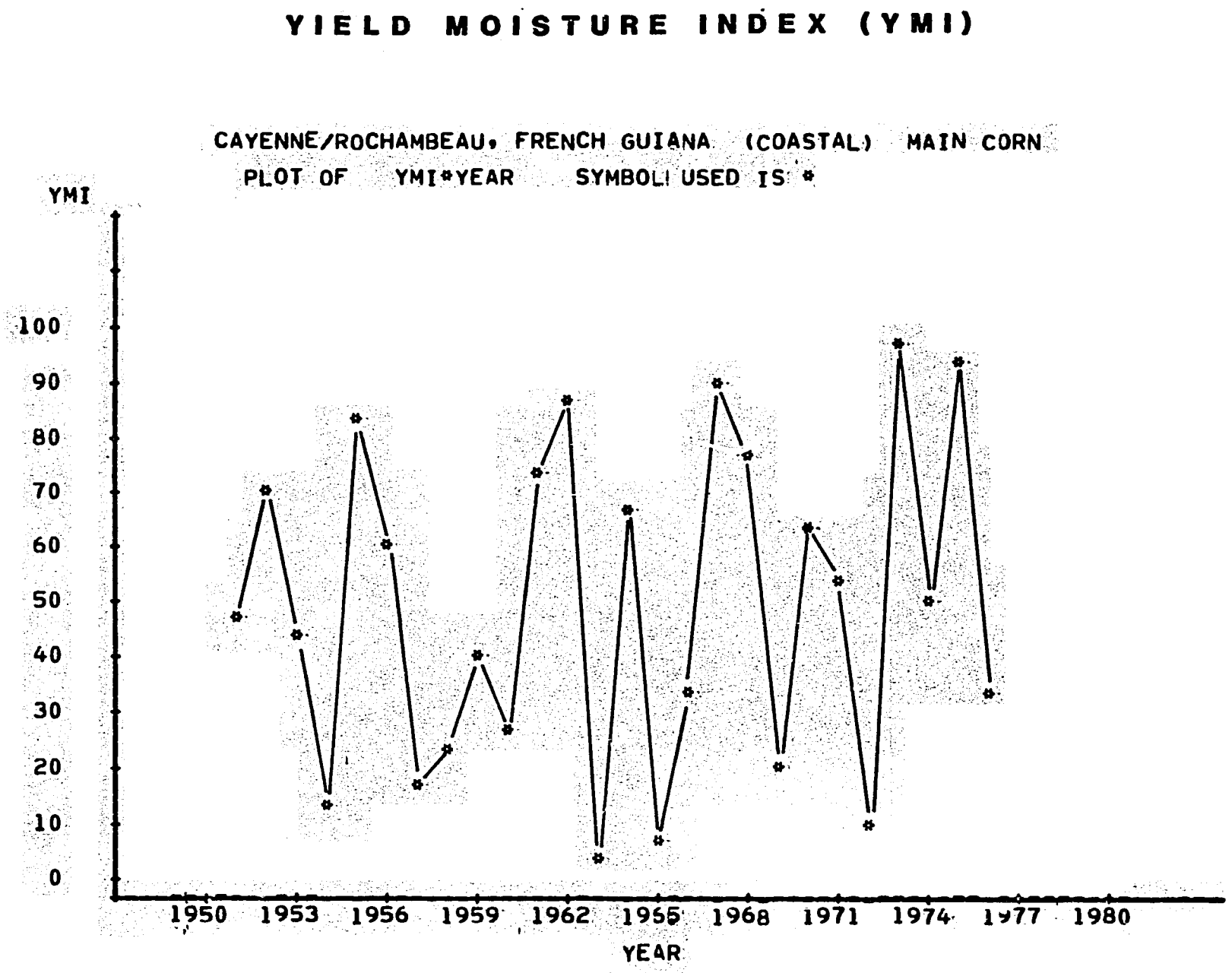


Figure 5.16. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Cayenne/Rochambeau (Coastal Region).

TABLE 5.10

FRENCH GUIANA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1982		Floods struck much of the northern half of the country.

F. GUYANA

1. Physical Environment

Located just north of the equator (between 1°N and 9°N and 57°E and 61°E) on the northeast coast of South America, Guyana has a total area of 214,970 square kilometers. The country is bounded by a 430-kilometer coastline facing the Atlantic Ocean on the northeast, Venezuela and Brazil, on the west, Suriname on the East and Brazil on the South (Figure 5.17).

Guyana can be divided into 3 major natural regions: (a) the Coastal Plain, (b) the Forest Zone, and (c) the Savannas (Figure 5.18). The Coastal Plain occupies approximately five percent of the total land area, while regions (b) and (c) account for 84 and 11 percent, respectively (Mitchell et al, 1969).

The Coastal Plain is a narrow belt (50-60 km wide) that extends from the Courantyne River on the border with Suriname to the Venezuelan border in the Northwest. This is the most densely populated region (over 650,000) and also the most widely cultivated area of the whole country. At present over 280,000 ha are under cultivation and rough grazing land covers about 180,000 ha. Much of the Plain is below sea level by as much as 1.5 m at high tide. Hence, it is rarely cultivated beyond 16 km inland, and the first two kilometers behind the sea defenses are generally used for either pasture or rice, which can survive the higher water table and extreme salinity of the soil.

The Forest Zone lies immediately behind the coastal belt and covers some 18,000,000 ha of typically equatorial rainforest. This hilly area, seamed by many river valleys, has poor sandy soils and contains a large number of tree species. An eroded plateau with softly undulating relief and forest-covered hills extends toward the northeast, ranging from 120 m in elevation in the interior to 15 m near the Coastal Plain where the plateau extends for about 40

Figure 5.17. Location and Boundaries of Guyana.

GUYANA

Figure 5.18. Natural Regions of Guyana.

miles from the coast. The Kaieteurian Plateau and the Pakaraima Mountains dominate west-central Guyana. The plateau is about 600 m in elevation and the mountains rise as high as 3000 m near Venezuela and Brazil. Although much lower in elevation, the plateau extends almost to the coast itself in the northwest.

The Savannas lie in three sub-regions. A coastal savanna sub-region with an area of 78,000 ha extends between the rivers Demerara and Courantyne. The largest savanna, the Rupunumi, is in the southwest around the river of the same name and covers some 1,100,000 ha. Further west, a third savanna sub-region covers 520,000 ha between the Pakaraima and the Kanuku mountains. The geographical location of the above mentioned natural regions is shown in Figure 5.19.

The equatorial zone where Guyana is located has the highest average annual temperature (with a range of only a few degrees), high humidity and very high rainfall. The mean annual temperature at the capital city of Georgetown is 27°C; inland, the increase in altitude is not sufficient to reduce temperatures significantly. Average annual rainfall is 2,300 mm, most of it occurring from December to July. Relative humidity ranges between 75 and 88 percent. The typical equatorial climate of Guyana has a definite effect on the production of sugar and rice.

2. Agricultural Practices

Agriculture is the main support of Guyana's economy, providing employment for over a third of its working population and contributing almost two-thirds of total exports in 1966. In the same year, agriculture accounted for almost 25 percent of the country's national income. However, about 20 percent of the food requirements were imported, and a decreasing per capita crop production during the last decade could be noted (Bonuzzi, 1970).

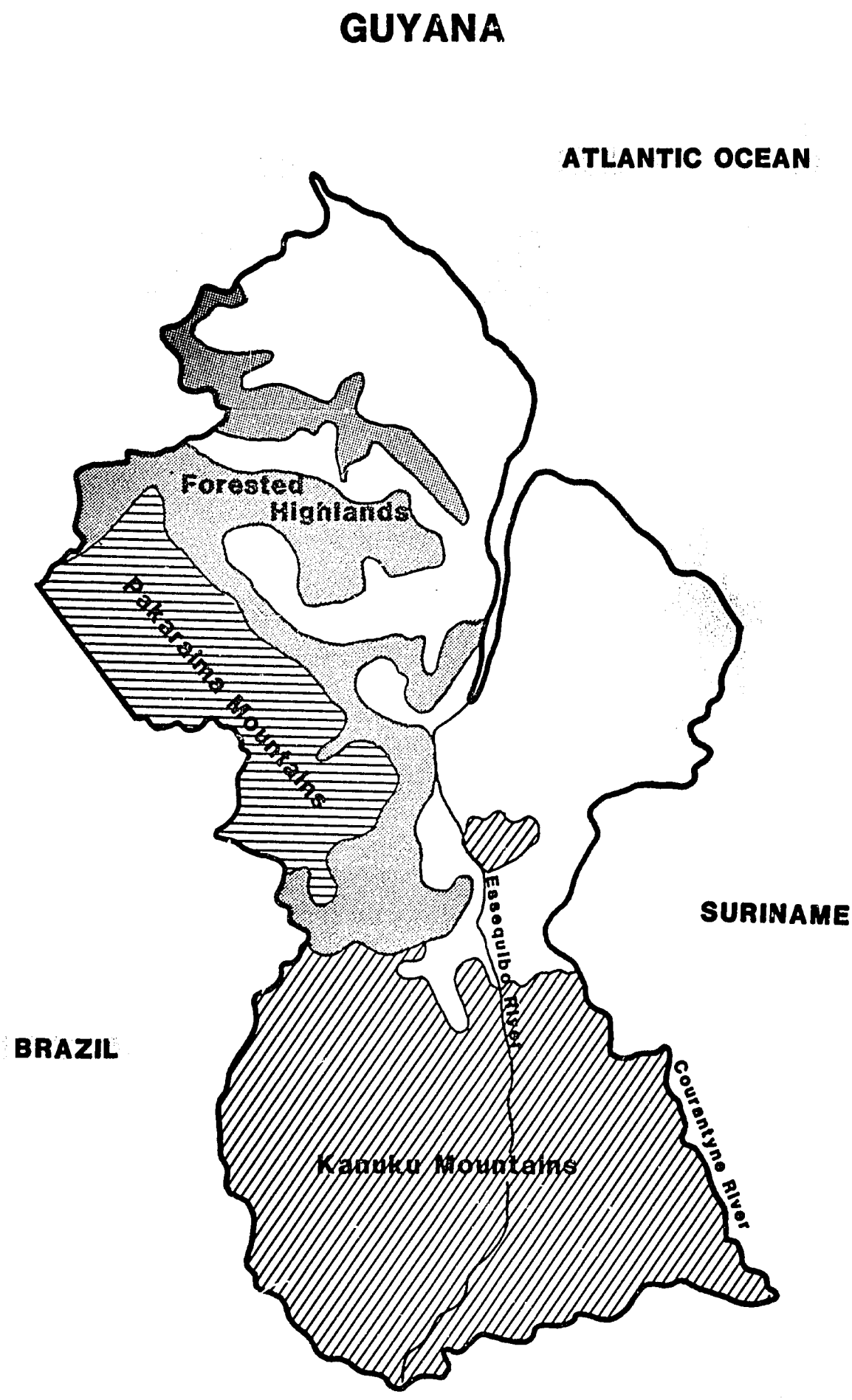


Figure 5.19. Major Physical Features of Guyana.

Only a very small area (2 percent of the total area in 1964) is actually under cultivation, including shifting cultivation and plantations (Figure 5.20). Cultivated land is dominated by sugar and rice, one-sixth is devoted to sugar and one-half to rice.

Two systems of agricultural organization and operation are recognized in Guyana. The plantation system, producing sugar and bananas, is characterized by high capital costs for drainage and irrigation, while the small-holding system is characterized by problems of drainage and irrigation, inefficient water utilization, pests and diseases, and poor soils. This system is chiefly devoted to rice production but also includes subsistence agriculture.

Cultivation methods are, on the whole, very simple and in many cases quite primitive. Crop rotation, where practiced, is usually limited to a two-year rotation. Fertilizers are chiefly used on the sugarcane plantations and on the more advanced farms growing rice by dry cultivation, though at a lower rate. The use of fertilizers is almost unknown on medium-size and small holdings. Mechanization is limited to the cultivation of rice on those farms where hired labor is employed.

Flood-fallowing is one unusual practice: fields are plowed, flooded for at least six months, and then drained and replanted.

3. Principal Crops

In addition to sugarcane and rice, which are the main agricultural products, bananas, coconuts, coffee, cacao, citrus, and other tropical fruits and vegetables are grown in varying amounts.

a. Sugarcane

Sugarcane is by far the most important crop grown in the country in terms of both area and value. It is grown in the Coastal Plain in narrow strips, running from the sea or river back to the surrounding swamps enclosed with dams to keep out the water (Figure 5.21).

GUYANA

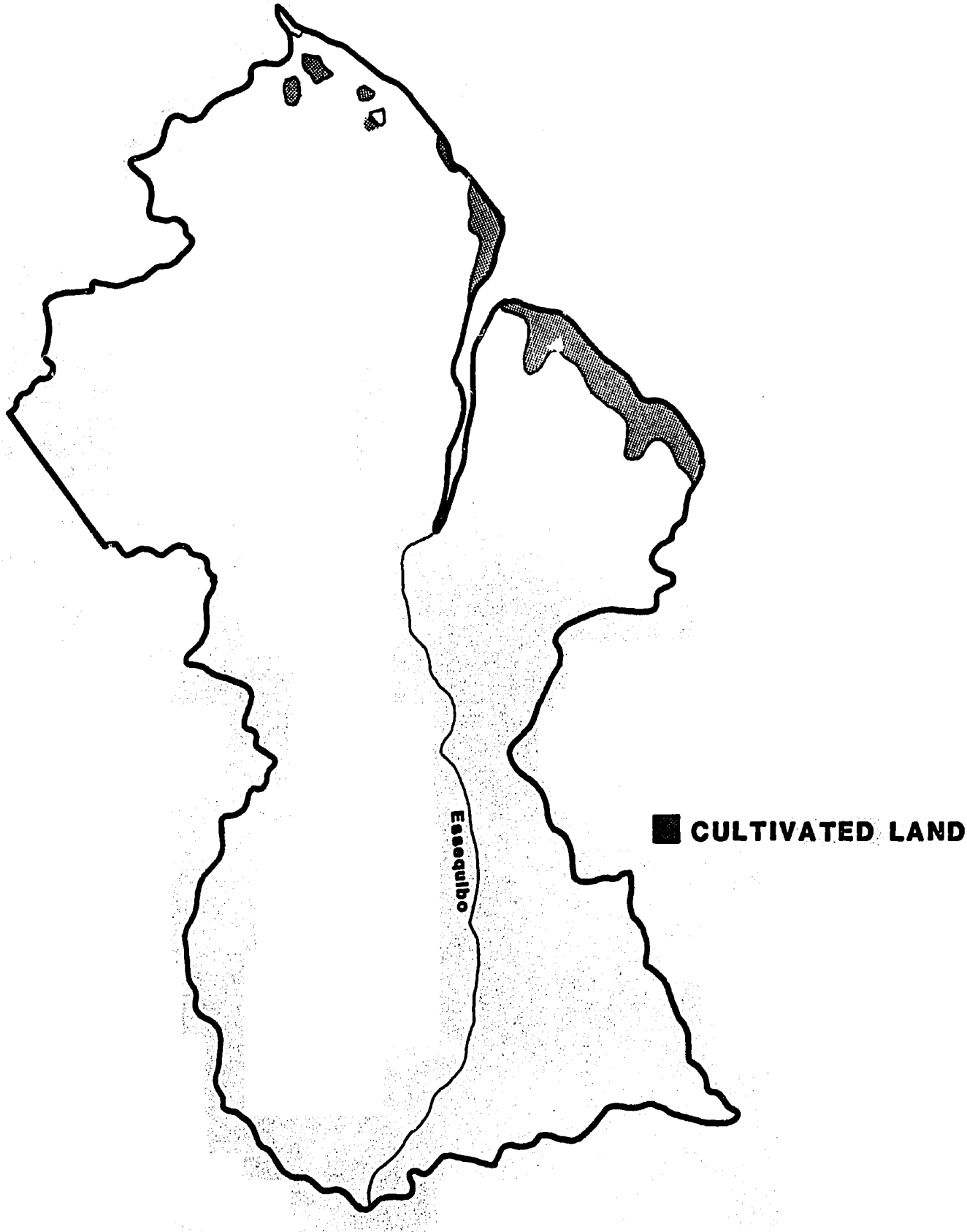


Figure 5.20. Agricultural Areas.

GUYANA

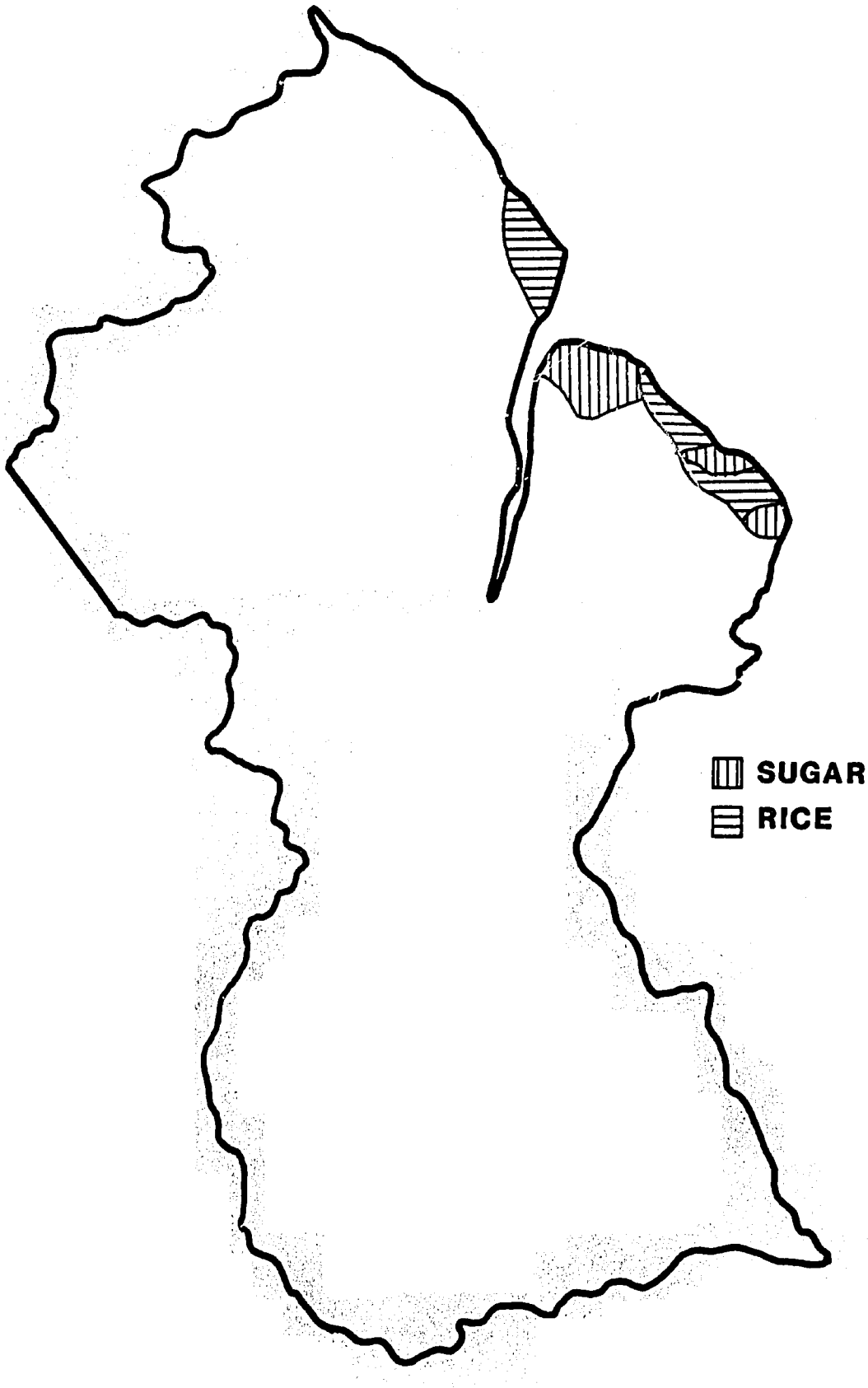


Figure 5.21. Distribution of Agricultural Crops in Guyana.

In Guyana, sugarcane requires drainage that keeps the soil aerated in order to promote growth and irrigation during the dry season. Thus polders are arranged to provide drainage and irrigation.

Due to the climatic conditions, the growing cycle of sugarcane is 12 to 18 months, which is longer than in other sugar-producing countries. Sugarcane is planted in the spring and fall dry seasons, and the harvest also takes place in the dry seasons (Table 5.11). Mechanization is not utilized to reduce production costs. Guayanese sugar is exported chiefly to the United Kingdom, Canada, and the United States. Rum, molasses and other by-products are also important export items.

b. Rice

Rice is cultivated in the coastal belt (particularly in the former swamps of the northeast) where heavy rainfall and flat alluvial soils provide excellent environmental conditions for this crop. Dry and shifting cultivation are frequently practiced.

Rice can be sown at different periods to yield both a spring and a summer harvest. The main crop is planted at the beginning of the long summer rainy season, around April or May, and is harvested in October (Table 5.11). In areas with good drainage and irrigation, two crops a year are not uncommon. This "small crop" is planted during the winter rainy season and reaped in the spring. Rice exports are directed mainly to the Caribbean countries.

c. Other Crops

Coconut trees have become of considerable importance in the country's agriculture. Coffee and cacao also constitute important export commodities. Corn, cassava, yams, and other vegetables, as well as bananas, citrus and other tropical fruits, are grown by small local farmers by shifting cultivation methods.

TABLE 5.11. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN GUYANA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn				//	//	—	—	OO	OO				Usually intercropped with other crops.
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Rice				//	//	—	—	—	OO	OO			
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	OO	OO	Harvested from 12 to 18 months after planting/cutting.
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Inland	Corn				//	//	—	—	OO	OO				
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

4. Agroclimatic Indices

Figure 5.22 shows the historical Yield Moisture Index (YMI) in percentiles for Georgetown (Coastal Region). The YMI was computed for a corn crop during the main growing season (March-August). Subnormal crop conditions are suggested by YMI values below the 10th percentile in 1934, 1939 and 1957. The critical YMI value for crop failure may be determined by using episodic data (Table 5.12) and historical crop yield data.

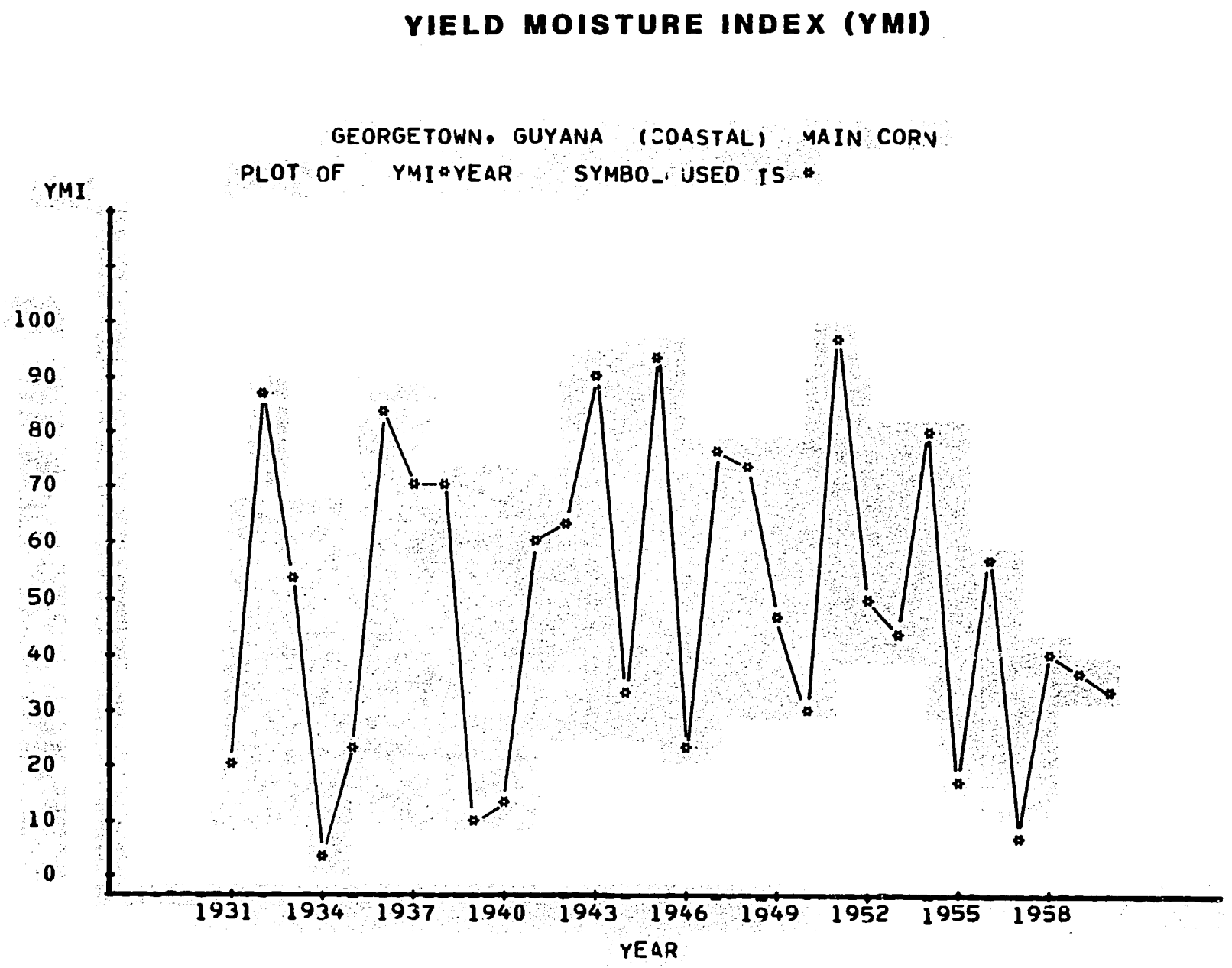


Figure 5.22. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Georgetown (Coastal Region).

TABLE 5.12

GUYANA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1954-58		1954-55 and 1957-58 were years with poor crops.
1963	April	A prolonged general strike caused a loss in sugar production. Excessive rains affected the rice crop.
1964		Dry weather affected most crops.
1968		Drought affected agricultural production.
1971		The rice crop was poor.
1973		Dry conditions persisted. This was a disastrous year for agriculture.
1975		Sugar production dropped due to a work stoppage.
1976		Adverse weather affected crops. Excessive rainfall from January to May caused serious mushroom crop problems.
1977		Rice production dropped 40 percent.
1979		Adverse weather and shortages of machinery and spare parts affected crop production.
1980		A storm in June damaged crops. Adverse weather affected the fall rice crop. The early arrival of the December rains curtailed fall sugarcane harvest.
1982		Sugar and rice output was very good.

G. PERU

1. Physical Environment

Peru is the third largest country in South America with an area of 1,285,215 square kilometers. It is bounded by Ecuador and Colombia in the north, Chile in the south, Brazil and Bolivia in the east, and the Pacific Ocean on the west (Figure 5.23).

The country has three clearly defined regions: the Costa, the Sierra and the Selva (Figure 5.24). The western region, the Costa, is a narrow belt of arid lowland bordering the Pacific Ocean, with a coastline of about 2,400 km. The Sierra is the backbone of Peru, consisting of a high mountain-chain (the Cordillera de los Andes) which crosses the country roughly southeast-northwest, and valleys and high plateaus (known as "altiplanos" or "punas") which break the continuity of the mountain system. The eastern region, the Selva or Montana, is a vast forested plain sloping gradually eastward to the borders with Colombia, Brazil and Bolivia.

The Costa

The coastal region consists of the dry plains and sand dunes of the littoral and of the dry Andean foothills below an altitude of 2,000 m. In all, the Costa includes about 11 percent of the national territory and is the most densely populated part of the country. Temperatures in this region are uniformly lower than those at similar latitudes in South America because of the influence of the cold Humboldt or Peru Current; the average air temperature ranges from 19 to 23°C during the year. The Costa receives little or no rainfall, rarely more than 50 mm. However, when heavy mists, known as "garua", cover the coastal ranges and lower foothills of the Andes a dense growth of quick-flowering plants and grasses flourishes briefly. At intervals, starting around

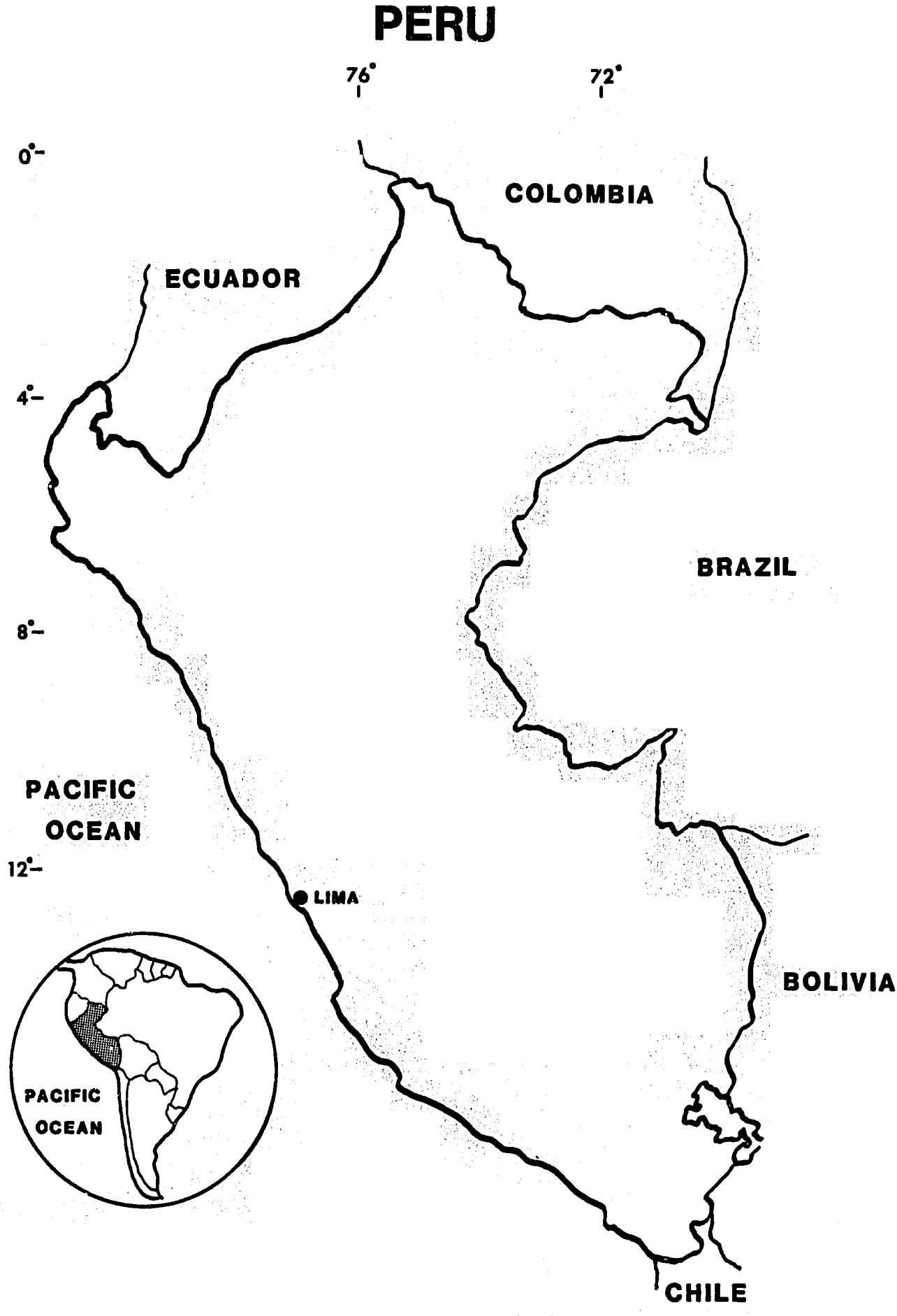


Figure 5.23. Location and Boundaries of Peru.

PERU

Figure 5.24. Natural Regions of Peru.

Christmas, an equatorial countercurrent called "El Nino," which might last for three months, causes climatic changes. Temperatures then rise rapidly from the seasonal 16°C to 27°C, with up to 400 mm of rainfall in a few days. The ensuing floods cause havoc as the ecological balance is abruptly disturbed.

The Sierra

The Sierra Region, about 26 percent of the national territory, consists of a high plateau which gradually rises as it extends southward. The pattern of the mountain system is highly mixed; tremendous canyons are cut below the high surfaces. The highest section has a number of snow-capped peaks of which the tallest, Mount Huascaran, is 6,729 m.

Temperatures vary considerably with altitude ranging from subtropical in sheltered valleys to glacial on the highest peaks. Mean annual rainfall also varies with altitude, the northern half of the plateau receiving more precipitation (700-2000 mm) than the southern part (500-1,000 mm). The snowline rises from 4500 m in the northern Sierra to 5,800 m in the south. The period of heavy rain is from September to April; there is a marked dry season during the winter.

The Selva

The Selva or Montana includes nearly 63 percent of Peru's land area. It is made up of two zones: the Selva Baja (Low Selva) and the Ceja de Selva (High Selva or brow of the Selva). Below the height of about 1,000 m is found the dense tropical rain forest of the Amazon that makes up the Selva Baja, a vast remote plain receiving more than 2,500 mm of rain annually.

The Ceja de Selva is a traditional zone between the Sierra and the Selva Baja, with altitudes ranging between 1,000 and 1,800 m. The vegetation of these eastern slopes varies considerably with altitude, aspect and slope: savanna selvatic, and mountain forest climaxes are found in association. Mean annual temperature is about 26°C while average annual rainfall ranges from 1,000 to 2,000 mm.

2. Agricultural Practices

By 1978 agriculture contributed less than 13 percent of Peru's GDP and employed about 42 percent of the labor force. According to the 1972 agricultural census, arable cropland amounted to 3.7 million hectares (less than 3 percent in the Sierra and 16.2 percent in the Selva). Total cropland, however, suffered a reduction by 1980 because of the prolonged drought from 1977 to 1980.

The three major natural regions present very different problems. The Costa is the most productive farming area, containing most of the large commercial farms and producing over 40 percent of all crops in terms of value. Cultivation is confined mostly to river valleys and is dependent on irrigation because of the near absence of rainfall. Irrigation combined with advanced technology and extensive mechanization produces high yields. The principal crops are sugarcane, cotton, rice, vegetables, and some fruits (Rossi, 1970).

In the Sierra, cropping is largely in the high valleys, in an unfavorable environment. Less than 25 percent of the fields were under irrigation in 1972, the bulk of the crops depending on limited and erratic rainfall. Fertility of fields has been declining and the period of fallow lengthening to 5-7 years. The growing season is short (November to March) and there is risk of frosts, especially above 3,700 m where crop yields diminish drastically.

The soils of the Selva Baja are considered marginal for cropping and more suited to grazing and forestry. Some seasonal crops are grown on flood plains of rivers after the annual high water recedes. The soils of the Ceja de Selva are better and offer some potential for agricultural development. By 1980 fruits, coffee, and tea were grown in this zone.

Irrigation continues to be the key to the productivity of the almost rainless coastal strip. In 1972 there were 1.3 million ha of irrigated cropland, 700,000 ha of which were in the Costa and 500,000 in the Sierra. However, due to uncontrolled and wasteful use of water, nearly 200,000 ha in the

Costa have gone out of production because of increasing salinity. With adequate drainage systems these fields could be returned to productivity in a few years.

Most farms in the Costa are characterized by innovation, efficiency and rising productivity, and employ modern farming techniques. Grain crops are grown in rotation with potatoes and legumes. Annual applications of about 100 kg per hectare of inorganic and organic fertilizers (particularly guano) are the rule. Some crops, especially cotton, rice and sugarcane, are rotated occasionally with potatoes and legumes. Farms in the other natural regions, by contrast, are characterized by traditional, wasteful methods and low yields. Use of certified seeds, fertilizers and machinery is extremely low, and losses in the grain harvest due to diseases, pests, and improper storage are very high.

3. Principal Crops

Corn, barley, wheat, rice, and potatoes are the major food crops in Peru while the main agricultural exports are cotton, sugar and coffee. Other minor crops include beans, cassava, sorghum, sweet potatoes and tobacco. The area and distribution of the main crops are illustrated in Figure 5.25. Table 5.13 shows an estimated regional crop calendar for subistence farming in Peru.

a. Corn

Corn is the most important crop in terms of area, occupying about 10 percent of the cropland. It is planted in all three regions but the bulk is in the Sierra. Productivity is much higher in the Costa, however, because fields are irrigated. Sanchez (1982) points out that there are corn varieties which can be grown under the warm conditions of the Costa and others with a shorter growing season or increased tolerance to drought conditions and low temperatures. The same holds true for potatoes.

Corn is cultivated up to 3,900 m of altitude. On the mountains, where corn is planted alone, the growing season depends on the rain. However, 30 percent of planted corn is under irrigation. Sowing takes place from September to January. In Cusco, at 1,000 m, sowing is done in November while in areas above

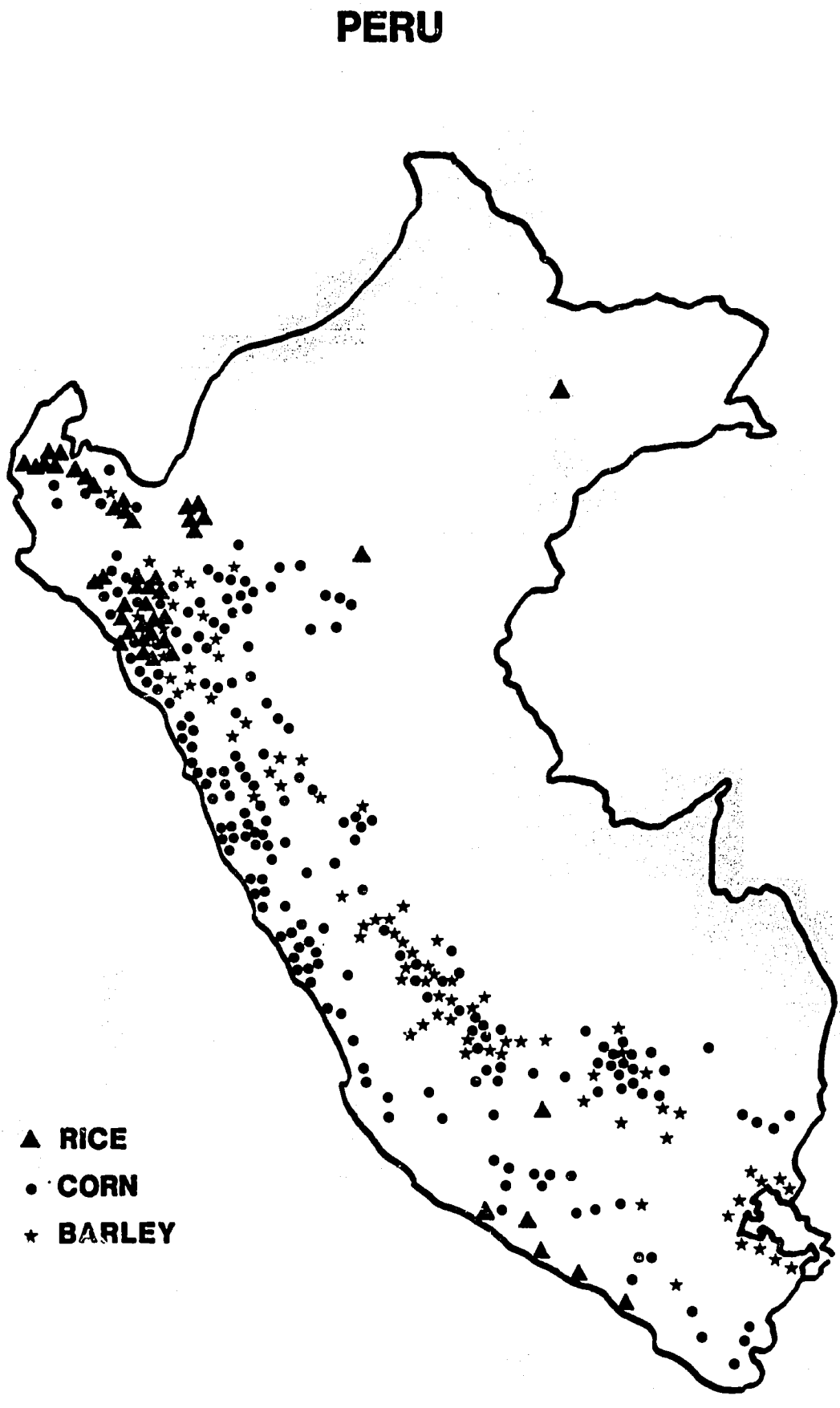


Figure 5.25. Distribution of the Main Agricultural Crops in Peru.

TABLE 5.13. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN PERU

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn	//	//	//	//	//	OO	OO	OO	OO	OO			Extended crop season due to irrigation.
	Beans			//	//	//	//	OO	OO	OO				Irrigated.
	Rice	//	OO	OO	OO	OO	OO			//	//	//	//	Irrigated.
	Sugarcane	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	Irrigated.
Northern Mountains	Corn	—	—	—	OO	OO	OO			//	//	//	//	Usually intercropped with beans and other crops.
	Beans	—	—	OO	OO	OO				//	//	//	//	
	Barley	//	//	—	—	OO	OO	OO				//	//	
	Rice	//	—	—	—	OO	OO				//	//	//	
	Potatoes	//	—	OO	OO	OO					//	//	//	
Northeast Mountains	Corn	—	—	OO	OO	OO				//	//	//	//	
	Potatoes	—	—	—	OO	OO					//	//	//	
Eastern	Corn	//	—	—	—	OO	OO				//	//	//	
	Beans	—	OO	OO	OO						//	//	//	
Southern Mountains[1]	Corn	—	—	—	OO	OO				//	//	//	—	
	Beans	—	OO	OO						//	//	//	—	
	Wheat	//	—	—	—	OO	OO					//	//	
	Barley	//	—	—	—	OO	OO					//	//	
	Potatoes	—	OO	OO	OO					//	//	//	—	
Southeast	Corn	//	—	—	OO	OO	OO					//	//	
	Beans	//	—	OO	OO							//	//	
	Potatoes	—	—	OO	OO	OO					//	//	//	

1/Source: Sanchez, W.A.,(1982).

2,000 m there are two sowings a year (October and January) and irrigation is needed. Consequently, two harvests a year are obtained.

The first frosts (January) affect early or late sowings since the plants are in their blooming or seedling stages. Similarly, early sowings can also be affected by heavy rains which cause flooding of the soil, premature budding, and rotting of the grains. Harvesting is done between May and July, especially in July. This coincides with the dry season which allows a regular ripening of the grains.

In Huancayo (3,150 m) potato follows corn the second year and corn is planted again the third year. Corn may be planted alone here, but usually it is planted with barley, lima beans or peas. In Huanuco and Ayacucho corn is sometimes planted with the native bean "sanandoja" or "bucona" because the latter is said to control a weed called "kikuyo." In Cajamarca, at 2,750 m, if wheat or barley is planted the first year, corn follows the second and third years. Here corn is associated with beans, "quinua", or "locayote."

Eighty percent of the corn fields in the Sierra are not fertilized. By contrast, fertilizers and improved varieties are the rule in the Costa.

b. Potatoes

Potatoes are the other main food crop and also the most important of all crops in terms of value, occupying 6 percent of the total cropland. Although the cultivated area is large, yields are generally low (Figure 5.26).

The greatest number of varieties can be found at 3,600-3,900 m. In 1971, 98 percent of the cultivated areas were in the Sierra, where only 13 percent of the plantations were irrigated. The remaining 2 percent was in the Costa, where most plantations were irrigated and yields were 3 times higher than in the Sierra. In general, yields are low, with late varieties very susceptible to diseases and adverse weather.

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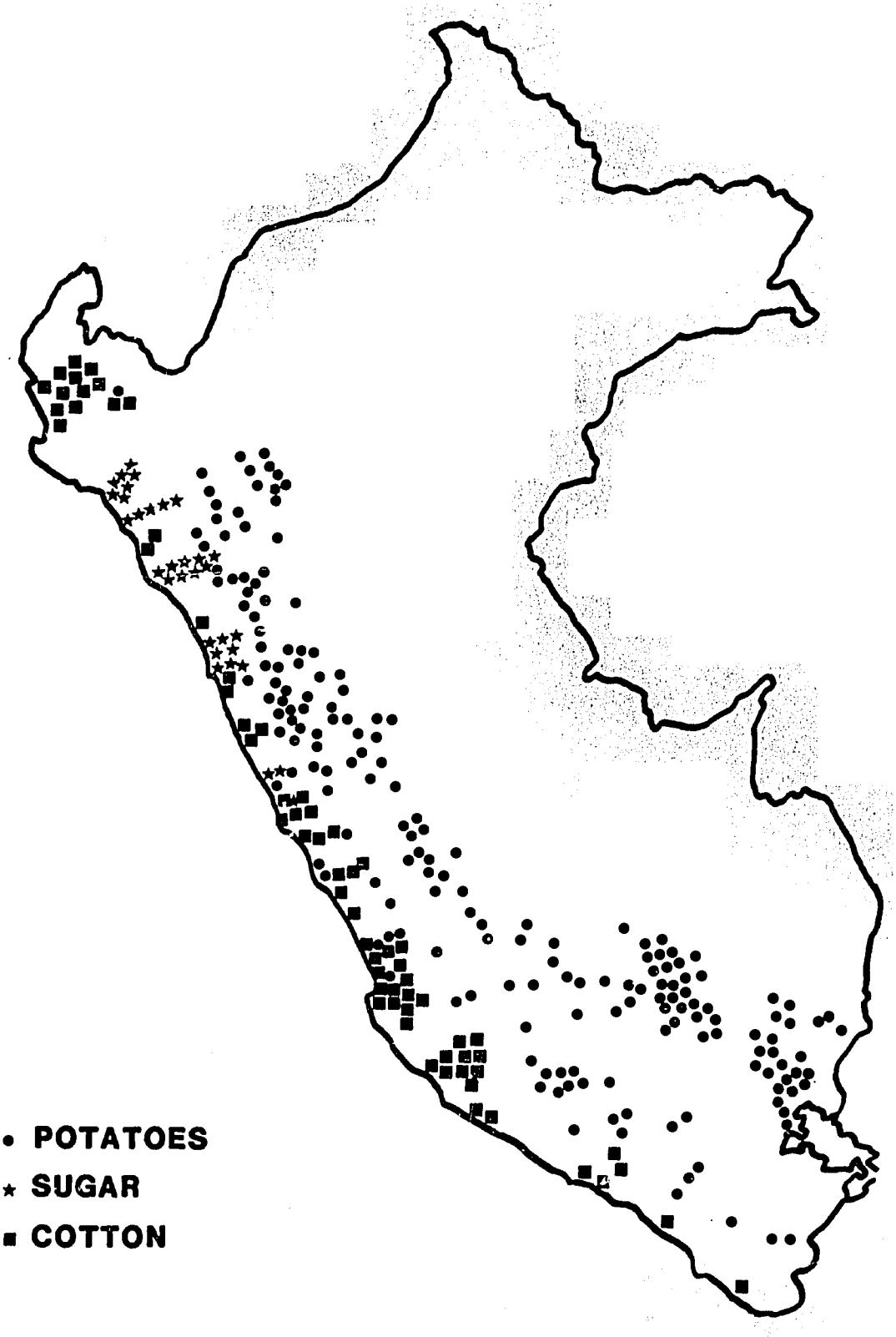

Figure 5.26. Distribution of Potatoes, Sugarcane and Cotton in Peru.

Since 87 percent of the land planted in potatoes is rainfed, the sowing season is spring (September-November) when temperatures increase and soil moisture is sufficient. The growing season is about 7 months. Harvest takes place from March to June (Table 5.13).

In Junin, at 3,100 m, irrigated plantations have 5-month growing seasons between winter and summer. Sowing begins in early July and the growing season ends in mid-December. With such a schedule the blight does not attack the plantations. In Cajamarca, on the other hand, the irrigated plantations are sown in April-May. This department, with a 6-month growing season, is the most important potato region in Peru.

The minimum altitude to grow potatoes for commercial purposes is 1,800-2,000 m., with the temperature ranging from 10° to 15°C.

The application of fertilizer in the Costa is a general practice although some fertilizer is also used in the Sierra (160 kg/ha of N and P) with positive results.

c. Barley

Most of the barley production is used for local consumption. Barley is cultivated both in the Sierra (without irrigation) and in the Costa (with irrigation).

There are some early varieties which have adapted to high altitudes (3,900-4,300 m) and are thus able to overcome low temperatures. Lima beans are usually rotated with barley in Huancayo and Ayacucho.

d. Wheat

Wheat is the sixth crop in terms of cultivated area. Wheat production in Peru is far from self-sufficiency; therefore, large amounts are imported in order to satisfy domestic needs.

Early varieties having a 125-day growing season can be found at 1,000-2,500 m while a late variety, "Huascaran", with a 190-day growing season grows at 3,000-4,000 m. The optimum altitude seems to be 2,000-3,200 m. At this altitude irrigation is very seldom used.

4. Agroclimatic Indices

Figure 5.27 shows the historical Yield Moisture Index (YMI) in percentiles for Huayao/Huancayo (Southern Mountain Region). The YMI was computed for a corn crop during the main growing season (October-April). Drought impacted crops are suggested by YMI values below the 15th percentile for the 1963, 1965 and 1968 crop growing seasons. The critical YMI value for crop failure may be determined by using episodic data (Table 5.14) and historical crop yield data.

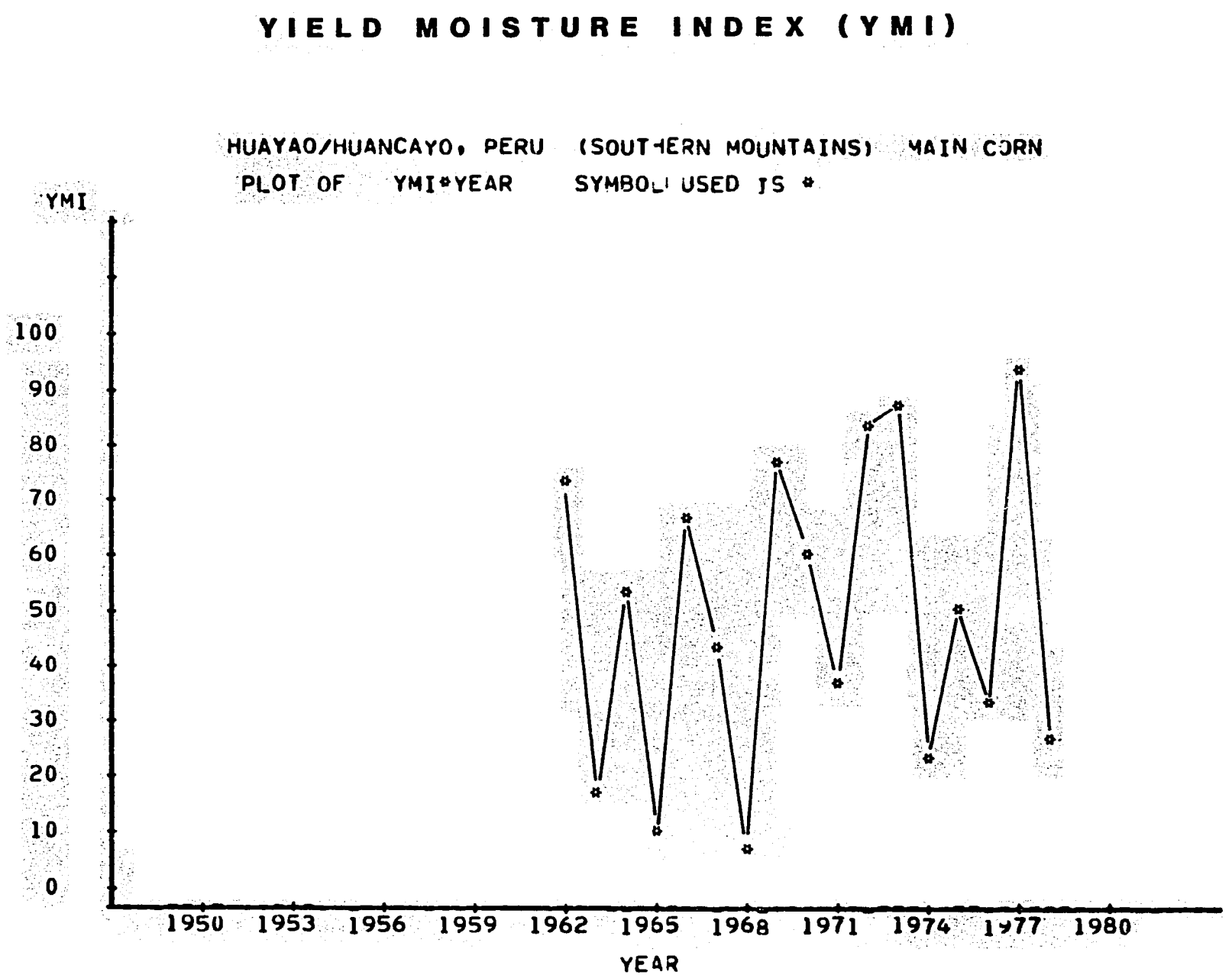

Figure 5.27. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Huayao/Huancayo (Southern Mountains Region).

TABLE 5.14

PERU

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1956		Drought prevailing in southern Peru reduced production.
1959-60		Severe drought reduced yields in the South.
1963-64		Chronic weather problems, fertilizer costs and low level technology continued to limit agricultural production.
1964-65		Unfavorable weather affected yields in the highlands and eastern areas.
1965		Rough rice production was down because cotton competed for irrigated areas in the northern coastal regions.
1966		Adverse weather affected crops and production declined for the second consecutive year.
1967		Flooding and unusually cold weather affected crops.
1968		A severe drought lowered production of many food crops.
1969		Rains were too late for cotton, sugar and rice.
1970		In the late 1970's a two-year drought in Puno caused severe crop losses.
1971		Better weather and better crops. Floods damaged crops.
1974		Rice production dropped creating crucial food problems.
1975		Food production rose slightly.

TABLE 5.14

PERU (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1976		Intensive rains in January and February and a severe October-November drought affected crops.
1977		Frosts, droughts and floods seriously damaged food crops in the Peruvian highlands. Puno region was affected by a severe drought in April and hailstorms and frosts in June that heavily damaged foodcrops.
1978		Serious drought limited expansion of early 1978 grain and oilseed crops and rice prospects in northern areas in April.
1979		The serious drought continued to reduce agricultural production. Rice, cotton and sugar were affected.
1980	February	Drought affected northern coastal provinces and southern Sierra province damaging agricultural production. Accumulated effects of the 3-year drought throughout most of Peru's agricultural zones reduced production greatly. In April floods occurred in the eastern Amazon region.
1981	October	Dry weather persisted in the highland area although there had been extensive floods in several areas of the country in March which replenished irrigation water.
1982	March	Drought conditions occurred in northern departments of Lambayeque, Piura and La Libertad. In central eastern areas crops were destroyed when the Ucayali River flooded.

H. SURINAME

1. Physical Environment

Located on the northeast coast of South America, Suriname is bounded on the north by the Atlantic Ocean, on the east by French Guiana, on the south by Brazil, and on the west by Guyana (Figure 5.28). The country's total land area of 181,450 square kilometers can be divided into three natural regions: (a) the Coastal Plain, (b) the Savannas, and (c) the Interior (Figure 5.29).

The fluvial Coastal Plain occupies some 21,000 square kilometers and contains the main agricultural areas. The low-lying terrain is dissected by numerous tidal rivers and canals. As much of this coastal area is below the level of high tide, diking and empoldering are necessary in order to utilize the land. Most of the soils found here, more fertile than those in the interior, are suitable for rice cultivation. Some of them, if adequately drained, are also suitable for pastures.

The Savanna belt, located south of the Coastal Plain, covers an area of 12,000 square kilometers while the hilly and mountainous isolated interior of the country extends to the Brazilian border, covering 110,000 square kilometers. The undeveloped soils in the interior are permeable, highly leached, and low in nutrients. The relief is rather steep, with eroded mountains and plateaus. All these features impose a limitation to agriculture, although there are some areas with good soils that can be developed.

Suriname has a hot, humid climate. Temperatures are uniform throughout the year, with an annual average of 27°C at Paramaribo, the nation's capital. Relative humidity is always high, averaging 81 percent. Rainfall is heavy on the coast and increases in the rugged and forested interior. Paramaribo has an

SURINAME

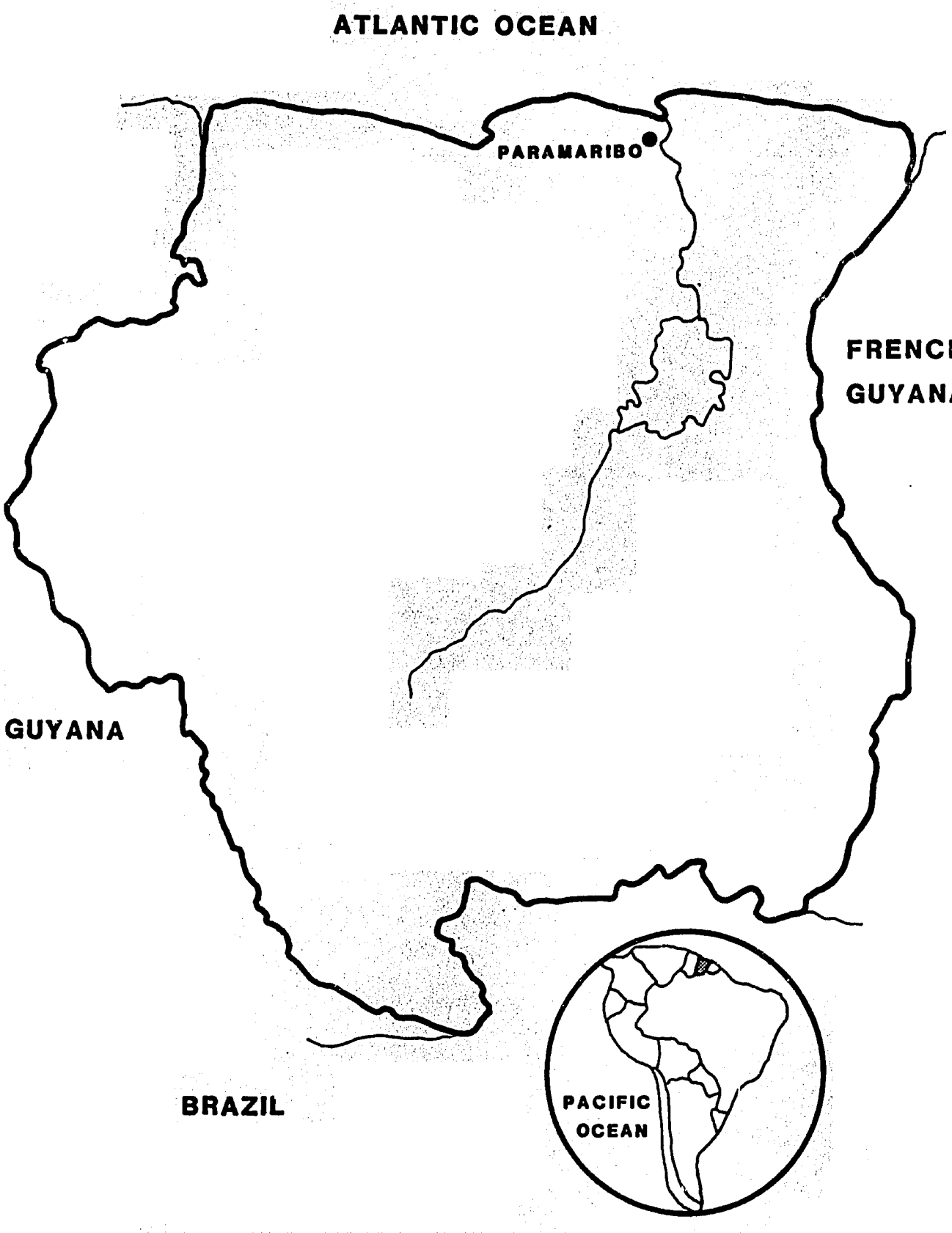

Figure 5.28. Location and Boundaries of Suriname.

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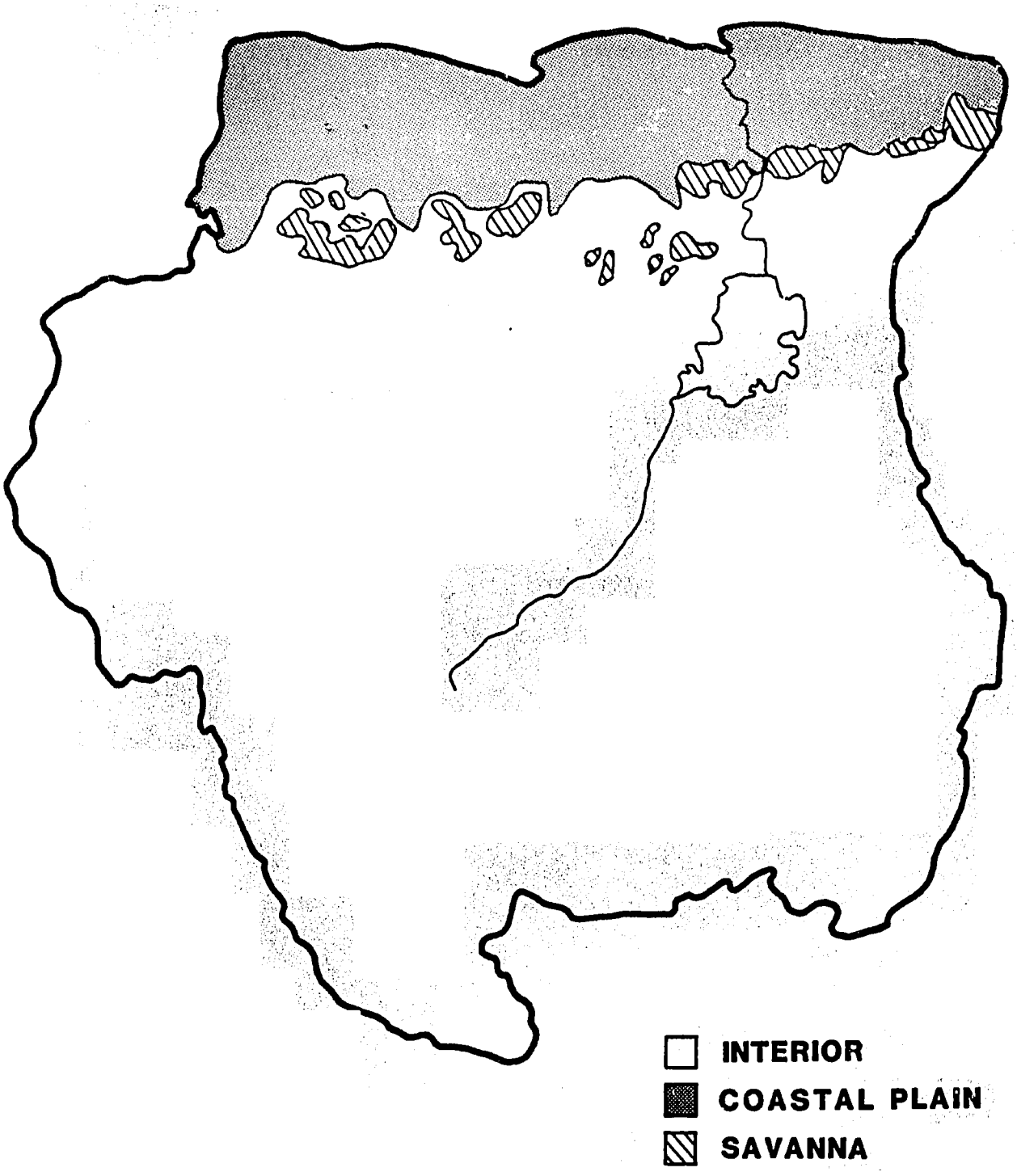

Figure 5.29. Natural Regions of Suriname.

annual precipitation of 2,300 mm. The average rainfall ranges between 800 and 2,000 mm on the coastal plain and between 2,000 and 3,000 mm in the rest of the country. In general, it can be said that Suriname has four seasons: a short dry season from February to April, a long rainy season from April to July, a long dry season from July to November, and a short rainy season from November to February.

2. Agricultural Practices

Less than one percent of the land area of Suriname is under cultivation, the remainder mostly covered by forests. Agricultural activities are concentrated in the Coastal Plain, where the distinctive feature is the polder system. Polders are areas closed by dikes from which water can be drained at low tide quickly enough to avoid damage to crops. This system was introduced for sugarcane growing but is now used for a variety of plantation crops. Most of the cultivated area is now empoldered (Tiggleman, 1970).

The large farms employ modern methods of crop production. About 23 percent of the farms use artificial fertilizers and manure while 19 percent of them use pesticides.

A shifting cultivation is practiced in the interior. The land is cleared and burned during the long dry season, and several crops are planted in the subsequent short rainy season. These include corn, okra, peanuts, rice, taro, manioc, yams, sweet potatoes, bananas, plantains, sugarcane, and pineapple. Each plot is used for only two years, after which it reverts to the quickly growing secondary vegetation.

3. Principal Crops

Rice, bananas, sugar, citrus fruits, cacao, and coffee are the major export crops. They occupy 80 percent of the total cropland (Figure 5.30).

Table 5.15 shows an estimated regional calendar for selected crops grown in Suriname.

SURINAME

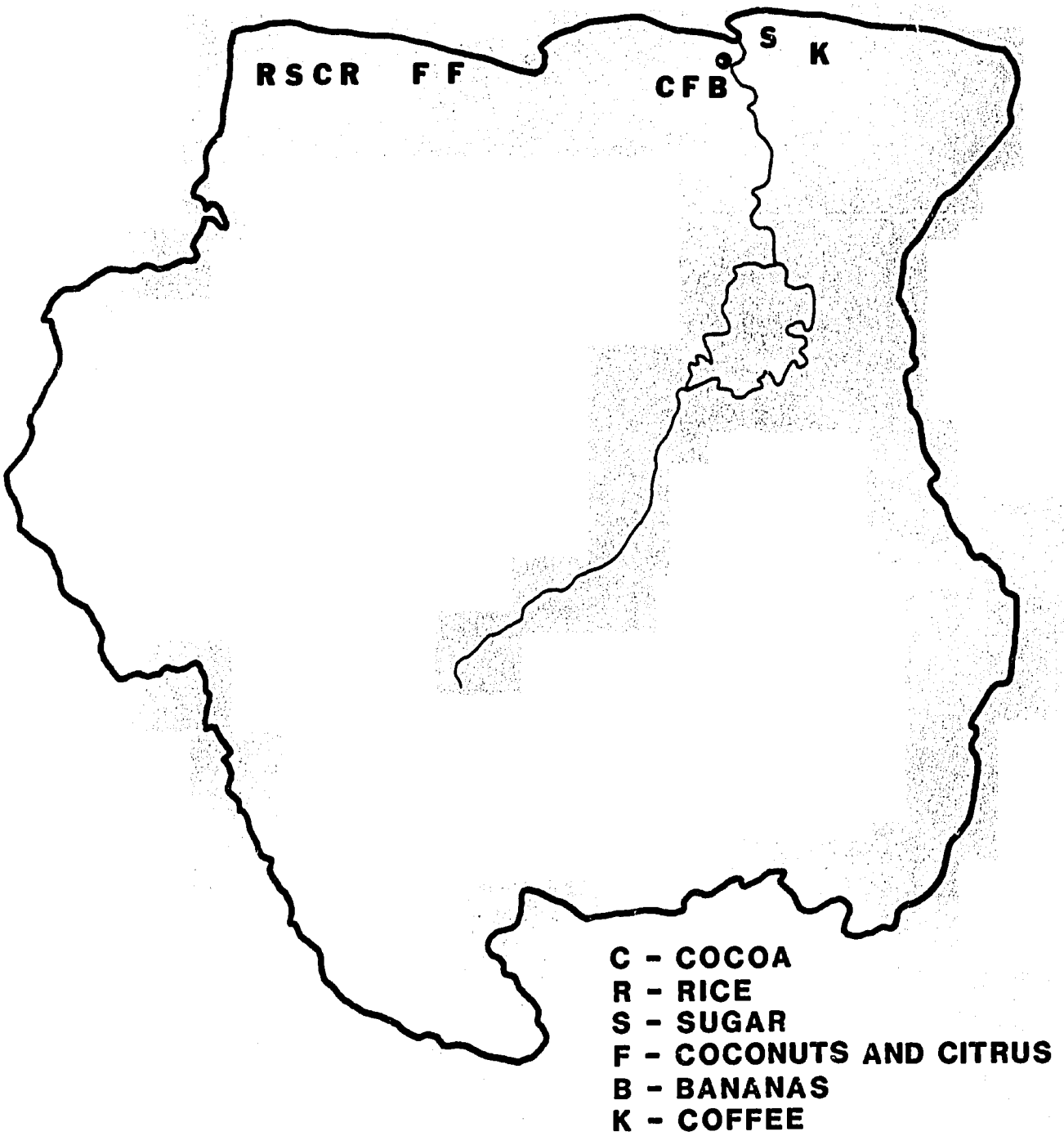

Figure 5.30. Distribution of the Main Agricultural Crops in Suriname.

TABLE 5.15. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN SURINAME

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Coastal	Corn			//	//	—	—	OO	OO					Usually intercropped with other crops.
	Rice			//	//	—	—	—	—	OO				
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Sugarcane	—	—	—	—	—	—	—	—	OO	OO	OO	OO	Harvested from 12 to 18 months after planting/cutting.
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
Inland	Corn			//	//	—	—	OO	OO					
	Rice			//	//	—	—	—	—	OO				
	Bananas	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Sugarcane	—	—	—	—	—	—	—	—	OO	OO	OO	OO	Harvested from 12 to 18 months after planting/cutting.
	Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	

Agriculture and fisheries combined accounted for only 10 percent of Suriname's GDP in 1962. In the same year, rice and citrus fruits were the most important agricultural exports.

4. Rice Yield Model

Rice yield data for Suriname for the period 1950-1965 were obtained from Have (1967). The Prince Bernhard and Wageningen data (Nickerie district) were subtracted from the national acreage and production data to provide a yield time series for small landholders for the period 1950-1965.

The Suriname rice yield model is based solely on precipitation data for the months of April through August (CEAS, 1979). The linear regression model is:

$$Y = 21.16 + 0.17\ (R - 42.1) - 0.067\ (R - 42.1)^2$$

where:

Y = the predicted yield in quintals per hectare,

R = the total precipitation (inches) for the period April through August, and

42.1 = the sample mean for R with $(R-42.1) \leq 0$.

The model has an explained variance (R^2) of 85 percent with a standard error of 1.38 quintals per hectare. The coefficients on the linear and quadratic terms are significant at the 0.06 and 0.001 probabilities levels, respectively. The model fit is presented by Figure 5.31.

5. Agroclimatic Indices

Figure 5.32 shows the historical Yield Moisture Index (YMI) in percentiles for Paramaribo (Coastal Region). The YMI was computed for a corn crop during the main growing season (March-June). Drought impacted crops are suggested by YMI values below the 15th percentile for the 1934, 1935, 1947, and 1957 crop growing seasons. The critical YMI value for crop failure may be determined by using episodic data (Table 5.16) and historical crop yield data.

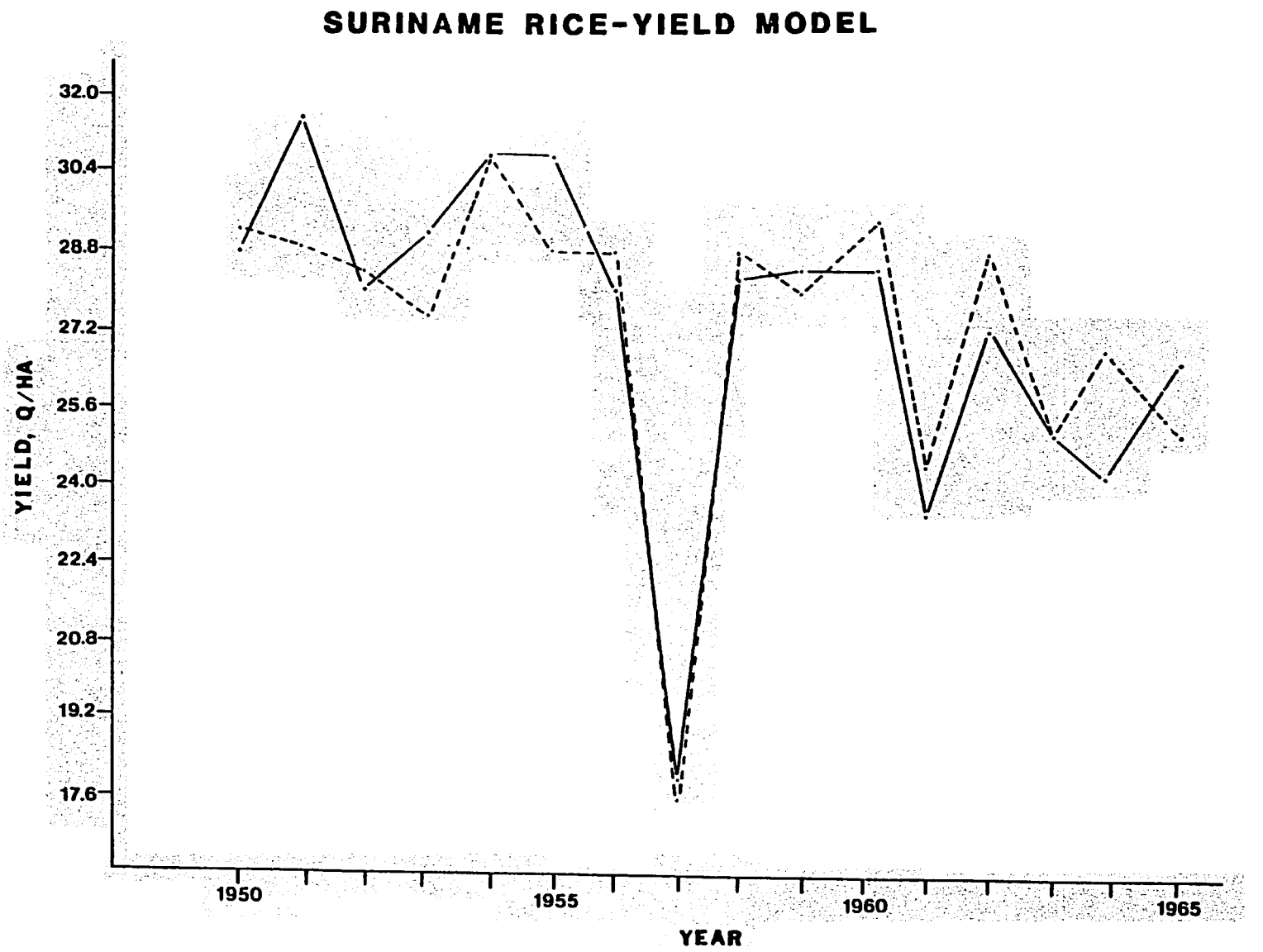

Figure 5.31. Comparison of actual yields (quintals per hectare) for small-landholders in Suriname and regression model fit for predicted yields.

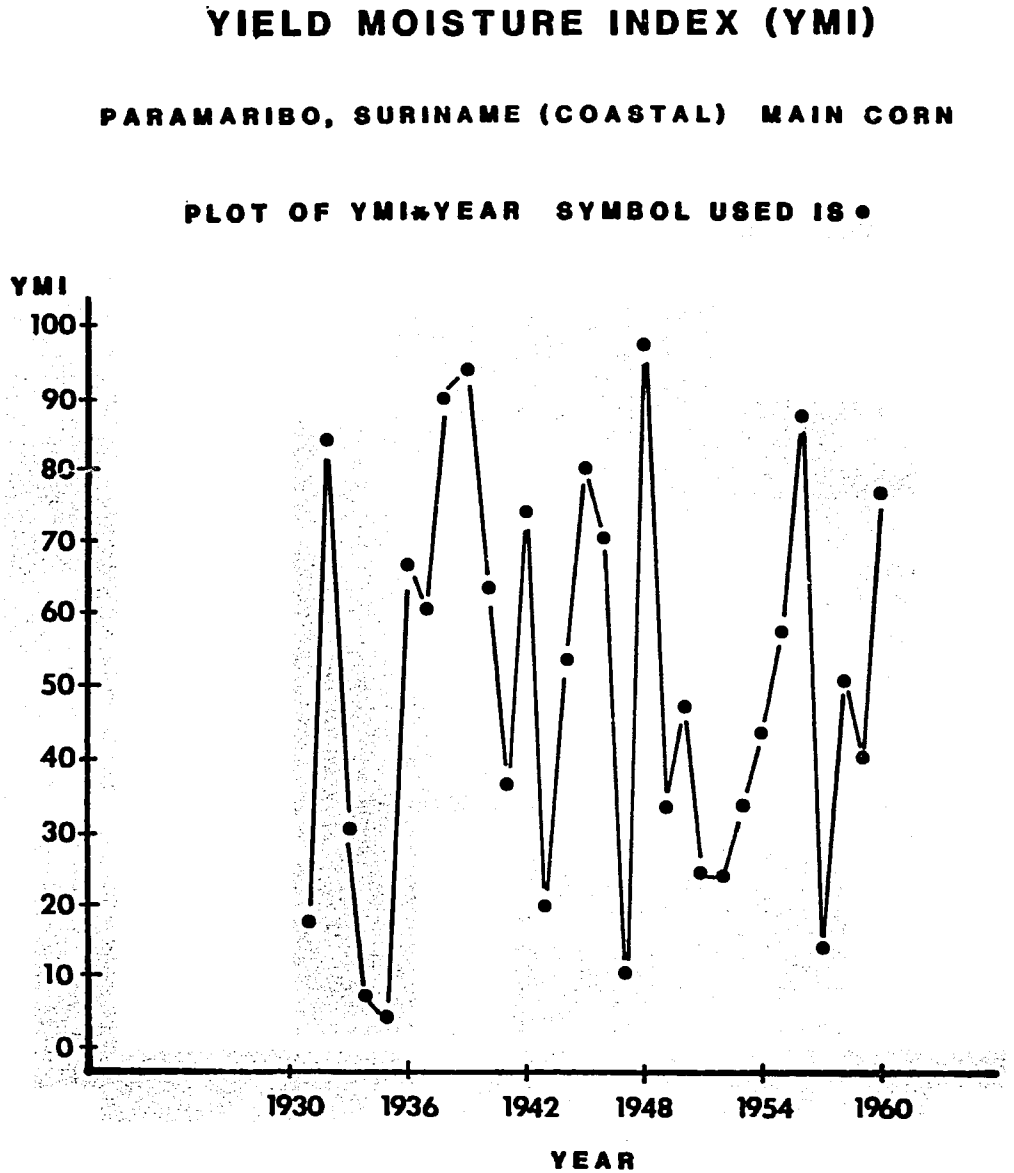

Figure 5.32. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn at Paramaribo (Coastal Region).

TABLE 5.16

SURINAME

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1957		A severe drought occurred over most of the country.
1959		Crops increased from increased acreage.
1963-64		A severe drought damaged crops.
1965		Agricultural production was up sharply over 1964.
1975		There was a prolonged cold spell in July.
1976		The country was very wet the first six months. There was a drought the last six months. In August Paramaribo was badly hit by storms that affected sugarcane production.
1980		Agricultural production was 42 percent higher than in the 1969-71 period.

I. VENEZUELA

1. Physical Environment

Venezuela, fifth in size among the South American countries, has an area of 912,050 square kilometers, including lakes and the islands scattered in the Caribbean Sea. A 2,800 km coastline extends from the Caribbean to the Atlantic, and some 4,800 km of continental border separates the country from Colombia, Brazil and Guyana (Figure 5.33).

Geographers customarily divide Venezuela into four natural regions: (a) the Maracaibo Lowlands, (b) the Northern Mountains, (c) the Orinoco Lowlands or Llanos and (d) the Guayana Highlands. The extent and boundaries of these regions can be seen in Figure 5.34.

The Maracaibo Lowlands comprise some 52,000 square kilometers of level plains around Lake Maracaibo and the Gulf of Venezuela. An open oval in shape, they extend south and west to the Venezuelan Andes and include the Paraguana Peninsula. The lower portions contain a luxuriant tropical forest while the vegetation close to the Caribbean is somewhat transitional from semideciduous dry forest to sparse shrub and desert growths.

Unfavorable climatic conditions in the southern region of the Maracaibo Lowlands have discouraged the use of the young alluvial soils found here. However, as the land rises southward to the Cordillera de Merida it becomes suitable for coffee and cacao cultivation. The land sloping upward to the west toward the Sierra de Perija has deep fertile soils, but much of the rest of the region has soils of poor quality.

Broken by several gaps, the Northern Mountains and their spur ranges extend close to the northern coastline from the Colombian border on the west to the Paria Peninsula on the east. At the border, the Eastern Cordillera de los Andes

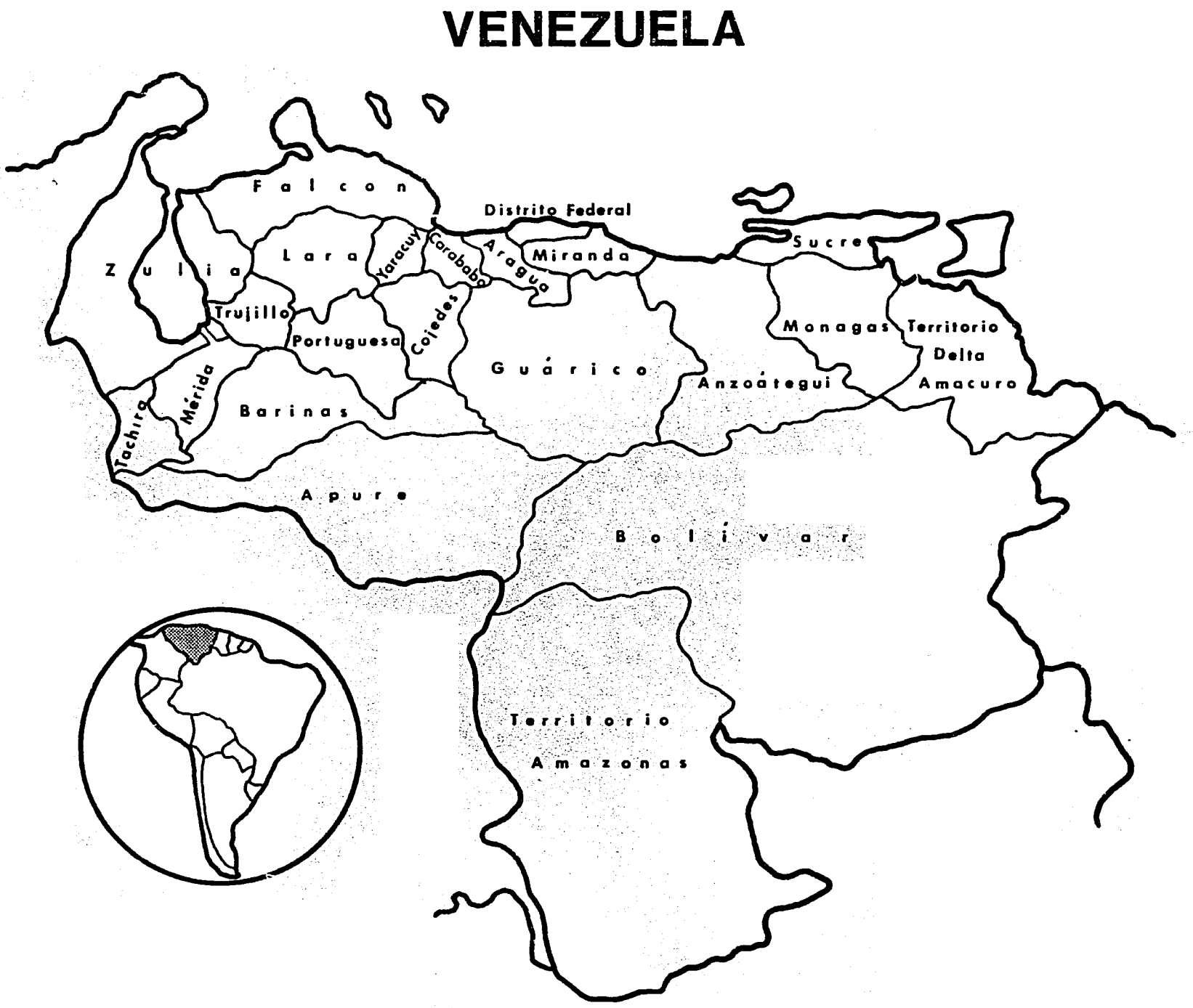

Figure 5.33. Location and Boundaries of Venezuela.

Figure 5.34. Natural Regions of Venezuela.

divide into the Sierra de Perija and the Cordillera de Merida. The latter, which contains the highest peak in the country (Pico Bolivar at 5,500 m), broadens northward to form the Segovia Highlands (Figure 5.34). This branch of the Andes terminates at the eastern end of the Cordillera de Merida. A coastal range, the Andes Venezolanos, then runs 500 km eastward to the Paria Peninsula. This coastal range is composed of the Central Highlands and the Eastern Highlands, separated by an extensive lowland gap. Two parallel ranges separated by an intermediate lateral depression constitute the coastal range. This depression has the densest population and the most intensive agriculture in the country. Between the Northern Mountains and the Caribbean lie a series of narrow valleys and depressions formed by the rivers that run north towards the Caribbean.

The Oriroco Lowlands, also referred to as the Llanos (plains), are the vast plains that extend from the Colombian border south of the Andes to the Atlantic Ocean and lie between the Northern Mountains and the Orinoco River. The region, covering 260,000 square kilometers, is drained by the Orinoco and its tributaries. Most of the plains are natural pastureland although a few small forests are also present. In addition, a large jungle swamp area can be found at the Orinoco Delta.

South of the Orinoco the Llanos gradually give way to the Guayana Highlands (Escudo de las Guayanas) and the terrain increases steadily in altitude southwards to a high plateau exceeding 3,000 m. The most conspicuous topographical feature of these 52 million-hectare highlands (57 percent of the national territory) is the Gran Sabana where Angel Falls, the world's highest waterfall, is located. The remote southern stretches of the Orinoco (southwestern portion of the Guayana Highlands) are flanked on the eastern side by the Venezuelan Amazonia. Annual rainfall is over 3,000 mm in these swampy flatlands. Jungle covers the entire region and flooding is common most of the year.

In addition to the mainland there are 72 islands of varied size and description. The most important is the mountainous island of Margarita, which is heavily populated and intensively farmed in its valleys.

Although the country is situated within the tropics (between 0° and 12°), the climate is varied. In general, the mean annual temperature exceeds 24°C over more than 90 percent of Venezuela. At higher altitudes (over 1,000 m) temperatures begin to fall, reaching 20°C in Merida. Ice forms above 4,000 m in the Sierra de Merida and permanent snow is found above 4,600 m.

There are four temperature zones. The tropical zone ("tierra caliente") is below 800 m with temperatures averaging over 24°C and a seasonal variation of 2°C. The temperate or moderate zone ("tierra templada") lies between 800 and 2,000 m and has temperatures of 10 to 24°C, with a seasonal range of 1.3°C. In the cool zone ("tierra fria"), between 2,000 and 3,000 m, the annual range is between 13° and 18°C with virtually no seasonal variation. Over 3,000 m, above the timberline, is the cold zone of the high mountain pastures ("paramos") where mean temperatures fall to the freezing point.

Annual rainfall ranges from less than 450 mm along the coast to over 2,600 mm in parts of the Orinoco Delta and in the eastern part of the Cordillera de Merida. Heaviest rainfalls (over 3,000 mm) occur in the Venezuelan Amazonia, causing severe floods similar to those in mid-1976.

In general, rainfall is subject to variations so pronounced that the rainier months (May through November) are customarily referred to as "invierno" (winter) and the remainder of the year as "verano" (summer). In July and August, however, rainfall diminishes slightly during the "veranillo" (little summer) de San Juan and increases again at the end of August. Farmers make use of these distinctive seasonal patterns to sow a second crop.

2. Agricultural Practices

Agriculture, generally the most important economic activity in Latin American countries, plays a secondary role in the Venezuelan economy. Petroleum production has gradually replaced agriculture as the top income producer. In the 1970-1974 period agriculture and livestock combined added only 6.7 percent to the GDP, the lowest percentage in Latin America. Moreover, the economic importance of agriculture has tended to decline in recent years and this trend is very likely to persist.

Most of the crop production takes place in the Northern Mountains while livestock is raised in the Maracaibo and Orinoco Lowlands. Farm practices vary in different parts of the country and on different types of holdings. Basically, four types of agricultural holdings can be distinguished in Venezuela: commercial farms, conucos, livestock holdings and parcelas.

Commercial farms usually specialize in the production of one or two crops, in the latter case one being sown in the rainy and the other in the dry season. On these farms, machinery, fertilizers, insecticides, and irrigation are generally used. In most of them, annual or semipermanent crops are grown. Very few are devoted to permanent crops, except those growing the principal agricultural exports of coffee and cacao.

Most farms in Venezuela are called conucos. These are generally small, use traditional, primitive methods, and employ family labor and hand implements. Fertilizers, insecticides and mechanization are beyond the means of most farmers of this class. The principal crop grown here is corn, sown both in April-May and September-October. Associations of 6 or 8 different crops in a 2 or 3 hectare lot are not unusual. These include beans, peas, bananas, yucca, potatoes and other tubers, basically for the consumption of the immediate family.

The term conucos also applies to small temporary farms in forested areas. Clearings are made with fire and crops sown in various associations (chiefly food crops) twice a year until the soil is exhausted. Land exploited in such a way is abandoned after three years.

Farms specializing in livestock raising are beyond the scope of the present study and therefore will not be discussed here.

The parcelas are plots of land given to beneficiaries of the agrarian reform (1960) ranging from 5 to 30 hectares in size. A semi-commercial type of agriculture characterizes this new kind of farm.

Yields of most crops in Venezuela are generally low compared with world averages. This is because much of the output comes from conucos in which primitive farming practices are employed. However, attempts are being made to increase yields everywhere by improving corn and other crops, while the general use of fertilizers, insecticides and irrigation is being encouraged.

3. Principal Crops

Corn and rice are the most important staples and the principal cereals consumed after imported wheat (Figure 5.35). Other food crops include barley, black and pinto beans, roots and tubers (yams, sweet and white potatoes, yucca, and manioc), tropical fruits (bananas, pineapples, plantains, Valencia oranges), and a large variety of green vegetables. Coffee is the principal foreign exchange earner among agricultural products. Tobacco, cacao, and sugarcane are also important cash crops. An estimated regional crop calendar for subsistence farming in Venezuela is shown in Table 5.17.

a. Corn

Corn is the principal food crop for both human consumption and animal feed. White corn is preferred for table use while yellow corn is used for animals.

The growing season of corn is about 13 months in the Northern Mountains and only 4 months in the coastal areas. In general, corn shows great adaptation to different altitudes and latitudes.

Figure 5.35. Distribution of Agricultural Crops in Venezuela.

TABLE 5.17. ESTIMATED REGIONAL CROP CALENDAR FOR SUBSISTENCE FARMING IN VENEZUELA

// Planting, — Vegetative/Flowering, OO Harvesting

Region	Crop	J	F	M	A	M	J	J	A	S	O	N	D	Comments
Northwest	Corn							//	//	—	—	OO	OO	
	Rice					//	//	—	—	—	OO	OO		
	Yuca or Cassava	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Potatoes							//	//	—	—	-O	OO	
	Beans							//	/-	—	OO	O		
Mountains	Corn			//	//	—	—	OO	OO					
	Rice			//	//	—	—	—	OO	OO				
	Yuca	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Potatoes				//	//	—	—	OO	OO	OO			
	Beans			//	/-	—	OO	O						
Northeast	Corn			//	//	—	—	OO	OO					
	Rice			//	//	—	—	—	OO	OO				
	Yuca	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Beans			//	/-	—	OO	O						
Central	Corn				//	//	—	—	OO	OO				Usually associated with other crops.
	Rice				//	//	—	—	—	OO	OO			
	Yuca	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	OO	
	Sugarcane	OO	OO	OO	—	—	—	—	—	—	—	—	OO	Harvested from 12 to 18 months after planting/cutting.
	Beans				//	//	—	—	OO	O				

Optimum plant density varies from 40,000 to 60,000 plants/ha, depending upon the amount of rainfall and the use of fertilizers. The application of 300-500 kg of fertilizer per hectare to improved varieties increases the yield to one ton/ha. Some mechanical sowing systems are used, but the harvesting is done manually.

Pest and disease control is deficient, sometimes resulting in serious losses. For example, a persistent corn blight during the early 1970's and severe floods in 1976 made heavy imports necessary.

b. Beans

Black and pinto beans are traditional staples grown in limited quantities. Over half of the production is for local consumption, and substantial imports are required to satisfy domestic needs.

Mean temperatures of 17°C and 2,000 m of altitude are adequate for beans in Venezuela. Rainfall amounts ranging from 200 to 350 mm during the growing season secure good harvests. For early varieties (75-day cycle), however, 150 mm are enough.

In Merida, at altitudes above 2,000 m, the growing season for a creole variety is about 135 days, blooming after 60-65 days. Since rainfall exceeds 1,500 mm here and beans are highly susceptible to excessive moisture, sowing is done during the dry season. If necessary, irrigation is applied in this case. It should also be pointed out that drought is particularly harmful to beans during the 2-week period prior to blooming.

c. Wheat

Most of the wheat consumed in the country is imported, and only small amounts of the varieties "Gonzalez" and "Lerma 52" are grown in the San Rafael region. They are planted in April and harvested in November. With a 220-day growing season, they are considered late varieties.

The variety "Gonzalez" is cultivated alone and rotated with potatoes. No irrigation or fertilizer is applied. Wheat yields in Venezuela are the lowest in the entire Andean region.

d. Barley

Domestic production is exclusively for human consumption while the beer industry uses imported barley. More resistant to heavy rain than corn and oats, barley is planted in early March and harvested in late January or early February. It is commonly grown in small plots and rotated with potatoes and oats. Yields are generally low when no fertilizers, pesticides, or improved varieties are used.

e. Potatoes

North American, European, and Andean varieties of potatoes are grown in Venezuela. The first two are planted at low altitudes (0-2,000 m) while the latter is found between 2,500 and 3,500 m.

In the Tachira region, near the Colombian border, potatoes can be planted year round since there is no frost danger and the relative humidity is always high. However, the appearance of potato blight is a serious danger. To avoid this disease, sowing is recommended for September or October.

Some farmers utilize fertilizers and irrigation but this is not the general rule.

4. Agroclimatic Indices

Figure 5.36 shows the historical Yield Moisture Index (YMI) in percentiles for Maiquetia (Mountain Region). The YMI was computed for a corn crop during the main growing season (April-November). In 1976, YMI values in the lower 5th percentile suggest poor crop conditions. The critical YMI value for crop failure may be determined by using episodic data (Table 5.18) and historical crop yield data.

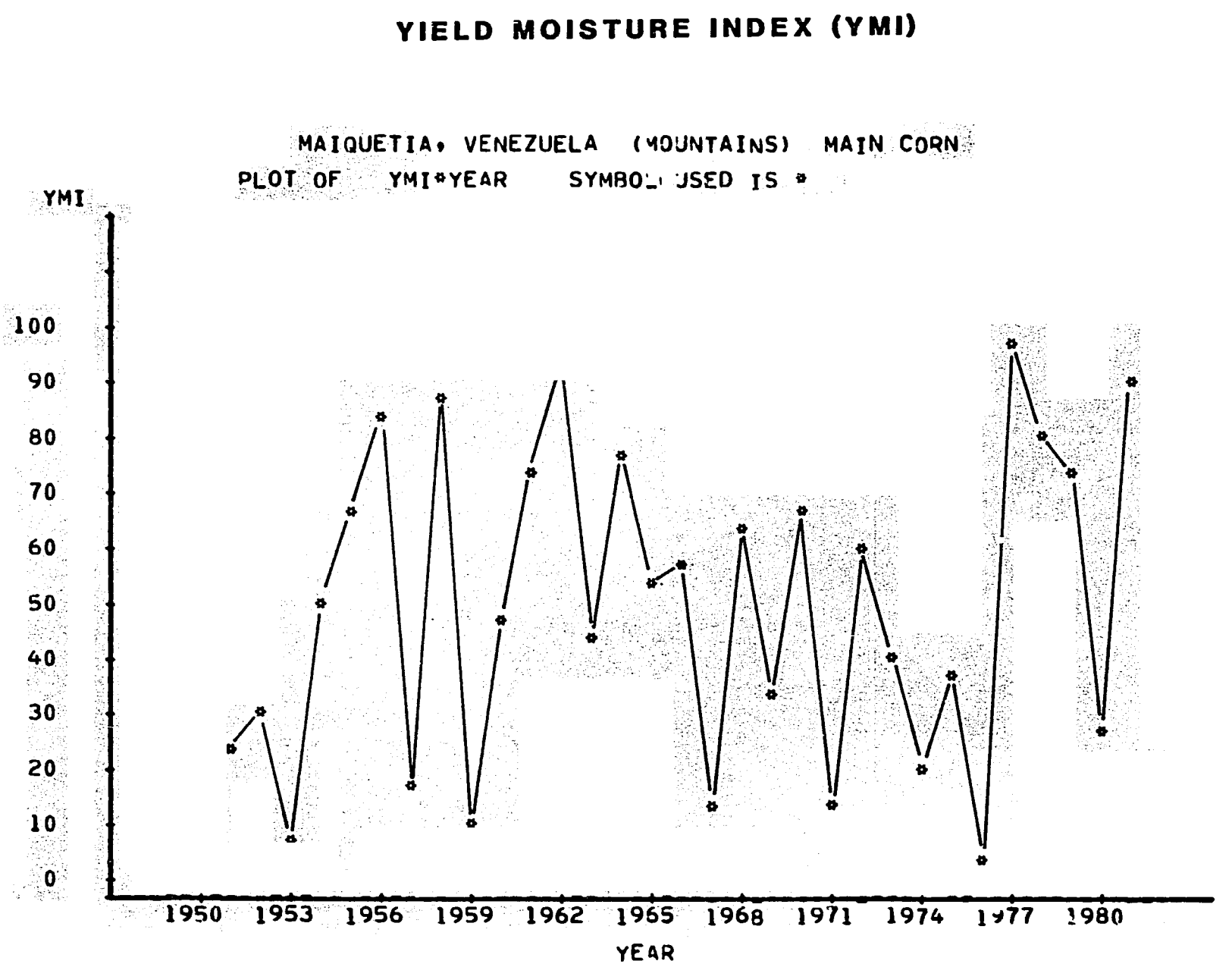

Figure 5.36. Yield Moisture Index (YMI) Expressed in Percentiles for Main Season Corn in Maiquetia (Mountains Region).

TABLE 5.18

VENEZUELA

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1960-62		There were unseasonable rains and drought.
1964		Excessive rain and flooding damaged the corn crop.
1964-65		Rice production was cut by drought.
1966		Dry weather affected crops and poor germination cut rice production.
1968		Rice production was down from a shift to other crops.
1969		Heavy rains delayed rice plantings which reduced yields.
1970		Poor harvests in the early 70s resulted partly from corn blight.
1971		Production was up.
1972		Heavy unseasonal rains struck the main crop growing areas.
1973		Drought affected agriculture.
1974		Agricultural output rose about 7 percent above 1973, but the state of Guarico suffered drought from the end of April until mid-July causing great losses to agriculture.
1975		Rice, corn and pulses continued increasing. Floods damaged crops around Caracus.
1976		Adverse weather damaged crops in central and southwestern states. Heavy rainfall in May destroyed the sesame crop especially in Barinas and Portuguesa. Disastrous flooding occurred in July when the Apure and Orinoco Rivers overflowed.

TABLE 5.18

VENEZUELA (cont.)

Summarized episodic event data on reported weather and non-weather factors having adverse impact on crop conditions and food security.

YEAR	MONTH	EPISODIC EVENT
1977		Agricultural production was good. Food shortages were carried over from the disastrous conditions in 1976, however.
1978		Agriculture made impressive gains.
1979		This was another good year with favorable weather which benefited agricultural production.
1980		Shortages of fertilizer and improved seeds and flooding in some main producing regions adversely affected agriculture, especially corn and rice.
1981		Unusually heavy rains destroyed a major share of the nation's crops, especially in northwestern regions.

CHAPTER VI

PROPOSED EARLY WARNING ASSESSMENTS

The primary purpose of these proposed early warning assessments is to provide timely, reliable information on the potential for drought-related food shortages. Impact assessments are based on a combination of biweekly weather analyses and monthly crop condition/food shortage indices. The impact of anomalous weather events including high winds, flooding, frost and others are also reported.

The data bases, background information, agroclimatic methods, and computer software necessary to implement these assessments are described in this report. The following sections briefly summarize proposed procedures for weather and crop condition/food shortage assessments and the computer software which has been developed for their implementation. This software package is referred to as the Agroclimatic Index System (AIS) which has two major components: 1) regional precipitation index analysis based on weekly precipitation data and 2) crop condition/food shortage analysis based on meteorological, climatological, crop calendar, crop statistics and episodic event data.

A. Biweekly Weather

Weather assessments are based on an analysis of regional precipitation and anomalous weather events. Qualitative impact statements are currently issued on a biweekly basis for 59 regions in Central and South America as defined in Appendix A. These assessments are similar to those issued for 107 regions in Southern Asia, 109 regions in Africa and 26 regions in the Caribbean Basin. The information sources and precipitation analysis procedures developed by the Climatic Assessment Branch of NOAA/NESDIS/AISC are described below.

Information sources include surface weather observations, climatological normals, historical data, surface and upper air analyses, and satellite imagery.

Ancillary information sources include abstracts from the New York Times Information Data Base, the U.S. Department of Agriculture foreign attache reports, and reports from the Foreign Broadcast Information Service. Real-time meteorological data are obtained by NOAA through the World Meteorological Organization/Global Telecommunications System (WMO/GTS).

In many regions that are highly prone to disastrous drought, the availability of real-time precipitation data is quite limited because of either very sparse station density or missing reports. Therefore, a major function is to quality control and, as appropriate, estimate precipitation within each assessment region to assess areas of potential or ongoing drought and provide input for agroclimatic models. For example, surface and upper air weather analyses provided by NOAA/National Weather Service are used to identify those regions in which atmospheric dynamics suggest the occurrence of precipitation. Additionally, satellite imagery from various meteorological satellites is also used as a tool to estimate precipitation.

Anomalous weather events such as reports of extreme wind and precipitation totals are summarized on a daily basis to provide a real-time, episodic event data base for use in assessment. Precipitation data are summarized on a weekly and monthly basis for use in biweekly weather assessments.

Figure 6.1 shows the components of the AIS regional precipitation index program. Input data include: 1) regional precipitation normals defined weekly for weather assessment regions, 2) an eight week precipitation data base for each region and 3) regionally estimated precipitation for the most current week used to update the eight week data base.

Three types of statistics are provided for each region: 1) weekly statistics which are used to obtain biweekly precipitation departures from normal, 2) eight week statistics and 3) drought statistics. These are indicated on Figure 6.1.

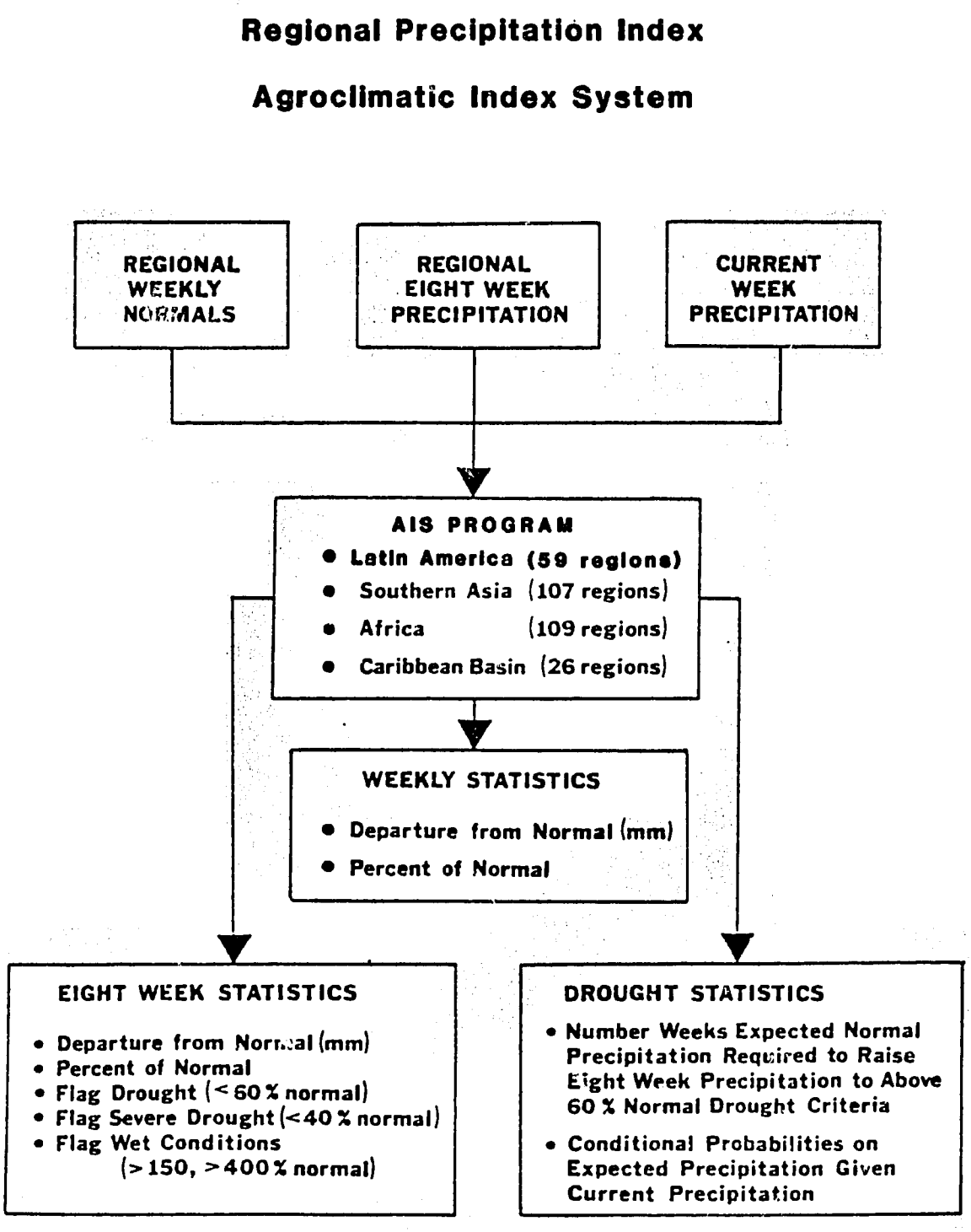

Figure 6.1. Components of Regional Precipitation Index Analysis Used in Biweekly Weather Assessments.

A drought condition is defined as eight weeks of precipitation which is less than 60 percent of normal. Severe drought conditions are defined as eight weeks of precipitation less than 40 percent of normal. Drought statistics as indicated on Figure 6.1 are also determined if regional precipitation is below 60 percent of normal.

If conditions within a region fall into the drought or severe drought categories, the impact is determined according to the crop calendar, local agroclimatic conditions, and vulnerability of food security to drought. Climatological normals which are readily available are used as the basis for objectively analyzing regional rainfall conditions; thus, a consistent reference level is established.

B. Crop Condition/Food Shortage Indices

Assessments to provide early warning information on the potential for drought-related food shortages are based primarily on the agroclimatic models discussed in this report. They include various agroclimatic indices developed for the regions provided in Appendix A. The models are run according to the countries, crop regions, and crop seasons indicated in the crop calendars provided in Appendix D. The model ouput is interpreted according to the agroclimatic analysis and data bases (meteorological, crop statistic and episodic event) provided as Supplements to this report.

The regionally appropriate agroclimatic indices and the criteria for their interpretation are established by: 1) agroclimatic background information including cultural practices and historical vulnerability according to episodic event data, 2) agroclimatic analysis of the data as discussed in this report and 3) results of climate/crop yield modeling for countries throughout Central and South America.

For example, drought-related food shortages are associated with cumulative precipitation and cumulative moisture stress terms defined for at least two to four months during the crop growing season. The nature of rice culture and subsistence cropping practices including extended planting seasons and mixtures of varieties determine this relationship. Moisture stress terms are most appropriate for the more arid crop production regions. Additionally, there is evidence that precipitation is nonlinearly related to crop productivity in the moister rainfall regimes, i.e., crop failure is associated with either "too little" or "too much" rainfall. Preseason rainfall conditions, either in the crop growing region or remote catchment basins serving as the source of irrigation water, are important in some regions. The magnitude of drought and its areal extent are directly related to potential food shortages in countries vulnerable to drought related food shortages.

Remote, densely populated areas in which upland or non-irrigated subsistence agricultural practices prevail are also vulnerable to drought. Agroclimatic indices derived from crop water requirement relationships represent the primary assessment tool. For example, the Yield Moisture Index (YMI) discussed in CEAS (1979a) should be used.

The development of quantified assessment procedures for regions in which sufficient moisture normally permits multiple cropping is a particular challenge. Some countries, e.g., Costa Rica, experience such agroclimatic conditions yet they are vulnerable to drought.

The AIS computer software is used to provide crop condition/food shortage assessment information for real-time analysis. Figure 6.2 shows the data bases, functions, some of the agroclimatic predictors, and model output provided by the AIS routine. Agroclimatic indices provide relative crop yield information based

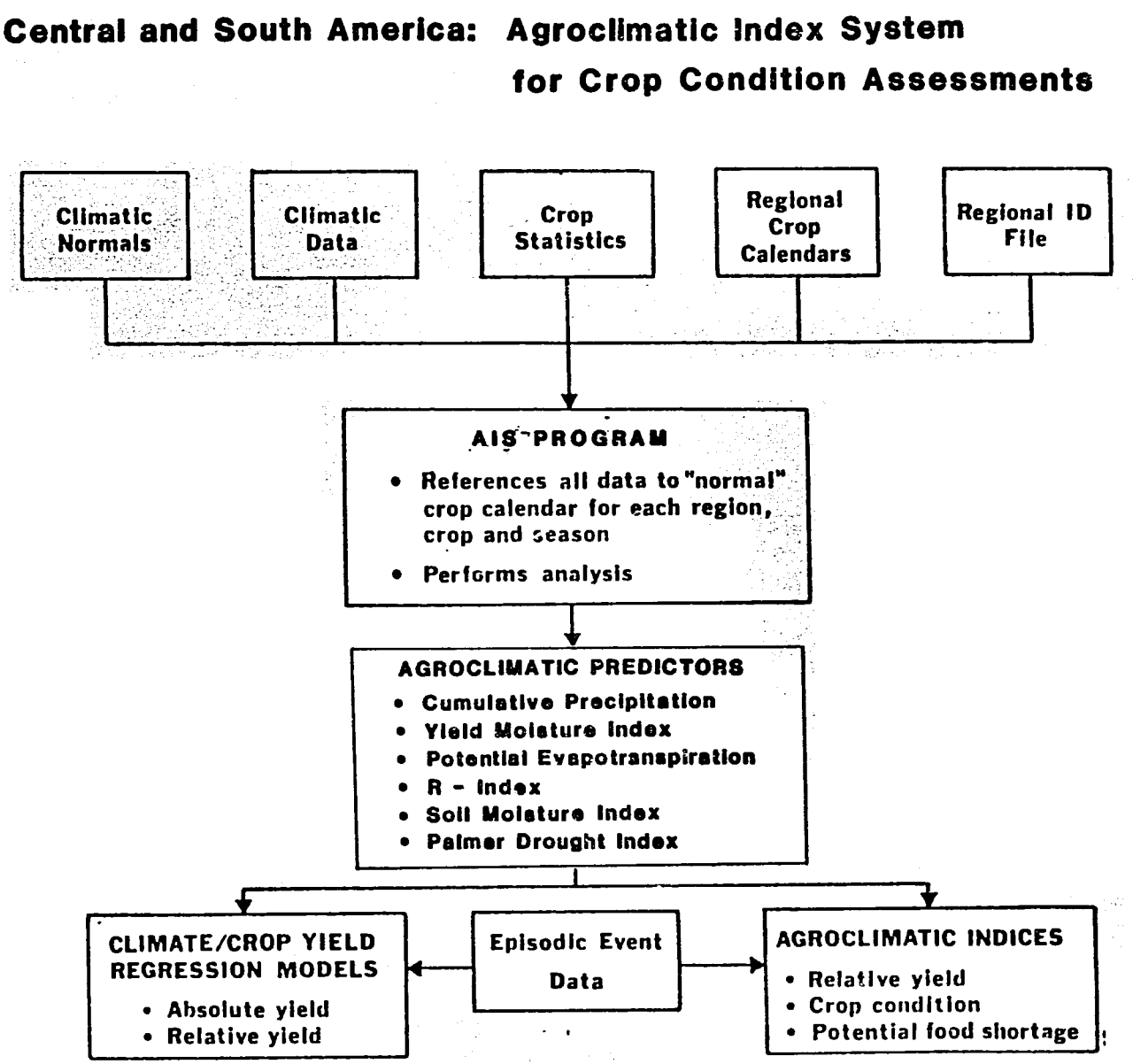

Figure 6.2. Data Bases, Components, and Products of Agroclimatic Index System (AIS) Used as the Basis for Early Warning Crop Condition/ Food Shortage Assessments in Central and South America.

on crop conditions related to potential food shortages. Episodic event data are used to interpret results.

Figure 6.3 shows the combined components of the early warning assessment program; biweekly weather analysis (on the left) and crop condition/food shortage (on the right). An integrated impact statement is provided to the user.

Biweekly weather assessments are issued regularly through the year. These assessments are usually released within five days following the end of the reporting period. Special or update assessments are also provided as requested.

The agroclimatic models are based on monthly meteorological and crop calendar data. Therefore, assessments based on crop condition/food shortage indices are issued within about five days into the following month. However, this type of assessment is only released at selected times during the calendar year, for example following a critical crop development stage such as flowering. Assessments on the potential for drought-related food shortages can be made on the order of 30-60 days prior to the harvest of the crop. This could represent a potential 3-6 month early warning prior to drought-related food shortages.

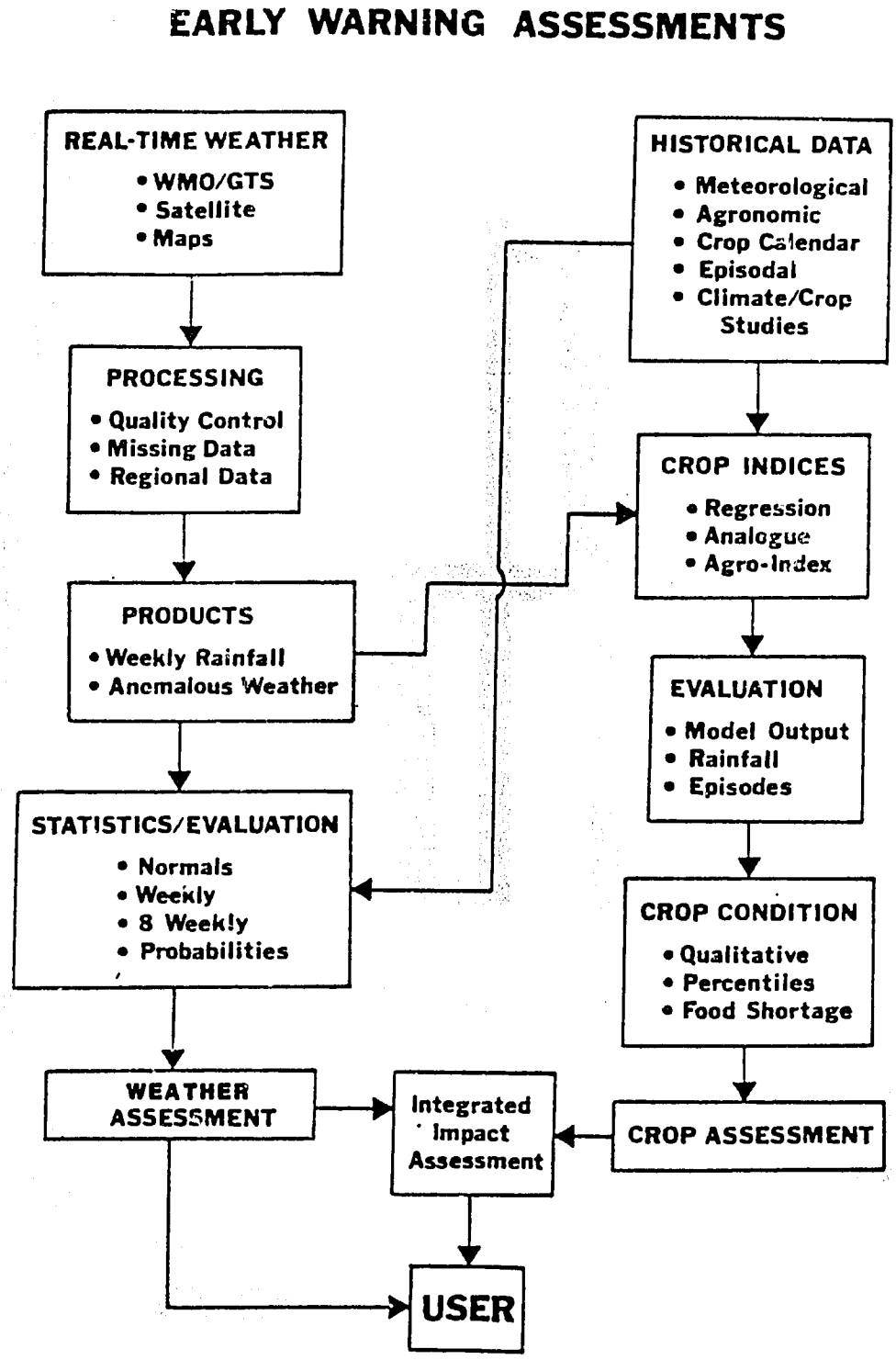

Figure 6.3. Early Warning Assessment System Showing Components of Weather Assessments (on the left) and Crop Condition/Food Shortage Assessments (on the right).

Chapter VII

THE EARLY WARNING PROGRAM: TEST AND EVALUATION

A. Overview

This chapter discusses the test and evaluation results for the Early Warning Program methods proposed in Chapter II.

The Early Warning Program is based on biweekly weather assessments and monthly assessments of crop conditions. Weather assessments begin with an analysis of precipitation amount, the most important meteorological element influencing crop productivity in Central and South America. Weather data are then interpreted by agroclimatic indices which indicate potential crop production in relative terms. Finally, the potential for abnormal food shortages is identified from these indices.

Regional agroclimatic indices are the core of the Early-Warning Program. These indices have two forms: statistical climate/crop yield models and crop condition indices. Various historical data bases were developed to determine the appropriate index for each region. Local agricultural practices, historical episodic reports and results of experimental studies were incorporated in the choice of each index. Episodic reports on documented occurrences of famine, drought, crop failure and other events are used to establish critical thresholds for potential food shortages and to interpret indices.

During the test and evaluation phase of the project the following objectives were accomplished.

1. Agroclimatic/crop condition indices were calibrated to establish the level of drought impact on subsistence crops.

2. AID/OFDA and other users (US/AID missions in Central and South American Embassies, United Nations/Food and Agriculture Organization, United Nations/Disaster Relief Organization and the U.S. Department of Agriculture) were provided with biweekly weather assessments and monthly assessments of climatic impact on subsistence food crops in countries of Central and South America.

3. Drought/Food shortage assessment reports were verified with available information such as in-country reports, newspaper articles, FAO assessments, etc.

4. The proposed Early Warning Program was tested and recommended for operational use.

B. Procedure

The AISC Early Warning Program for assessing drought related food shortages in Central and South America is outlined in Figure 7.1. Qualitative biweekly weather assessments and weekly updates are routinely issued by the AISC/Climatic Assessment Branch (CAB), Washington, D.C. for 23 agroclimatic regions in Central America and 36 agroclimatic regions in South America. The assessments are based on analysis for climatically similar regions (Figures 3.6 and 3.7) and include regional rainfall analysis and statements of the impact of anomalous weather events on crops. Because of data availability, weather assessments for South America include rainfall analysis at station level. Monthly quantitative crop conditions and potential food shortage assessments, are provided by AISC Models Branch to CAB for inclusion in the weather assessment report. Agroclimatic crop condition/food shortages indices are used for the monthly assessment.

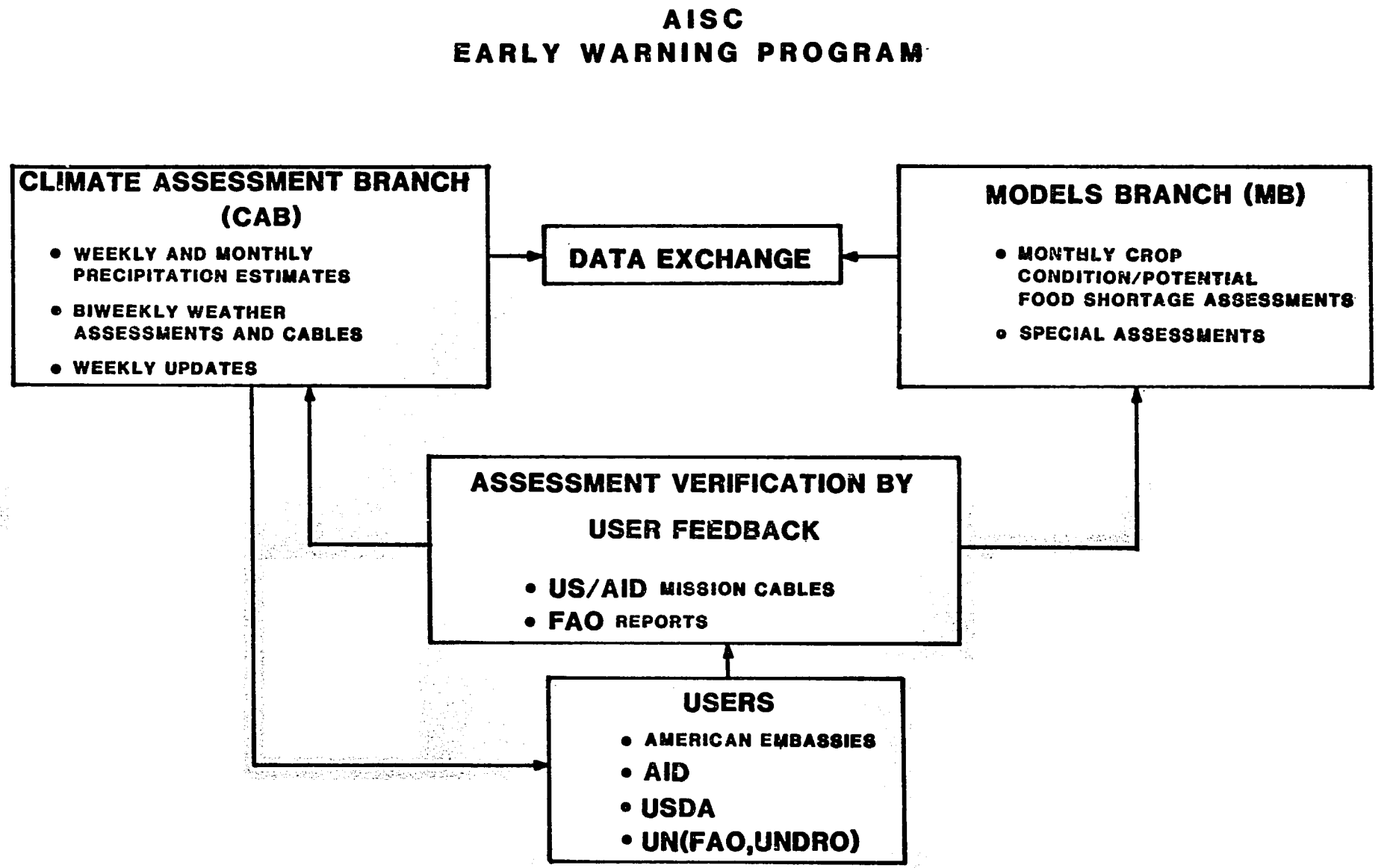

Figure 7.1. Components of the AISC/EARLY WARNING PROGRAM.

Crop and weather data bases are discussed in Chapter II. Real-time rainfall data for the available stations are obtained by CAB through the World Meteorological Organization Global Telecommunication System. The space network of reporting stations or missing reports requires extensive quality control of the data and as appropriate, estimating regional or station rainfall for input into agroclimatic models. Surface and upper air weather analyses provided by NOAA/National Weather Service are used to identify rainfall occurrence. Additionally, satellite imagery from various meteorological satellite is used as a tool for estimating rainfall. Rainfall data are summarized on a weekly and monthly basis.

Extreme weather events such as extreme winds and precipitation totals are taken into account on a daily basis to provide a real-time, episodic event data base. These data are used to adapt assessments to abnormal weather events.

The agroclimatic/crop condition indices as proposed in Chapter II are the primary basis for the assessment of drought impact and potential for abnormal food shortages. Quantitative and qualitative assessments are provided for countries experiencing drought. The early warning crop condition assessments are designed to provide decision makers with timely and reliable information on drought impact and potential for abnormal food shortages in these countries.

Assessment verification was accomplished by using reports from the press, FAO, US/AID missions and USDA attaches. Historic episodic event data were used to calibrate the Yield Moisture Index (YMI), and to establish threshold values for the YMI at which a crop failure is observed. Historical YMI was plotted and drought years identified using episodic information. Those YMI values at which drought impact was recorded were then defined as threshold values.

C. Results

The Early Warning Program for assessing drought impact on subsistence agriculture in Central and South America has been fully implemented and tested during the 1982/83 growing seasons. Some of the assessments have been verified through user feedback.

The YMI was computed for corn, beans, rice, wheat and potatoes and then calibrated at the regional level for Central America and at the station level for South America. The recommended YMI categories for assessing the drought impact on crops include: 1) moderate drought impact (15-30th percentile range on a scale 0 to 100) and 2) severe drought impact (below 15th percentile). Categories vary for different regions, stations and crops. For those regions or stations without historical data the index was expressed as percent of normal.

The AISC monthly crop condition assessments for the 1982/83 growing seasons were based on the YMI categories established from the calibration results. For example, the extreme drought observed during 1982/83 growing season in Southern Peru and Northern Bolivia was successfully identified using AISC/crop condition indices. Summarized crop condition assessments issued during the 1982/83 growing season are shown in Table 7.1. Biweekly weather assessments and their updates were cabled to the users such as the US/AID missions and FAO.

1. Central America

Costa Rica

Guanacaste province experienced both drought and hurricane damages to major commercial and subsistence crops during the 1982 growing season. Index (YMI) values for autumm corn computed for Puntarenas station are shown in Figure 7.2. The YMI value for 1982 is below the 15th percentile suggesting severe drought impact. Agricultural losses were first reported in AISC cable issued on September 23, 1982 (Table 7.1).

This assessment was verified by newspaper reports (La Gaceta, 9-7-82). During the 1983 growing season, below normal rainfall in May and June caused significant losses in subsistence agriculture. Corn and sorghum crops were mainly affected. These assessments and their verification are summarized in Table 7.1.

Guatemala

The southern region experienced heavy rains and flooding caused by Hurricane Paul during September, 1982. Extensive damages to several crops were reported (AISC, 9-28-82). The assessment verification was obtained from FAO reports (FAO, 10-19-82).

Honduras

Severe flooding occurred in the southern region during May 20-27, 1982. Extreme crop damages were reported by AISC (Table 7.1). On June 11, 1983 FAO reported that a tropical storm and flooding destroyed crops.

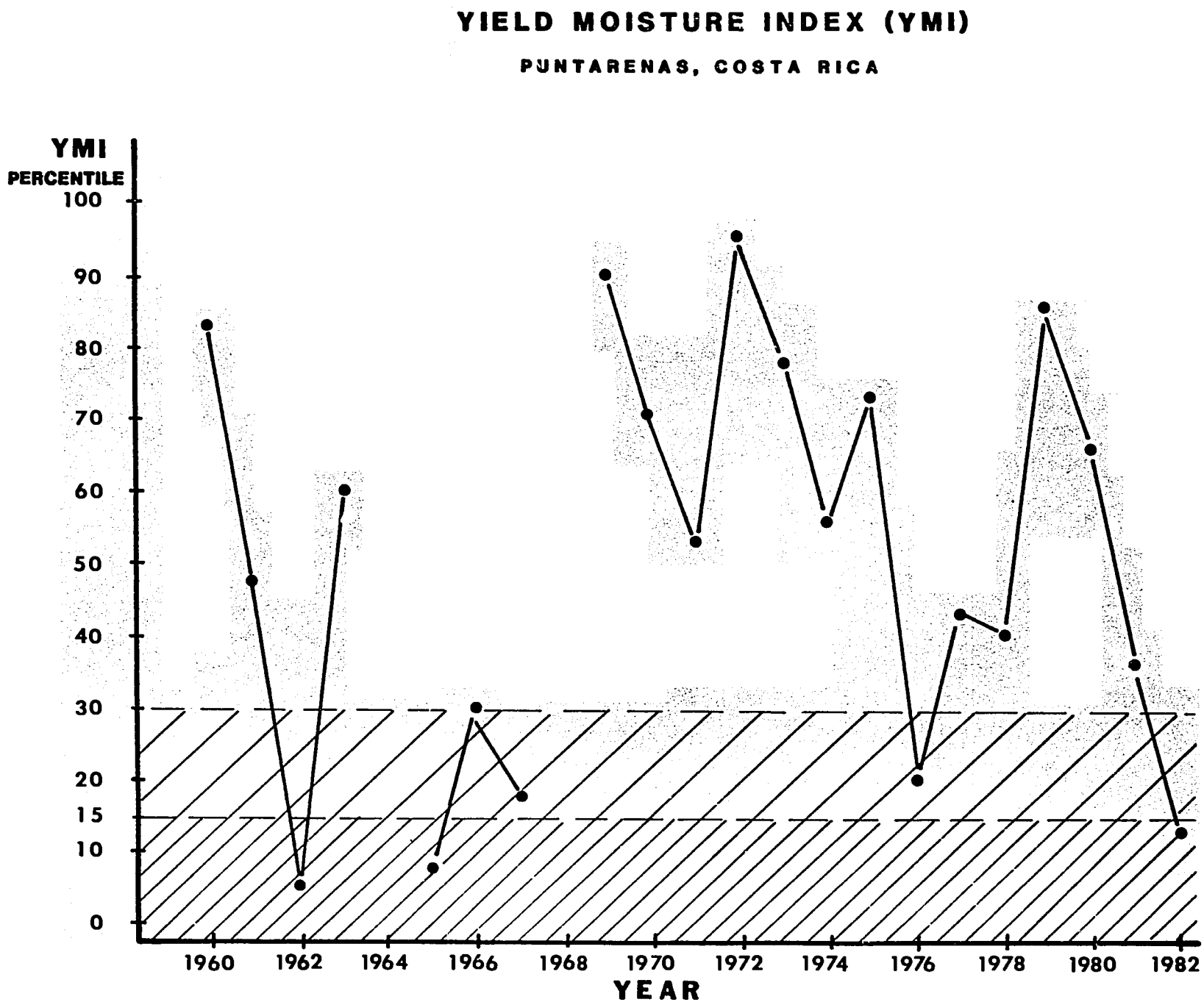

Figure 7.2. Yield Moisture Index (YMI) Expressed in Percentiles for Corn at Puntarenas, Costa Rica.

TABLE 7.1. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From different Sources (Source and Date)
Costa Rica	Guanacaste Province	Drought	A light to moderate drought from mid-July to August caused damage to livestock and cotton. August was unsually dry especially in western and central sections. (AISC 9-23-82)	Government of Costa Rica declared a national emergency because of drought that hit Guanacaste province during the last 2 months. (LA GACETA, 9-7-82)
		Hurricane	Hurricane Paul in late September brought moisture that was too late to reverse summer drought damage but improved prospects for secondary season crops being sown. (AISC 9-28-82)	Heavy rains occurred the last two weeks in September. (CABLE, 9-82)
		Drought	Rainfall during the first half of May was 40-80% of normal, a trend which is becoming increasingly critical to subsistence agriculture in many areas. (AISC 5-1-83)	The severe drought in this province forced farmers to hold off planting 10,000 hectares in corn and sorghum. (LA NACION, 5-29-83)
		Drought	Below normal rainfall in June (50-80%) decreased the prospect of a successful harvest. Corn crops planted on schedule were seriously taxed by the dry weather. (AISC 6-12-83)	Dry weather continued in June, further delaying spring maize sowing and affecting crops already in the fields. (FAO, 7-18-83)
Guatemala	Southern	Heavy rains	Heavy rains from hurricane Paul damaged corn, rice, sorghum, beans, wheat, sesame, tomatoes, coffee, peanut and onion crops. (AISC 9-23-82)	Torrential rains during the second half of September flooded large areas especially in the southern portion, damaging crops. (FAO, 10-19-82)

TABLE 7.1 EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Honduras	Southern	Flooding	May 20-27 Honduras and Nicaragua had severe flooding when a tropical disturbance produced torrential rains. Extensive crop damage occurred - basic grain loss was 30%, banana 60% and rice 65%. (AISC 6-7-82)	May 22 tropical storm hit southern region of Honduras near Nicaraguan border causing floods that destroyed crops. (FAO, 6-11-82)
Panama	Veraguas, Herrera and Los Santos Provinces	Drought	The southwestern region had suffered from dry weather since March and up to 50% of the total rice, beans and corn were destroyed by the drought. (AISC, 5-15 to 28, 83)	Six months of severe drought destroyed food livestock. Veraguas province was declared a disaster area. (CABLE, 5-17-83) Below normal rains continued in the southwest, seriously jeopardizing crop prospects, (FAO, 6-17-83)

Panama

The southwestern region (Veraguas, Herrera and Los Santos provinces) was affected by severe drought conditions since March. Significant losses up to 50 percent of the total rice, corn and beans were reported (AISC, 5-15-83). These assessments were verified by State Department Cable (Panama 4594) and FAO reports (6-17-83).

2. South America

Bolivia

The Altiplano region experienced severe drought conditions during the 1982/83 crop growing season. Agroclimatic/crop condition indices were in the 5th to 10th percentile range suggesting extensive crop damages particularly in the vicinity of Lake Titicaca. Crop losses may have surpassed $100 million and livestock deaths were expected to occur throughout the winter dry season Figures 7.3, 7.4 and 7.5 show historical YMI values for El Alto and for corn at the early and late vegetative and flowering crop growth stages. During the early vegetative stage (September-October, 1982) the YMI was in the 30th percentile suggesting moderate drought impact. The index value dropped to 10th percentile at late vegetative stage (November, 1982-January 1983). This YMI value is generally associated with severe drought conditions. At the flowering stage (February-March, 1983) the agroclimatic index was in the 3rd percentile which indicates severe drought occurring once in about 33 years. The lead-time provided by the YMI at the end of March was between 2-3 months prior to harvest. Drought impact on the Altiplano agriculture was reported by AISC cables on May 1, May 15 and June 12, 1983. Delays on issuing the crop condition assessments were due to testing procedures on station rainfall estimates using satellite information.

AISC assessment verification was obtained through FAO and Wall Street Journal reports (Table 7.2).

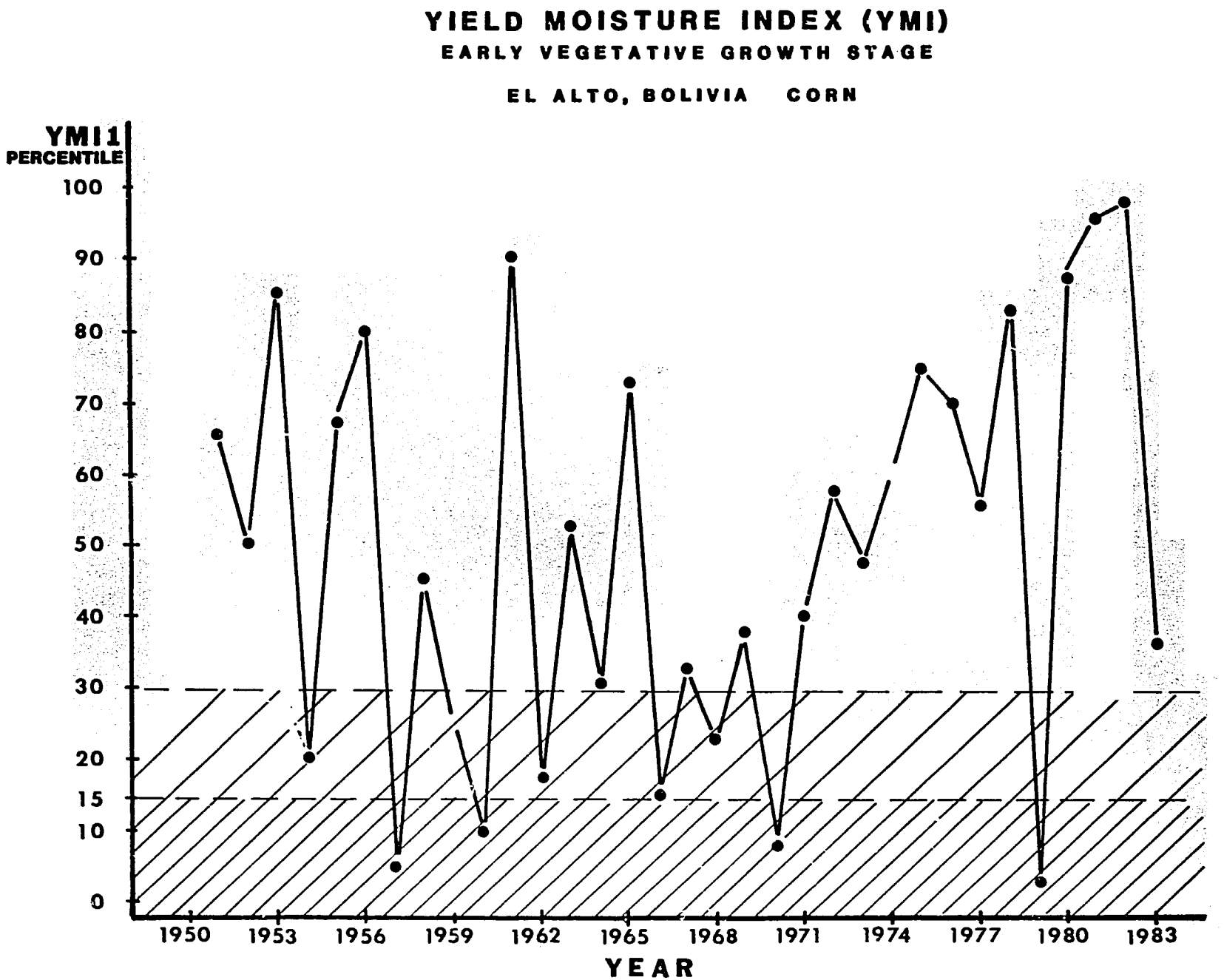

Figure 7.3. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Early Vegetative Growth Stage at El Alto, Bolivia.

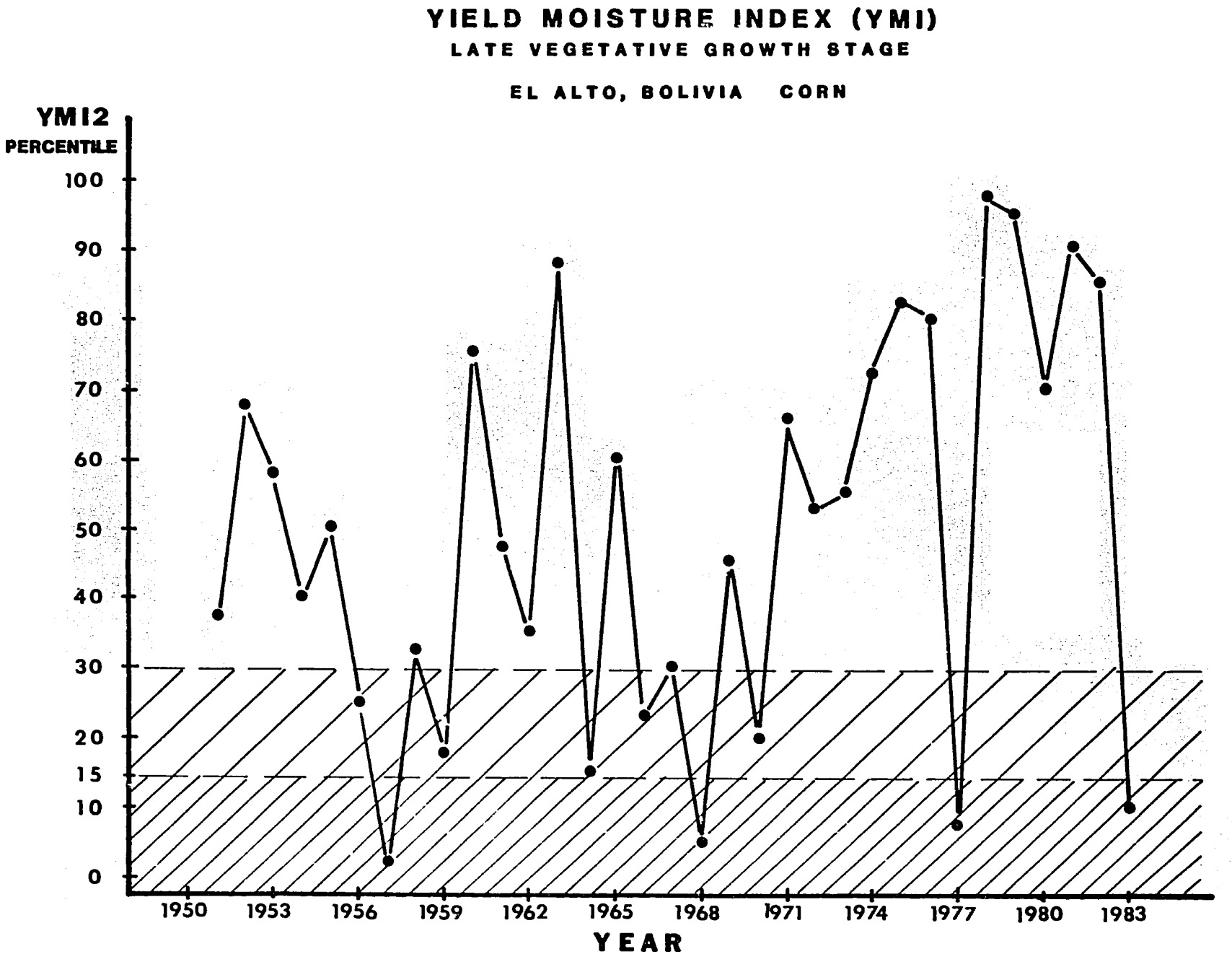

Figure 7.4. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Late Vegetative Growth Stage at El Alto, Bolivia.

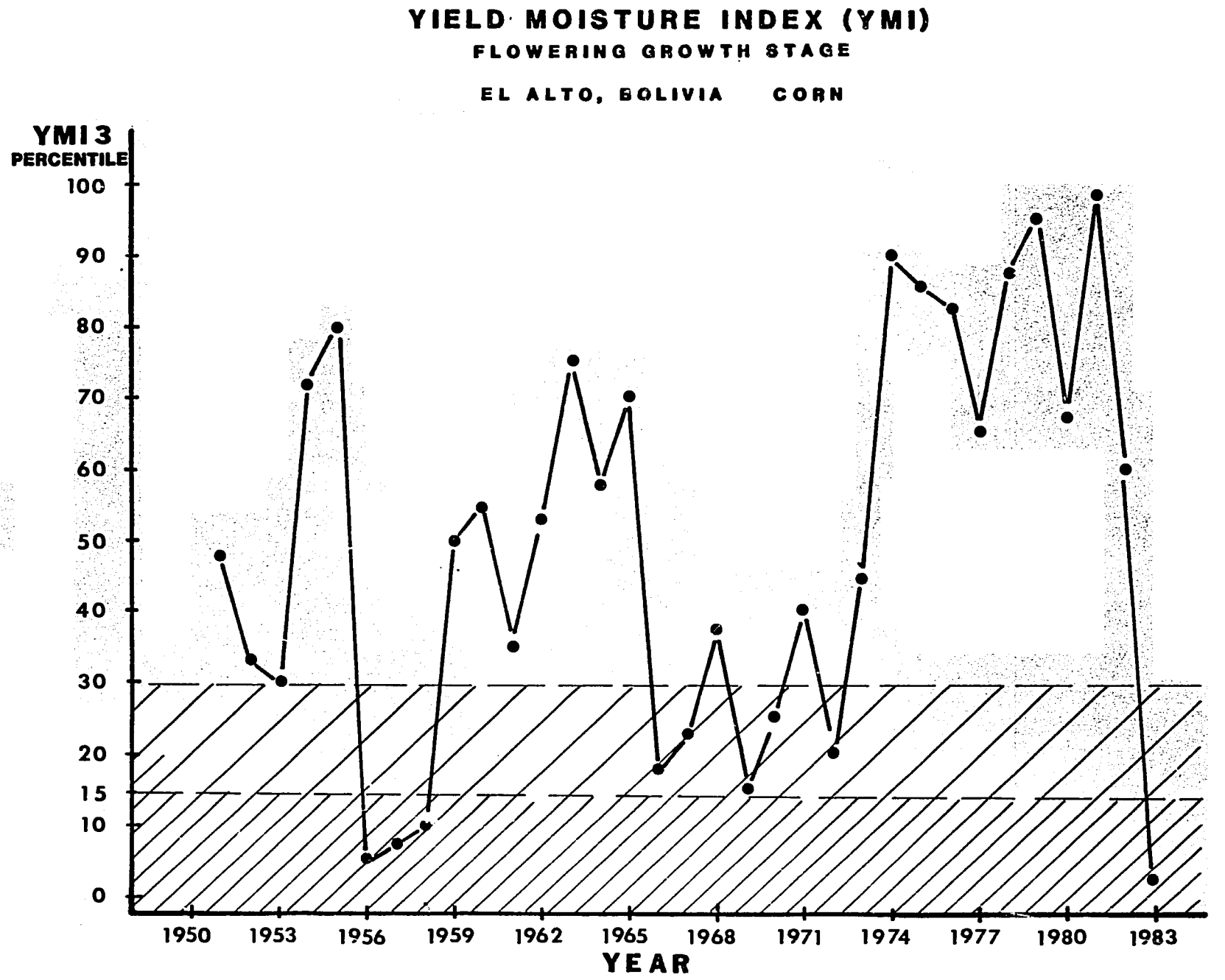

Figure 7.5. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Flowering Growth Stage at El Alto, Bolivia.

TABLE 7.2 EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Bolivia	Altiplano	Drought	Severe drought had existed in the highly populated Altiplano (highlands) region for eight weeks. Agroclimatic crop condition indices were in about 5-10th percentile range. The Altiplano area in the vicinity of Lake Titicaca was the most severely affected. (AISC 5-1-83)	1983 cereal and potato crop production had been recently estimated by the government to be 40% to 50% lower than in 1982 following drought in western departments. (FAO 4-15-83)
		Drought	Continued dryness offered no relief to drought stricken areas. The hard-hit Altiplano region received virtually no rainfall and the effects were widespread and disastrous. Estimates in crop losses alone were approximately $100 million. The rainy season in the affected areas had ended and normally the next few months were dry. (AISC 5-15-83)	Severe drought affected large areas in Altiplano and high valleys causing damage to subsistence crops, pasture and livestock. Farm holders families (48% of the national population) in seven departments were facing food shortage and worsening conditions if present weather conditions continued. (FAO 6-17-83)
		Drought	Normal seasonal dryness continued in the drought-affected areas where November-April rainfall (as little as 30% of normal) devastated subsistence agriculture. Livestock deaths were expected to occur throughout the winter dry season. (AISC 6-12-83)	Subsistence farmers lost between 70% and 90% of their harvests of potatoes, barley and corn as a result of drought. Food shortages resulted. (WSJ 7-26-83)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Ecuador	Coastal	Drought	Stress on coffee trees, livestock, cereals and grains was likely occurring, as an intense moisture deficiency had developed. (AISC 3-25-82)	A severe drought hit Manabi province in the central coastal area causing loss of cash and staple crops and pastures. Lack of water supply for irrigation and domestic use was becoming critical. (FAO 4-16-82)
	Sierra	Drought	Rainfall continued to be insufficient to alleviate drought conditions. It was scanty and limited to widely scattered areas. A significant impact was expected in the agricultural Sierra region. (AISC 7-15-82)	Dry conditions persisted in El Oro province where some pest attacks to the maize crop were reported. (FAO 9-10-82)
	Southern	Drought	Drought continued to affect limited areas in Southern Ecuador. A significant increase in rainfall was needed to replenish domestic water levels and to support the upcoming spring planting season. (AISC 9-10-82)	Drought persisted in southern areas during August and September. Rain was urgently needed to allow sowing of spring crops. (FAO 10-19-82)
	Central Sierra	Drought	Although drought continued to affect much of the Sierra, the size of the stricken area had been considerably reduced. (AISC 11-4-82)	Drought continued to affect parts of the Sierra region although scattered spring rains fell in mid-Oct. Sowing of spring crops was underway in various areas but soil moisture was well below normal. Additional rain was essential during the next few weeks to allow irrigation system to operate. (FAO 11-15-82)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Ecuador	Coastal and Central Sierra	Flooding	During the month of December several days of heavy rainfall triggered extensive flooding in the Daule river valley between the Andes mountains and the Pacific Ocean. The hardest hit provinces were Los Rios and Guayas. Guayaquil, the nation's largest city, is located within that region. Ground weather reports since early December were insufficient to determine precise rainfall amounts and the full extent of effects. Satellite imagery, press releases and diplomatic resources revealed considerable human and property loss in what appears to be the region's worst flooding in 50 years. Guayaquil was nearly isolated and washouts and mudslides on the main highway from Quito to the Pacific Coast caused major disruptions in transportation. Banana and cocoa crops, grown principally in the flood-stricken area, was thought to have suffered some flood damage. (AISC 1-13-83)	Torrential rains since November relieved drought in coastal areas and Central Andean regions, but caused extensive floods that greatly damaged agriculture. Guayas and Los Rios provinces were worst affected and were declared disaster areas. Other provinces including El Oro, Esmeralda and Manabi were also affected. Production of 15,000 ha soya, 12,000 ha maize, 5,000 ha bananas, 12,000 ha rice and 10,000 ha sugarcane were lost. Winter plantings scheduled at this time were prevented. The food situation was critical. (FAO 1-14-83)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Ecuador	Coastal and Central Sierra	Flooding	Periods of torrential rainfall for the third consecutive week caused a pronounced worsening of flood conditions in already-stricken areas. The heaviest downpours occurred January 15-17, during which time the flood zone expanded to include all the remaining coastal provinces. Washed out bridges isolated El Oro province from most surrounding regions. Heavy rains of recent weeks which preceded the normal rainy season, were described as the worst of the century. Many people were killed, thousands left homeless and millions of dollars lost from damages. (AISC 1-27-83)	Heavy rains continued in areas already affected by extensive floods, affecting nearly 1/3 of the country. 15,000 people were isolated in Loja province because access roads were destroyed. (FAO 3-18-83)
		Heavy rains	Synoptic summaries were incomplete but satellite imagery and other ancillary data sources indicated that thunderstorms and rainshowers were resumed in parts of Ecuador. In Guayaquil, Ecuador's largest population center, total rainfall was 200 mm (250% of normal). (AISC 4-3-83)	Persisting heavy rains aggravated the flood situation in Sierra and Coastal regions. Planting of maize and rice in some recuperated areas of St. Elena and Manabi provinces was in progress, but danger of new floods existed. The food supply in affected areas continued difficult. (FAO 4-15-83)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Ecuador	Coastal and Central Sierra	Heavy rains	Precipitation in most of Ecuador tapered off in recent weeks, but the return of scattered heavy rainfall renewed the threat of flooding in some coastal regions. Guayaquil and parts of the surrounding river basin had 250-300 mm of rain (over 500% of normal). A return of widespread flooding would present a major setback to the national economy, which still had not recovered from the floods of December '82 to February '83. (AISC 5-15-83)	Rainfall decreased in May in most flood affected areas but continued in Guayaquil and neighboring coastal areas. Damage to food crops was reportedly heavy. In Manabi province the maize crop was endangered by the flooding and inability to be harvested. (FAO 6-17-83)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Peru	Northern	Drought	Drought occurring for 9-17 weeks dried up water supplies. The rice crop, mostly irrigated in that area, was expected to be reduced up to 50 percent. (AISC 5-5-82)	A severe drought occurred in March where most of the rice crop is produced. (FAO 5-14-82)
		Drought	Severe drought continued and water supplies were inadequate. Rice yields were expected to be lower and planting of potatoes and grains in coastal areas was expected to be late. (AISC 5-19-82)	In March severe drought affected departments of Piura, Lambayeque and La Libertad where most of the rice crop is produced. (FAO 6-11-82)
		Drought	Rainfall continued to be insufficient to alleviate drought conditions. It was scanty and limited to widely scattered areas. A significant impact was likely in the agricultural Sierra regions. (AISC 7-15-82)	Drought during March-June was expected to reduce maize yields. (FAO 7-16-82)
		Light Rains	As the intertropical zone of convergence drifted southward (even though the incursion was brief) it brought widely scattered periods of light rain and drizzle. With these, moisture levels continued to improve and the drought which lasted since mid-April generally weakened. (AISC 8-13-82)	Little rain during July alleviated drought which had persisted since March and reduced rice yields. (FAO 8-13-82)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Peru	Puno Dept.	Drought	There had been an 8-week drought and agroclimatic crop condition indices were in about the 5-10th percentile range. The Altiplano area in the vicinity of Lake Titicaca was the most severely affected. (AISC 5-1-83)	Drought affected this southeastern department and destroyed 70% of the crops. The area was declared a disaster. (FAO 3-18-83)
	Northern	Flooding	Periods of moderate-to-heavy rainfall continued to cause disastrous flooding and landslides in northern Peru. The heaviest downpours which occurred during March 25-30 were 100-300 mm (150-450% of normal). Due to damaged crops in Ancash region, the government declared a state of emergency. Subsistence crops had to be replanted. (AISC 3-20-83)	Extensive flooding continued in northern coastal departments of Tumbes and Piura. Recently, rains led to new landslides and further damage. (FAO 4-15-83)
	Northern	Flooding	Thunderstorms and rainshowers resumed. 80 mm (over 500% of normal) fell on the city of Piura where a state of emergency already existed. (AISC 3-16-83)	Disaster situation was reported in northern departments of Piura, Tumbes and La Libertad due to continuing rains and river overflows. Rice and corn crops were lost and heavy losses occurred to sugarcane plantations. (FAO 5-20-83)

TABLE 7.2. EPISODIC EVENTS (DROUGHT, FLOODING, ETC.) AND WEATHER/CROP CONDITION ASSESSMENTS ISSUED FOR THE 1982/83 CROP SEASON IN CENTRAL AND SOUTH AMERICA (CONT.)

Country	Region	Event	Summarized Weather/Crop Condition Assessment Report Issued by AISC (Source and Date)	Summarized Report of Episodic Events (Drought, Flooding, Etc.) From Different Sources (Source and Date)
Peru	Southern	Drought	Continued dryness offered no relief to drought stricken areas. The hard-hit Altiplano region received virtually no rainfall, while central Peru had only scant amounts (less than 10 mm). The drought effects were widespread and disastrous. Crop and livestock losses were estimated at nearly $150 million. (AISC 5-15-83)	Drought seriously affected farming and caused a dramatic famine in the departments of Cusco, Arequipa, Apurimac, Huancavelica, Ayacucho and particularly Puno. (AFP 7-12-83)

Ecuador

Droughts and floodings were the major events in the Coastal and Sierra regions for 1982 and 1983.

In early 1982 severe drought conditions were reported in Manabi province (coastal region) causing loss of cash and subsistance crops and pastures. Crop water stress due to an intense moisture deficiency was first reported by AISC on March 25, 1982.

During 1982 the Sierra region also experienced drought impact which lasted until November 1982 (AISC, 7-15-82 and 11-4-82). Spring planting was delayed due to below normal rainfall during August and September. Scattered rains fell in mid-October allowing planting of spring crops but soil moisture was well below normal. Flooding and crop damages were reported by AISC (Table 7.2). During late 1982 and early 1983, both the Coastal and the Sierra regions experienced heavy rainfall and extensive flooding. Los Rios and Guayas provinces were particularly affected with the worst flooding in 50 years. Banana and cocoa crops suffered flood damage. The weather/crop condition assessments were verified by FAO reports (Table 7.2).

Peru

Droughts and floodings in extensive areas were reported during 1982 and 1983.

In Northern Peru drought conditions in March, 1982 caused reduced rice yields and delayed planting of potatoes and grain crops. During late 1982 and early 1983 heavy rains occurred in the Northern regions. Disastrous flooding and landslides affected several departments including Piura, Tumbes, and La Libertad. Subsistance crops were severely damaged. These AISC weather/crops conditions assessments were verified by FAO reports (Table 7.2).

In Southern Peru, particularly the Altiplano area, severe drought conditions were observed during the 1982/83 crop growing season. Figures 7.6, 7.7, and 7.8 show historical YMI for Juliaca and for corn at early and late vegetative and flowering growth stages. During the early vegetative growth stage (September-October, 1982), YMI values were in the 65-70th percentile range suggesting normal or above normal conditions. However, at the end of the late vegetative stage (November, 1982 - January, 1983) the crop condition index was in the 20th percentile which is generally associated with moderate drought impact. During the critical flowering growth stage, the YMI dropped even further to 5th percentile suggesting severe drought conditions and drought occurrences of about once every 20 years. Again the lead-time provided by the agroclimate index at the end of March was between 2-3 months before harvest.

These assessment were verified by FAO and Associated France Press reports (Table 7.2).

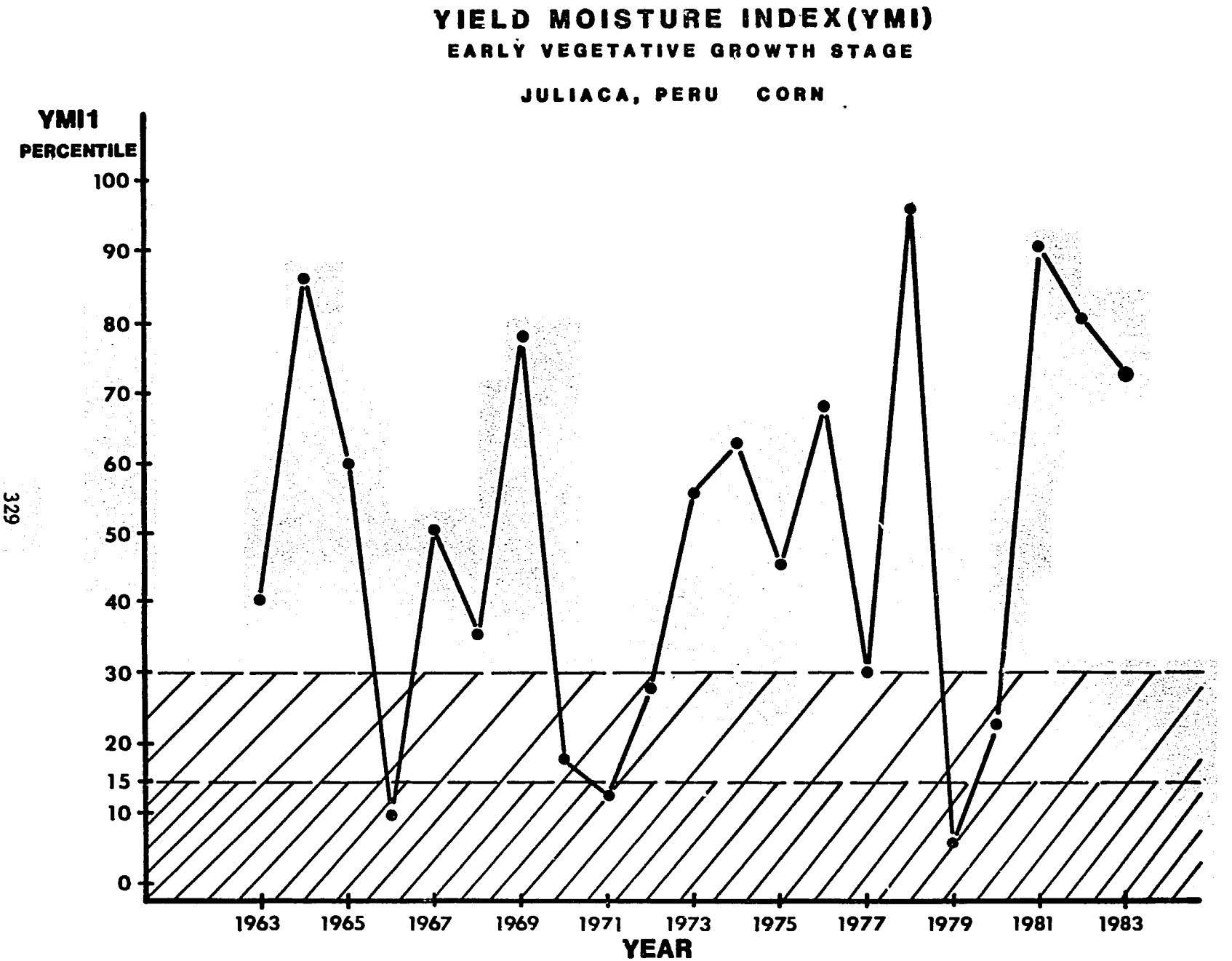

Figure 7.6. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Early Vegetative Growth Stage at Juliaca, Peru.

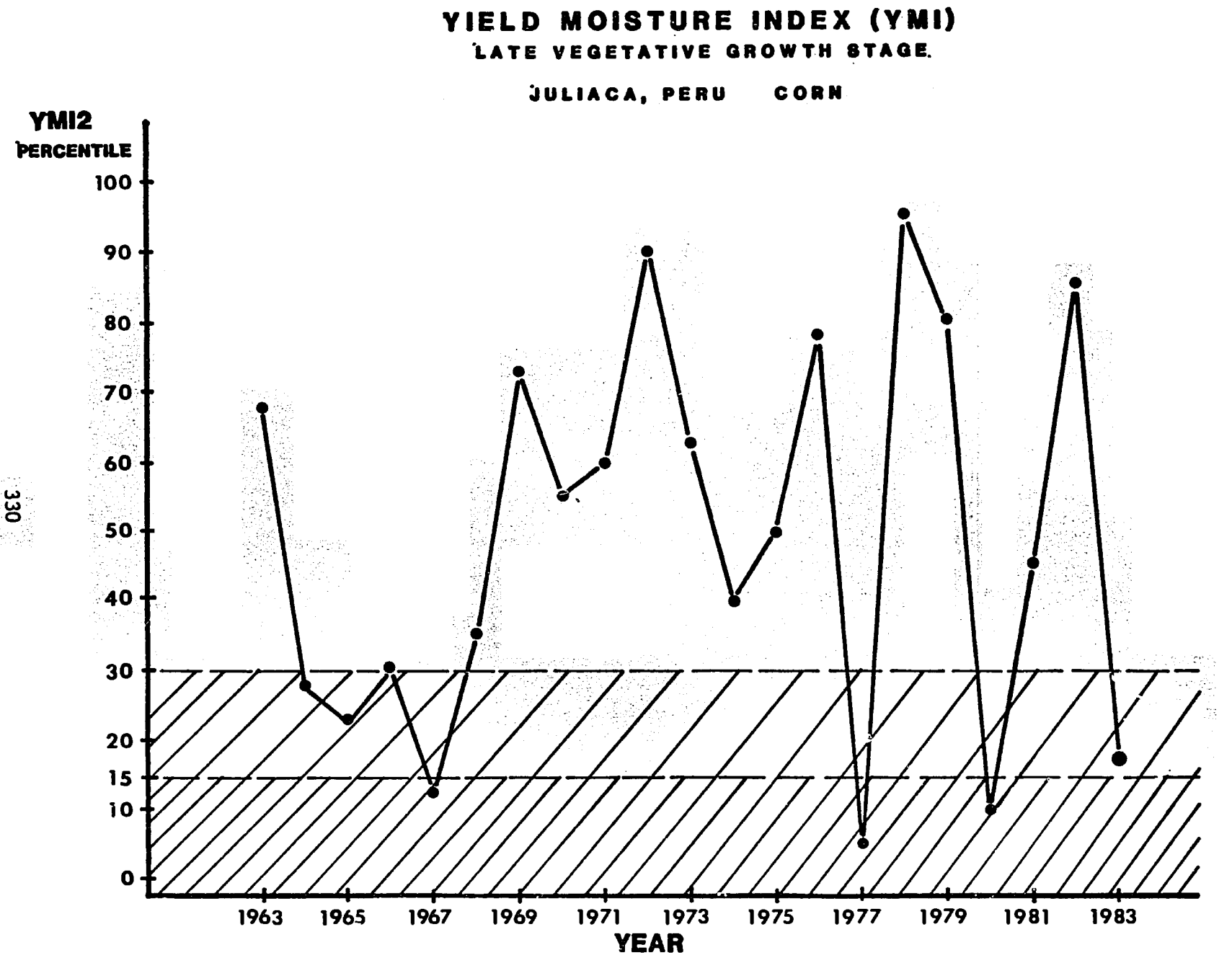

Figure 7.7. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Late Vegetative Growth Stage at Juliaca, Peru.

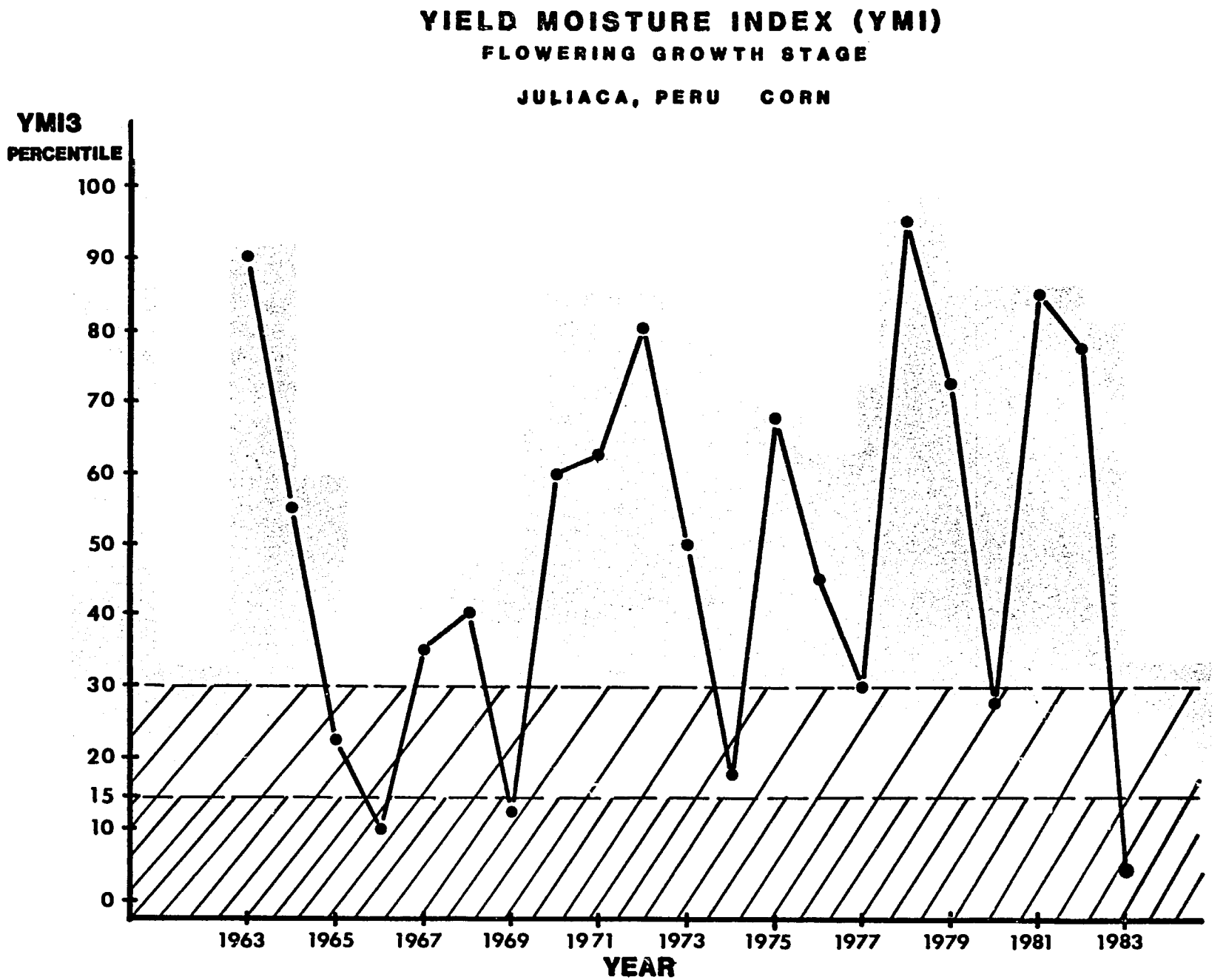

Figure 7.8. Yield Moisture Index (YMI) Expressed in Percentiles for Corn during the Flowering Growth Stage at Juliaca, Peru.

CHAPTER VIII

SUMMARY

The goal of this project has been accomplished; an Early Warning Assessment Program has been developed to provide reliable information on the potential for disastrous subsistence food shortages due to drought in developing countries of Central and South America. This proposed early warning program, based on a combination of biweekly weather and crop condition/food shortage assessments, is objectively determined by climate/crop relationships. It is also sufficiently economical for practical real-time operation.

These assessments have the capacity to provide useful information by about 30-60 days prior to the final harvest of the crop. This could represent a potential 3-6 month early warning prior to drought-related food shortages.

The data bases, background information, techniques, agroclimatic models, and computer software necessary to implement these assessments have been developed. Preliminary agroclimatic models and crop condition/food shortage assessment methods are proposed. This early warning program has been tested and evaluated prior to implementation on an operational basis. The goals of test and evaluation included: 1) refinement and calibration of proposed models, 2) routine assessments in a test and evaluation mode, 3) encouragement of user feedback and 4) continued agroclimatic analysis relative to food security and climate vulnerability within Central and South America.

The test and evaluation phase provided experience in the preparation of assessment reports. Case study analyses and verification analysis resulted in technical modification and recommended improvements in assessment procedures.

It is suggested that this program can potentially benefit AID in attaining the following goals:

1) to monitor and assess potential and actual disaster situations due to drought in these developing countries, thereby providing increased lead-time for planning strategies on food assistance.
2) to increase the U.S. technical capacity to define disaster-prone conditions and to recommend disaster-avoidance measures.
3) to apply and transfer both technology and information to developing countries, international organizations and others.

Within the context of applying weather and climatic data to agroclimatic systems, the methods proposed are: 1) inexpensive, 2) timely, 3) consistent with known agronomic practices in these countries and 4) considered to be potentially capable of providing reliable early warning information.

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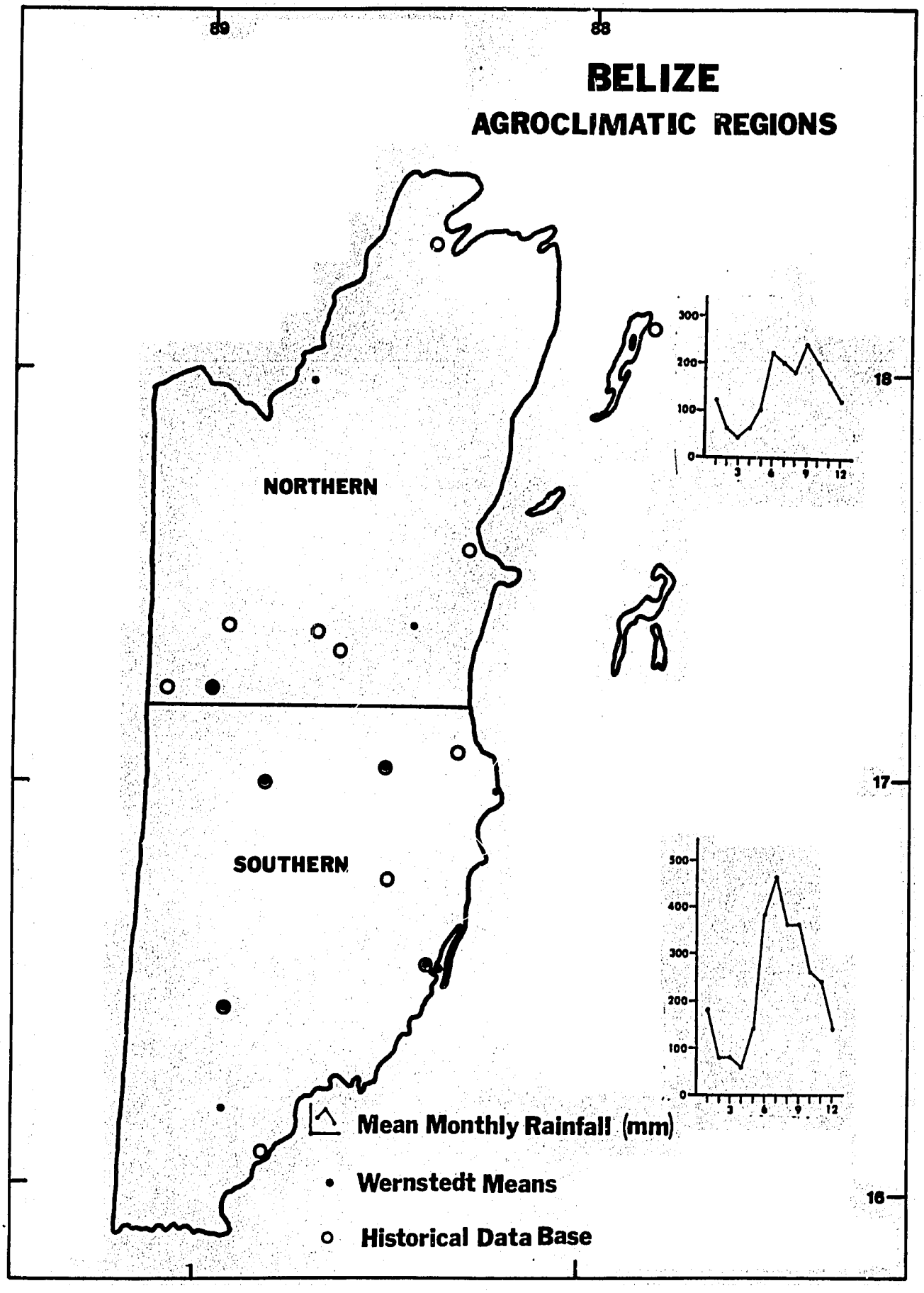
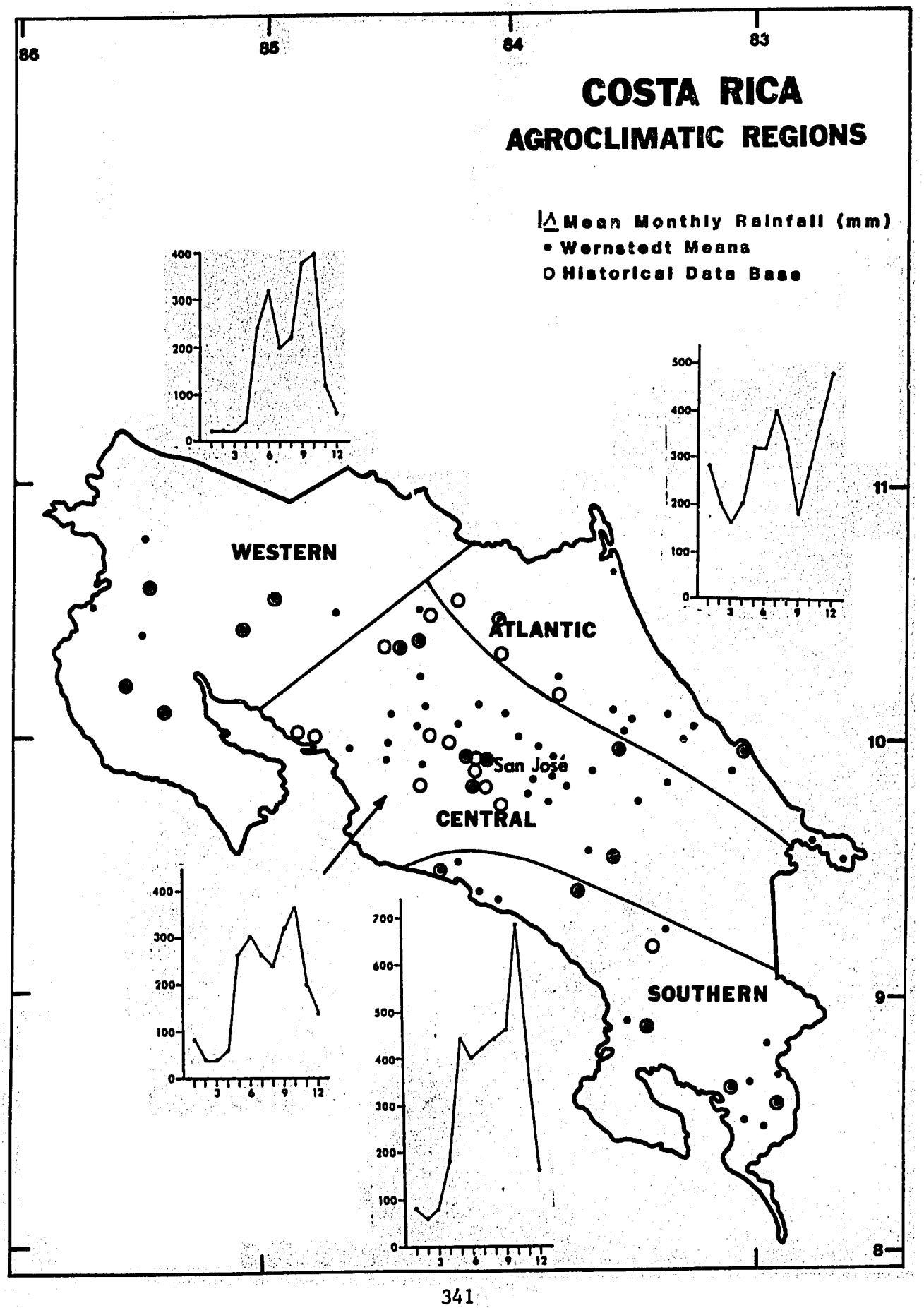
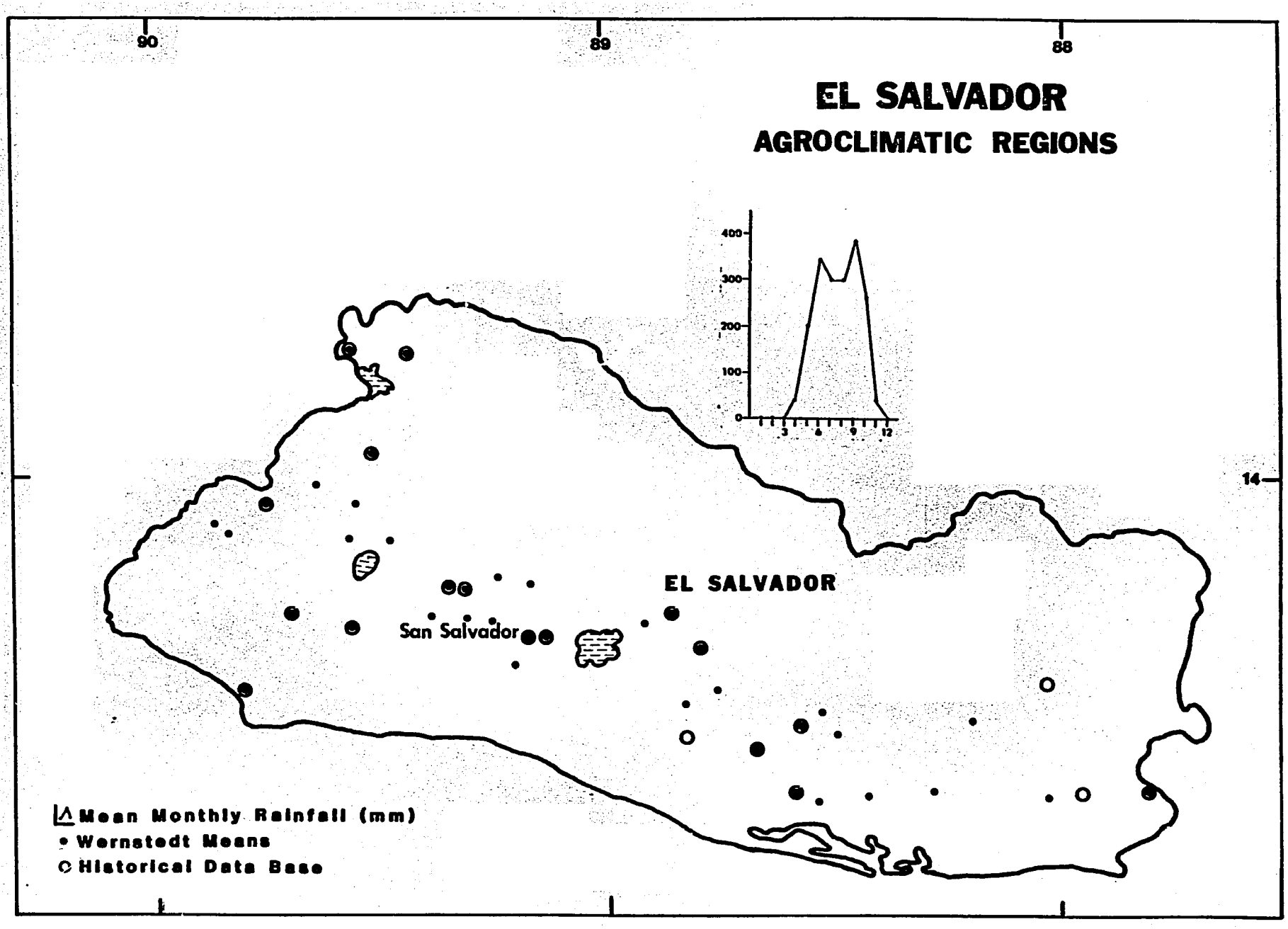
APPENDIX A

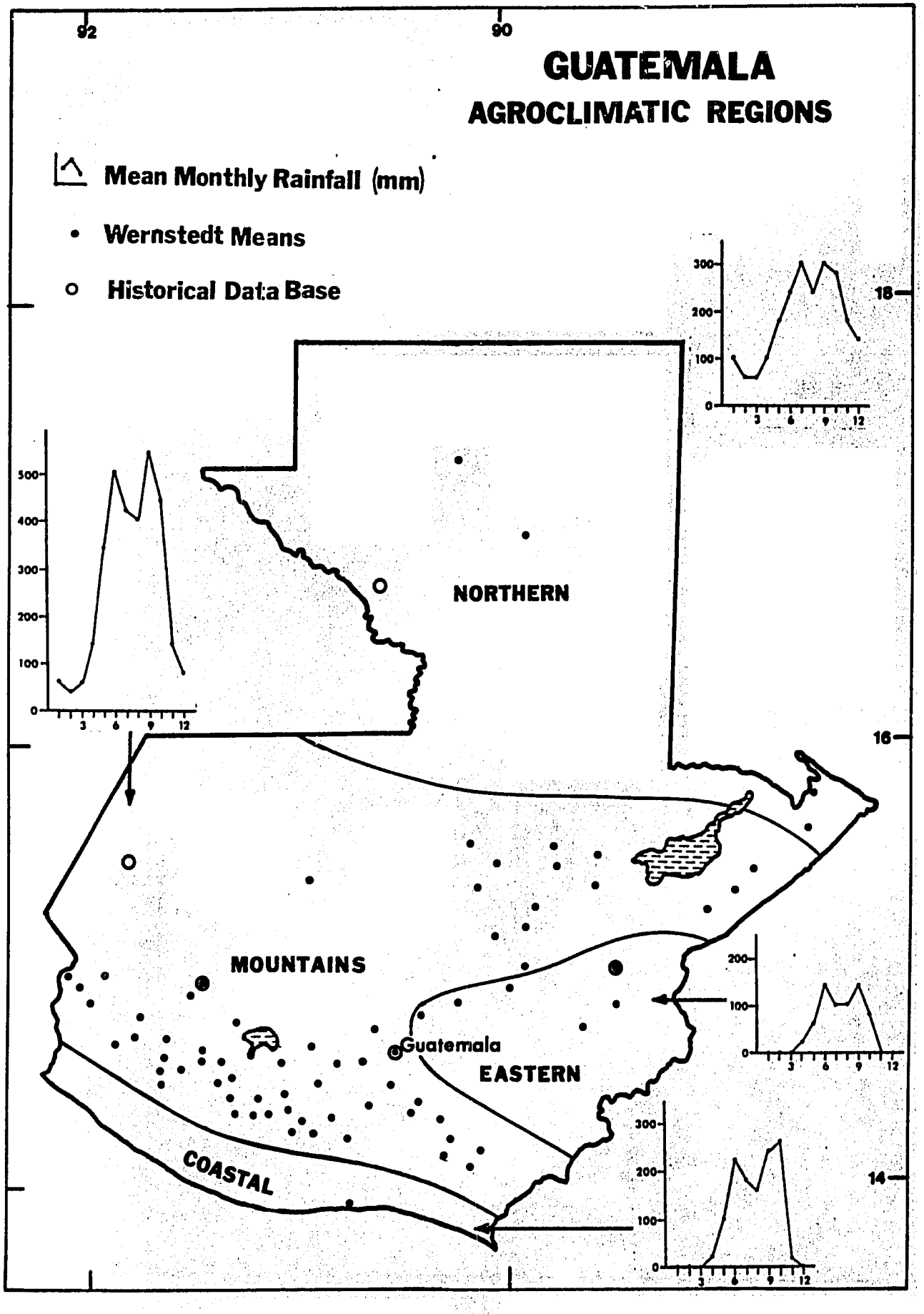
AGROCLIMATIC/WEATHER ASSESSMENT REGIONS

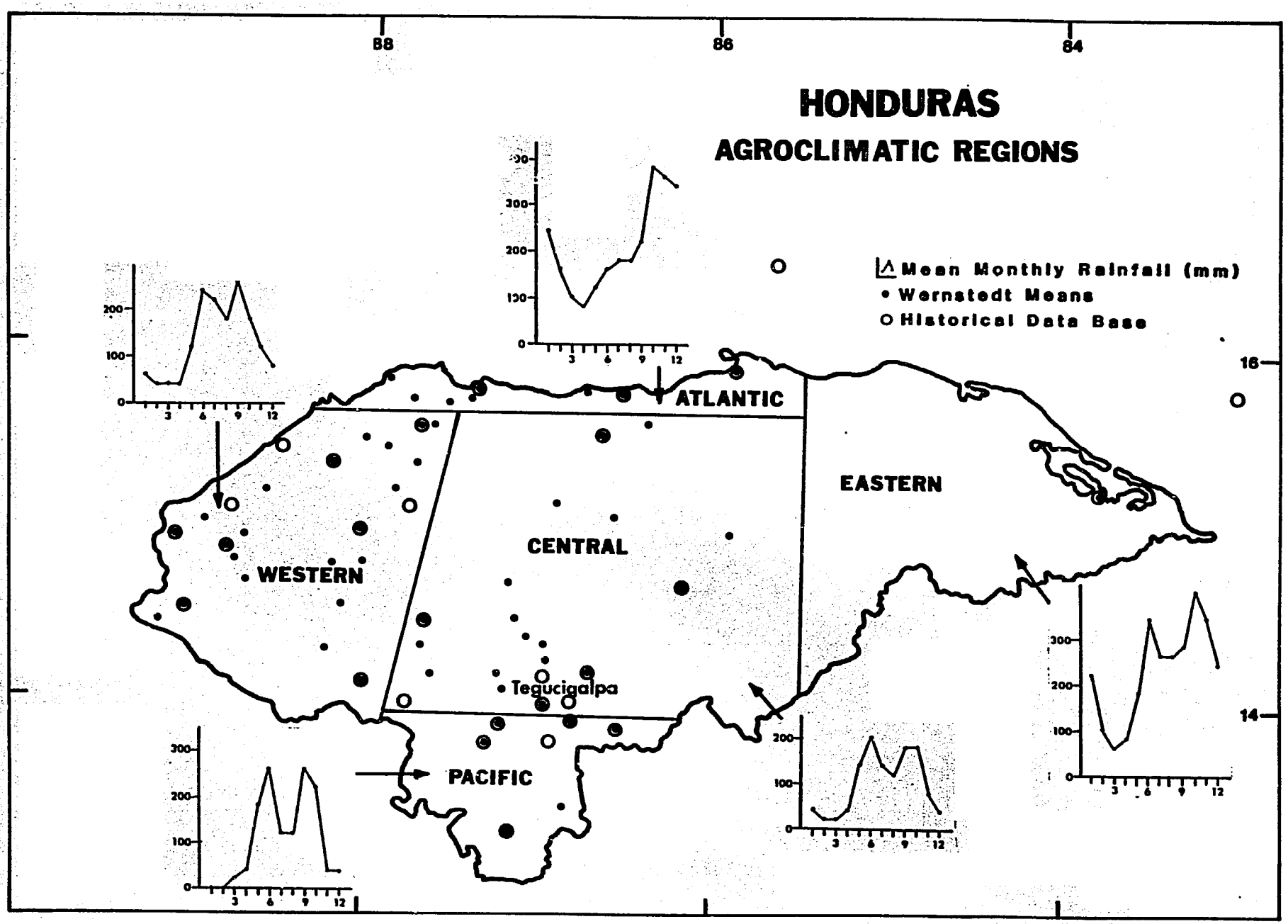
Each country was divided into agroclimatic regions. These are used, in part, for weather assessment analysis. Individual country maps show agroclimatic regions, histograms of the mean monthly rainfall for each region, the location of the stations (Wernstedt, 1972) used for calculating the mean regional rainfall and the location of the stations comprising the historical meteorological data base.

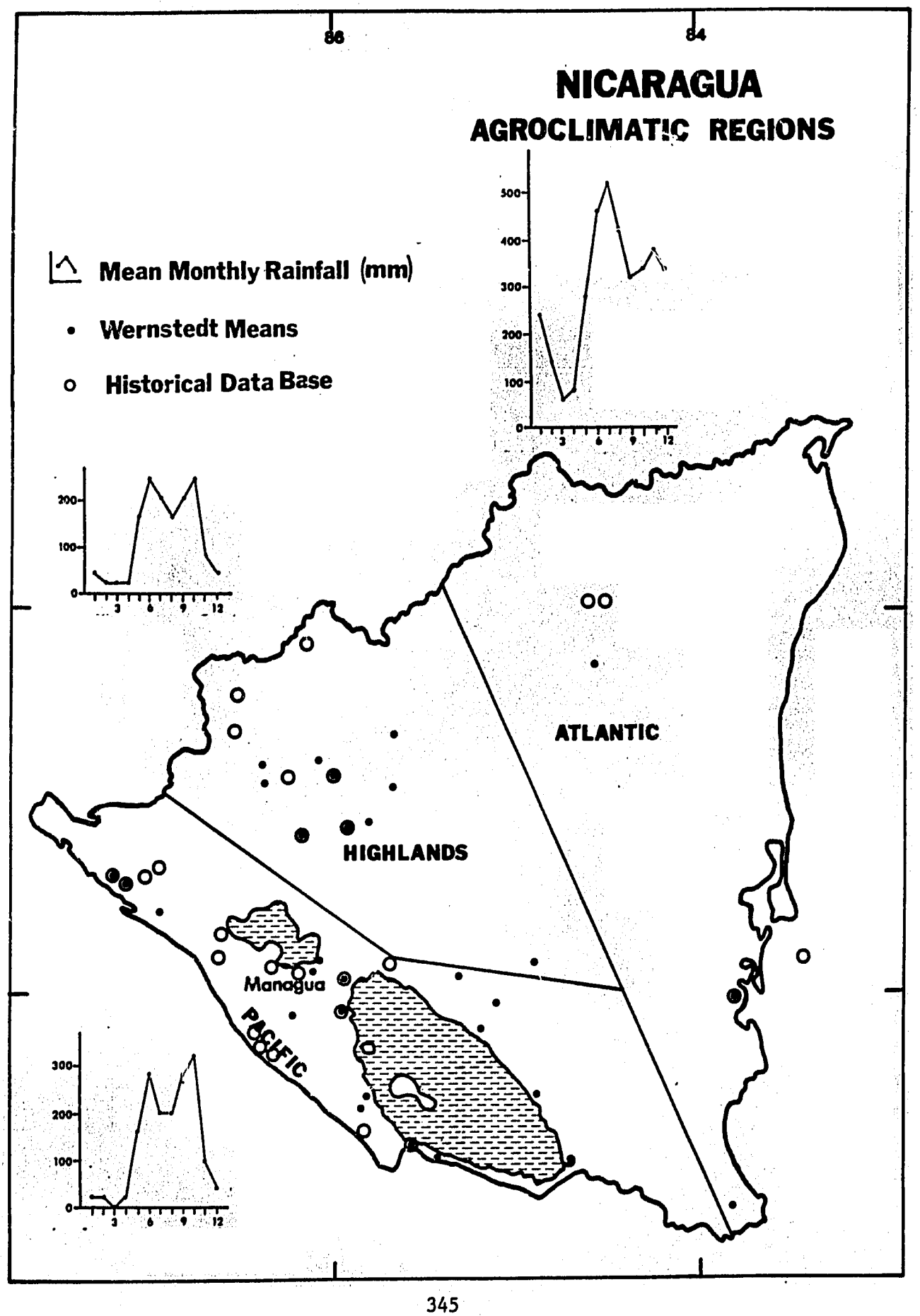

89
88
BELIZE
AGROCLIMATIC REGIONS
NORTHERN
SOUTHERN
18
17
16
300
200
100
0
3
6
9
12
500
400
300
200
100
0
3
6
9
12
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base

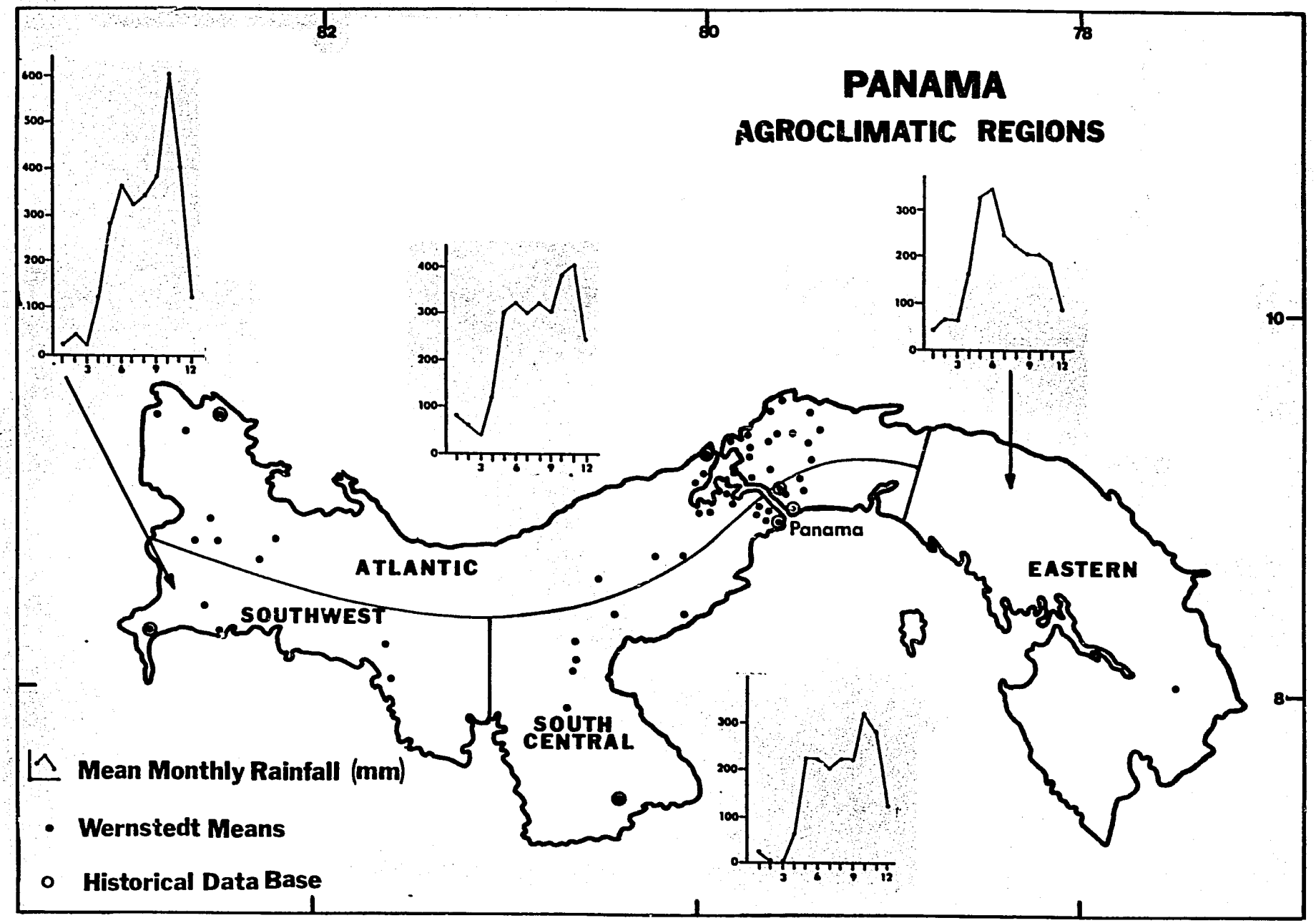

86
85
84
83
COSTA RICA
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
• Wernstedt Means
O Historical Data Base
WESTERN
ATLANTIC
CENTRAL
SOUTHERN
San José
11
10
9
8

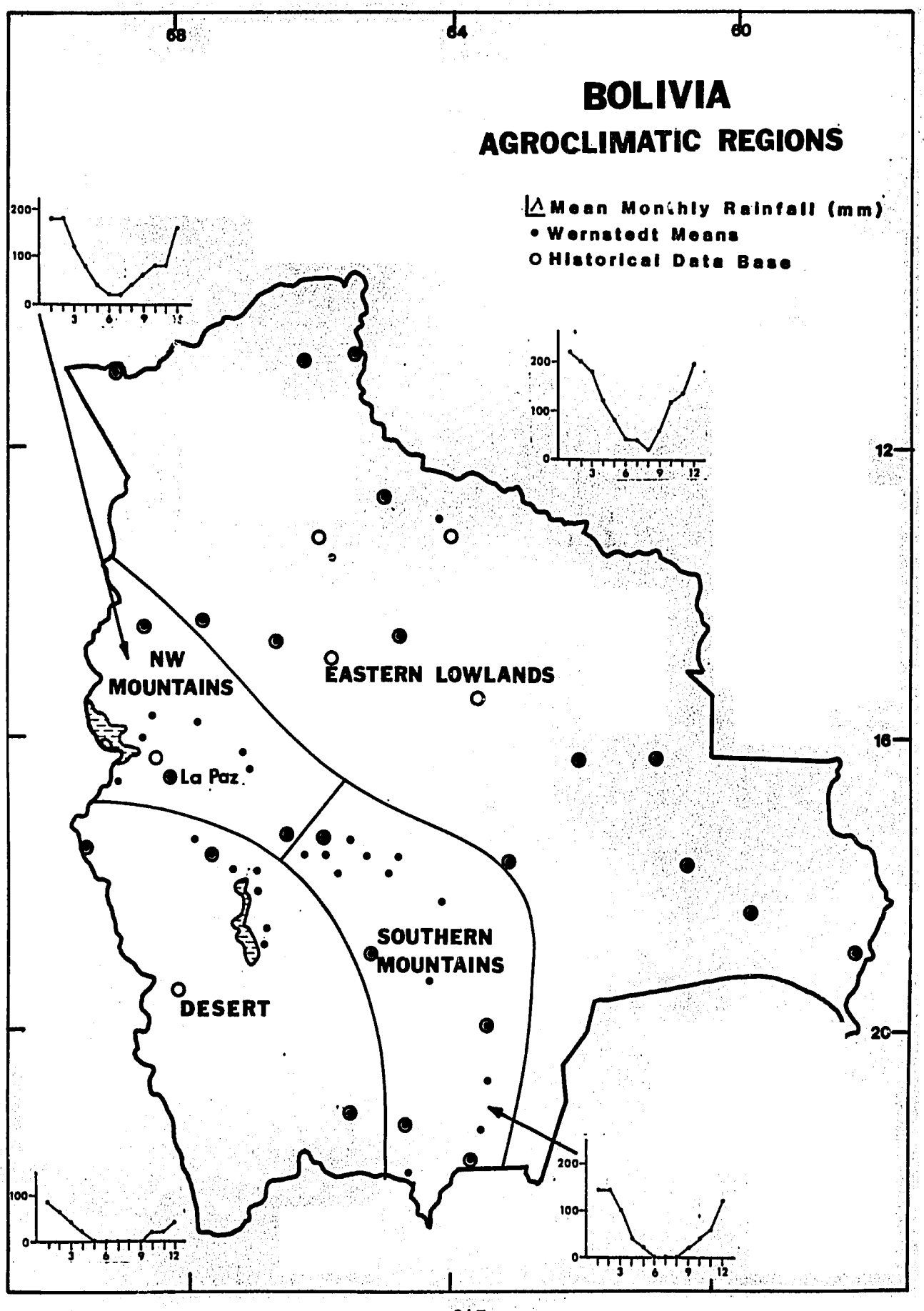

EL SALVADOR
AGROCLIMATIC REGIONS
90
89
88
14
400
300
200
100
0
3
6
9
12
EL SALVADOR
San Salvador
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base

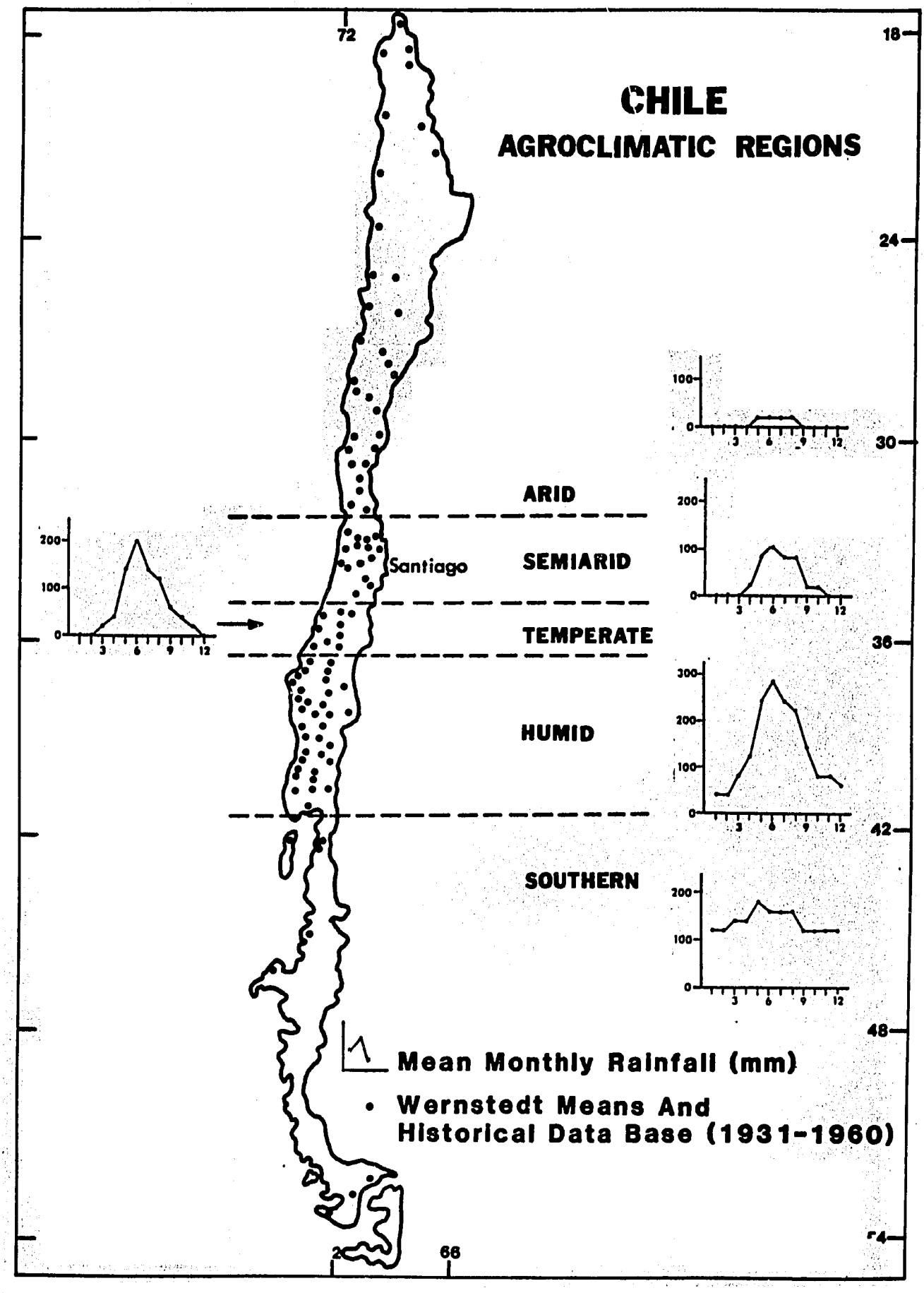

92
90
GUATEMALA
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base
18
16
14
NORTHERN
MOUNTAINS
EASTERN
COASTAL
Guatemala
0
100
200
300
400
500
3
6
9
12

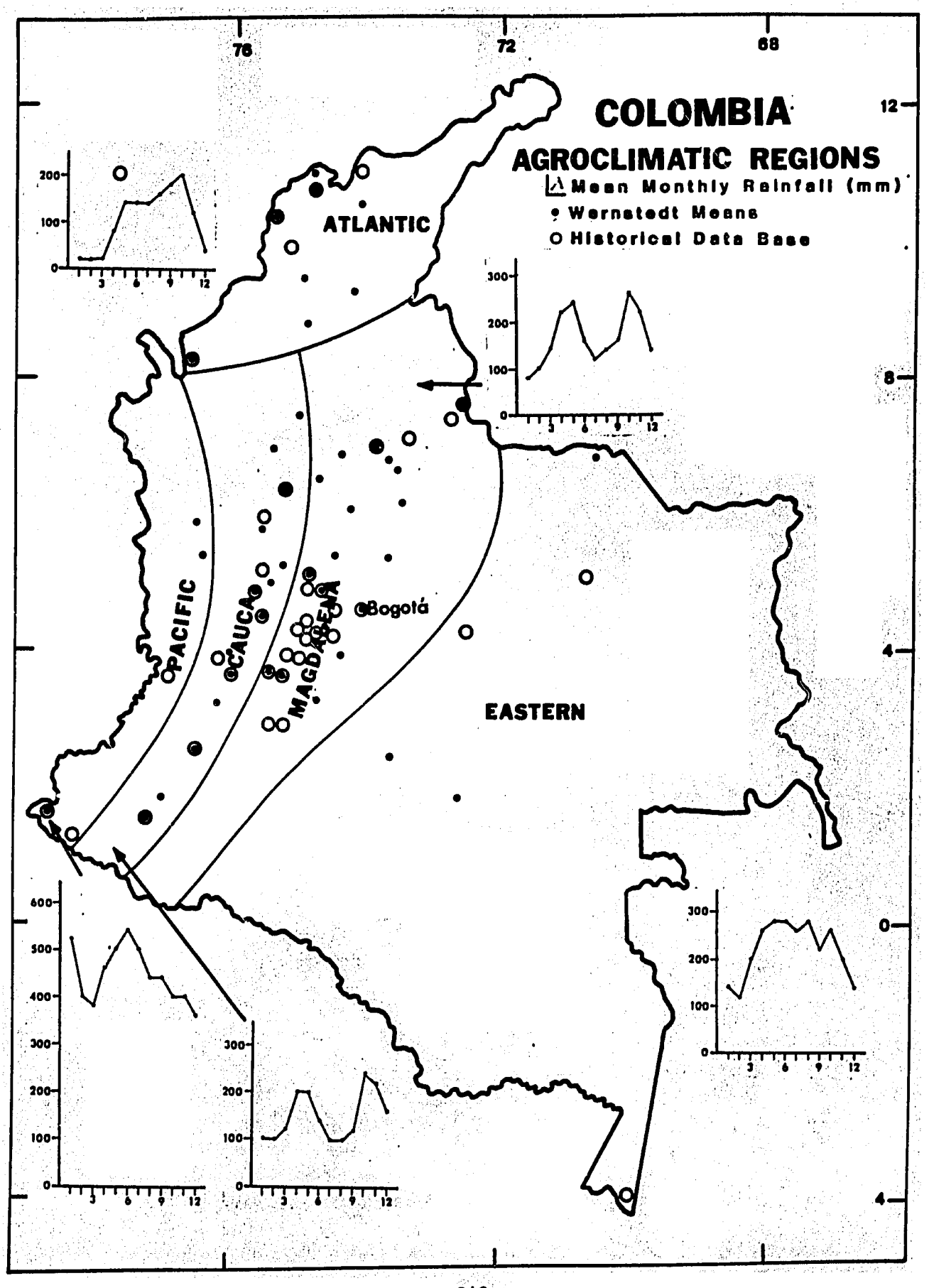

HONDURAS
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
• Wernstedt Means
O Historical Data Base
88
86
84
16
14
ATLANTIC
EASTERN
CENTRAL
WESTERN
PACIFIC
Tegucigalpa

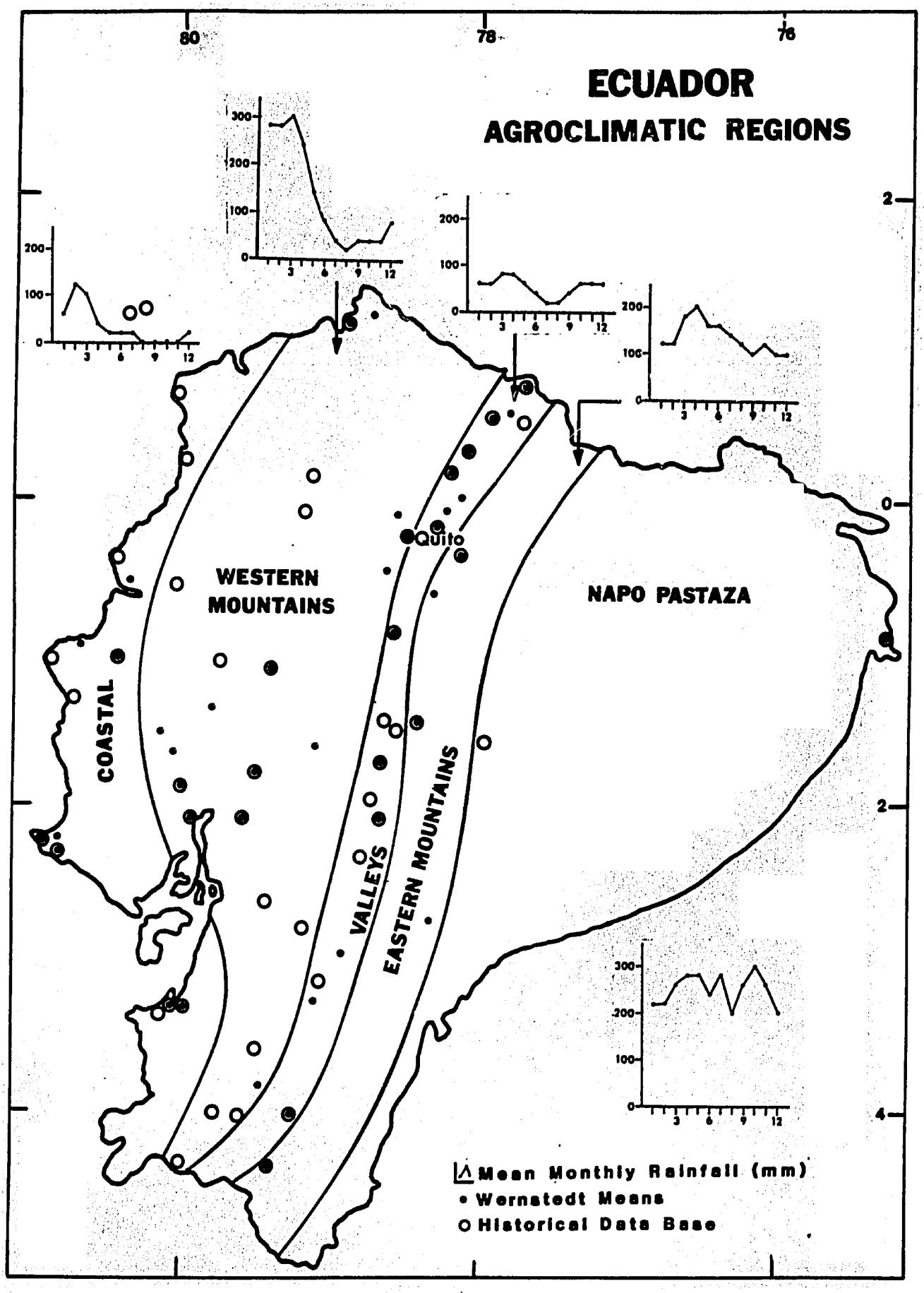

86
84
NICARAGUA
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base
ATLANTIC
HIGHLANDS
PACIFIC
Managua

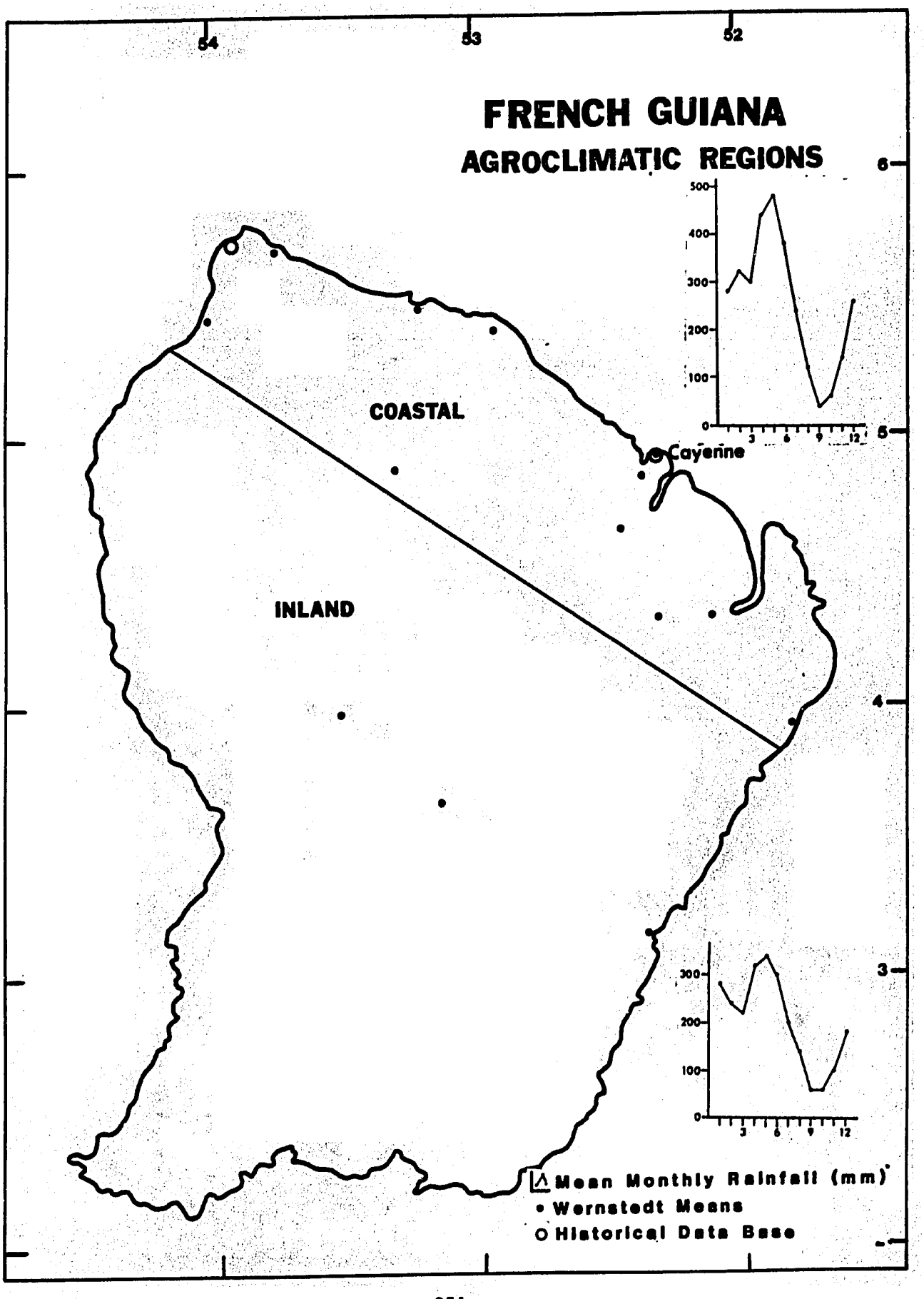

PANAMA
AGROCLIMATIC REGIONS
82
80
78
10
8
ATLANTIC
SOUTHWEST
SOUTH CENTRAL
EASTERN
Panama
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base

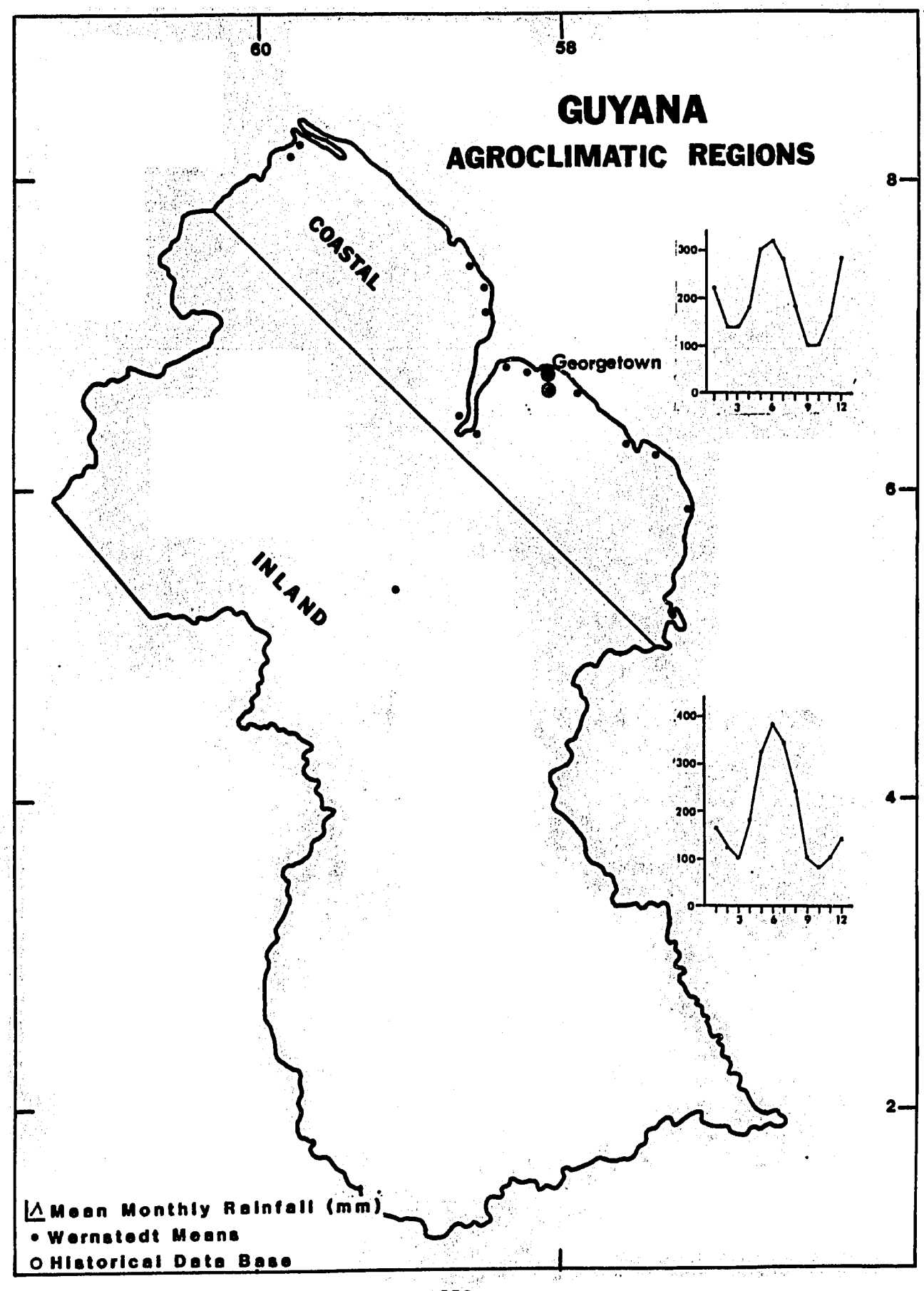

BOLIVIA
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
• Wernstedt Means
O Historical Data Base
68
64
60
12
16
20
NW MOUNTAINS
EASTERN LOWLANDS
La Paz
SOUTHERN MOUNTAINS
DESERT
200
100
0
3
6
9
12

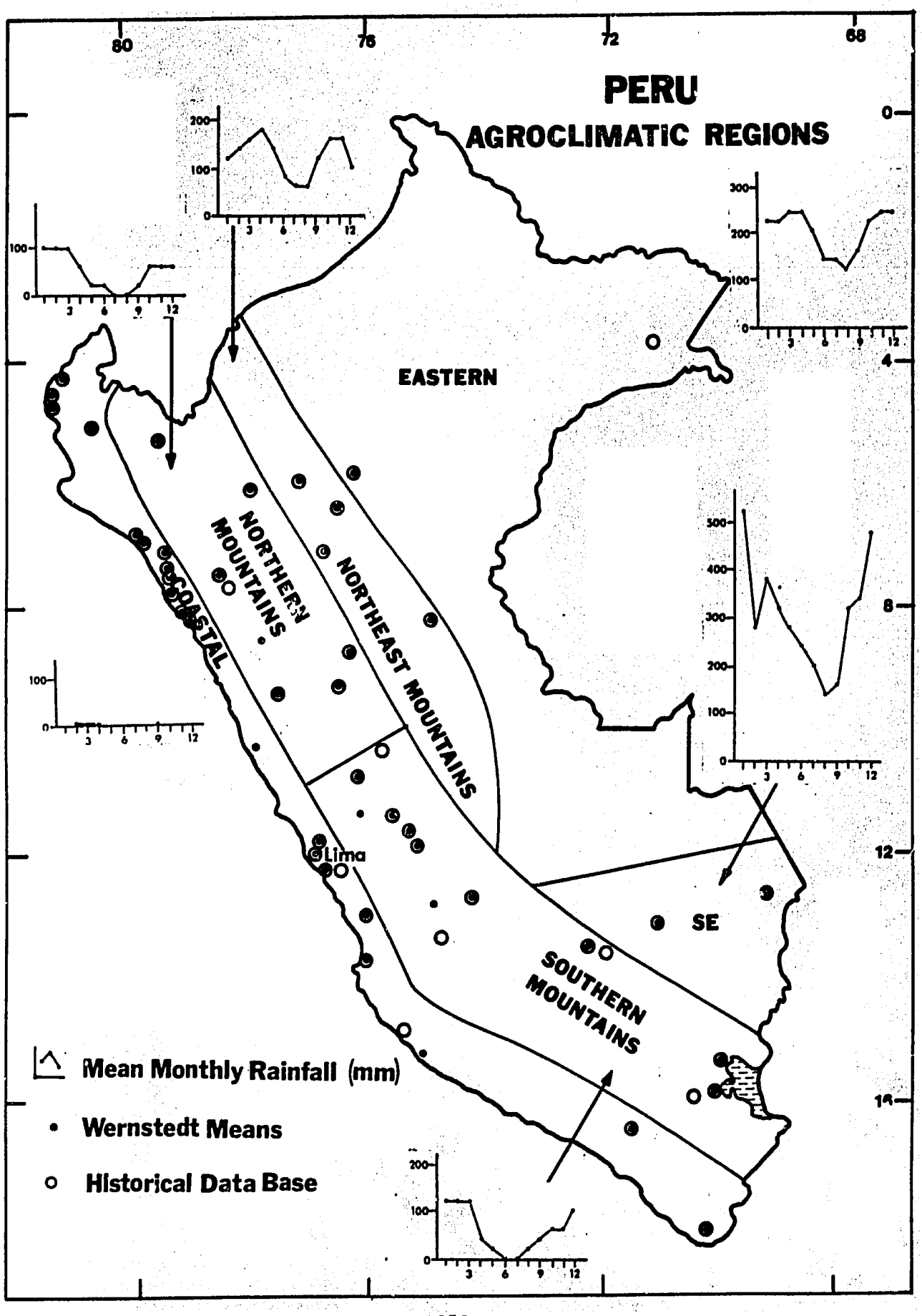

CHILE
AGROCLIMATIC REGIONS
ARID
SEMIARID
TEMPERATE
HUMID
SOUTHERN
Santiago
Mean Monthly Rainfall (mm)
• Wernstedt Means And Historical Data Base (1931-1960)
72
18
24
30
36
42
48
66

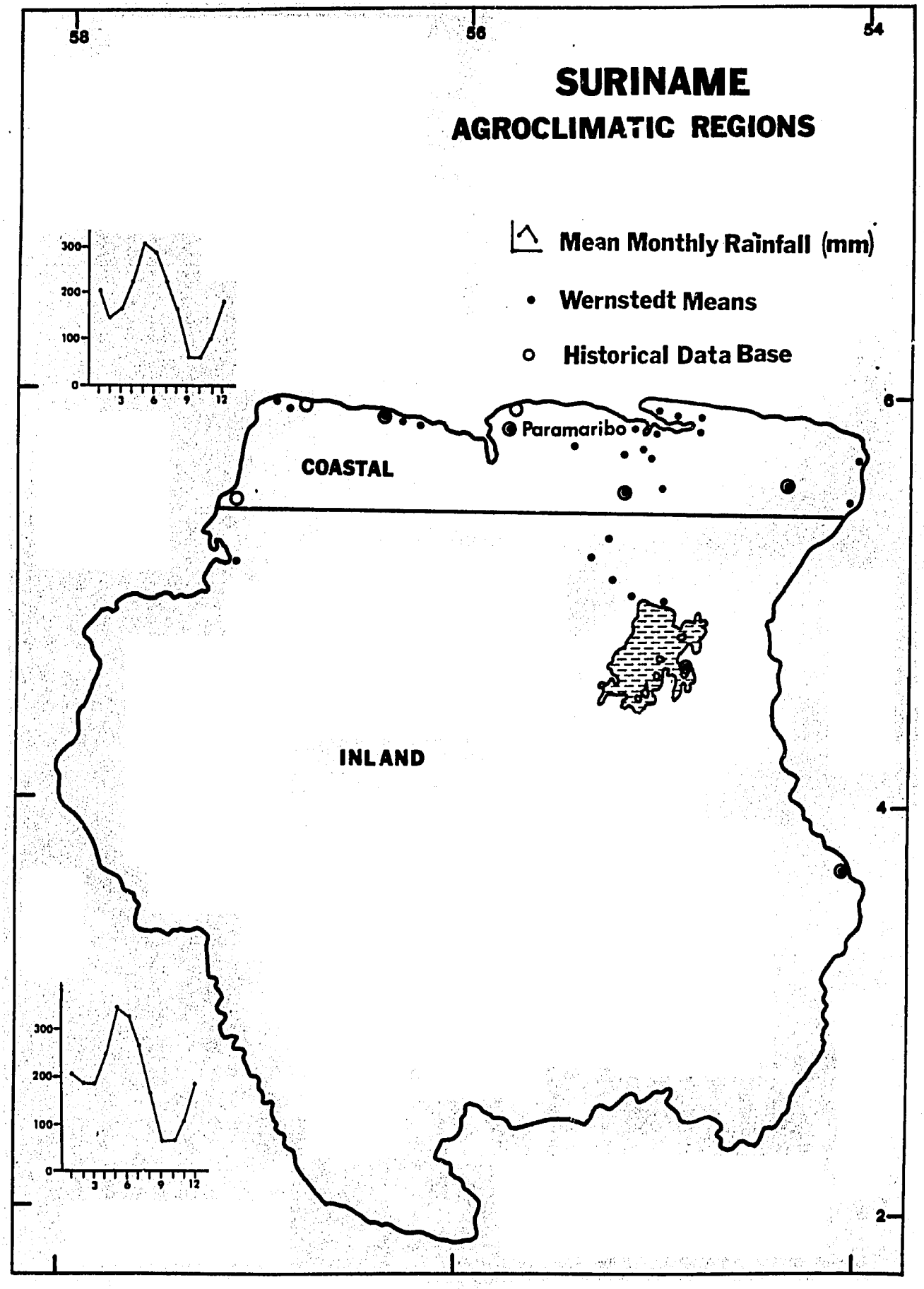

COLOMBIA
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base
ATLANTIC
PACIFIC
CAUCA
MAGDALENA
EASTERN
Bogotá
76
72
68
12
8
4
0
4

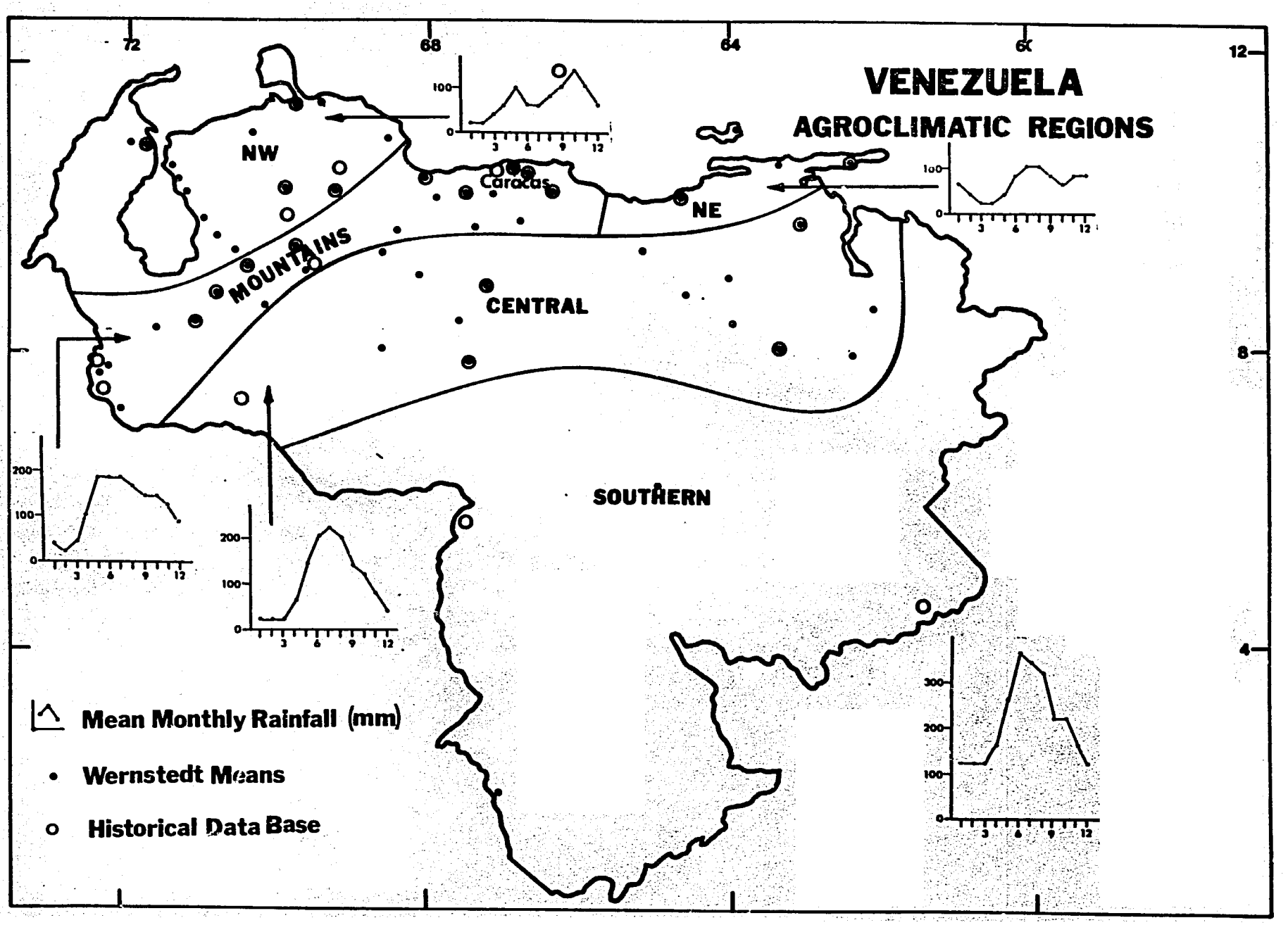

ECUADOR
AGROCLIMATIC REGIONS
80
78
76
2
0
2
4
Quito
WESTERN MOUNTAINS
NAPO PASTAZA
COASTAL
VALLEYS
EASTERN MOUNTAINS
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base


FRENCH GUIANA
AGROCLIMATIC REGIONS
COASTAL
INLAND
Cayenne
54
53
52
6
5
4
3
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base


GUYANA
AGROCLIMATIC REGIONS
60
58
8
6
4
2
COASTAL
INLAND
Georgetown
300
200
100
0
3
6
9
12
400
300
200
100
0
3
6
9
12
Mean Monthly Rainfall (mm)
• Wernstedt Means
O Historical Data Base


PERU
AGROCLIMATIC REGIONS
EASTERN
NORTHERN MOUNTAINS
NORTHEAST MOUNTAINS
COASTAL
SOUTHERN MOUNTAINS
SE
Lima
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base


58
56
54
SURINAME
AGROCLIMATIC REGIONS
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base
300
200
100
0
3
6
9
12
Paramaribo
COASTAL
INLAND
6
4
2


VENEZUELA
AGROCLIMATIC REGIONS
NW
MOUNTAINS
Caracas
NE
CENTRAL
SOUTHERN
Mean Monthly Rainfall (mm)
Wernstedt Means
Historical Data Base
72
68
64
60
12
8
4

APPENDIX B

Mean monthly temperature (^{o}C), solar radiation (cal/cm^2 day), vapor pressure (mb), relative sunshine (%), wind speed (m/s), relative humidity (%), pan evaporation (mm/month) and solar radiation at the top of the atmosphere (cal/cm^2 day).

*** TEMPERATURE (C) DATA FOR SELECTED STATIONS ***
-- CENTRAL AND SOUTH AMERICA -***

OBS	COUNTRY	STATION	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
1	BELIZE	BELIZE INTERNATIONAL AIRPORT	23.5	24.8	26.1	27.2	27.6	28.3	27.6	28.3	27.4	28.1	26.1	24.7
2	BOLIVIA	APOLO	21.0	21.0	21.0	20.0	19.0	18.0	18.0	19.5	21.0	21.5	21.5	21.5
3	BOLIVIA	CAMIRI	25.7	25.1	24.4	21.3	19.2	17.2	17.8	18.6	23.9	25.5	25.9	26.0
4	BOLIVIA	CHARANA	9.7	9.7	9.5	8.2	5.9	3.4	3.4	4.8	6.8	9.0	10.5	10.5
5	BOLIVIA	COBIJA	25.6	25.2	25.3	24.4	23.7	22.7	22.3	23.9	25.6	26.0	25.6	25.8
6	BOLIVIA	COCHABAMBA	17.7	17.7	17.6	16.4	14.2	12.3	12.3	13.7	16.2	18.1	18.6	18.5
7	BOLIVIA	CONCEPCION	25.2	25.5	25.0	23.4	22.0	21.1	20.9	23.1	26.0	26.4	25.9	26.1
8	BOLIVIA	EL ALTO	9.2	8.8	8.8	9.0	8.3	7.3	7.5	8.1	8.6	9.9	10.1	9.3
9	BOLIVIA	LA PAZ	12.5	12.5	12.0	11.5	10.5	10.0	9.0	10.0	10.5	12.5	12.5	12.0
10	BOLIVIA	MAGDALENA	26.7	27.2	27.3	26.5	25.6	24.9	24.8	26.6	27.8	27.9	27.6	27.3
11	BOLIVIA	ORURO	12.2	11.9	11.9	10.3	6.9	4.3	4.1	5.9	8.6	11.3	12.4	12.6
12	BOLIVIA	PUERTO SUAREZ	28.0	27.9	27.6	24.9	22.9	21.5	20.8	23.4	26.3	27.8	27.6	28.7
13	BOLIVIA	RIBERALTA	26.4	26.5	26.6	26.1	25.9	25.3	25.2	26.6	27.7	27.3	27.1	27.0
14	BOLIVIA	ROBORE	27.8	28.0	26.9	24.7	23.1	22.2	21.4	24.3	27.2	27.9	27.9	28.8
15	BOLIVIA	RURRENABAQUE	26.4	26.7	26.7	25.6	24.1	22.7	22.2	23.8	26.2	26.9	27.1	27.4
16	BOLIVIA	SAN I. DE VELASCO	25.2	25.0	24.9	23.2	21.4	20.5	20.0	22.5	25.4	26.2	25.8	26.0
17	BOLIVIA	SAN JOAQUIN	26.5	24.0	26.7	26.2	25.4	24.9	24.8	26.2	27.7	27.7	27.4	27.3
18	BOLIVIA	SAN JOSE	26.6	26.7	26.9	24.8	22.4	21.4	21.8	23.9	26.5	27.4	27.1	27.3
19	BOLIVIA	SANTA CRUZ	25.4	25.7	25.1	22.6	20.9	19.1	19.7	21.3	23.7	24.3	25.2	26.1
20	BOLIVIA	TRINIDAD	26.8	27.3	27.5	25.9	24.7	23.6	23.5	25.2	27.2	27.5	27.5	27.8
21	BOLIVIA	YACUIBA	26.9	25.4	24.5	20.3	17.8	15.6	16.5	19.4	23.1	24.9	25.8	26.7
22	CHILE	ANTOFAGASTA/CERRO MORENO	19.9	20.1	18.5	16.2	15.1	13.5	13.1	13.5	14.5	15.2	16.8	18.4
23	CHILE	ARICA/CHACALLUTA	22.1	22.3	21.3	19.6	18.0	16.7	15.9	15.8	16.6	17.6	19.1	20.7
24	CHILE	CABO RAPER	11.0	11.0	10.0	9.0	8.0	7.0	6.0	6.0	6.0	8.0	9.0	10.0
25	CHILE	CONCEPCION	18.0	17.2	15.1	12.8	11.1	9.7	9.1	9.1	10.6	12.6	14.8	16.9
26	CHILE	CORRIDA DE CORI	-1.0	-1.5	-2.5	-5.0	-7.5	-10.0	-10.0	-9.0	-7.5	-6.5	-3.5	-1.5
27	CHILE	CRISTO REDENTOR	4.0	3.6	1.8	-0.6	-4.5	-5.9	-6.7	-6.5	-5.5	-3.5	-1.0	2.4
28	CHILE	EASTER ISLAND	23.0	23.0	23.0	22.0	21.0	18.0	18.0	18.0	18.0	19.0	20.0	22.0
29	CHILE	EVANGELISTAS	8.7	8.8	8.3	7.2	6.0	4.8	4.4	4.4	4.9	5.5	6.4	7.6
30	CHILE	IQUIQUE/CAVANCHA	20.9	20.8	19.7	18.3	17.2	16.0	15.4	15.4	16.1	17.1	18.5	19.8
31	CHILE	JUAN FERNANDEZ	19.0	19.0	17.0	17.0	16.0	14.0	13.0	12.0	13.0	13.0	15.0	17.0
32	CHILE	LA SERENA	18.2	18.4	16.9	14.9	13.4	12.1	11.7	12.0	12.7	14.0	15.5	17.0
33	CHILE	PUERTO MONTT /EL TEPUAL	15.2	14.8	13.2	11.2	9.3	8.0	7.6	7.8	8.8	10.6	12.2	13.9
34	CHILE	PUNTA ARENAS MAG.	11.7	10.6	8.9	6.7	4.2	2.5	2.5	2.9	4.6	7.1	8.5	10.2
35	CHILE	SAN PEDRO	11.2	11.2	10.0	8.5	6.8	6.1	5.7	5.5	6.4	7.8	8.8	10.2
36	CHILE	SANTIAGO	20.0	19.3	17.2	13.9	10.9	8.4	8.1	9.1	11.6	13.8	16.5	18.9
37	CHILE	VALDIVIA	17.0	16.4	14.5	11.8	9.7	8.2	7.7	8.0	9.3	11.5	13.3	15.3
38	CHILE	VALPARAISO	18.0	17.9	16.7	14.9	13.5	12.2	11.8	12.0	12.9	14.1	15.7	17.2
39	COLOMBIA	ANDAGOYA	26.8	27.2	27.6	27.5	27.4	27.1	27.2	27.3	27.2	27.0	26.7	27.0
40	COLOMBIA	ARAUCA	27.1	27.4	28.0	27.6	26.5	26.1	25.7	26.5	26.7	27.1	27.2	27.4
41	COLOMBIA	BAJO CALIMA	26.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	27.0	26.0	26.0	26.0
42	COLOMBIA	BARRANCABERMEJA	29.3	29.6	29.7	29.3	28.9	28.9	29.1	28.8	28.6	28.2	28.6	29.1
43	COLOMBIA	BARRANQUILLA	26.8	26.9	27.4	28.4	28.9	28.7	28.7	28.9	28.6	28.2	28.1	28.0
44	COLOMBIA	BOGOTA/EL DORADO	12.6	13.2	13.7	13.7	13.7	13.2	12.9	12.9	12.8	12.9	13.1	13.1
45	COLOMBIA	CARTAGENA	26.0	26.0	27.0	27.0	28.0	27.0	27.0	27.0	27.0	28.0	28.0	27.0
46	COLOMBIA	CHINACOTA	19.0	19.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.0
47	COLOMBIA	CHINCHINA	21.0	21.0	21.0	21.0	21.0	20.0	21.0	21.0	20.0	20.0	20.0	20.0
48	COLOMBIA	CONSACA	18.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	18.0	18.0
49	COLOMBIA	ESPINAL	28.0	28.2	27.7	27.3	27.3	27.6	28.1	28.5	28.5	27.3	27.1	27.6
50	COLOMBIA	LA FLORIDA	17.3	17.5	17.5	17.4	17.5	17.3	17.5	17.9	17.9	17.2	16.9	17.2
51	COLOMBIA	MANZANARES	19.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.0	19.0	19.0
52	COLOMBIA	MEDELLIN	21.2	21.7	21.9	21.8	21.7	21.7	21.5	21.4	21.3	21.1	21.1	20.9
53	COLOMBIA	PALMIRA	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0	24.0
54	COLOMBIA	PUEBLO BELLO	20.0	20.0	21.0	21.0	21.0	21.0	21.0	21.0	22.0	20.0	20.0	20.0
55	COLOMBIA	TUMACO	25.6	25.9	26.2	26.4	26.2	26.1	26.2	26.2	25.6	25.6	25.3	25.6

*** TEMPERATURE (C) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
56	COLOMBIA	TURBO	26.4	26.4	26.4	26.3	25.4	26.1	26.3	26.4	26.6	26.5	26.6	26.2
57	COLOMBIA	URIBIA	28.8	29.4	29.9	30.4	31.0	31.4	31.6	31.3	30.7	29.9	29.5	29.2
58	COLOMBIA	VILLAVICIENCIO	26.6	26.9	27.1	25.8	25.6	25.4	25.2	25.5	26.0	26.3	26.2	26.0
59	COLOMBIA	YOLOMBO	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	19.0	19.0	19.0
60	COSTA RICA	EL COCO/AERO****COSTA RI	22.0	22.8	23.5	23.8	23.1	22.5	22.5	22.5	22.3	22.0	22.1	22.1
61	COSTA RICA	LA COLA	24.0	24.0	25.0	25.0	26.0	26.0	26.0	26.0	26.0	26.0	25.0	25.0
62	COSTA RICA	OROTINA	27.2	27.4	28.4	28.3	27.1	25.6	25.4	26.0	25.6	25.5	25.7	26.1
63	COSTA RICA	SAN JOSE	19.0	19.3	20.3	21.0	21.4	21.2	20.6	20.8	20.9	20.6	19.9	19.3
64	COSTA RICA	TURRIALBA,I.I.C.A	20.0	20.0	21.0	24.0	23.0	23.0	22.0	22.0	22.0	22.0	22.0	21.0
65	COSTA RICA	VILLA MILLS	6.0	6.9	7.8	8.1	8.1	8.1	7.8	7.9	7.6	7.0	6.5	6.2
66	ECUADOR	AMBATO	14.4	14.3	14.4	14.4	13.8	13.3	12.6	12.7	13.4	14.3	14.6	14.7
67	ECUADOR	BAQUERIZO-S.C.	25.0	26.0	26.0	26.0	25.0	24.0	23.0	22.0	22.0	22.0	23.0	24.0
68	ECUADOR	CANAR	11.1	10.9	11.0	11.0	11.3	10.4	10.2	10.6	10.9	11.1	10.8	11.1
69	ECUADOR	ESMERALDAS	25.0	26.0	26.0	26.0	26.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
70	ECUADOR	GUAYAQUIL-AP	25.5	26.0	26.4	26.3	25.6	24.4	23.5	23.2	23.8	24.0	24.6	25.4
71	ECUADOR	IBARRA	15.9	16.0	16.2	16.2	16.2	16.0	16.0	16.0	16.3	16.0	15.8	15.9
72	ECUADOR	IZOBAMBA	12.0	12.0	11.5	11.5	12.0	11.5	11.5	11.5	12.0	11.5	11.5	12.0
73	ECUADOR	MANTA	26.0	26.0	26.0	26.0	25.0	24.0	23.0	23.0	23.0	24.0	24.0	25.0
74	ECUADOR	PICHILINGUE	25.5	26.0	26.0	26.0	25.5	24.0	23.0	23.5	24.5	24.5	24.5	25.5
75	ECUADOR	PORTOVIEJO	26.5	26.3	27.0	27.0	26.0	25.5	25.5	24.5	25.5	25.5	25.5	26.0
76	ECUADOR	PUYO	21.5	21.3	21.5	21.5	21.5	20.5	20.5	21.0	21.5	21.5	22.0	22.0
77	ECUADOR	QUITO-M SUCRE	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
78	ECUADOR	QUITO-OB	13.0	13.0	12.9	13.0	13.1	13.0	12.9	13.1	13.2	12.9	12.8	13.0
79	ECUADOR	RIOBAMBA	13.6	13.7	13.5	13.5	13.2	12.4	12.2	12.4	12.5	13.4	13.7	13.8
80	ECUADOR	SAN LORENZO	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
81	ECUADOR	TULCAN	11.0	11.1	11.2	11.3	11.4	10.7	10.2	10.1	10.6	11.2	11.4	11.4
82	EL SALVADOR	ACAJUTLA	25.8	26.4	27.5	28.2	28.0	27.0	26.9	26.9	26.4	26.3	26.4	26.0
83	EL SALVADOR	SAN SALVADOR	22.1	22.4	23.5	24.2	23.7	23.1	22.9	23.0	22.5	22.4	22.0	22.0
84	EL SALVADOR	SANTA CRUZ PORILLO	26.0	26.0	27.0	28.0	28.0	27.0	27.0	27.0	26.0	26.0	26.0	26.0
85	EL SALVADOR	SANTA TECLA	20.0	20.0	21.0	22.0	22.0	21.0	21.0	22.0	21.0	21.0	20.0	20.0
86	FR GUIANA	CAYENNE/ROCHAMBEAU	25.2	25.3	25.6	25.7	25.5	25.1	25.2	25.6	26.2	26.2	25.9	25.4
87	FR GUIANA	MARIPASOULA	24.5	24.3	24.8	25.1	25.0	24.7	24.8	25.3	25.6	26.0	26.0	25.2
88	GUATEMALA	COBAN	17.0	18.0	18.0	20.0	21.0	21.0	20.0	20.0	20.0	19.0	18.0	18.0
89	GUATEMALA	GUATEMALA CITY	16.3	17.0	18.4	19.5	19.6	18.7	18.5	18.7	18.3	17.7	16.7	16.3
90	GUYANA	GEORGETOWN	26.3	26.4	26.8	27.1	27.0	26.7	26.7	27.2	27.7	27.7	27.4	26.7
91	GUYANA	NEW AMSTERDAM	26.8	27.0	27.1	26.9	27.2	27.1	27.2	27.5	27.9	27.8	27.7	27.2
92	GUYANA	ST. IGNATIUS	27.7	27.9	28.2	28.1	27.4	26.7	26.5	27.2	28.5	29.1	28.8	28.4
93	HONDURAS	CATACAMAS	21.9	23.2	24.4	26.2	26.6	25.8	24.4	24.9	25.6	25.1	23.6	22.6
94	HONDURAS	SAN PEDRO SULA	23.1	24.3	25.9	27.4	28.1	27.9	27.1	27.6	27.7	26.3	25.2	23.7
95	HONDURAS	SANTA ROSA DE COPAN	17.2	18.7	20.2	21.8	21.9	21.9	21.1	21.4	21.4	20.5	18.9	17.2
96	HONDURAS	TEGUCIGALPA	19.3	20.3	21.9	23.3	23.6	23.1	22.5	22.8	22.9	22.1	20.7	19.6
97	HONDURAS	TELA	23.2	23.7	25.1	26.2	26.8	27.1	26.7	26.8	27.2	25.9	24.5	23.5
98	NICARAGUA	BLUEFIELDS	25.0	25.0	26.0	27.0	27.0	27.0	26.0	27.0	27.0	26.0	26.0	25.0
99	NICARAGUA	EL RECREO	27.0	28.0	29.0	30.0	30.0	29.0	29.0	28.0	30.0	29.0	28.0	27.0
100	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	26.3	27.2	28.6	29.3	29.4	27.2	26.9	27.2	26.9	26.5	26.3	26.1
101	NICARAGUA	PUERTO CABEZAS	25.0	25.0	26.0	27.0	27.0	27.0	26.0	27.0	27.0	27.0	26.0	25.0
102	PANAMA	BALBOA HEIGHTSALBROOF: AFB	26.6	26.9	27.6	27.9	27.2	26.8	26.9	26.8	26.6	26.2	26.2	26.6
103	PANAMA	CRISTOBAL	26.8	26.8	27.0	27.2	26.8	26.4	26.6	26.6	25.6	26.5	26.1	26.4
104	PANAMA	JAQUE	26.1	26.1	26.7	26.7	26.1	26.1	25.6	25.6	25.6	25.0	25.6	25.6
105	PERU	AREQUIPA	13.9	13.9	13.5	14.1	13.8	13.2	13.1	13.8	14.4	13.6	13.9	14.1
106	PERU	CAJAMARCA	15.0	15.0	15.0	15.0	14.0	13.0	13.0	14.0	14.0	15.0	15.0	15.0
107	PERU	CHICLAYO	23.5	25.0	25.0	23.5	22.0	20.5	19.5	19.0	19.5	19.5	20.5	22.0
108	PERU	CUSCO	14.0	14.0	14.0	13.0	11.0	11.0	10.0	11.0	13.0	14.0	14.0	14.0
109	PERU	EL ALTO	23.0	24.0	25.0	24.0	22.0	20.0	19.0	19.0	19.0	19.0	20.0	22.0
110	PERU	HUAYAO/HUANCAYO	12.0	12.0	12.0	12.0	11.0	10.0	10.0	11.0	12.0	12.0	12.0	12.0

*** TEMPERATURE (C) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
111	PERU	IMATA	5.0	6.0	5.0	4.0	2.0	0.0	0.0	0.0	2.0	3.0	4.0	5.0
112	PERU	IQUITOS	26.0	26.0	26.0	25.0	26.0	25.0	25.0	25.0	26.0	26.0	27.0	26.0
113	PERU	JAUJA	13.0	13.0	13.0	12.0	12.0	12.0	11.0	12.0	13.0	13.0	14.0	13.0
114	PERU	LAMBAYEQUE	23.0	24.0	24.0	22.0	21.0	19.0	18.0	18.0	18.0	19.0	20.0	21.0
115	PERU	LIMA-CALLAO/AP	21.5	22.3	21.9	20.1	17.8	16.0	15.3	15.1	15.4	16.3	17.7	19.4
116	PERU	LIMA/C. DE MARTE	21.0	22.0	22.0	20.0	18.0	16.0	15.0	15.0	15.0	16.0	17.0	19.0
117	PERU	PAUCARANY	4.0	4.0	4.0	2.0	0.0	-2.0	-1.0	0.0	1.0	2.0	2.0	3.0
118	PERU	PTO MALDONADO	26.0	26.0	25.5	25.5	25.0	23.0	23.0	25.0	26.0	26.0	26.5	26.0
119	PERU	PUNO	9.0	9.0	9.0	7.0	7.0	6.0	6.0	7.0	8.0	9.0	10.0	10.0
120	PERU	SAN JUAN	22.0	23.0	22.0	21.0	19.0	17.0	15.5	15.5	16.0	17.0	18.5	20.5
121	PERU	TACNA	21.5	22.0	21.0	18.5	16.0	14.5	13.5	14.5	15.5	16.5	18.5	20.0
122	PERU	TINGO MARIA	23.0	23.0	24.0	24.0	23.0	23.0	23.0	23.0	23.0	24.0	24.0	24.0
123	SURINAM	N.W.NICKERIE	26.5	26.7	26.9	27.2	27.2	27.1	27.2	27.8	28.3	28.1	27.9	27.1
124	SURINAM	PARAMARIBO	26.4	26.6	27.0	27.2	26.8	26.8	27.1	27.9	28.5	28.5	28.0	26.9
125	SURINAM	SIPALIWINI	26.1	26.1	26.0	26.4	26.3	26.3	26.5	27.1	27.9	28.6	27.7	27.1
126	SURINAM	TAFELBERG	24.9	24.9	25.3	25.5	25.4	25.3	25.7	26.4	27.0	27.3	26.8	25.7
127	SURINAM	ZANDERIJ	25.0	24.8	25.2	25.5	25.5	25.4	25.6	26.2	26.7	26.8	26.2	25.4
128	VENEZ	BARCELONA	25.2	25.5	26.4	27.2	27.8	26.7	26.0	26.2	26.7	27.0	26.5	25.9
129	VENEZ	BARQUISIMETO	23.0	23.0	24.0	25.0	24.0	24.0	23.0	24.0	24.0	24.0	24.0	23.0
130	VENEZ	CARACAS/CAGIGAL	19.2	19.7	20.7	21.7	22.0	21.5	21.1	21.6	21.8	21.5	20.8	19.9
131	VENEZ	CARACAS/CARLOTA	20.1	20.3	21.6	22.4	23.3	22.3	21.9	22.2	22.2	22.1	21.6	20.9
132	VENEZ	CIUDAD BOLIVAR	26.4	26.9	27.7	28.5	28.3	27.1	27.2	27.6	28.3	28.2	27.6	26.9
133	VENEZ	COLONIA TOVAR	15.7	16.1	17.0	17.5	17.5	16.7	16.5	16.9	17.1	17.1	16.9	16.2
134	VENEZ	GUIRIA	26.0	26.0	27.0	28.0	28.0	27.0	27.0	27.0	28.0	28.0	27.0	26.0
135	VENEZ	LA ORCHILA ISLAND	26.0	26.0	27.0	27.0	28.0	28.0	28.0	28.0	29.0	28.0	28.0	27.0
136	VENEZ	LAS PIEDRAS	26.9	27.2	27.7	28.6	29.2	29.5	29.5	30.2	30.3	29.5	28.6	27.2
137	VENEZ	MAIQUETIA	24.7	24.5	24.6	25.5	26.3	26.2	26.4	27.2	27.5	27.6	26.7	25.5
138	VENEZ	MARACAIBO/LA CH	26.8	26.9	27.2	27.8	28.4	28.6	28.6	28.8	28.7	28.1	27.9	27.4
139	VENEZ	MARACAY-B.A.SUCRE	23.3	23.9	25.1	26.0	26.0	24.8	23.9	24.3	24.5	24.4	24.3	23.8
140	VENEZ	MATURIN	25.0	25.0	26.0	27.0	27.0	26.0	26.0	26.0	26.0	26.0	26.0	25.0
141	VENEZ	MERIDA	17.7	18.2	19.0	19.2	19.4	19.1	18.3	19.3	19.4	19.0	18.4	18.0
142	VENEZ	PTO. AYACUCHO	28.5	29.3	29.5	28.1	26.6	25.4	25.2	25.7	26.3	26.8	27.3	27.7
143	VENEZ	SAN ANTONIO	23.8	24.6	25.6	26.1	26.8	26.8	26.8	27.2	27.4	26.3	25.2	24.3
144	VENEZ	SAN CARLOS DE RIO NEGRO	26.3	26.3	26.5	25.9	25.6	25.7	25.4	25.9	26.6	26.7	26.7	26.2
145	VENEZ	SAN FERNANDO	26.7	27.6	28.8	29.0	27.4	25.9	25.5	26.2	27.0	27.2	27.2	26.8
146	VENEZ	SANTA ELENA	21.6	22.0	22.4	22.3	22.0	21.4	20.9	21.2	21.4	21.8	21.7	21.5
147	VENEZ	TIMEREMOS	24.0	24.0	25.0	25.0	25.0	25.0	25.0	26.0	26.0	26.0	25.0	24.0

*** SOLAR RADIATION (CAL / CM2 DAY) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
1	COLOMBIA	BOGOTA/EL DORADO	453	445	418	375	377	393	407	413	415	355	386	401
2	ECUADOR	IZOBAMBA	364	354	349	322	353	348	362	383	385	358	359	362
3	ECUADOR	PICHILINGUE	314	333	330	339	289	238	228	247	267	257	248	264
4	ECUADOR	PORTOVIEJO	280	297	330	345	304	253	276	304	329	305	283	289
5	ECUADOR	PUYO	244	243	224	248	259	255	252	280	296	292	286	245
6	PANAMA	FT. SHERMAN	461	504	510	504	414	364	351	365	381	382	340	391
7	PERU	AREQUIPA	720	637	634	608	529	505	520	583	650	703	726	685
8	PERU	HUAYAO/HUANCAYO	634	577	563	563	531	540	542	580	617	642	667	620
9	VENEZ	BARCELONA	567	509	548	543	507	578	502	507	516	487	453	438
10	VENEZ	CORO	478	543	590	560	546	543	568	581	576	491	467	453
11	VENEZ	MERIDA	509	537	562	565	501	487	521	544	542	492	492	492
12	VENEZ	SAN FERNANDO	424	464	470	410	344	334	364	376	399	407	414	413
13	VENEZ	SANTA ELENA	448	479	509	512	427	416	442	465	502	479	456	415

*** VAPOR PRESSURE (MB) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	TV1	TV2	TV3	TV4	TV5	TV6	TV7	TV8	TV9	TV10	TV11	TV12
1	BELIZE	BELIZE INTERNATIONAL AIRPORT	24.2	23.3	25.7	28.7	28.7	29.7	30.0	30.4	30.3	29.2	26.8	23.7
2	CHILE	ANTOFAGASTA/CERRO MORENO	17.2	17.6	16.2	15.5	13.2	12.1	11.0	11.8	12.5	12.8	13.7	15.2
3	CHILE	ARICA/CHACALLUTA	19.2	20.7	19.7	17.1	15.7	14.6	14.2	15.3	14.9	15.5	16.4	18.1
4	CHILE	CONCEPCION	14.6	14.3	13.4	12.4	11.6	10.6	10.0	9.7	10.6	11.5	12.6	13.9
5	CHILE	CORRIDA DE CORI	3.0	3.0	2.5	1.5	1.0	1.0	1.0	1.0	1.0	1.5	2.0	2.5
6	CHILE	CRISTO REDENTOR	4.6	4.3	3.7	3.2	2.6	2.2	2.0	2.0	2.4	3.0	3.6	4.1
7	CHILE	EVANGELISTAS	9.8	9.9	9.4	8.9	8.2	7.6	7.3	7.3	7.6	7.6	8.3	9.2
8	CHILE	IQUIQUE/CAVANCHA	19.5	19.4	19.0	17.0	15.9	14.5	13.8	13.8	14.5	15.4	16.6	18.0
9	CHILE	LA SERENA	16.1	16.5	15.4	13.9	12.6	11.4	11.1	11.3	11.7	12.8	13.7	14.9
10	CHILE	PUERTO MONTT /EL TEPUALI	13.7	14.0	13.0	11.5	10.4	9.4	9.0	8.9	9.7	10.5	11.6	12.8
11	CHILE	PUNTA ARENAS MAG.	9.5	8.8	8.2	7.5	6.6	6.0	5.9	5.9	6.4	7.1	7.5	8.6
12	CHILE	SAN PEDRO	11.8	12.0	11.2	10.2	9.1	8.6	8.4	8.2	8.7	9.6	10.3	11.2
13	CHILE	SANTIAGO	13.8	14.1	13.5	11.6	10.6	9.2	9.0	9.4	10.5	11.4	12.0	12.9
14	CHILE	VALDIVIA	14.1	14.2	13.2	11.9	11.2	10.1	9.4	9.4	9.8	10.8	11.7	13.2
15	CHILE	VALPARAISO	14.9	15.2	14.4	13.2	12.4	11.4	11.1	11.1	11.6	12.1	12.7	13.7
16	COLOMBIA	BOGOTA/EL DORADO	10.8	10.5	11.3	11.8	11.8	11.2	10.5	10.7	10.5	11.7	11.8	11.7
17	COLOMBIA	LA FLORIDA	15.3	15.2	15.5	15.7	15.7	14.9	13.7	13.3	13.7	15.1	15.5	15.7
18	EL SALVADOR	ACAJUTLA	22.9	24.0	25.1	28.0	28.8	29.1	28.7	29.0	28.6	28.2	25.9	23.7
19	EL SALVADOR	SAN SALVADOR	13.0	12.9	13.8	15.5	17.1	17.5	17.1	17.1	17.4	16.7	14.6	13.6
20	FR GUIANA	CAYENNE/ROCHAMBEAU	27.6	27.3	27.3	28.0	28.6	28.2	27.5	27.5	27.3	27.2	27.6	28.1
21	FR GUIANA	MARIPASOULA	27.1	26.9	27.0	27.6	28.2	27.6	27.2	27.1	26.7	26.4	26.8	27.5
22	GUYANA	GEORGETOWN	27.4	26.8	26.9	28.1	29.0	29.3	29.0	29.4	29.2	29.2	29.2	28.3
23	GUYANA	NEW AMSTERDAM	26.0	25.5	24.9	26.0	27.7	27.1	27.5	27.3	28.3	28.1	27.6	27.3
24	SURINAM	PARAMARIBO	28.4	27.9	28.0	29.1	29.9	29.9	29.3	29.5	29.3	29.5	29.6	29.2

*** RELATIVE SUNSHINE (%) DATA FOR SELECTED STATIONS ***
-- CENTRAL AND SOUTH AMERICA -***

OBS	COUNTRY	STATION	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
1	BOLIVIA	EL ALTO	45	43	39	47	63	72	68	61	52	47	44	46
2	CHILE	ANTOFAGASTA/CERRO MORENO	78	80	65	63	57	57	55	49	50	43	49	66
3	CHILE	ARICA/CHACALLUTA	48	47	52	56	41	32	27	23	13	38	47	46
4	CHILE	CONCEPCION	58	61	54	46	31	25	32	39	44	55	57	63
5	CHILE	JUAN FERNANDEZ	57	56	41	36	33	33	30	31	41	51	60	58
6	CHILE	SANTIAGO	76	75	71	59	36	32	36	40	45	53	64	74
7	CHILE	VALDIVIA	56	60	53	37	22	17	22	28	31	31	44	45
8	CHILE	VALPARAISO	64	66	57	51	36	27	29	35	41	43	52	59
9	COLOMBIA	BAJO CALIMA	31	32	23	20	26	30	33	25	29	27	26	32
10	COLOMBIA	BOGOTA/EL DORADO	48	41	38	23	27	28	34	39	35	29	33	41
11	COLOMBIA	CARTAGENA	71	74	67	61	68	49	66	63	60	60	65	79
12	COLOMBIA	CHINACOTA	43	45	36	26	35	37	40	44	43	39	39	39
13	COLOMBIA	CHINCHINA	48	48	58	62	59	58	55	54	55	63	63	57
14	COLOMBIA	CONSACA	44	42	35	31	40	47	49	56	46	35	37	40
15	COLOMBIA	LA FLORIDA	48	47	41	33	36	41	46	52	45	37	35	43
16	COLOMBIA	MANZANARES	41	44	37	33	37	40	45	47	45	37	34	35
17	COLOMBIA	PALMIRA	57	56	53	45	45	53	55	55	50	46	47	44
18	COLOMBIA	PUEBLO BELLO	79	76	62	52	43	45	54	53	49	48	57	69
19	COLOMBIA	YOLOMBO	51	51	41	37	47	55	63	61	58	43	38	41
20	COSTA RICA	LA COLA	41	44	42	41	36	31	30	37	42	36	38	36
21	COSTA RICA	SAN JOSE	60	66	66	57	41	31	32	35	41	37	39	51
22	COSTA RICA	TURRIALBA.I.I.C.A	41	47	45	41	34	31	30	34	39	39	39	38
23	ECUADOR	AMBATO	46	42	37	40	39	34	33	33	38	44	46	47
24	ECUADOR	BAQUERIZO-S.C.	41	64	62	64	63	63	51	46	40	43	45	47
25	ECUADOR	CANAR	39	35	31	35	43	42	51	47	41	37	42	41
26	ECUADOR	GUAYAQUIL-AP	28	33	38	41	44	34	35	39	44	33	31	37
27	ECUADOR	IBARRA	44	41	36	34	43	41	45	49	45	40	40	42
28	ECUADOR	IZOBAMBA	44	41	35	33	43	41	51	51	46	41	42	44
29	ECUADOR	PICHILINGUE	21	24	27	31	23	15	13	17	17	14	14	17
30	ECUADOR	PORTOVIEJO	22	23	29	40	31	20	27	35	34	31	26	27
31	ECUADOR	PUYO	20	22	13	17	20	22	21	27	27	26	29	24
32	ECUADOR	QUITO-M SUCRE	44	41	36	39	44	52	59	59	70	45	47	47
33	ECUADOR	QUITO-OB	48	42	38	36	47	47	57	53	52	44	59	49
34	ECUADOR	RIOBAMBA	39	41	30	38	41	42	42	47	39	40	34	42
35	ECUADOR	SAN LORENZO	28	29	34	35	26	21	22	24	21	25	21	21
36	ECUADOR	TULCAN	34	30	30	25	34	32	34	37	34	31	30	29
37	EL SALVADOR	ACAJUTLA	86	86	81	70	62	53	65	67	56	64	79	86
38	EL SALVADOR	SAN SALVADOR	85	77	82	63	58	44	60	73	48	60	75	86
39	EL SALVADOR	SANTA CRUZ PORILLO	83	85	80	74	68	58	68	73	61	66	73	82
40	EL SALVADOR	SANTA TECLA	89	85	80	68	58	46	62	64	50	59	77	88
41	FR GUIANA	CAYENNE/ROCHAMBEAU	38	36	40	43	37	43	55	62	71	72	65	50
42	FR GUIANA	MARIPASOULA	41	42	44	50	41	45	56	73	68	74	62	51
43	GUYANA	GEORGETOWN	51	56	56	53	47	44	56	64	66	61	60	50
44	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	61	59	69	58	51	32	37	50	47	51	54	63
45	PANAMA	BALBOA HEIGHTSALBROOF: AFB	60	68	74	77	51	46	36	38	45	44	43	61
46	PANAMA	CRISTOBAL	69	64	74	64	50	40	40	45	45	46	41	59
47	PERU	AREQUIPA	55	53	65	83	82	87	83	86	82	79	80	82
48	PERU	CUSCO	36	34	45	59	67	67	73	65	54	52	51	39
49	PERU	EL ALTO	44	44	44	40	42	36	36	35	35	34	36	43
50	PERU	HUAYAO/HUANCAYO	46	43	46	55	64	74	73	66	55	54	55	51
51	PERU	LAMBAYEQUE	58	57	54	59	58	45	41	45	51	51	55	57
52	PERU	LIMA/C. DE MARTE	49	54	57	57	35	12	10	9	9	20	32	39
53	PERU	TINGO MARIA	29	29	30	36	44	46	50	57	46	43	37	31
54	SURINAM	PARAMARIBO	47	50	52	48	44	51	62	71	77	76	64	49
55	SURINAM	SIPALIWINI	42	35	40	37	36	33	62	61	77	79	56	42

*** RELATIVE SUNSHINE (%) DATA FOR SELECTED STATIONS ***
-- CENTRAL AND SOUTH AMERICA -***

OBS	COUNTRY	STATION	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
56	SURINAM	TAFELBERG	36	39	42	42	44	47	54	66	68	68	55	46
57	VENEZ	BARCELONA	84	86	82	73	67	56	61	62	69	73	75	78
58	VENEZ	BARQUISIMETO	67	65	64	49	47	52	56	59	60	55	63	62
59	VENEZ	CARACAS/CAGIGAL	64	69	64	53	51	51	56	58	59	58	58	59
60	VENEZ	CARACAS/CARLOTA	67	74	69	59	51	52	61	59	58	58	60	61
61	VENEZ	CIUDAD BOLIVAR	66	70	71	63	62	54	62	66	70	71	71	68
62	VENEZ	COLONIA TOVAR	54	61	52	39	34	34	35	41	43	42	40	49
63	VENEZ	GUIRIA	64	68	67	64	61	55	61	60	61	62	63	62
64	VENEZ	LA ORCHILA ISLAND	80	85	82	73	70	76	75	78	86	83	82	71
65	VENEZ	MAIQUETIA	60	66	64	53	57	59	65	68	66	57	57	55
66	VENEZ	MARACAIBO/LA CH	76	74	66	54	48	54	65	65	58	52	61	69
67	VENEZ	MARACAY-B.A.SUCRE	77	79	77	61	55	54	60	59	62	62	70	72
68	VENEZ	MATURIN	56	69	67	59	53	43	49	53	61	58	62	61
69	VENEZ	MERIDA	69	67	60	51	46	44	52	54	52	50	55	66
70	VENEZ	PTO. AYACUCHO	85	78	69	53	40	35	37	41	51	56	66	74
71	VENEZ	SAN ANTONIO	54	54	49	39	46	40	46	53	55	53	54	53
72	VENEZ	SAN FERNANDO	78	81	77	60	49	41	46	48	57	66	74	76
73	VENEZ	SANTA ELENA	54	58	54	50	42	38	45	50	66	65	58	53
74	VENEZ	TIMEREMOS	48	51	51	50	47	42	54	61	67	62	59	50

*** WIND SPEED (M / S) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
1	BOLIVIA	APOLO	3.1	2.7	2.2	2.2	2.2	2.7	2.7	2.7	2.7	3.1	2.7	2.7
2	BOLIVIA	EL ALTO	1.8	1.8	1.8	1.8	1.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2
3	BOLIVIA	LA PAZ	1.8	1.3	1.8	1.8	1.3	1.8	2.2	1.8	1.8	1.8	1.8	1.3
4	BOLIVIA	ORURO	2.7	2.2	2.2	1.8	1.8	1.8	1.8	2.2	2.2	2.2	2.2	2.7
5	BOLIVIA	SANTA CRUZ	4.4	4.0	3.6	3.6	4.0	5.3	5.8	5.8	5.8	5.3	4.4	4.4
6	BOLIVIA	YACUIBA	1.8	1.8	1.8	1.8	1.8	1.8	2.2	2.7	3.1	2.7	2.7	2.2
7	CHILE	ANTOFAGASTA/CERRO MORENO	4.0	4.0	4.0	4.0	2.0	4.0	2.0	2.0	2.0	4.0	4.0	4.0
8	CHILE	ARICA/CHACALLUTA	6.0	6.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	6.0
9	CHILE	CONCEPCION	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
10	CHILE	CORRIDA DE CORI	13.0	13.0	13.0	12.0	13.0	16.0	14.0	13.0	14.0	15.0	15.0	13.0
11	CHILE	CRISTO REDENTOR	8.3	8.3	8.0	7.8	7.5	8.0	7.2	7.5	7.5	7.2	8.0	9.2
12	CHILE	EVANGELISTAS	9.0	9.0	12.0	15.0	12.0	9.0	9.0	15.0	12.0	15.0	12.0	12.0
13	CHILE	IQUIQUE/CAVANCHA	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
14	CHILE	LA SERENA	2.0	2.0	2.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0	2.0	2.0
15	CHILE	PUERTO MONTT /EL TEPUAL	4.0	2.0	2.0	4.0	4.0	4.0	6.0	4.0	4.0	4.0	4.0	4.0
16	CHILE	PUNTA ARENAS MAG.	4.0	4.0	4.0	4.0	2.0	2.0	2.0	4.0	4.0	4.0	4.0	4.0
17	CHILE	SAN PEDRO	7.0	4.0	4.0	9.0	9.0	9.0	9.0	7.0	9.0	7.0	7.0	9.0
18	CHILE	SANTIAGO	2.0	2.0	2.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0	2.0	2.0
19	CHILE	VALDIVIA	2.0	2.0	2.0	2.0	2.0	4.0	2.0	4.0	2.0	1.0	2.0	2.0
20	CHILE	VALPARAISO	4.0	4.0	2.0	2.0	2.0	4.0	4.0	2.0	4.0	4.0	4.0	4.0
21	COLOMBIA	BARRANQUILLA	6.2	6.8	6.6	4.9	3.4	2.9	3.8	3.4	2.9	2.7	3.9	5.3
22	COLOMBIA	TURBO	3.8	4.7	4.0	3.6	2.9	3.8	2.9	3.1	3.1	3.8	2.7	4.7
23	ECUADOR	BAQUERIZO-S.C.	4.3	3.4	3.1	4.7	5.3	6.3	5.3	5.2	5.2	4.9	5.4	5.5
24	ECUADOR	GUAYAQUIL-AP	2.8	2.4	2.5	3.0	2.9	2.7	3.2	4.0	3.8	3.8	3.3	3.6
25	ECUADOR	IZOBAMBA	3.3	3.4	3.4	3.2	3.2	3.7	4.8	4.6	4.3	3.3	3.2	3.3
26	ECUADOR	PICHILINGUE	1.4	1.3	1.5	1.4	1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.5
27	ECUADOR	PORTOVIEJO	2.3	1.9	2.0	2.0	2.0	1.7	1.8	2.4	2.6	2.5	2.5	2.6
28	ECUADOR	PUYO	1.4	1.4	1.4	1.5	1.4	1.2	1.3	1.4	1.4	1.4	1.6	1.4
29	ECUADOR	QUITO-OB	0.7	0.8	0.8	0.7	0.8	1.0	1.3	1.4	1.1	0.7	0.7	0.7
30	EL SALVADOR	SAN SALVADOR	3.4	2.8	2.8	2.4	2.0	1.7	1.8	1.8	1.7	1.9	2.7	3.2
31	FR GUIANA	CAYENNE/ROCHAMBEAU	3.4	3.8	4.0	3.6	3.2	2.8	2.8	3.2	3.7	3.9	3.6	3.4
32	FR GUIANA	MARIPASOULA	1.7	1.8	2.2	1.7	1.5	1.3	1.3	1.3	1.3	1.6	1.6	1.5
33	GUYANA	GEORGETOWN	3.1	3.3	3.5	3.4	3.0	2.5	2.2	2.2	2.5	2.6	2.6	2.8
34	HONDURAS	TEGUCIGALPA	5.7	5.7	4.6	4.6	4.1	4.1	4.1	4.1	4.1	4.1	5.1	5.1
35	HONDURAS	TELA	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	2.6	2.6	2.6	2.6
36	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	4.3	4.8	4.8	4.7	4.1	3.1	3.5	3.4	2.7	2.3	2.8	3.5
37	PANAMA	BALBOA HEIGHTSALBROOK AFB	3.7	4.3	4.2	3.8	2.7	2.1	2.3	2.3	2.1	2.2	2.3	2.9
38	PANAMA	CRISTOBAL	5.5	5.9	5.7	5.4	3.4	2.5	3.2	3.0	2.4	2.3	2.9	4.5
39	PERU	AREQUIPA	3.6	3.1	3.1	3.1	3.6	4.0	4.0	4.0	3.6	3.6	3.1	3.6
40	PERU	CAJAMARCA	1.3	1.3	1.3	1.3	1.3	2.2	2.7	2.7	2.2	1.8	1.3	1.3
41	PERU	CHICLAYO	4.9	4.4	4.4	4.9	4.9	4.4	4.4	4.9	4.9	5.3	4.9	5.3
42	PERU	CUSCO	2.2	2.2	2.2	1.8	1.8	2.2	2.7	3.1	3.1	3.1	2.7	2.7
43	PERU	IQUITOS	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.3	0.9
44	PERU	LIMA-CALLAO/AP	3.1	2.7	2.7	2.7	2.2	1.8	2.2	2.7	2.7	2.7	3.1	3.1
45	PERU	PTO MALDONADO	2.2	2.2	1.8	2.2	1.8	1.8	1.8	2.2	2.2	2.2	2.2	2.2
46	PERU	SAN JUAN	4.4	4.4	4.4	4.4	4.9	4.9	4.9	5.3	5.3	5.3	4.9	5.3
47	PERU	TACNA	2.2	2.2	2.2	2.2	2.2	1.8	1.8	1.8	1.8	2.2	2.2	2.2
48	PERU	TINGO MARIA	0.4	0.4	0.9	0.4	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
49	SURINAM	PARAMARIBO	1.4	1.6	1.8	1.6	1.3	1.1	1.2	1.4	1.6	1.6	1.5	1.4
50	SURINAM	SIPALIWINI	1.1	1.1	1.0	1.1	0.8	0.7	0.9	0.7	1.0	1.2	1.1	1.1
51	SURINAM	TAFELBERG	1.3	1.3	1.1	0.9	1.0	1.1	1.1	1.2	1.3	1.3	0.9	1.1
52	VENEZ	BARCELONA	2.1	2.3	2.2	2.3	2.2	1.7	1.6	1.6	1.7	1.7	1.7	1.8
53	VENEZ	CARACAS/CAGIGAL	2.7	3.1	3.5	3.1	3.2	3.4	3.1	2.8	2.6	2.6	2.6	2.7
54	VENEZ	COLONIA TOVAR	1.0	0.9	0.9	0.8	0.7	0.8	0.8	0.7	0.7	0.7	0.8	0.8
55	VENEZ	MARACAIBO/LA CH	3.1	3.7	3.7	3.8	2.4	2.4	2.5	2.4	2.1	2.0	2.3	2.6

*** WIND SPEED (M / S) DATA FOR SELECTED STATIONS ***
*** CENTRAL AND SOUTH AMERICA ***

OBS	COUNTRY	STATION	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12
56	VENEZ	MERIDA	1.8	1.9	2.4	2.2	1.7	1.6	1.6	1.9	1.9	1.7	1.5	1.8
57	VENEZ	PTO. AYACUCHO	2.2	1.9	1.4	1.2	0.9	0.8	0.8	1.1	0.9	1.1	1.3	1.4
58	VENEZ	SAN FERNANDO	2.5	2.8	2.6	2.4	1.7	1.5	1.3	1.3	1.5	1.7	2.0	2.5
59	VENEZ	SANTA ELENA	1.3	1.4	1.5	1.4	1.1	0.9	0.9	0.9	1.0	1.1	1.0	1.1

*** RELATIVE HUMIDITY (%) DATA FOR SELECTED STATIONS ***
-- CENTRAL AND SOUTH AMERICA -***

OBS	COUNTRY	STATION	HR1	HR2	HR3	HR4	HR5	HR6	HR7	HR8	HR9	HR10	HR11	HR12
1	BOLIVIA	CAMIRI	69	71	72	73	71	71	61	52	47	52	56	63
2	BOLIVIA	CHARANA	54	59	52	40	35	34	33	34	36	36	38	42
3	BOLIVIA	COBIJA	86	88	86	86	85	83	81	75	75	80	83	84
4	BOLIVIA	COCHABAMBA	58	60	54	47	40	36	35	35	38	39	43	50
5	BOLIVIA	CONCEPCION	80	79	79	77	76	76	68	58	59	63	70	75
6	BOLIVIA	EL ALTO	71	73	70	66	52	45	52	48	56	61	60	64
7	BOLIVIA	LA PAZ	68	71	65	55	49	42	40	47	56	53	55	65
8	BOLIVIA	MAGDALENA	82	83	81	80	79	75	71	66	66	72	75	79
9	BOLIVIA	ORURO	54	54	48	41	34	30	29	32	39	34	36	43
10	BOLIVIA	PUERTO SUAREZ	76	76	73	74	75	77	69	62	58	61	66	69
11	BOLIVIA	RIBERALTA	82	84	83	83	80	77	70	64	66	75	78	80
12	BOLIVIA	ROBORE	71	71	71	72	72	70	63	55	53	61	65	65
13	BOLIVIA	RURRENABAQUE	83	81	80	80	81	81	80	75	71	73	76	78
14	BOLIVIA	SAN I. DE VELASCO	82	83	82	81	79	78	69	62	61	67	71	76
15	BOLIVIA	SAN JOAQUIN	82	82	80	80	78	75	70	63	65	72	76	79
16	BOLIVIA	SAN JOSE	74	73	71	69	70	72	64	61	60	61	66	68
17	BOLIVIA	SANTA CRUZ	75	74	73	75	77	78	70	62	60	66	66	69
18	BOLIVIA	TRINIDAD	82	81	79	78	77	76	73	68	56	72	74	77
19	BOLIVIA	YACUIBA	68	70	72	77	75	72	61	50	47	53	59	63
20	COLOMBIA	ANDAGOYA	74	77	75	74	82	82	85	85	85	86	82	82
21	COLOMBIA	ARAUCA	65	61	60	72	81	82	82	80	79	78	80	73
22	COLOMBIA	BARRANCABERMEJA	79	78	79	77	77	75	75	74	74	80	77	75
23	COLOMBIA	BARRANQUILLA	80	77	80	79	80	82	80	81	83	85	83	81
24	COLOMBIA	ESPINAL	70	70	72	76	78	75	66	64	69	73	74	72
25	COLOMBIA	MEDELLIN	65	64	66	71	73	68	65	64	67	73	73	70
26	COLOMBIA	TUMACO	86	86	87	85	86	86	85	86	86	86	85	86
27	COLOMBIA	TURBO	85	85	85	84	85	86	85	87	87	88	87	87
28	COLOMBIA	URIBIA	59	58	56	58	61	60	54	56	61	70	71	64
29	COLOMBIA	VILLAVICIENCIO	75	71	72	81	82	83	80	79	80	81	80	78
30	COSTA RICA	SAN JOSE	80	80	80	79	84	86	86	85	86	88	84	82
31	ECUADOR	BAQUERIZO-S.C.	80	80	81	80	78	77	79	79	79	77	75	78
32	ECUADOR	GUAYAQUIL-AP	78	81	81	78	78	79	78	76	75	74	74	72
33	ECUADOR	IZOBAMBA	82	83	83	85	82	79	74	72	75	82	84	82
34	ECUADOR	PICHILINGUE	86	86	87	87	87	88	87	84	82	81	80	80
35	ECUADOR	PORTOVIEJO	76	78	80	78	77	78	77	76	76	76	76	73
36	ECUADOR	PUYO	89	89	89	89	89	89	89	87	87	88	88	88
37	ECUADOR	QUITO-OB	81	81	82	84	80	76	70	69	72	81	82	81
38	GUATEMALA	GUATEMALA CITY	70	68	69	70	76	83	81	79	83	82	76	73
39	GUYANA	ST. IGNATIUS	64	63	60	64	72	80	79	74	64	60	64	64
40	HONDURAS	CATACAMAS	78	72	65	63	70	79	83	82	80	82	83	79
41	HONDURAS	SAN PEDRO SULA	83	77	76	73	75	79	81	80	80	83	86	87
42	HONDURAS	SANTA ROSA DE COPAN	86	79	75	71	77	82	83	82	84	86	89	90
43	PERU	AREQUIPA	57	63	59	49	37	29	27	26	29	30	34	44
44	PERU	CAJAMARCA	67	67	72	69	64	58	55	55	57	64	64	64
45	PERU	CHICLAYO	73	73	73	75	75	76	80	80	79	79	77	76
46	PERU	CUSCO	64	66	55	61	55	48	47	46	51	51	52	59
47	PERU	HUAYAO/HUANCAYO	73	78	77	72	65	57	56	55	61	64	62	68
48	PERU	IQUITOS	80	81	82	84	83	82	81	79	78	79	80	80
49	PERU	LIMA-CALLAO/AP	83	83	84	85	86	85	85	87	87	85	83	83
50	PERU	PTO MALDONADO	80	81	80	77	76	76	72	67	63	72	74	78
51	PERU	SAN JUAN	77	76	75	75	76	78	78	79	79	79	78	78
52	PERU	TACNA	65	65	66	70	76	79	78	78	77	74	70	67
53	PERU	TINGO MARIA	81	81	81	80	78	79	78	76	77	79	78	80
54	SURINAM	PARAMARIBO	82	80	78	81	85	85	82	78	75	76	78	82
55	SURINAM	SIPALIWINI	77	76	78	79	80	78	76	73	68	62	69	71

*** RELATIVE HUMIDITY (%) DATA FOR SELECTED STATIONS ***
-- CENTRAL AND SOUTH AMERICA -***

OBS	COUNTRY	STATION	HR1	HR2	HR3	HR4	HR5	HR6	HR7	HR8	HR9	HR10	HR11	HR12
56	SURINAM	TAFELBERG	83	81	80	80	82	82	79	76	72	70	74	78
57	VENEZ	BARCELONA	74	72	70	71	73	80	82	82	80	78	78	76
58	VENEZ	CARACAS/CAGIGAL	80	78	76	77	80	83	83	82	81	82	84	82
59	VENEZ	CARACAS/CARLOTA	81	78	76	77	80	82	83	83	83	83	84	83
60	VENEZ	CIUDAD BOLIVAR	78	73	71	70	74	80	80	79	77	77	78	79
61	VENEZ	COLONIA TOVAR	80	79	77	80	85	88	88	88	88	87	86	83
62	VENEZ	LAS PIEDRAS	13	10	5	3	24	10	5	19	31	74	80	39
63	VENEZ	MARACAIBO/LA CH	75	75	74	76	77	75	74	73	74	77	77	76
64	VENEZ	MARACAY-B.A.SUCRE	70	66	62	66	74	77	79	81	80	78	76	74
65	VENEZ	MERIDA	79	77	78	82	82	82	81	78	78	82	84	82
66	VENEZ	PTO. AYACUCHO	69	66	64	75	83	86	86	85	83	81	80	76
67	VENEZ	SAN ANTONIO	80	76	75	73	69	65	64	62	65	73	79	81
68	VENEZ	SAN FERNANDO	71	65	62	63	76	84	86	86	83	81	80	76
69	VENEZ	SANTA ELENA	79	77	75	80	85	89	89	88	84	81	83	82

*** PAN EVAPORATION (MM / MONTH) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -*

OBS	COUNTRY	STATION	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
1	COLOMBIA	BOGOTA/EL DORADO	40	42	42	36	37	41	46	45	47	34	33	34
2	COLOMBIA	LA FLORIDA	27	27	24	21	24	34	52	55	52	28	27	21
3	EL SALVADOR	SAN SALVADOR	214	223	236	189	146	87	87	87	63	90	151	202
4	FR GUIANA	CAYENNE/ROCHAMBEAU	75	78	99	88	66	60	76	92	115	126	105	80
5	FR GUIANA	MARIPASOULA	53	47	61	55	46	46	52	65	82	99	86	60
6	GUYANA	GEORGETOWN	105	118	144	136	116	94	108	128	144	142	119	97
7	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	286	297	392	380	325	141	166	170	125	114	144	231
8	PANAMA	BALBOA HEIGHTSALBROOF AFB	128	138	164	148	106	80	81	80	77	80	78	112
9	PANAMA	CRISTOBAL	117	129	147	145	108	93	82	85	85	89	80	104
10	PERU	LAKE TITICACA	96	54	137	146	131	144	130	140	118	129	140	115
11	SURINAM	PARAMARIBO	138	140	165	155	146	143	162	182	191	189	159	138
12	SURINAM	SIPALIWINI	134	125	143	137	140	149	168	171	192	194	151	138
13	SURINAM	TAFELBERG	125	122	148	144	145	142	155	178	175	177	147	135
14	SURINAM	ZANDERIJ	143	145	162	159	147	151	175	189	190	190	164	145
15	VENEZ	BARCELONA	156	162	180	175	147	105	90	82	93	109	106	123
16	VENEZ	CARACAS/CAGIGAL	81	91	114	100	100	88	87	82	82	78	60	71
17	VENEZ	COLONIA TOVAR	55	50	74	55	40	31	33	32	35	33	34	42
18	VENEZ	MARACAIBO/LA CH	148	147	173	161	132	124	141	145	129	111	108	134
19	VENEZ	MERIDA	84	84	91	70	65	58	70	81	80	67	57	69
20	VENEZ	PTO. AYACUCHO	166	165	163	94	58	43	43	47	51	60	75	98
21	VENEZ	SAN FERNANDO	182	213	270	216	121	66	55	54	61	78	95	138
22	VENEZ	SANTA ELENA	72	72	92	71	54	39	40	48	64	72	57	61

*** SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE (CAL/CM2 DAY) DATA FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	QA1	QA2	QA3	QA4	QA5	QA6	QA7	QA8	QA9	QA10	QA11	QA12
1	BELIZE	BELIZE INTERNATIONAL AIRPORT	642.5	726.9	839.0	931.5	988.3	1006.8	1005.5	971.4	899.7	788.3	682.8	623.4
2	BOLIVIA	APOLO	994.4	960.6	906.5	804.6	705.2	648.4	666.5	746.4	850.5	933.0	980.2	993.8
3	BOLIVIA	CAMIRI	1020.3	973.7	887.5	752.1	647.9	585.0	605.4	696.2	820.0	927.1	998.3	1024.6
4	BOLIVIA	CHARANA	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
5	BOLIVIA	COBIJA	969.1	959.5	916.7	834.3	747.8	696.4	712.5	782.7	868.5	932.8	960.9	964.7
6	BOLIVIA	COCHABAMBA	1005.5	971.4	899.7	788.3	682.8	623.4	642.5	726.9	839.0	931.5	988.3	1006.8
7	BOLIVIA	CONCEPCION	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
8	BOLIVIA	EL ALTO	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
9	BOLIVIA	LA PAZ	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
10	BOLIVIA	MAGDALENA	982.2	964.6	912.1	819.9	726.9	672.7	689.8	765.0	859.1	933.5	971.1	979.7
11	BOLIVIA	ORURO	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
12	BOLIVIA	PUERTO SUAREZ	1015.6	973.2	891.8	771.0	659.7	597.9	617.9	706.7	826.6	928.8	995.3	1018.9
13	BOLIVIA	RIBERALTA	969.1	959.5	916.7	834.3	747.8	696.4	712.5	782.7	868.5	932.8	960.9	964.7
14	BOLIVIA	ROBORE	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
15	BOLIVIA	RURRENABAQUE	988.4	966.7	909.4	812.4	716.1	660.6	678.2	755.8	854.1	933.4	975.8	986.9
16	BOLIVIA	SAN I. DE VELASCO	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
17	BOLIVIA	SAN JOAQUIN	982.2	964.6	912.1	819.9	726.9	672.7	689.8	765.0	859.1	933.5	971.1	979.7
18	BOLIVIA	SAN JOSE	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
19	BOLIVIA	SANTA CRUZ	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
20	BOLIVIA	TRINIDAD	994.4	968.6	906.5	804.6	705.2	648.4	666.5	746.4	850.5	933.0	980.2	993.8
21	BOLIVIA	YACUIBA	1028.8	973.7	878.0	743.5	623.8	558.8	579.9	674.8	806.0	922.8	1003.7	1035.2
22	CHILE	ANTOFAGASTA/CERRO MORENO	1032.7	973.4	872.9	733.9	611.5	545.5	567.0	663.8	798.7	920.2	1006.0	1040.1
23	CHILE	ARICA/CHACALLUTA	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
24	CHILE	CABO RAPER	1022.0	848.0	608.0	447.0	275.0	205.0	233.0	379.0	600.0	766.0	966.0	1057.0
25	CHILE	CONCEPCION	1058.3	939.6	773.9	578.5	426.3	352.7	377.8	493.0	671.7	856.2	1008.9	1081.0
26	CHILE	CORRIDA DE CORI	1039.7	971.8	861.8	714.1	586.5	518.6	540.9	641.3	783.3	914.2	1009.8	1049.1
27	CHILE	CRISTO REDENTOR	1055.5	954.6	807.2	626.6	481.3	409.3	432.1	544.7	712.4	879.7	1014.5	1073.7
28	CHILE	EASTER ISLAND	1045.6	969.1	849.7	693.4	560.9	491.3	514.2	618.1	765.9	907.2	1012.6	1057.2
29	CHILE	IQUIQUE/CAVANCHA	1020.3	973.7	887.5	762.1	647.9	585.0	605.4	696.2	820.0	927.1	998.3	1024.6
30	CHILE	JUAN FERNANDEZ	1056.6	951.2	799.2	614.9	467.7	395.2	418.2	532.0	702.5	874.2	1013.9	1075.8
31	CHILE	LA SERENA	1052.6	963.1	829.6	660.9	521.7	449.8	473.5	582.1	740.7	894.7	1014.7	1065.7
32	CHILE	PUERTO MONTT /EL TEPUAL	1057.3	920.5	736.9	527.8	371.8	295.9	321.2	439.4	627.7	828.8	1001.0	1084.7
33	CHILE	SAN PEDRO	1022.0	842.0	597.0	434.0	262.0	192.0	220.0	365.0	589.0	758.0	944.0	1057.0
34	CHILE	SANTIAGO	1055.5	954.6	807.2	626.6	481.3	409.3	432.1	544.7	712.4	879.7	1014.5	1073.7
35	CHILE	VALDIVIA	1057.9	925.6	746.5	540.7	385.9	310.1	335.4	452.9	639.0	836.0	1003.3	1084.1
36	CHILE	VALPARAISO	1055.5	954.6	807.2	626.6	481.3	409.3	432.1	544.7	712.4	879.7	1014.5	1073.7
37	COLOMBIA	ANDAGOYA	776.3	830.6	890.2	924.2	924.2	913.8	923.6	937.6	923.6	869.7	805.8	763.6
38	COLOMBIA	ARAUCA	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9
39	COLOMBIA	BAJO CALIMA	786.2	837.8	892.9	921.8	917.1	904.5	915.1	933.0	923.8	875.0	814.7	774.1
40	COLOMBIA	BARRANCABERMEJA	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9
41	COLOMBIA	BARRANQUILLA	712.5	782.7	868.5	932.8	960.9	964.7	969.1	959.5	916.7	834.3	747.8	696.4
42	COLOMBIA	BOGOTA/EL DORADO	776.3	830.6	890.2	924.2	924.2	913.8	923.6	937.6	923.6	869.7	805.8	763.6

*** SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE (CAL/CM2 DAY) DATA FOR SELECTED STATIONS ***
*** CENTRAL AND SOUTH AMERICA ***

OBS	COUNTRY	STATION	QA1	QA2	QA3	QA4	QA5	QA6	QA7	QA8	QA9	QA10	QA11	QA12
56	COLOMBIA	VILLAVICIENCIO	786.2	837.8	892.9	921.8	917.1	904.5	915.1	933.0	923.8	875.0	814.7	774.1
57	COLOMBIA	YOLOMBO	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9
58	COSTA RICA	EL COCO/AERO****COSTA RI	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
59	COSTA RICA	LA COLA	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
60	COSTA RICA	OROTINA	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
61	COSTA RICA	SAN JOSE	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
62	COSTA RICA	TURRIALBA.I.I.C.A	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
63	COSTA RICA	VILLA MILLS	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
64	ECUADOR	AMBATO	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
65	ECUADOR	BAQUERIZO-S.C.	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
66	ECUADOR	CANAR	906.5	928.1	923.7	880.1	823.4	784.5	796.0	843.0	895.3	919.1	909.9	895.0
67	ECUADOR	ESMERALDAS	813.2	856.2	899.3	912.9	894.6	875.3	888.4	917.6	922.6	889.4	838.4	803.0
68	ECUADOR	GUAYAQUIL-AP	897.6	923.0	923.3	884.9	830.2	793.0	803.9	849.7	897.5	916.1	902.4	885.3
69	ECUADOR	IBARRA	813.2	856.2	899.3	912.9	894.6	875.3	888.4	917.6	922.6	889.4	838.4	803.0
70	ECUADOR	IZOBAMBA	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
71	ECUADOR	MANTA	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
72	ECUADOR	PICHILINGUE	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
73	ECUADOR	PORTOVIEJO	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
74	ECUADOR	PUYO	897.6	923.0	923.3	884.9	830.2	793.0	803.9	849.7	897.5	916.1	902.4	885.3
75	ECUADOR	QUITO-M SUCRE	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
76	ECUADOR	QUITO-OB	888.4	917.6	922.6	889.4	838.4	803.0	813.2	856.2	899.3	912.9	894.6	875.3
77	ECUADOR	RIOBAMBA	897.6	923.0	923.3	884.9	830.2	793.0	803.9	849.7	897.5	916.1	902.4	885.3
78	ECUADOR	SAN LORENZO	813.2	856.2	899.3	912.9	894.6	875.3	888.4	917.6	922.6	889.4	838.4	803.0
79	ECUADOR	TULCAN	813.2	856.2	899.3	912.9	894.6	875.3	888.4	917.6	922.6	889.4	838.4	803.0
80	EL SALVADOR	ACAJUTLA	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
81	EL SALVADOR	SAN SALVADOR	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
82	EL SALVADOR	SANTA CRUZ PORILLO	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
83	EL SALVADOR	SANTA TECLA	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
84	FR GUIANA	CAYENNE/ROCHAMBEAU	776.3	830.6	890.2	924.2	924.2	913.8	923.6	937.6	923.6	869.7	305.8	763.6
85	FR GUIANA	MARIPASOULA	786.2	837.8	892.9	921.8	917.1	904.5	915.1	933.0	923.8	875.0	814.7	774.1
86	GUATEMALA	COBAN	666.5	746.4	850.5	933.0	980.2	993.8	994.4	968.6	906.5	804.6	705.2	648.4
87	GUATEMALA	GUATEMALA CITY	666.5	746.4	850.5	933.0	980.2	993.8	994.4	968.6	906.5	804.6	705.2	648.4
88	GUYANA	GEORGETOWN	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9
89	GUYANA	NEW AMSTERDAM	766.1	823.2	887.3	926.3	930.9	922.9	931.8	941.9	923.2	865.9	796.6	752.8
90	GUYANA	ST. IGNATIUS	796.0	843.0	895.3	919.1	909.9	895.0	906.5	928.1	923.7	880.1	823.4	784.5
91	HONDURAS	CATACAMAS	666.5	746.4	850.5	933.0	980.2	993.8	994.4	968.6	906.5	804.6	705.2	648.4
92	HONDURAS	SAN PEDRO SULA	666.5	746.4	850.5	933.0	980.2	993.8	994.4	968.6	906.5	804.6	705.2	648.4
93	HONDURAS	SANTA ROSA DE COPAN	666.5	746.4	850.5	933.0	980.2	993.8	994.4	968.6	906.5	804.6	705.2	648.4
94	HONDURAS	TEGUCIGALPA	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
95	HONDURAS	TELA	654.6	736.7	844.9	932.4	984.4	1000.4	1000.1	970.2	903.2	796.5	694.1	636.0
96	NICARAGUA	BLUEFIELDS	701.3	774.0	864.0	933.3	966.1	972.3	975.8	962.2	914.5	827.2	737.4	684.6
97	NICARAGUA	EL RECREO	701.3	774.0	864.0	933.3	966.1	972.3	975.8	962.2	914.5	827.2	737.4	684.6
98	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	701.3	774.0	864.0	933.3	966.1	972.3	975.8	962.2	914.5	827.2	737.4	684.6
99	NICARAGUA	PUERTO CABEZAS	678.2	755.8	854.1	933.4	975.8	986.9	988.4	966.7	909.4	812.4	716.1	660.6
100	PANAMA	BALBOA HEIGHTSALBROOF AFB	734.5	799.6	876.8	931.1	949.7	948.7	954.9	953.3	920.1	847.7	768.0	719.5
101	PANAMA	CRISTOBAL	734.5	799.6	876.8	931.1	949.7	948.7	954.9	953.3	920.1	847.7	768.0	719.5
102	PANAMA	FT. SHERMAN	734.5	799.6	876.8	931.1	949.7	948.7	954.9	953.3	920.1	847.7	768.0	719.5
103	PANAMA	JAQUE	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9
104	PERU	AREQUIPA	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
105	PERU	CAJAMARCA	939.7	946.0	922.4	860.1	787.3	741.9	755.8	815.6	884.1	928.2	937.4	931.7
106	PERU	CHICLAYO	939.7	946.0	922.4	860.1	787.3	741.9	755.8	815.6	884.1	928.2	937.4	931.7
107	PERU	CUSCO	988.4	966.7	909.4	812.4	716.1	660.6	678.2	755.8	854.1	933.4	975.8	986.9
108	PERU	EL ALTO	915.1	933.0	923.8	875.0	814.7	774.1	786.2	837.8	892.9	921.8	917.1	904.5
109	PERU	HUAYAO/HUANCAYO	975.8	962.6	914.5	827.2	737.4	684.6	701.3	774.0	864.0	933.3	966.1	972.3
110	PERU	IMATA	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4

*** SOLAR RADIATION AT THE TOP OF THE ATMOSPHERE (CAL/CM2 DAY) DATA FOR SELECTED STATIONS ***
*** CENTRAL AND SOUTH AMERICA ***

OBS	COUNTRY	STATION	QA1	QA2	QA3	QA4	QA5	QA6	QA7	QA8	QA9	QA10	QA11	QA12
111	PERU	IQUITOS	915.1	933.0	923.8	875.0	814.7	774.1	786.2	837.8	892.9	921.8	917.1	904.5
112	PERU	JAUJA	975.8	962.2	914.5	827.2	737.4	684.6	701.3	774.0	864.0	933.3	966.1	972.3
113	PERU	LAKE TITICACA	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
114	PERU	LAMBAYEQUE	939.7	946.0	922.4	860.1	787.3	741.9	755.8	815.6	884.1	928.2	937.4	931.7
115	PERU	LIMA-CALLAO/AP	975.8	962.6	914.5	827.2	737.4	684.6	701.3	774.0	864.0	933.3	966.1	972.3
116	PERU	LIMA/C. DE MARTE	975.8	962.6	914.5	827.2	737.4	684.6	701.3	774.0	864.0	933.3	966.1	972.3
117	PERU	PAUCARANY	1005.5	971.4	899.7	788.3	682.8	623.4	642.5	726.9	839.0	931.5	988.3	1006.8
118	PERU	PTO MALDONADO	982.2	964.6	912.1	819.9	726.9	672.7	689.8	765.0	859.1	933.5	971.1	979.7
119	PERU	PUNO	1000.1	970.2	903.2	796.5	694.1	636.0	654.6	736.7	844.9	932.4	984.4	1000.4
120	PERU	SAN JUAN	994.4	968.6	906.5	804.6	705.2	648.4	666.5	746.4	850.5	933.0	980.2	993.6
121	PERU	TACNA	1010.7	972.5	895.9	779.8	671.3	610.8	630.3	716.9	832.9	930.3	991.9	1013.0
122	PERU	TINGO MARIA	954.9	953.3	920.1	847.7	768.0	719.5	734.5	799.6	876.8	931.1	949.7	948.7
123	SURINAM	N.W.NICKERIE	766.1	823.2	887.3	926.3	930.9	922.9	931.8	941.9	923.2	865.9	796.6	752.8
124	SURINAM	PARAMARIBO	766.1	823.2	887.3	926.3	930.9	922.9	931.8	941.9	923.2	865.9	796.6	752.8
125	SURINAM	SIPALIWINI	803.9	849.7	897.5	916.1	920.4	885.3	897.6	923.0	923.3	884.9	830.2	793.0
126	SURINAM	TAFELBERG	786.2	837.8	892.9	921.8	917.0	904.5	915.1	933.0	923.8	875.0	814.7	774.1
127	SURINAM	ZANDERIJ	776.3	830.6	890.2	924.2	924.2	913.8	923.6	937.6	923.6	869.7	805.8	763.6
128	VENEZ	BARCELONA	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
129	VENEZ	BARQUISIMETO	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
130	VENEZ	CARACAS/CAGIGAL	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
131	VENEZ	CARACAS/CARLOTA	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
132	VENEZ	CIUDAD BOLIVAR	745.2	807.7	880.6	929.7	943.7	940.3	947.4	949.8	921.4	854.0	777.7	730.8
133	VENEZ	COLONIA TOVAR	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
134	VENEZ	CORO	712.5	782.7	868.5	932.8	960.9	964.7	969.1	959.5	916.7	834.3	747.8	696.4
135	VENEZ	GUIRIA	712.5	782.7	868.5	932.8	960.9	964.7	969.1	959.5	916.7	834.3	747.8	696.4
136	VENEZ	LA ORCHILA ISLAND	701.3	774.0	864.0	933.3	966.1	972.3	975.8	962.2	914.5	827.2	737.4	684.6
137	VENEZ	LAS PIEDRAS	701.3	774.0	864.0	933.3	966.1	972.3	975.8	962.2	914.5	827.2	737.4	684.6
138	VENEZ	MAIQUETIA	712.5	782.7	868.5	932.8	960.9	964.7	969.1	959.5	916.7	834.3	747.8	696.4
139	VENEZ	MARACAIBO/LA CH	712.5	782.7	868.5	932.8	960.9	964.7	969.1	959.5	916.7	834.3	747.8	696.4
140	VENEZ	MARACAY-B.A.SUCRE	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
141	VENEZ	MATURIN	723.6	791.3	872.8	932.1	955.4	956.8	962.1	956.5	918.5	841.1	758.0	708.0
142	VENEZ	MERIDA	734.5	799.6	876.8	931.1	949.7	948.7	954.9	953.3	920.1	847.7	768.0	719.5
143	VENEZ	PTO. AYACUCHO	766.1	823.2	887.3	926.3	930.9	922.9	931.8	941.9	923.2	865.9	796.6	752.8
144	VENEZ	SAN ANTONIO	745.2	807.7	880.6	929.7	943.7	940.3	947.4	949.8	921.4	854.0	777.7	730.8
145	VENEZ	SAN CARLOS DE RIO NEGRO	803.9	849.7	897.5	916.1	902.4	885.3	897.6	923.0	923.3	884.9	830.2	793.0
146	VENEZ	SAN FERNANDO	745.2	807.7	880.6	929.7	943.7	940.3	947.4	949.8	921.4	854.0	777.7	730.8
147	VENEZ	SANTA ELENA	776.3	830.6	890.2	924.2	924.2	913.8	923.6	937.6	923.6	869.7	805.8	763.6
148	VENEZ	TIMEREMOS	755.8	815.6	884.1	928.2	937.4	931.7	939.7	946.0	922.4	860.1	787.3	741.9

APPENDIX C

POTENTIAL EVAPOTRANSPIRATION NORMALS AND CLIMATIC DIAGRAMS

Tables in this appendix contain potential evapotranspiration estimates (mm/month) by Penman, Thornthwaite and Hargreaves methods. In addition, climatic diagrams for selected stations are included.

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY PENMAN METHOD FOR SELECTED STATIONS ***
*** CENTRAL AND SOUTH AMERICA ***

OBS	COUNTRY	STATION	PENMAN1	PENMAN2	PENMAN3	PENMAN4	PENMAN5	PENMAN6	PENMAN7	PENMAN8	PENMAN9	PENMAN10	PENMAN11	PENMAN12
1	BOLIVIA	EL ALTO	119	102	100	82	64	49	56	73	91	110	114	120
2	CHILE	ANTOFAGASTA/CERRO MORENO	168	142	123	86	60	48	49	67	89	116	133	157
3	CHILE	ARICA/CHACALLUTA	142	119	115	93	66	50	50	55	61	98	117	134
4	CHILE	CONCEPCION	143	110	84	45	24	15	16	31	57	95	122	148
5	CHILE	SANTIAGO	163	127	104	57	34	22	24	42	70	106	136	163
6	CHILE	VALDIVIA	132	101	73	32	12	6	6	21	41	67	101	120
7	CHILE	VALPARAISO	147	117	90	53	31	25	28	39	66	96	123	145
8	ECUADOR	BAQUERIZO-S.C.	133	139	152	149	144	134	124	125	125	134	134	138
9	ECUADOR	GUAYAQUIL-AP	99	96	114	112	108	86	91	105	114	110	102	116
10	ECUADOR	IZOBAMBA	93	87	93	84	85	77	88	95	96	95	89	91
11	ECUADOR	PICHILINGUE	74	75	88	87	72	53	52	63	67	66	63	70
12	ECUADOR	PORTOVIEJO	87	79	99	109	91	67	80	97	101	101	89	95
13	ECUADOR	PUYO	66	65	58	59	60	56	58	71	74	77	79	72
14	ECUADOR	QUITO-OB	92	84	92	83	84	76	83	89	93	94	95	90
15	EL SALVADOR	SAN SALVADOR	101	103	141	146	151	137	151	153	124	116	100	95
16	FR GUIANA	CAYENNE/ROCHAMBEAU	103	102	127	128	124	122	139	150	155	151	126	108
17	FR GUIANA	MARIPASOULA	101	100	122	127	122	119	134	152	143	144	121	107
18	GUYANA	GEORGETOWN	114	117	145	146	143	131	147	157	153	143	123	111
19	PERU	AREQUIPA	138	117	120	96	77	59	66	85	106	127	133	147
20	PERU	CUSCO	119	103	110	90	72	59	64	84	102	121	122	123
21	PERU	TINGO MARIA	91	82	91	84	83	75	82	98	97	108	100	96
22	SURINAM	PARAMARIBO	107	109	135	134	132	132	149	163	162	155	126	107
23	SURINAM	SIPALIWINI	110	104	123	121	123	112	139	144	154	156	124	113
24	SURINAM	TAFELBERG	101	100	122	122	127	123	135	150	147	144	117	106
25	VENEZ	BARCELONA	117	122	155	161	169	148	154	155	150	143	120	113
26	VENEZ	CARACAS/CAGIGAL	92	99	128	130	138	132	138	139	129	117	96	89
27	VENEZ	COLONIA TOVAR	71	77	96	96	99	95	99	103	95	86	71	67
28	VENEZ	MARACAIBO/LA CH	125	129	158	159	159	160	176	175	154	136	122	119
29	VENEZ	MERIDA	89	93	119	119	123	117	126	129	118	107	90	86
30	VENEZ	PTO. AYACUCHO	143	139	158	141	129	116	122	129	131	131	123	125
31	VENEZ	SAN FERNANDO	129	137	171	165	149	130	137	141	142	142	128	125
32	VENEZ	SANTA ELENA	100	102	123	122	119	109	118	124	128	122	103	97

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY THORNTHWAITE METHOD FOR SELECTED STATIONS ***
*** CENTRAL AND SOUTH AMERICA ***

OBS	COUNTRY	STATION	THORT1	THORT2	THORT3	THORT4	THORT5	THORT6	THORT7	THORT8	THORT9	THORT10	THORT11	THORT12
1	BELIZE	BELIZE INTERNATIONAL AIRPORT	85	104	126	147	155	170	155	170	151	166	126	102
2	BOLIVIA	APOLO	81	81	81	73	65	58	58	69	81	86	86	86
3	BOLIVIA	CAMIRI	125	118	109	76	58	43	47	53	103	123	128	129
4	BOLIVIA	CHARANA	56	56	55	48	36	22	22	30	41	52	60	60
5	BOLIVIA	COBIJA	122	116	117	104	95	83	79	98	122	128	122	125
6	BOLIVIA	COCHABAMBA	70	70	69	62	49	39	39	46	61	73	76	75
7	BOLIVIA	CONCEPCION	117	121	114	93	77	68	66	89	128	134	127	130
8	BOLIVIA	EL ALTO	49	47	47	48	45	40	41	44	46	53	54	50
9	BOLIVIA	LA PAZ	57	57	54	52	47	44	39	44	47	57	57	55
10	BOLIVIA	MAGDALENA	137	147	149	133	116	105	103	135	159	162	155	149
11	BOLIVIA	ORURO	62	60	60	52	34	21	20	29	43	57	63	64
12	BOLIVIA	PUERTO SUAREZ	163	161	155	109	81	65	58	88	131	159	155	178
13	BOLIVIA	RIBERALTA	132	133	135	126	122	112	111	135	157	149	145	143
14	BOLIVIA	ROBORE	159	163	142	105	83	72	63	99	147	161	161	180
15	BOLIVIA	RURRENABAQUE	133	138	138	120	98	80	74	94	130	142	146	151
16	BOLIVIA	SAN I. DE VELASCO	117	115	112	92	72	64	59	84	120	131	126	129
17	BOLIVIA	SAN JOAQUIN	134	93	137	128	115	107	105	128	157	157	151	149
18	BOLIVIA	SAN JOSE	137	139	140	108	77	66	71	96	135	151	146	149
19	BOLIVIA	SANTA CRUZ	121	125	117	87	70	54	59	74	99	107	118	130
20	BOLIVIA	TRINIDAD	140	149	153	123	104	90	86	111	147	153	153	159
21	BOLIVIA	YACUIBA	141	122	111	68	48	34	40	60	95	116	127	139
22	CHILE	ANTOFAGASTA/CERRO MORENO	85	86	75	60	54	45	43	45	50	54	64	74
23	CHILE	ARICA/CHACALLUTA	94	96	86	74	63	54	49	49	54	60	71	83
24	CHILE	CABO RAPER	60	60	54	49	44	39	34	34	34	44	50	55
25	CHILE	CONCEPCION	81	77	64	52	43	36	33	33	40	51	63	75
26	CHILE	EASTER ISLAND	99	99	99	85	80	57	57	57	57	65	72	90
27	CHILE	IQUIQUE/CAVANCHA	87	86	78	69	61	53	49	50	54	60	70	79
28	CHILE	JUAN FERNANDEZ	81	81	68	68	62	50	45	40	45	45	56	68
29	CHILE	LA SERENA	78	79	70	58	49	42	40	42	46	53	61	70
30	CHILE	PUERTO MONTT /EL TEPUAL	72	70	61	51	41	34	32	33	38	48	56	65
31	CHILE	SAN PEDRO	62	61	55	47	39	35	33	32	37	44	49	57
32	CHILE	SANTIAGO	91	86	73	54	38	26	25	30	42	54	69	84
33	CHILE	VALDIVIA	79	76	65	51	40	32	30	31	38	49	59	70
34	CHILE	VALPARAISO	77	76	68	58	50	43	41	42	47	53	63	72
35	COLOMBIA	ANDAGOYA	138	146	155	152	150	144	146	148	146	142	136	142
36	COLOMBIA	ARAUCA	144	151	164	155	132	125	117	132	136	144	146	151
37	COLOMBIA	BAJO CALIMA	124	143	143	143	143	143	143	143	143	124	124	124
38	COLOMBIA	BARRANCABERMEJA	199	209	212	199	186	186	192	183	177	166	177	192
39	COLOMBIA	BARRANQUILLA	135	137	148	173	186	181	181	187	178	168	165	163
40	COLOMBIA	BOGOTA/EL DORADO	51	54	57	57	57	54	53	53	52	53	54	54
41	COLOMBIA	CARTAGENA	122	122	142	142	164	142	142	142	142	164	164	142
42	COLOMBIA	CHINACOTA	67	67	75	75	75	75	75	75	75	75	75	67
43	COLOMBIA	CHINCHINA	80	80	80	80	80	72	80	80	72	72	72	72
44	COLOMBIA	CONSACA	63	70	70	70	70	70	70	70	70	70	63	63
45	COLOMBIA	ESPINAL	163	168	156	147	147	154	166	176	176	147	142	154
46	COLOMBIA	LA FLORIDA	63	65	65	64	65	63	65	67	67	63	61	63
47	COLOMBIA	MANZANARES	67	75	75	75	75	75	75	75	75	67	67	67
48	COLOMBIA	MEDELLIN	79	84	86	85	84	84	82	81	80	78	78	77
49	COLOMBIA	PALMIRA	101	101	101	101	101	101	101	101	101	101	101	101
50	COLOMBIA	PUEBLO BELLO	72	72	80	80	80	80	80	80	89	72	72	72
51	COLOMBIA	TUMACO	119	124	129	133	129	127	129	129	119	119	114	119
52	COLOMBIA	TURBO	132	132	132	130	114	126	130	132	136	134	136	128
53	COLOMBIA	URIBIA	179	200	219	239	265	284	294	279	252	219	204	193
54	COLOMBIA	VILLAVICIENCIO	136	142	145	122	119	115	112	117	125	131	129	125
55	COLOMBIA	YOLOMBO	75	75	75	75	75	75	75	75	75	67	67	67

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY THORNTHWAITE METHOD FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	THORT1	THORT2	THORT3	THORT4	THORT5	THORT6	THORT7	THORT8	THORT9	THORT10	THORT11	THORT12
56	COSTA RICA	EL COCO/AERO++++COSTA RI	83	91	99	102	94	88	88	89	86	83	84	84
57	COSTA RICA	LA COLA	97	97	111	111	127	127	127	127	127	127	111	111
58	COSTA RICA	OROTINA	147	151	172	170	145	117	114	124	117	115	119	126
59	COSTA RICA	SAN JOSE	65	67	75	81	84	83	78	79	80	78	72	67
60	COSTA RICA	TURRIALBA.I.I.C.A	68	68	76	106	95	95	85	85	85	86	86	76
61	COSTA RICA	VILLA MILLS	38	43	48	49	49	49	48	48	47	44	41	39
62	ECUADOR	AMBATO	58	59	58	58	55	52	48	49	53	58	59	60
63	ECUADOR	BAQUERIZO-S.C.	114	128	128	128	114	101	89	78	78	78	89	101
64	ECUADOR	CANAR	51	50	51	51	52	48	47	49	50	51	50	51
65	ECUADOR	ESMERALDAS	111	127	127	127	127	111	111	111	111	111	111	111
66	ECUADOR	GUAYAQUIL-AP	120	127	134	132	121	104	92	88	96	98	107	118
67	ECUADOR	IBARRA	59	60	61	61	61	60	60	60	62	60	59	59
68	ECUADOR	IZOBAMBA	53	53	50	50	53	50	50	50	53	50	50	53
69	ECUADOR	MANTA	128	128	128	128	113	99	87	87	87	99	99	113
70	ECUADOR	PICHILINGUE	120	127	127	127	120	99	86	92	105	105	105	120
71	ECUADOR	PORTOVIEJO	134	134	143	143	126	117	117	102	117	117	117	126
72	ECUADOR	PUYO	82	82	82	82	82	73	73	78	82	82	87	87
73	ECUADOR	QUITO-M SUCRE	54	54	54	54	54	54	54	54	54	54	54	54
74	ECUADOR	QUITO-OB	54	54	53	54	54	54	53	54	55	53	53	54
75	ECUADOR	RIOBAMBA	56	57	56	56	54	50	49	50	51	55	57	58
76	ECUADOR	SAN LORENZO	125	125	125	125	125	125	125	125	125	125	125	125
77	ECUADOR	TULCAN	51	51	52	52	53	49	46	46	49	52	53	53
78	EL SALVADOR	ACAJUTLA	120	131	153	168	164	142	140	140	131	129	131	123
79	EL SALVADOR	SAN SALVADOR	83	87	98	106	101	94	92	93	88	87	82	82
80	EL SALVADOR	SANTA CRUZ PORILLO	124	124	143	164	163	142	142	143	124	124	124	124
81	EL SALVADOR	SANTA TECLA	71	71	79	88	88	79	79	88	79	79	71	71
82	FR GUIANA	CAYENNE/ROCHAMBEAU	114	115	120	121	118	112	113	120	130	130	125	117
83	FR GUIANA	MARIPASOULA	105	105	109	113	112	107	109	116	121	127	127	115
84	GUATEMALA	COBAN	55	62	62	76	84	84	76	75	77	69	62	62
85	GUATEMALA	GUATEMALA CITY	55	59	69	76	77	71	69	71	68	64	58	55
86	GUYANA	GEORGETOWN	128	130	138	144	142	136	136	146	157	157	151	136
87	GUYANA	NEW AMSTERDAM	137	141	144	139	146	143	146	152	161	159	157	146
88	GUYANA	ST. IGNATIUS	156	151	168	166	149	133	129	144	176	192	184	173
89	HONDURAS	CATACAMAS	75	90	105	131	137	125	105	112	122	115	95	93
90	HONDURAS	SAN PEDRO SULA	81	101	123	151	165	161	145	155	157	130	112	89
91	HONDURAS	SANTA ROSA DE COPAN	53	53	75	88	89	89	82	85	85	77	65	53
92	HONDURAS	TEGUCIGALPA	62	72	84	98	102	96	90	93	94	86	73	64
93	HONDURAS	TELA	86	92	112	130	140	145	138	140	147	125	103	90
94	NICARAGUA	BLUEFIELDS	109	109	125	143	143	143	125	143	143	125	125	109
95	NICARAGUA	EL RECREO	137	162	190	221	221	189	189	161	221	190	162	137
96	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	127	146	178	196	199	145	139	146	139	131	127	123
97	NICARAGUA	PUERTO CABEZAS	108	108	125	143	143	143	125	143	143	143	125	108
98	PANAMA	BALBOA HEIGHTSALBROOF AFB	134	140	155	161	146	138	140	138	134	127	127	134
99	PANAMA	CRISTOBAL	139	139	143	147	139	131	135	135	117	133	126	131
100	PANAMA	JAQUE	127	127	138	138	127	127	119	119	119	109	119	119
101	PERU	AREQUIPA	56	56	54	57	55	52	52	55	59	54	56	57
102	PERU	CAJAMARCA	60	60	60	60	54	49	49	54	54	60	60	60
103	PERU	CHICLAYO	101	118	118	101	86	72	64	60	64	64	72	86
104	PERU	CUSCO	60	60	60	54	44	44	39	44	55	60	60	60

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY THORNTHWAITE METHOD FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	THORT1	THORT2	THORT3	THORT4	THORT5	THORT6	THORT7	THORT8	THORT9	THORT10	THORT11	THORT12
105	PERU	EL ALTO	97	107	118	107	87	69	61	61	61	61	69	87
106	PERU	HUAYAO/HUANCAYO	54	54	54	54	49	43	43	49	54	54	54	54
107	PERU	IQUITOS	126	126	126	110	126	110	110	110	126	126	144	126
108	PERU	JAUJA	55	55	55	50	50	50	45	50	55	55	61	55
109	PERU	LAMBAYEQUE	98	108	108	89	80	64	57	57	57	64	72	80
110	PERU	LIMA-CALLAO/AP	91	97	94	80	63	52	48	47	48	54	63	75
111	PERU	LIMA/C. DE MARTE	88	95	95	80	66	53	47	47	47	53	59	73
112	PERU	PTO MALDONADO	127	127	119	119	111	84	84	111	127	127	135	127
113	PERU	PUNO	51	51	51	40	40	35	35	40	46	51	56	56
114	PERU	SAN JUAN	93	102	93	85	70	56	46	46	49	56	66	81
115	PERU	TACNA	92	96	88	70	54	45	40	45	51	57	70	81
116	PERU	TINGO MARIA	91	91	103	103	91	91	91	91	91	103	103	103
117	SURINAM	N.W.NICKERIE	131	135	139	145	146	143	146	159	171	166	161	144
118	SURINAM	PARAMARIBO	129	133	141	145	137	137	143	161	176	176	164	139
119	SURINAM	SIPALIWINI	125	125	123	131	129	129	132	144	161	178	157	144
120	SURINAM	TAFELBERG	108	108	114	117	116	114	121	133	144	149	140	121
121	SURINAM	ZANDERIJ	110	107	113	119	118	116	119	129	138	140	130	116
122	VENEZ	BARCELONA	111	116	132	147	159	137	124	128	137	143	134	123
123	VENEZ	BARQUISIMETO	90	90	102	115	102	102	90	102	102	102	102	90
124	VENEZ	CARACAS/CAGIGAL	64	68	76	85	88	83	80	84	86	84	77	70
125	VENEZ	CARACAS/CARLOTA	69	70	82	90	99	89	85	88	88	87	82	76
126	VENEZ	CIUDAD BOLIVAR	128	139	156	175	171	143	145	154	171	168	154	139
127	VENEZ	COLONIA TOVAR	56	58	64	67	67	62	61	63	64	64	63	59
128	VENEZ	GUIRIA	122	122	142	164	163	142	142	142	164	164	142	123
129	VENEZ	LA ORCHILA ISLAND	121	121	141	141	163	163	163	163	189	164	164	141
130	VENEZ	LAS PIEDRAS	134	141	154	178	195	205	205	228	232	205	178	141
131	VENEZ	MAIQUETIA	104	101	103	117	130	129	132	147	153	155	138	117
132	VENEZ	MARACAIBO/LA CH	135	138	144	155	173	178	178	184	181	166	161	149
133	VENEZ	MARACAY-B.A.SUCRE	91	98	115	125	128	110	98	104	106	105	104	97
134	VENEZ	MATURIN	109	109	126	143	143	125	126	126	126	126	126	109
135	VENEZ	MERIDA	61	65	70	72	73	71	69	72	73	70	66	63
136	VENEZ	PTO. AYACUCHO	175	196	201	166	133	111	108	116	128	138	148	157
137	VENEZ	SAN ANTONIO	92	103	119	127	140	140	140	147	151	131	113	99
138	VENEZ	SAN CARLOS DE RIO NEGRO	130	130	134	123	118	120	115	123	136	138	138	129
139	VENEZ	SAN FERNANDO	136	155	183	188	150	120	113	126	142	146	146	138
140	VENEZ	SANTA ELENA	82	86	90	89	86	80	76	79	80	84	83	81
141	VENEZ	TIMEREMOS	95	98	112	112	112	112	112	127	127	127	112	98

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY HARGRAVES METHOD FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

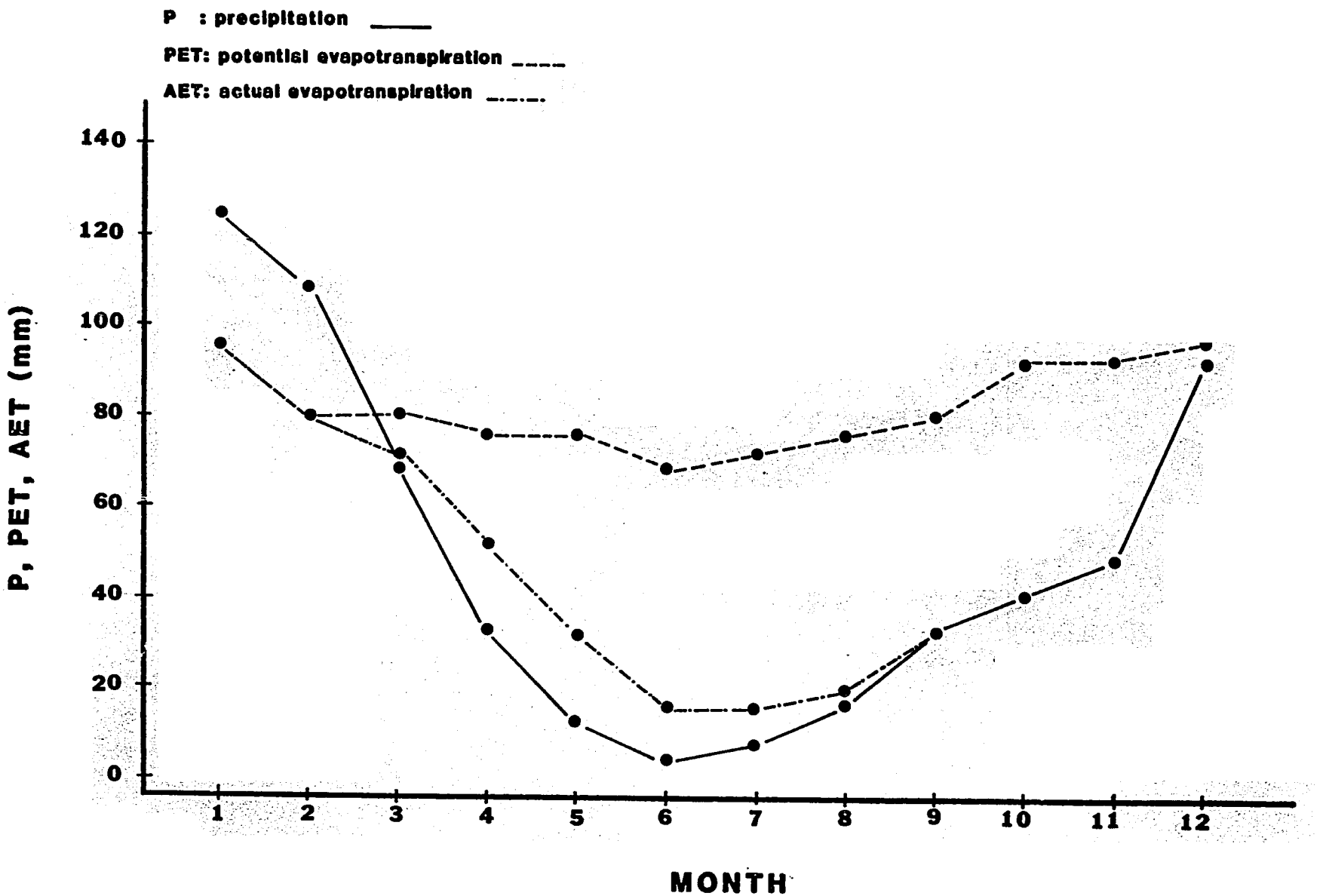
OBS	COUNTRY	STATION	HARGRS1	HARGRS2	HARGRS3	HARGRS4	HARGRS5	HARGRS6	HARGRS7	HARGRS8	HARGRS9	HARGRS10	HARGRS11	HARGRS12
1	BOLIVIA	EL ALTO	95	81	80	74	74	67	70	77	81	93	93	96
2	CHILE	ANTOFAGASTA/CERRO MORENO	179	155	133	99	79	65	67	76	92	106	124	159
3	CHILE	ARICA/CHACALLUTA	134	115	122	103	72	54	51	54	51	95	116	126
4	CHILE	CONCEPCION	141	114	91	57	35	24	29	41	60	94	117	146
5	CHILE	JUAN FERNANDEZ	144	115	88	62	46	35	36	45	66	94	122	140
6	CHILE	SANTIAGO	181	144	123	76	45	32	36	49	72	105	140	176
7	CHILE	VALDIVIA	134	109	85	44	23	15	19	29	43	63	94	114
8	CHILE	VALPARAISO	149	123	103	69	45	32	35	48	67	90	116	141
9	COLOMBIA	BAJO CALIMA	87	89	85	79	94	98	108	93	98	89	79	88
10	COLOMBIA	BOGOTA/EL DORADO	78	70	81	63	70	67	77	84	75	67	64	71
11	COLOMBIA	CARTAGENA	141	142	169	168	191	157	185	180	164	159	144	149
12	COLOMBIA	CHINACOTA	85	85	93	81	99	98	107	113	105	95	83	79
13	COLOMBIA	CHINCHINA	110	107	137	142	144	133	139	140	131	136	122	114
14	COLOMBIA	CONSACA	95	91	98	92	103	105	112	124	109	97	88	90
15	COLOMBIA	LA FLORIDA	96	91	100	90	95	95	105	116	105	94	82	89
16	COLOMBIA	MANZANARES	86	89	96	91	100	99	111	116	108	91	78	78
17	COLOMBIA	PALMIRA	132	125	143	133	136	139	147	151	139	133	121	116
18	COLOMBIA	PUEBLO BELLO	127	123	139	132	130	128	144	142	131	116	109	116
19	COLOMBIA	YOLOMBO	100	98	106	103	119	124	139	137	126	102	86	86
20	COSTA RICA	LA COLA	92	94	115	117	118	106	108	120	120	104	91	85
21	COSTA RICA	SAN JOSE	101	105	133	130	119	102	106	110	109	98	6	92
22	COSTA RICA	TURRIALBA,I.I.C.A	83	88	108	114	106	98	98	104	104	98	86	79
23	ECUADOR	AMBATO	92	81	84	82	77	65	66	69	78	92	90	93
24	ECUADOR	BAQUERIZO-S.C.	131	152	166	158	149	135	125	123	118	127	126	133
25	ECUADOR	CANAR	80	71	75	72	77	68	77	80	78	80	80	81
26	ECUADOR	GUAYAQUIL-AP	96	98	118	115	114	89	92	102	114	103	7	109
27	ECUADOR	IBARRA	89	82	91	88	98	90	99	106	100	94	85	86
28	ECUADOR	IZOBAMBA	86	78	79	72	80	71	83	87	86	84	80	85
29	ECUADOR	PICHILINGUE	78	79	94	96	77	55	53	64	67	64	61	69
30	ECUADOR	PORTOVIEJO	82	78	101	116	93	56	82	99	102	100	85	89
31	ECUADOR	PUYO	69	69	58	61	64	61	62	77	79	82	84	76
32	ECUADOR	QUITO-M SUCRE	89	80	85	82	84	84	94	99	110	92	89	90
33	ECUADOR	QUITO-OB	92	81	86	79	87	80	92	94	95	91	99	92
34	ECUADOR	RIOBAMBA	82	79	73	77	77	70	73	83	77	84	74	85
35	ECUADOR	SAN LORENZO	85	83	106	106	89	75	81	88	79	87	72	71
36	ECUADOR	TULCAN	63	57	66	60	71	53	67	72	68	66	60	58
37	EL SALVADOR	ACAJUTLA	145	148	184	184	187	167	189	187	155	152	144	142
38	EL SALVADOR	SAN SALVADOR	131	127	168	159	164	141	165	177	133	134	125	128
39	EL SALVADOR	SANTA CRUZ PORILLO	143	145	181	188	195	174	193	195	160	153	137	138
40	EL SALVADOR	SANTA TECLA	127	125	156	156	157	136	159	166	130	128	131	123
41	FR GUIANA	CAYENNE/ROCHAMBEAU	112	107	132	137	133	133	155	168	173	170	144	123
42	FR GUIANA	MARIPASOULA	115	111	135	143	135	133	153	180	177	172	142	125
43	GUYANA	GEORGETOWN	126	125	155	155	153	143	164	178	173	160	140	124
44	NICARAGUA	MANAGUA/LAS MERCEDES A NICARAG	126	127	174	170	173	134	145	162	144	138	122	125
45	PANAMA	BALBOA HEIGHTSALBROOF AFB	132	139	179	190	161	148	141	143	142	132	115	131
46	PANAMA	CRISTOBAL	142	135	177	170	159	139	145	152	138	136	113	128
47	PERU	AREQUIPA	124	107	119	117	104	93	96	113	124	136	141	151
48	PERU	CUSCO	102	89	102	96	87	78	83	90	97	112	112	105

*** POTENTIAL EVAPOTRANSPIRATION ESTIMATES BY HARGRAVES METHOD FOR SELECTED STATIONS ***
- CENTRAL AND SOUTH AMERICA -

OBS	COUNTRY	STATION	HARGRS1	HARGRS2	HARGRS3	HARGRS4	HARGRS5	HARGRS6	HARGRS7	HARGRS8	HARGRS9	HARGRS10	HARGRS11	HARGRS12
49	PERU	EL ALTO	118	111	125	106	99	79	81	85	88	92	94	112
50	PERU	HUAYAO/HUANCAYO	104	90	97	92	88	82	86	93	96	106	107	108
51	PERU	LAMBAYEQUE	153	141	149	133	121	94	93	104	115	129	133	143
52	PERU	LIMA/C. DE MARTE	127	124	135	112	73	40	39	42	45	67	86	105
53	PERU	TINGO MARIA	98	88	99	97	99	92	102	121	112	121	110	103
54	SURINAM	PARAMARIBO	123	124	151	148	148	150	173	190	190	183	148	125
55	SURINAM	SIPALIWINI	123	113	135	130	134	121	164	170	188	192	144	124
56	SURINAM	TAFELBERG	111	109	134	135	141	137	154	175	173	170	137	122
57	VENEZ	BARCELONA	150	152	184	183	189	165	175	176	174	170	148	144
58	VENEZ	BARQUISIMETO	126	123	152	143	145	147	174	161	150	137	127	119
59	VENEZ	CARACAS/CAGIGAL	111	116	140	136	143	137	146	150	141	131	113	107
60	VENEZ	CARACAS/CARLOTA	118	123	150	148	150	143	158	156	144	136	118	113
61	VENEZ	CIUDAD BOLIVAR	142	144	178	175	182	161	178	185	182	175	152	142
62	VENEZ	COLONIA TOVAR	87	93	107	98	99	93	97	105	100	94	79	82
63	VENEZ	GUIRIA	132	135	168	175	183	166	180	177	169	160	136	127
64	VENEZ	LA ORCHILA ISLAND	145	149	185	183	195	198	204	206	203	183	156	136
65	VENEZ	MAIQUETIA	124	128	156	152	171	168	183	188	173	153	130	119
66	VENEZ	MARACAIBO/LA CH	146	143	169	162	167	171	192	191	168	149	137	138
67	VENEZ	MARACAY-B.A.SUCRE	137	139	173	164	165	155	165	164	157	148	136	132
68	VENEZ	MATURIN	131	133	164	163	164	143	156	161	159	147	132	124
69	VENEZ	MERIDA	112	110	130	125	127	119	132	136	125	116	104	109
70	VENEZ	PTO. AYACUCHO	172	163	183	158	142	126	133	142	149	152	148	154
71	VENEZ	SAN ANTONIO	112	112	132	123	141	128	142	154	148	135	117	110
72	VENEZ	SAN FERNANDO	155	158	190	174	162	141	151	157	161	165	154	150
73	VENEZ	SANTA ELENA	118	119	138	134	128	116	127	136	148	145	122	115
74	VENEZ	TIMEREMOS	116	116	143	144	145	134	155	169	167	155	131	116

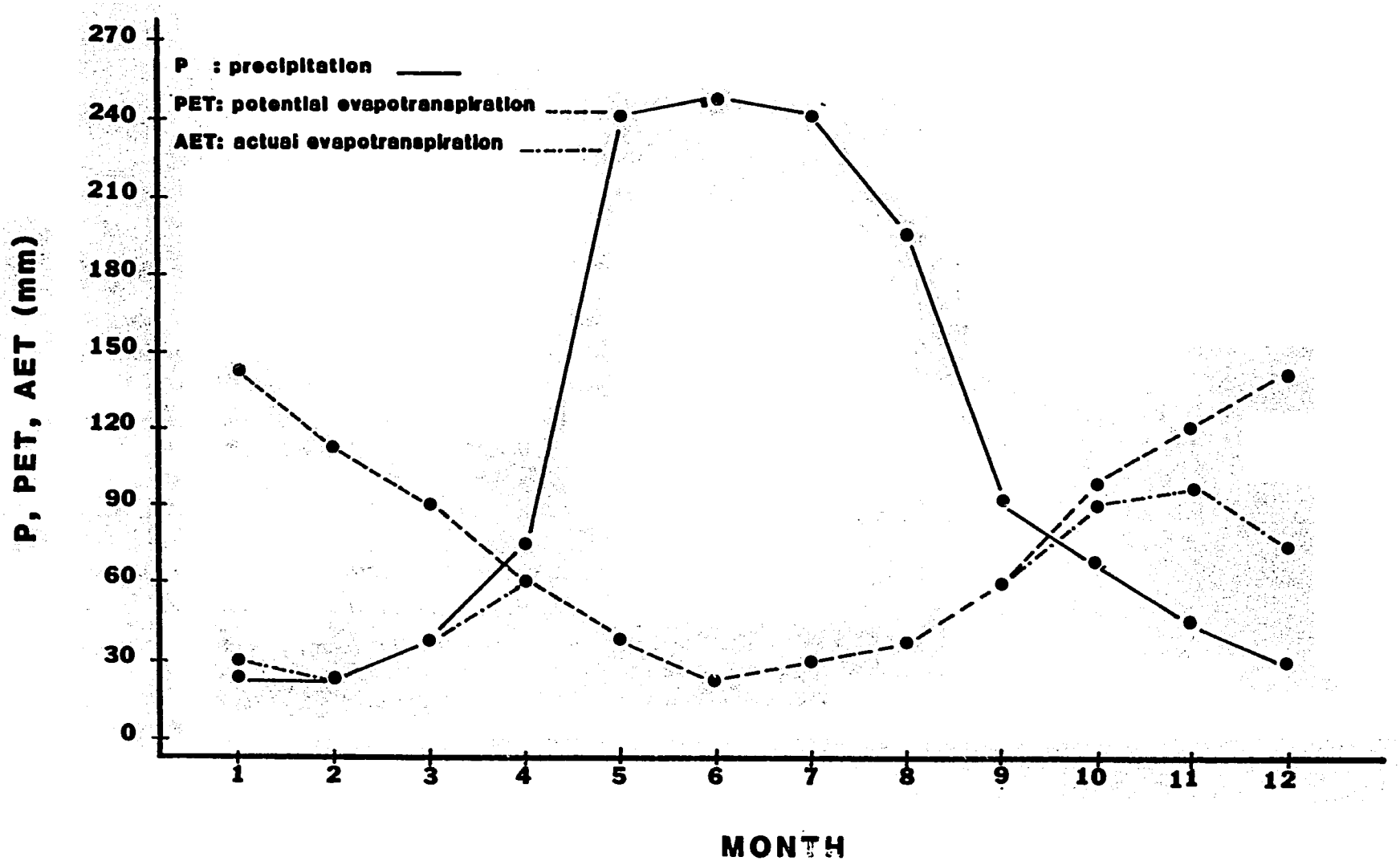
CLIMATIC DIAGRAM

EL ALTO, BOLIVIA



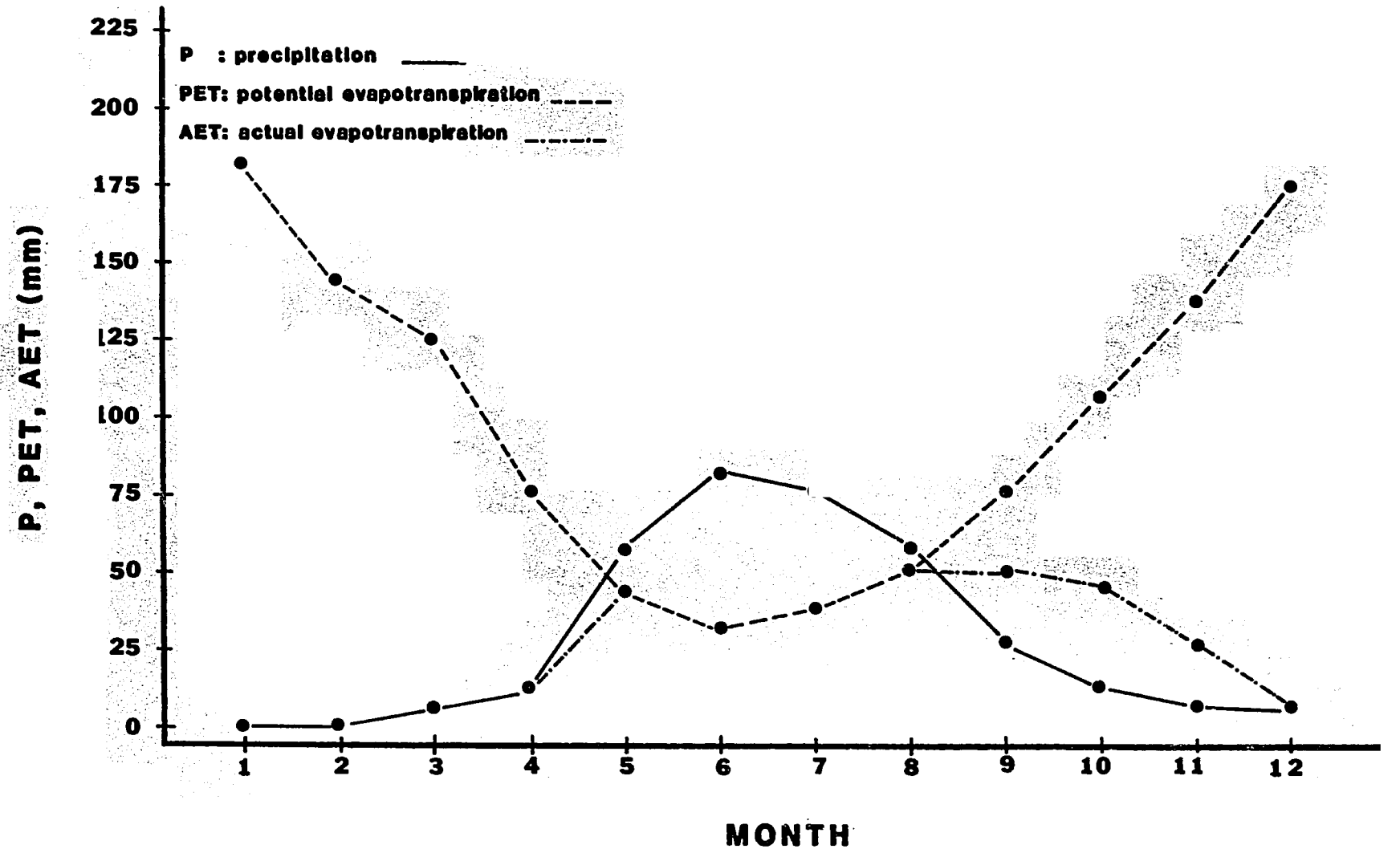
CLIMATIC DIAGRAM

CONCEPCION, CHILE



CLIMATIC DIAGRAM

SANTIAGO, CHILE



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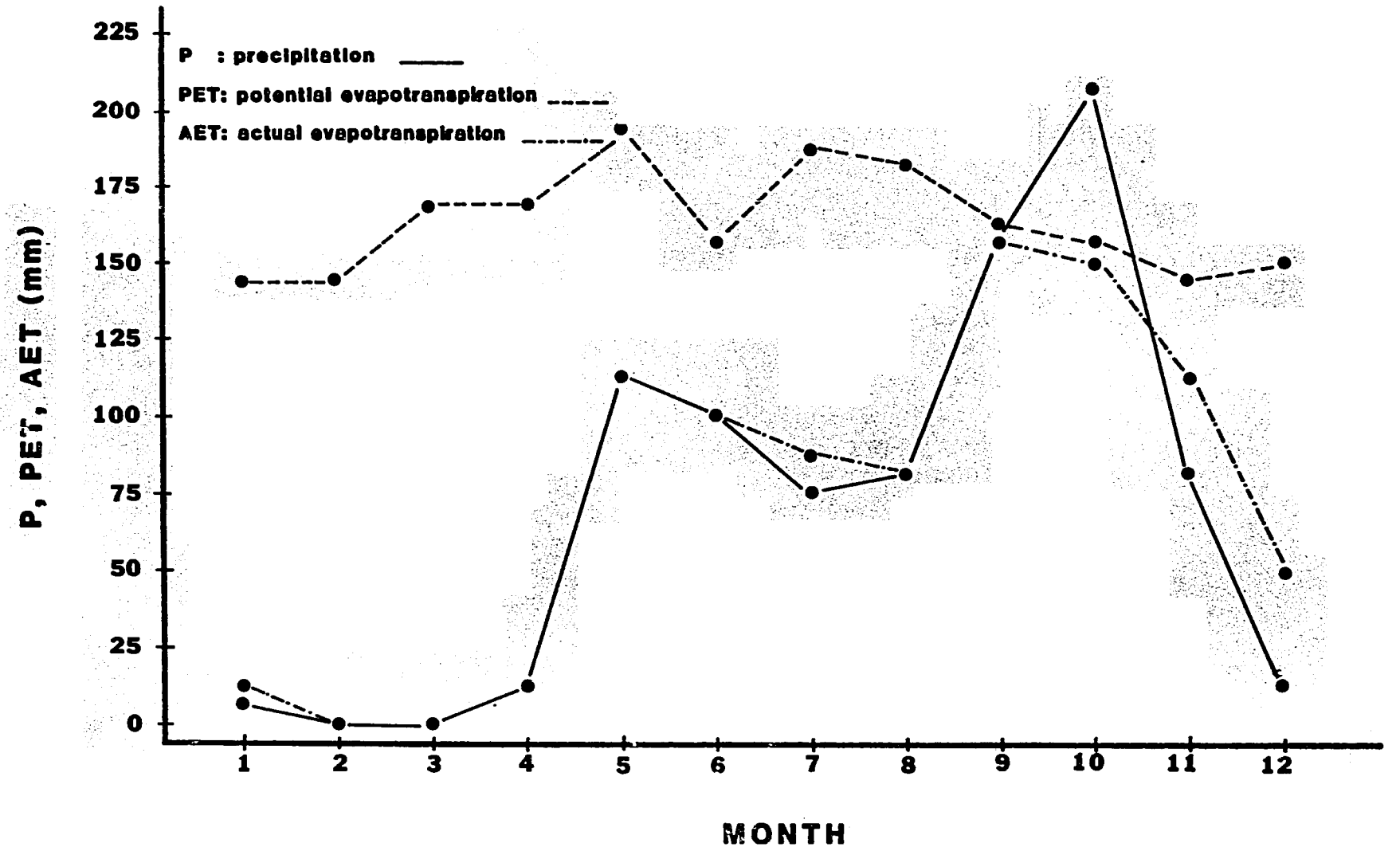
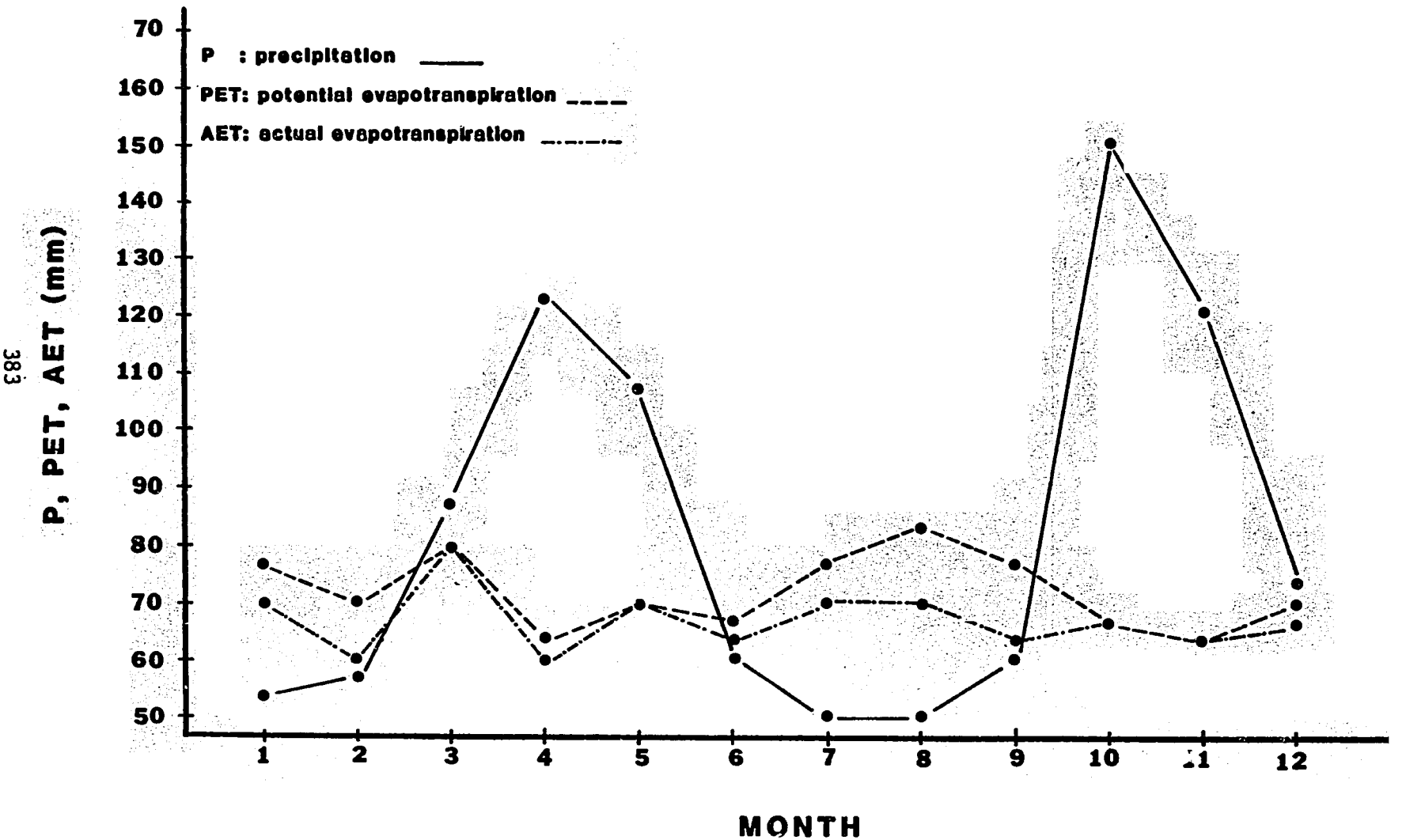
BARRANQUILLA, COLOMBIA



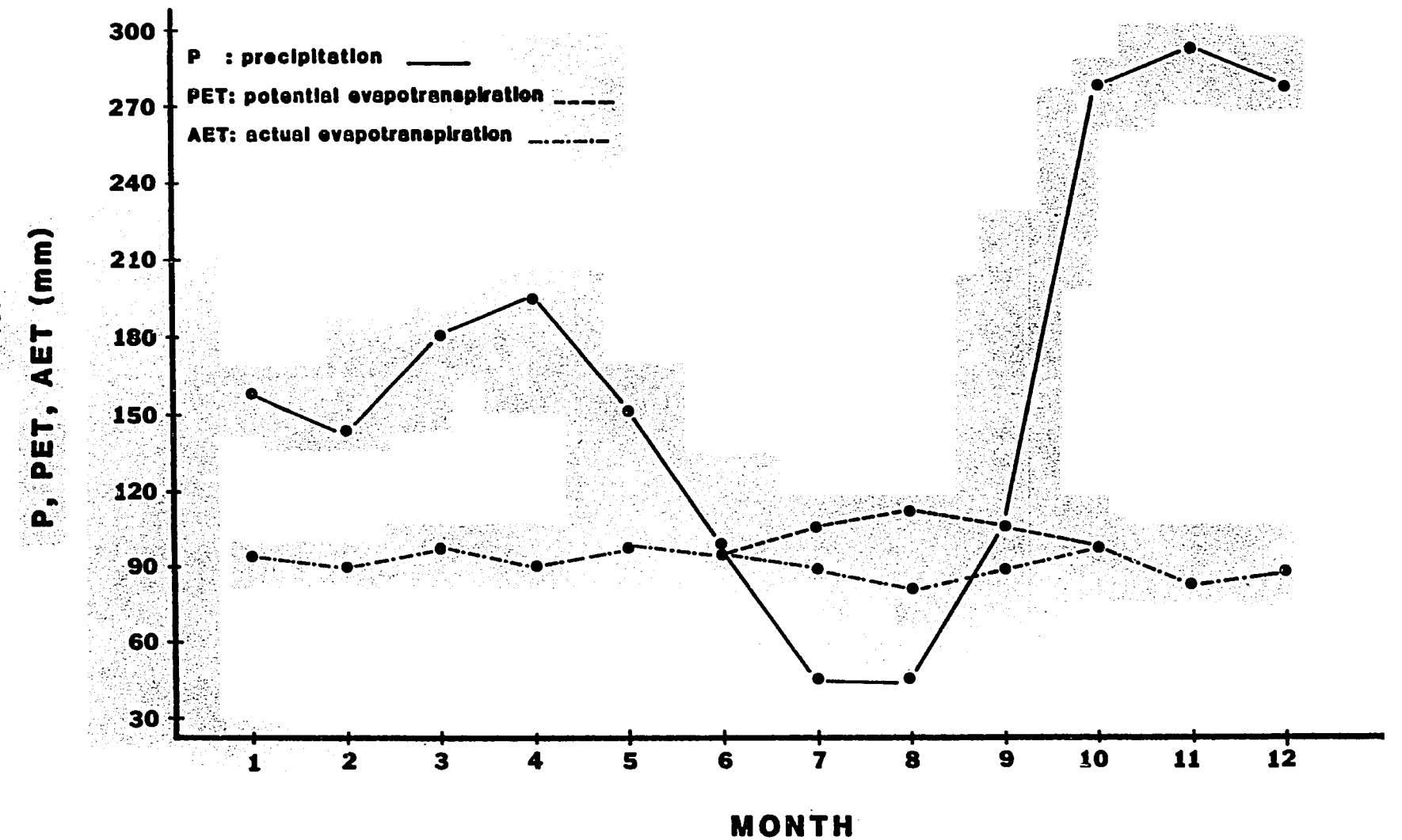
CLIMATIC DIAGRAM

BOGOTA/EL DORADO, COLOMBIA



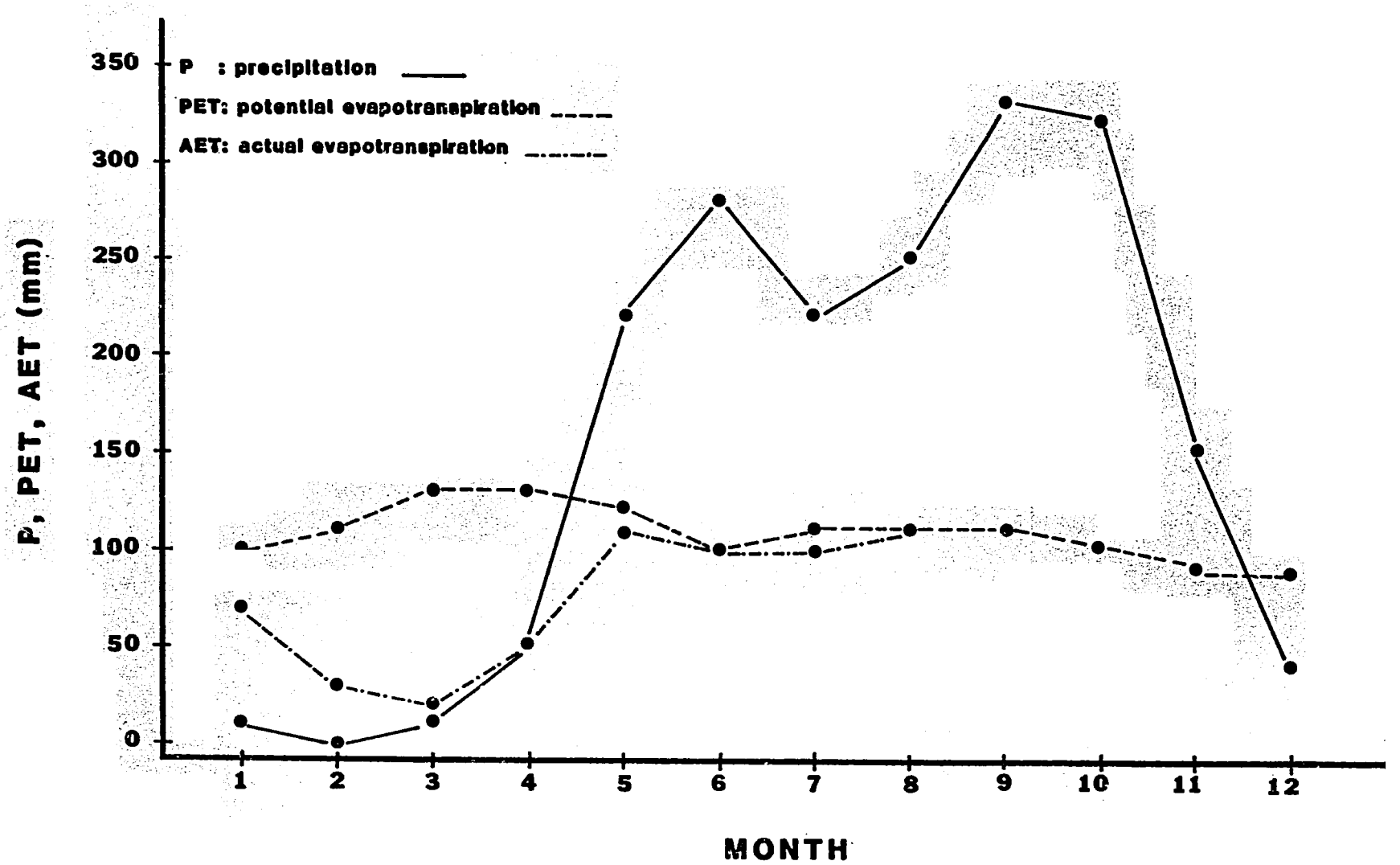
CLIMATIC DIAGRAM

POPAYAN, COLOMBIA



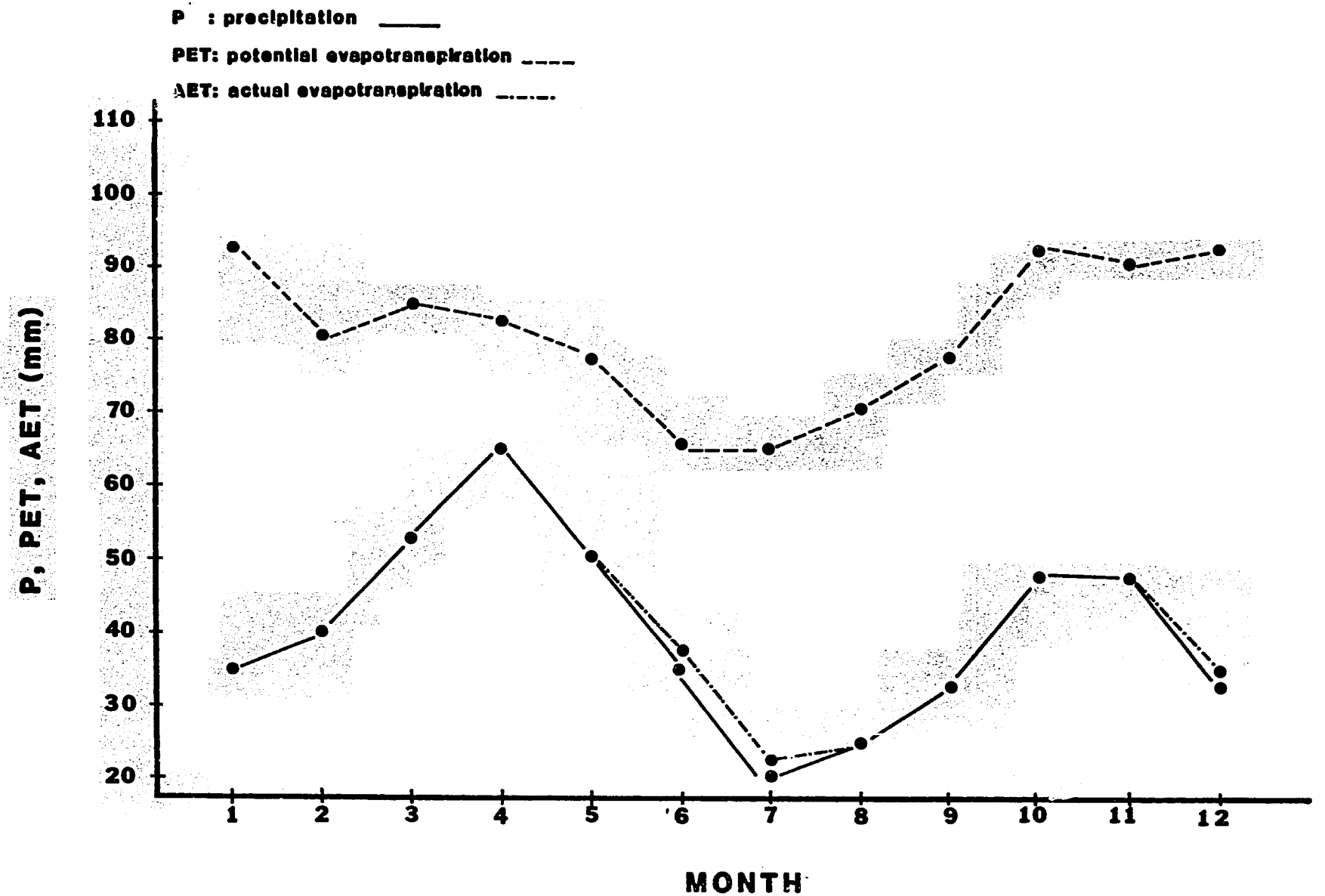
CLIMATIC DIAGRAM

SAN JOSE/LA SABANA, COSTA RICA



CLIMATIC DIAGRAM

AMBATO, ECUADOR



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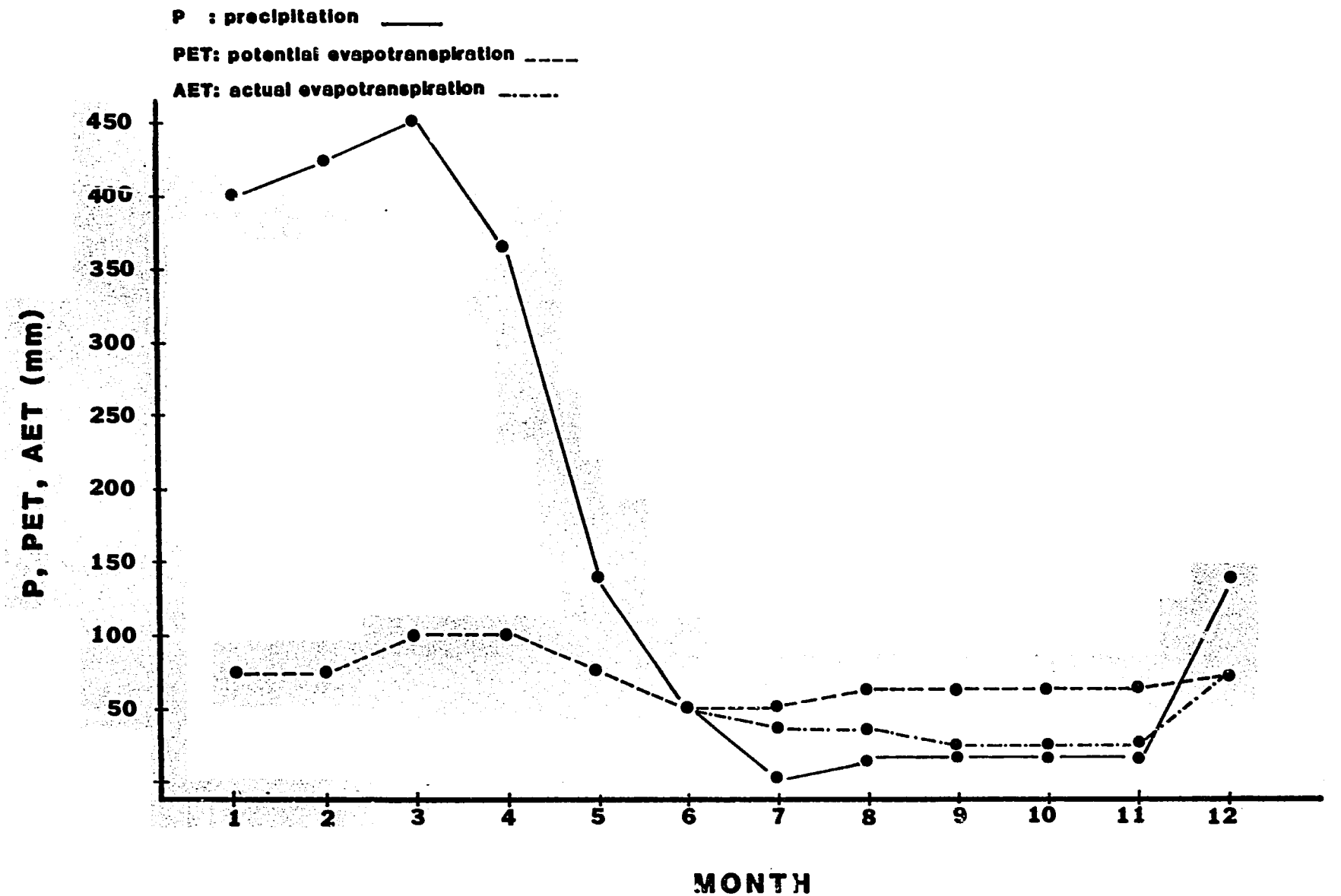
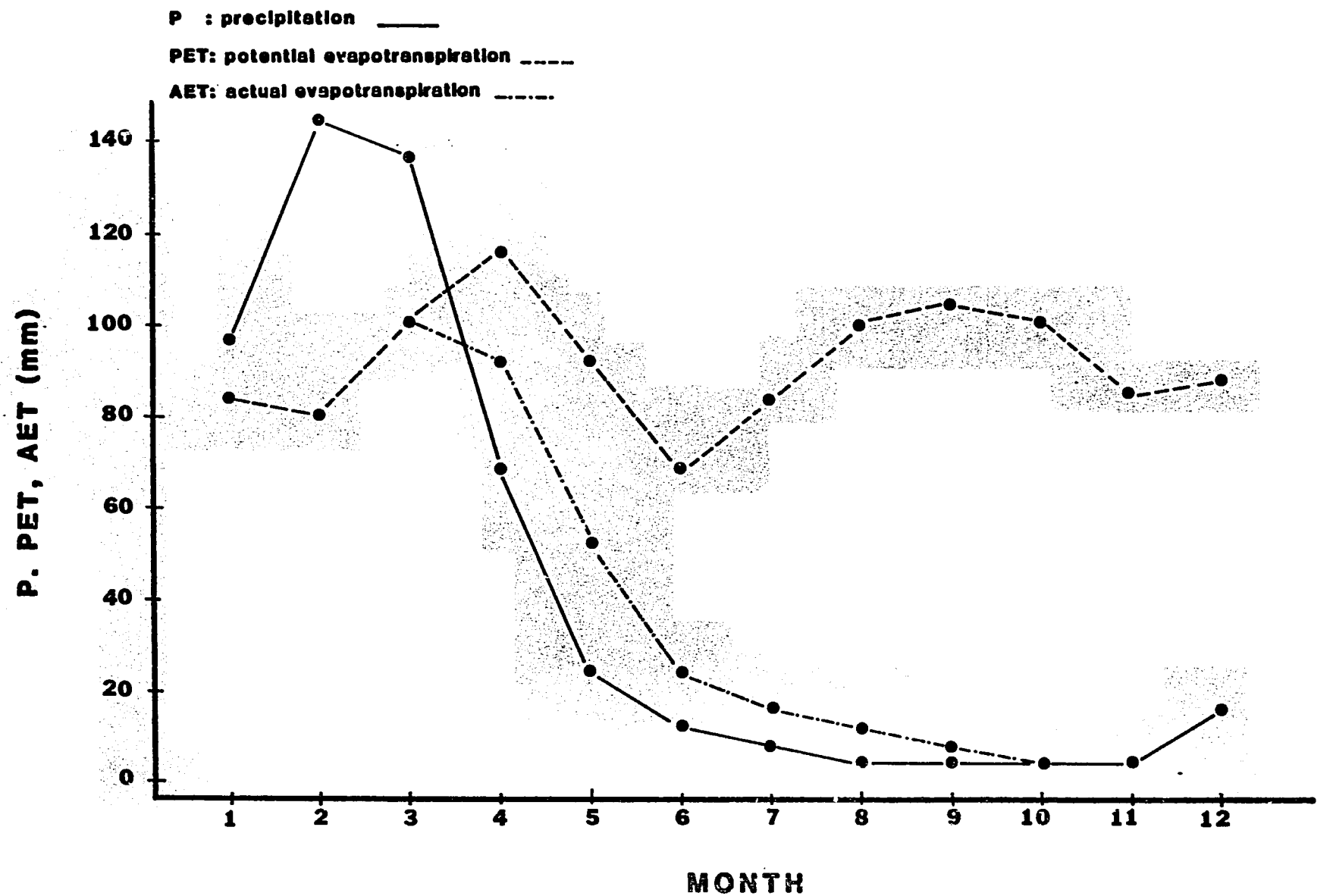
PICHILINGUE, ECUADOR



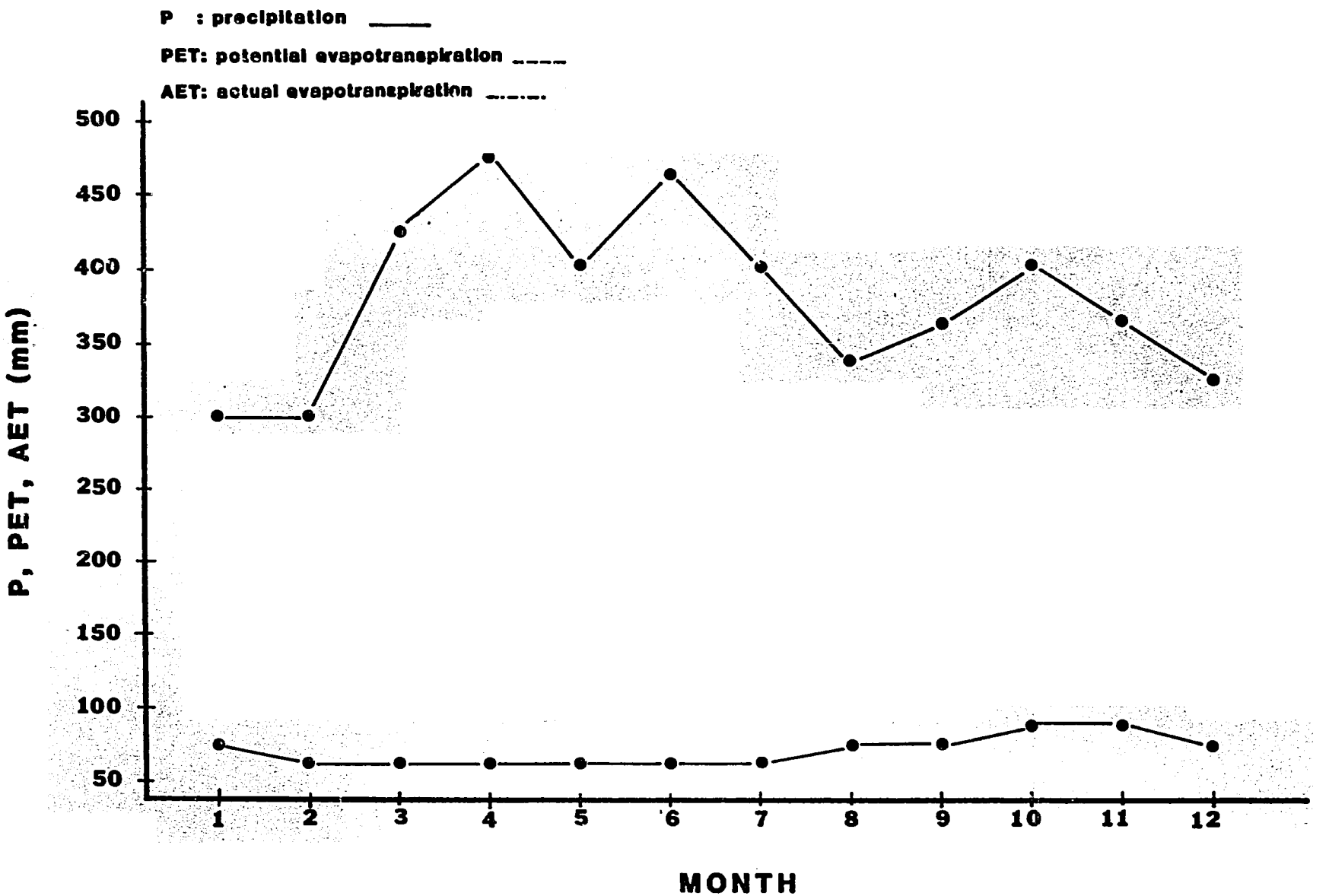
CLIMATIC DIAGRAM

PORTOVIEJO, ECUADOR



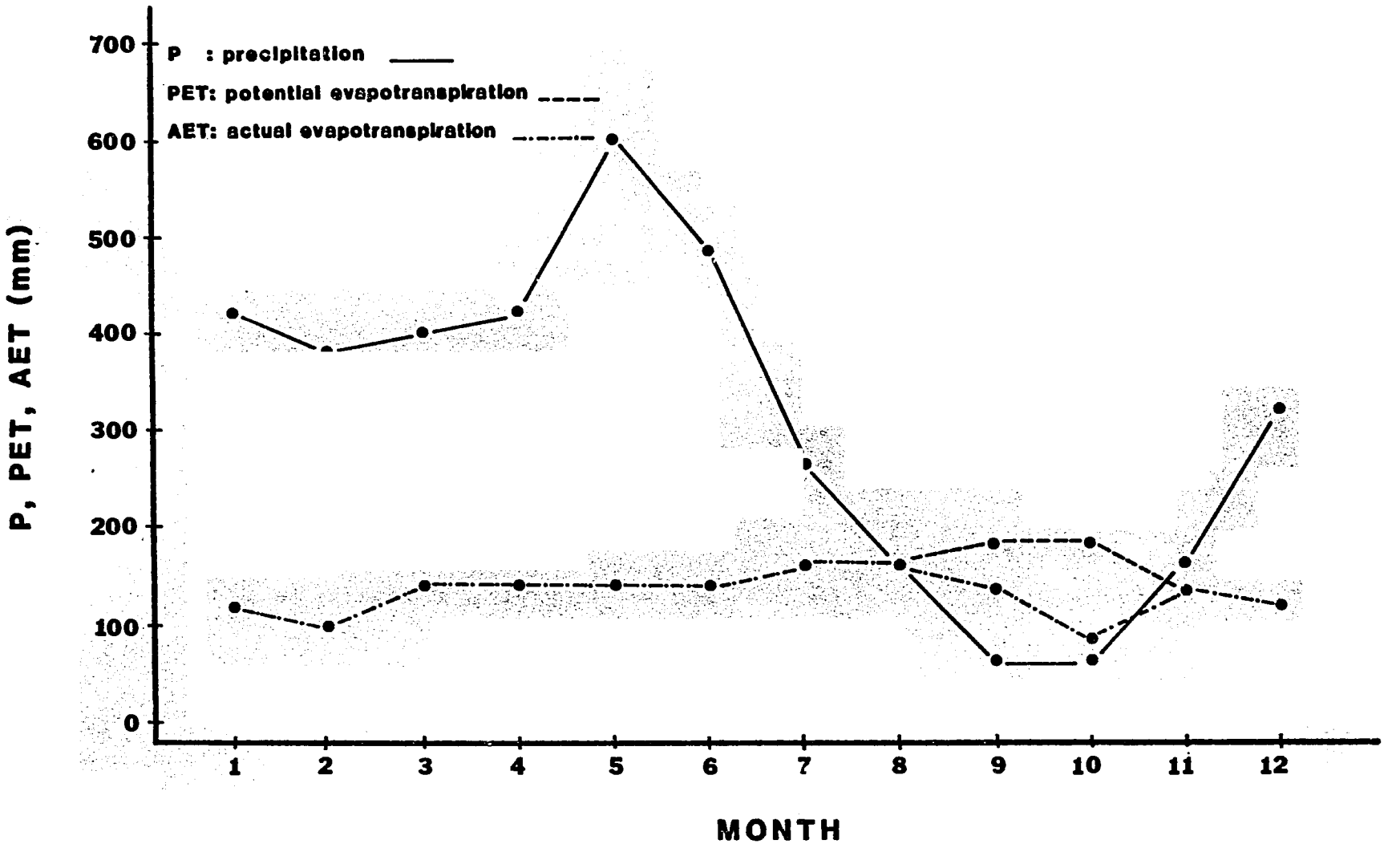
CLIMATIC DIAGRAM

PUYO, ECUADOR



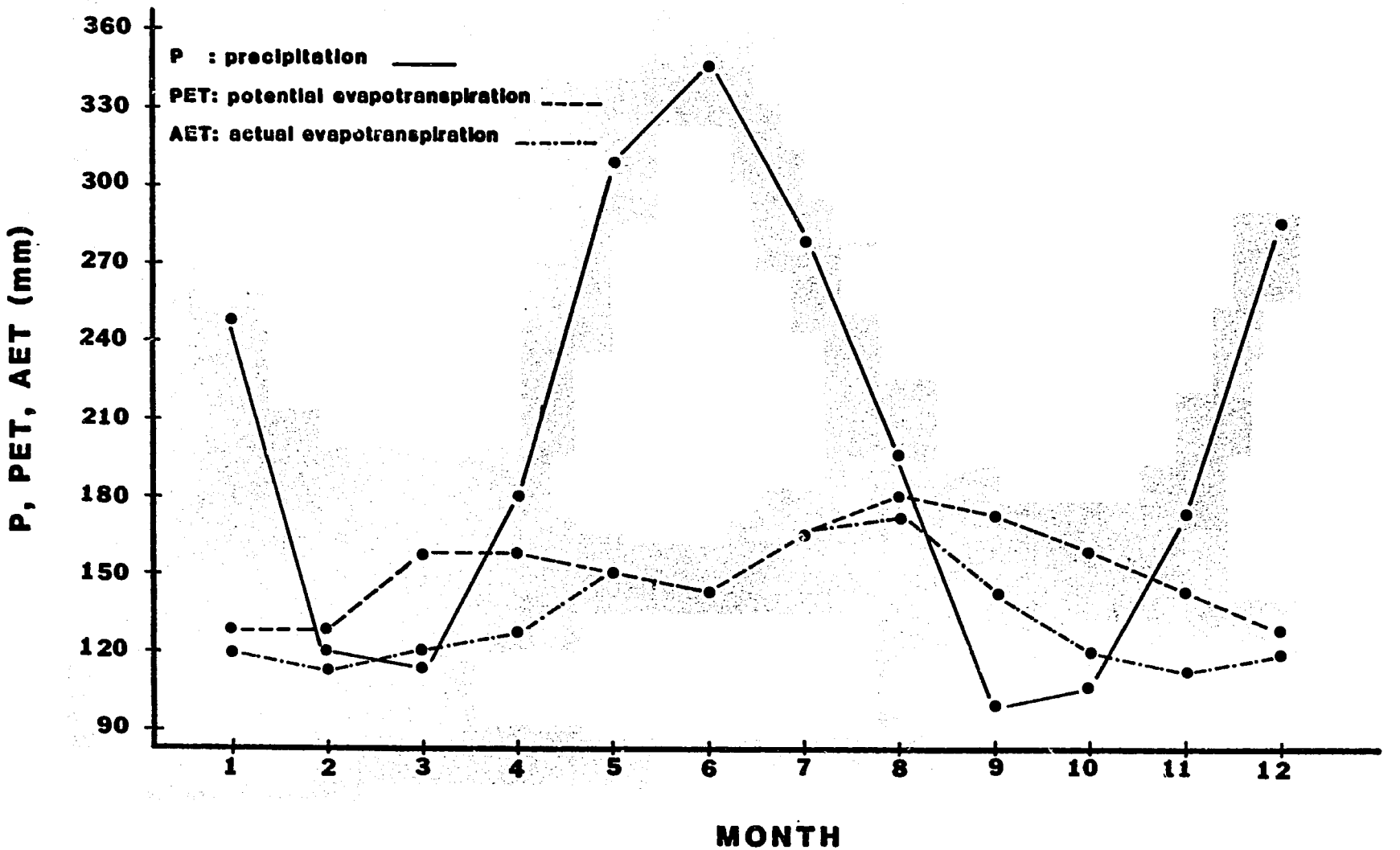
CLIMATIC DIAGRAM

CAYENNE/ROCHAMBEAU, FRENCH GUIANA



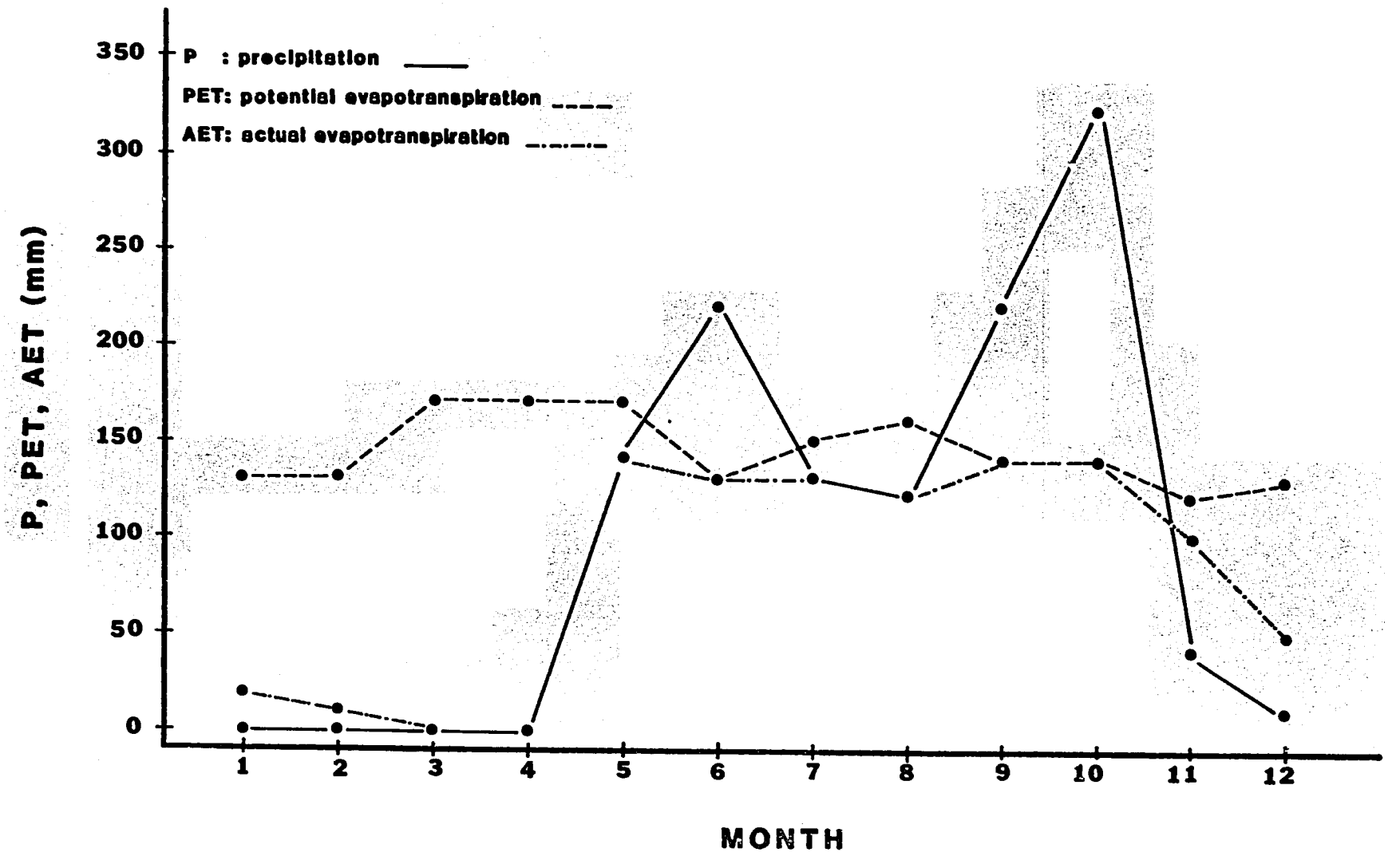
CLIMATIC DIAGRAM

GEORGETOWN, GUYANA



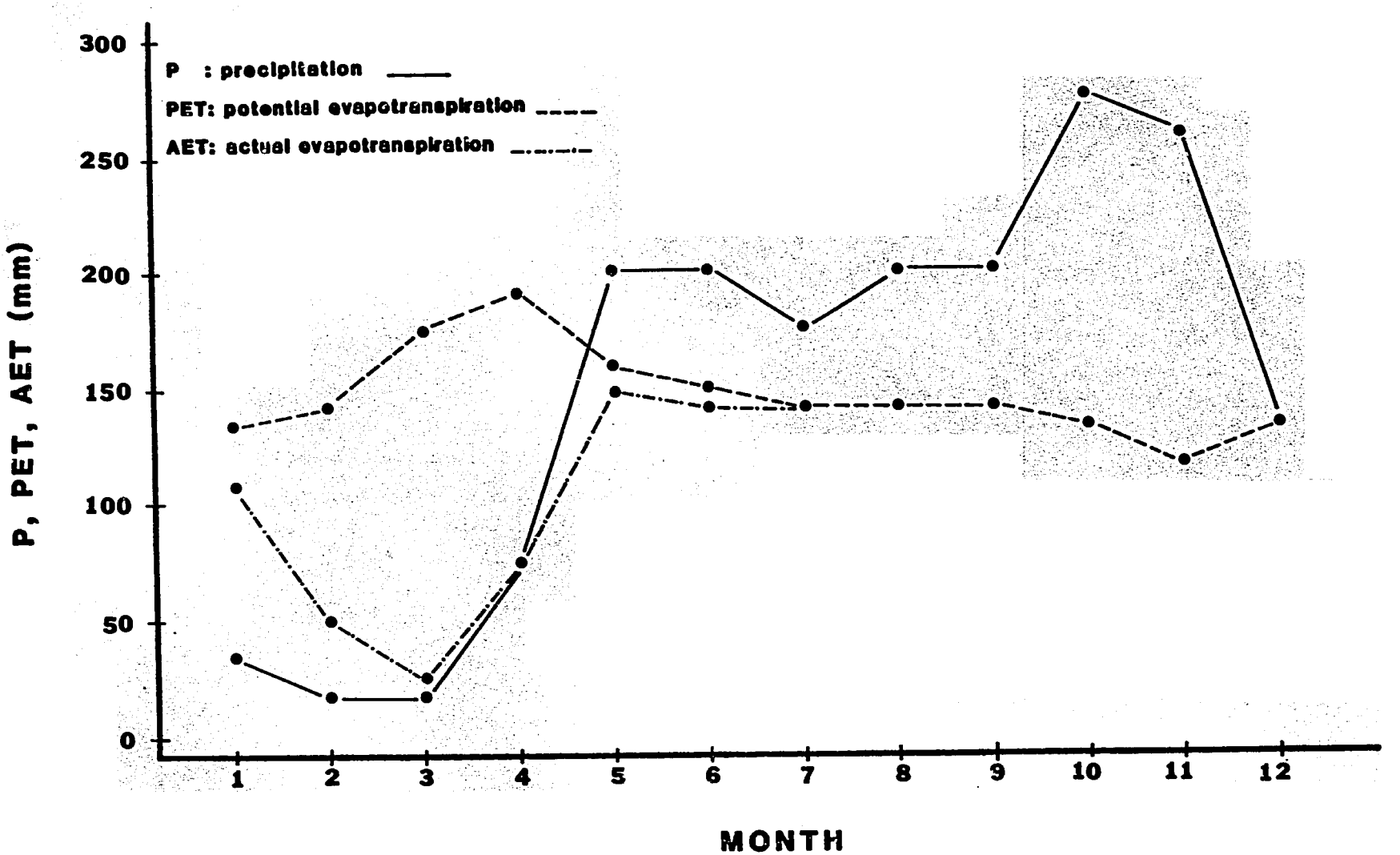
CLIMATIC DIAGRAM

MANAGUA/LAS MERCEDES, NICARAGUA



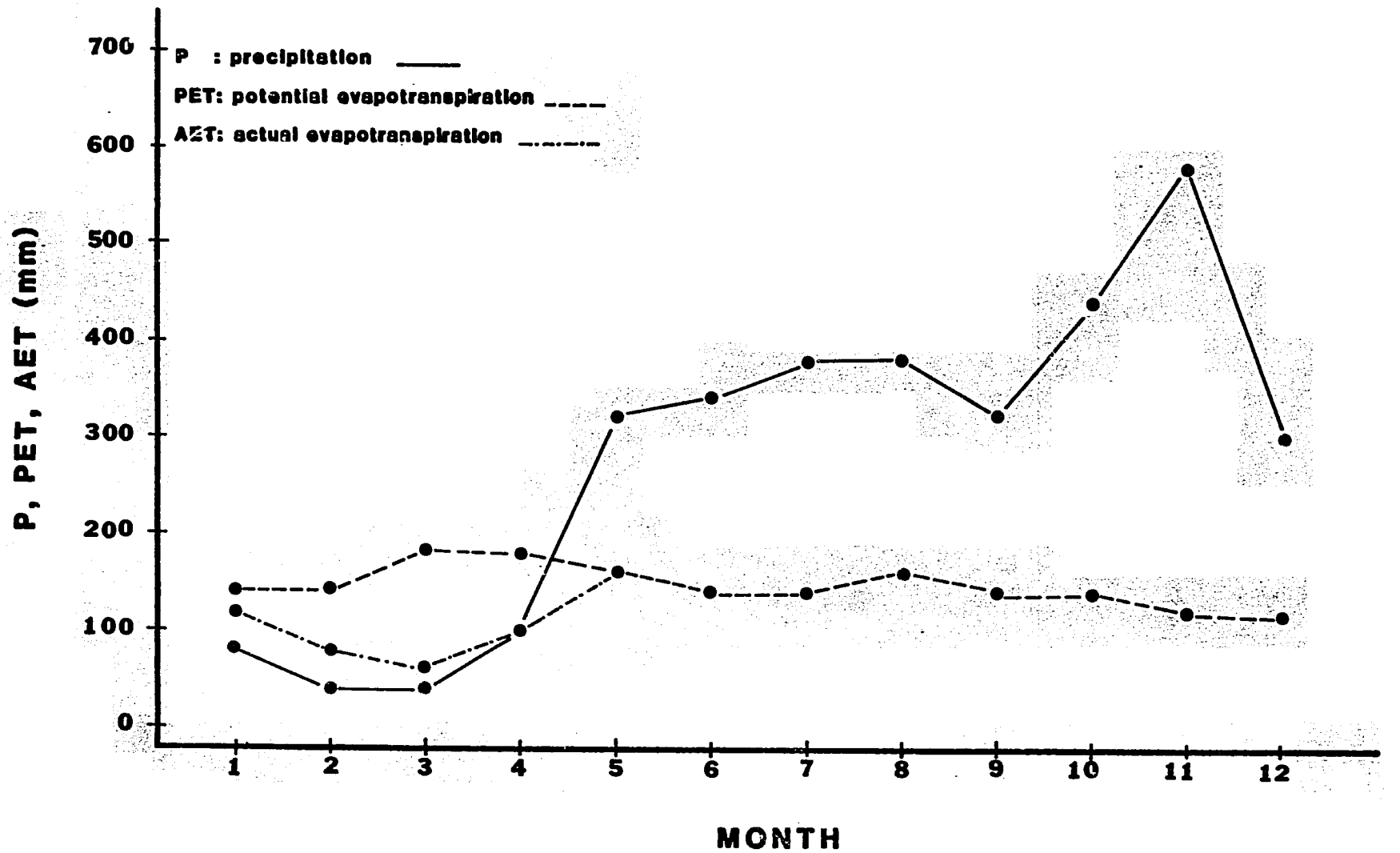
CLIMATIC DIAGRAM

BALBOA HEIGHTSALBROOF AFB, PANAMA



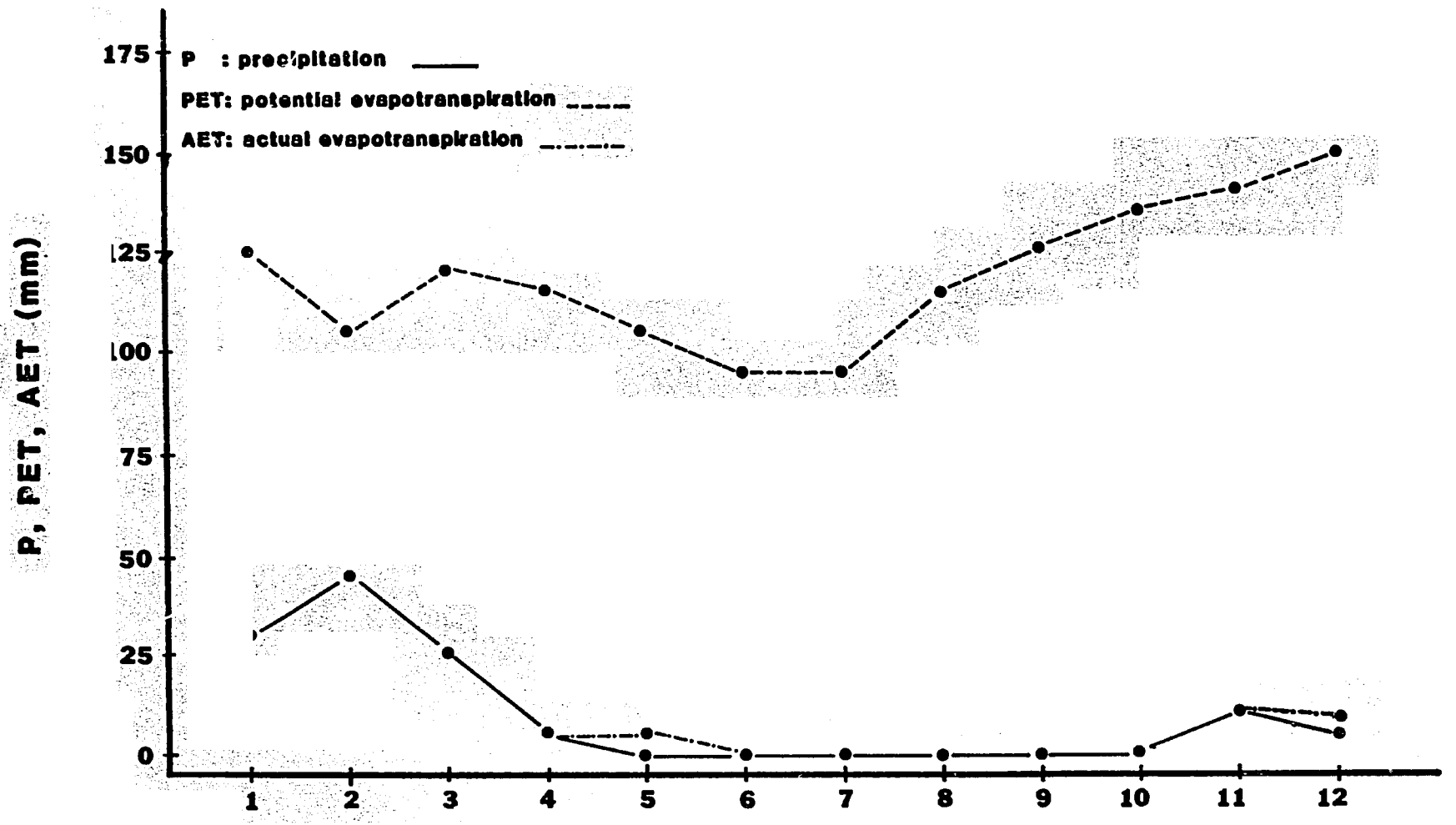
CLIMATIC DIAGRAM

CRISTOBAL, PANAMA



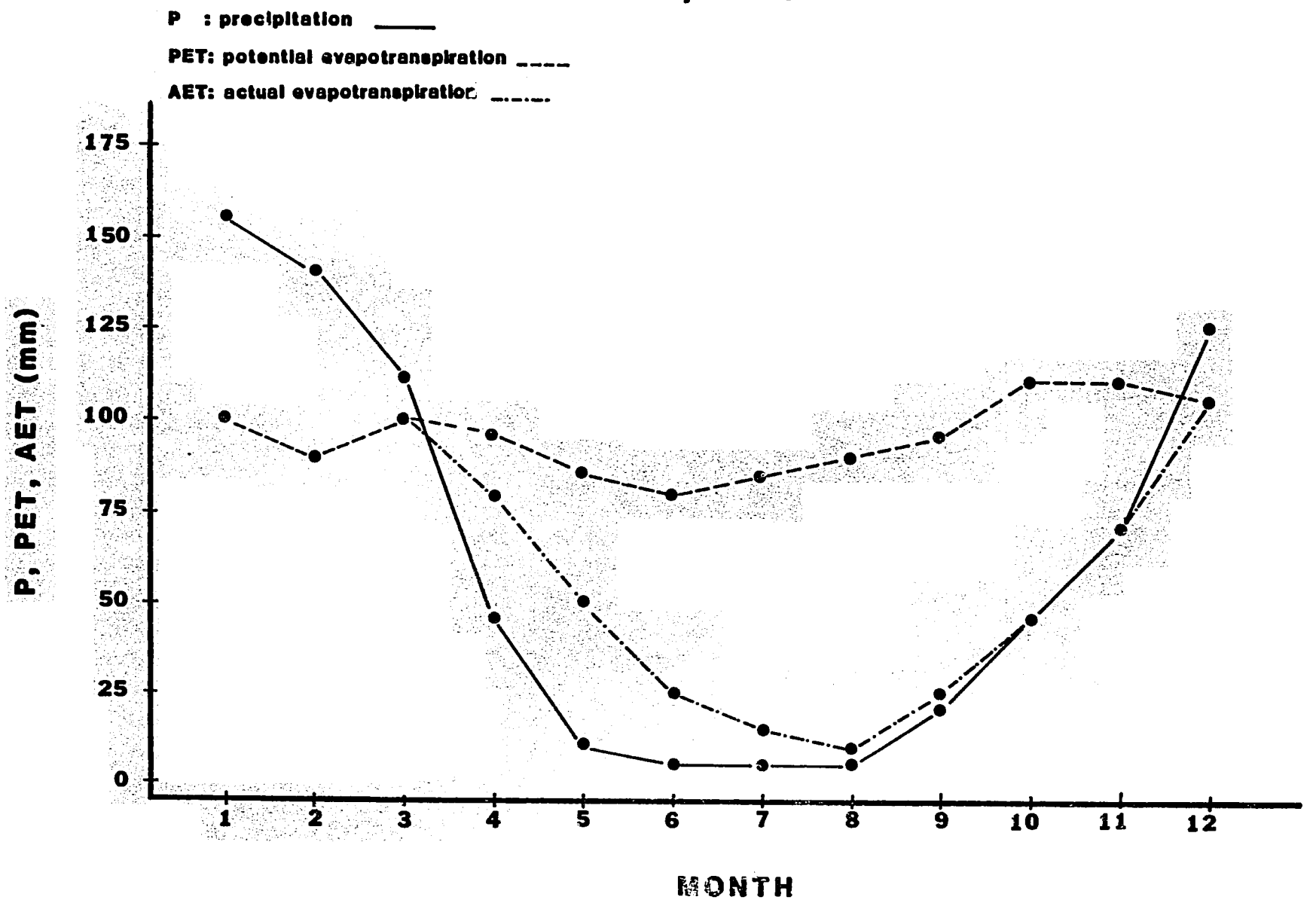
CLIMATIC DIAGRAM

AREQUIPA, PERU



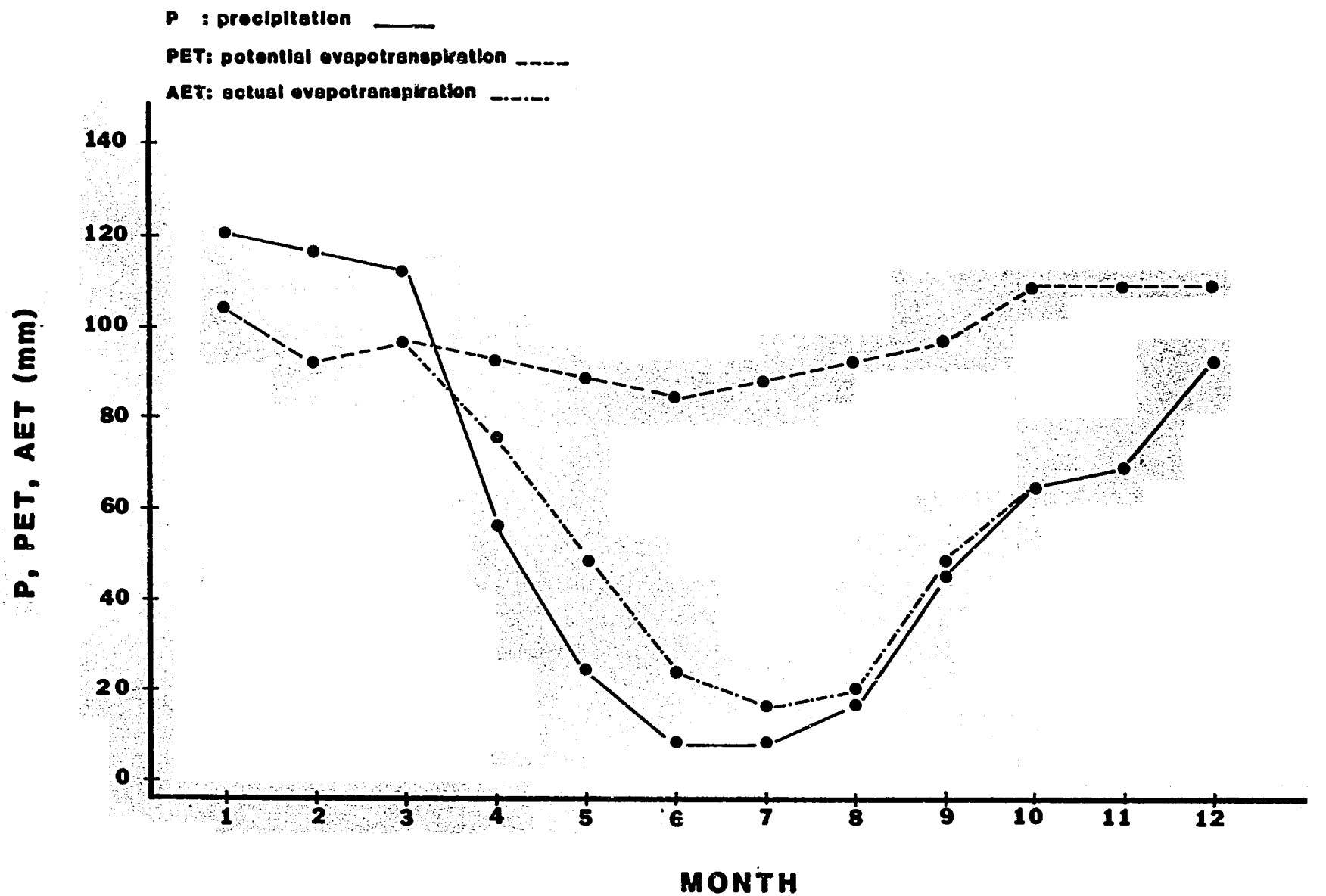
CLIMATIC DIAGRAM

CUSCO, PERU



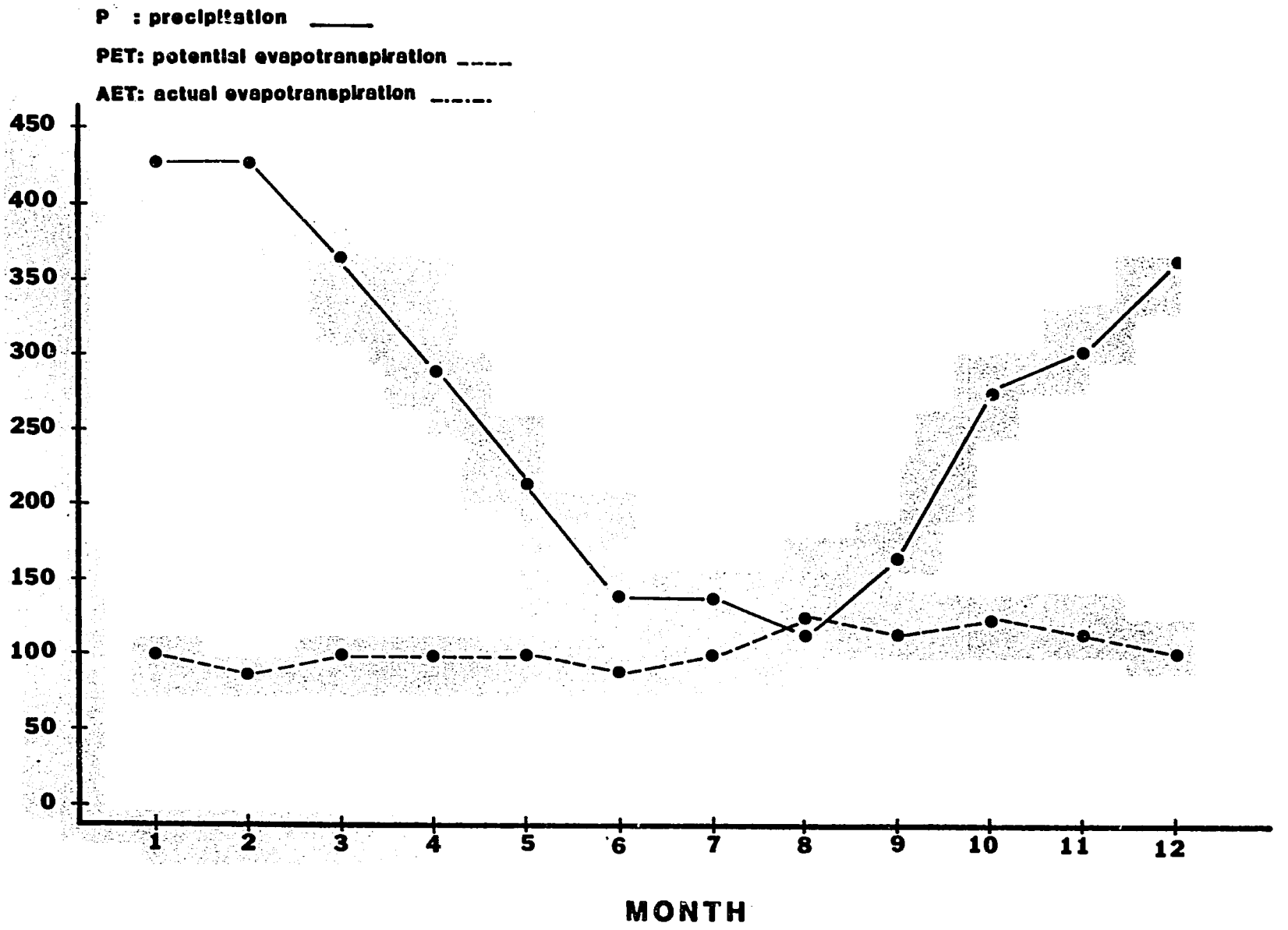
CLIMATIC DIAGRAM

HUAYAO/HUANCAYO, PERU



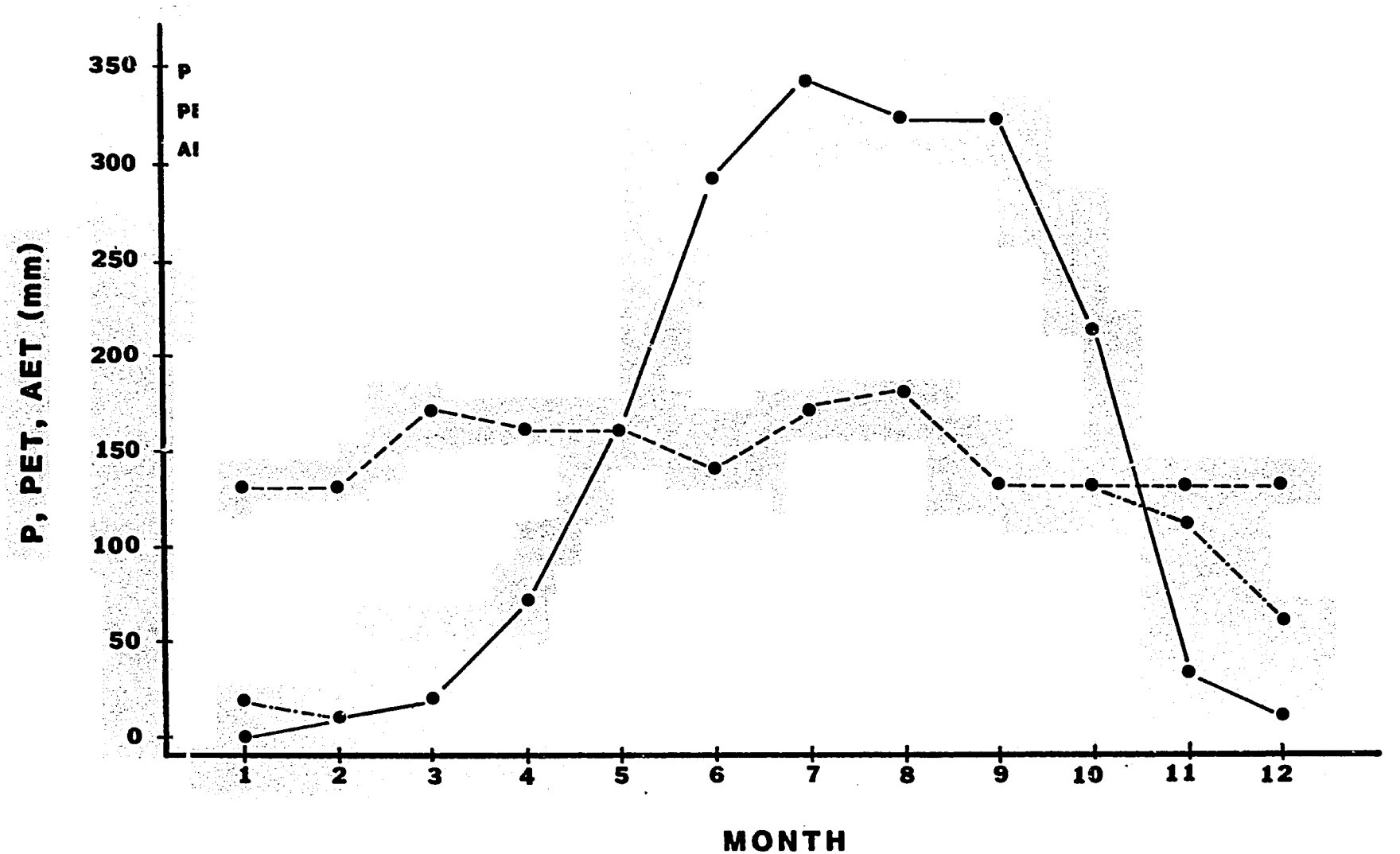
CLIMATIC DIAGRAM

TINGO MARIA, PERU



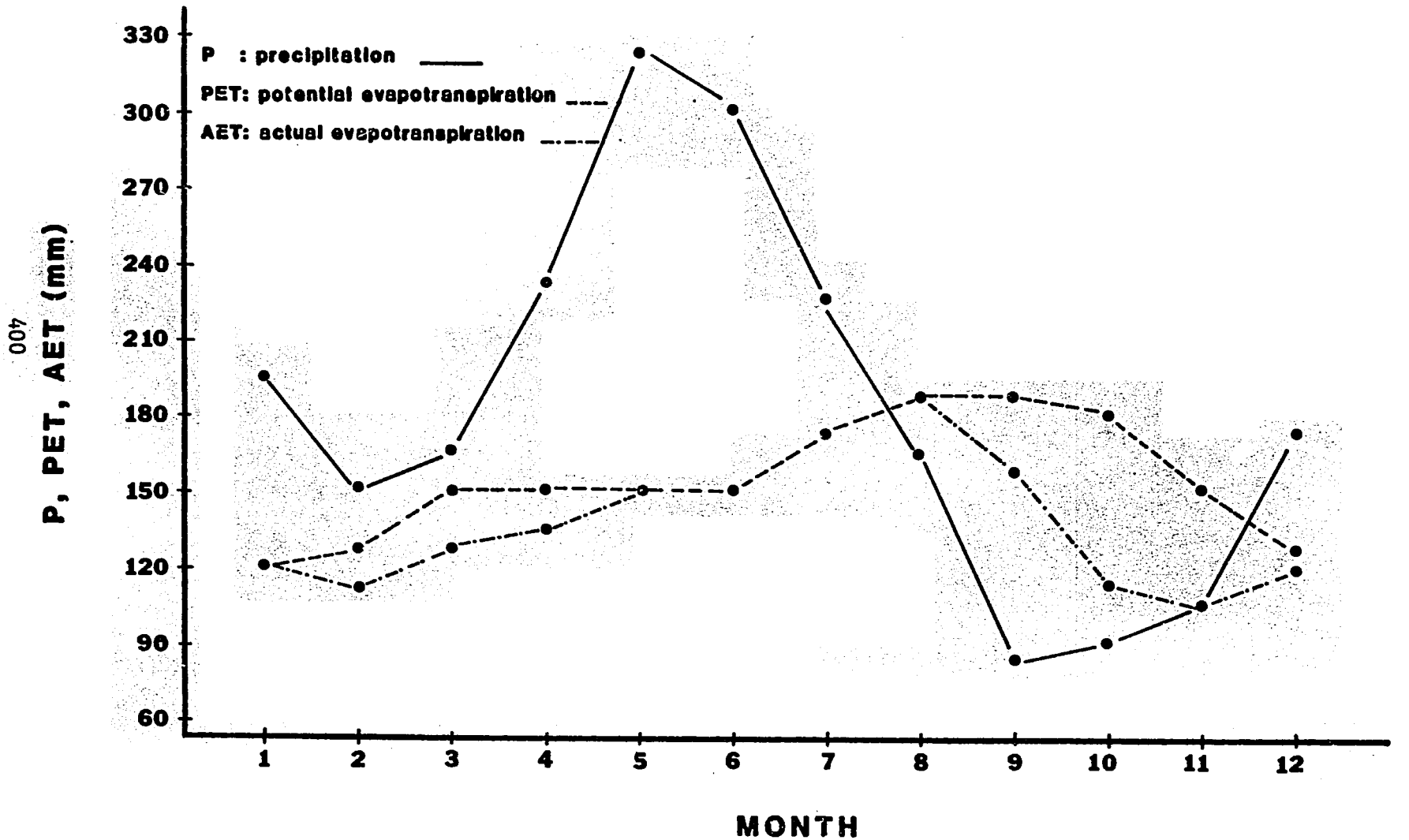
CLIMATIC DIAGRAM

SAN SALVADOR, EL SALVADOR



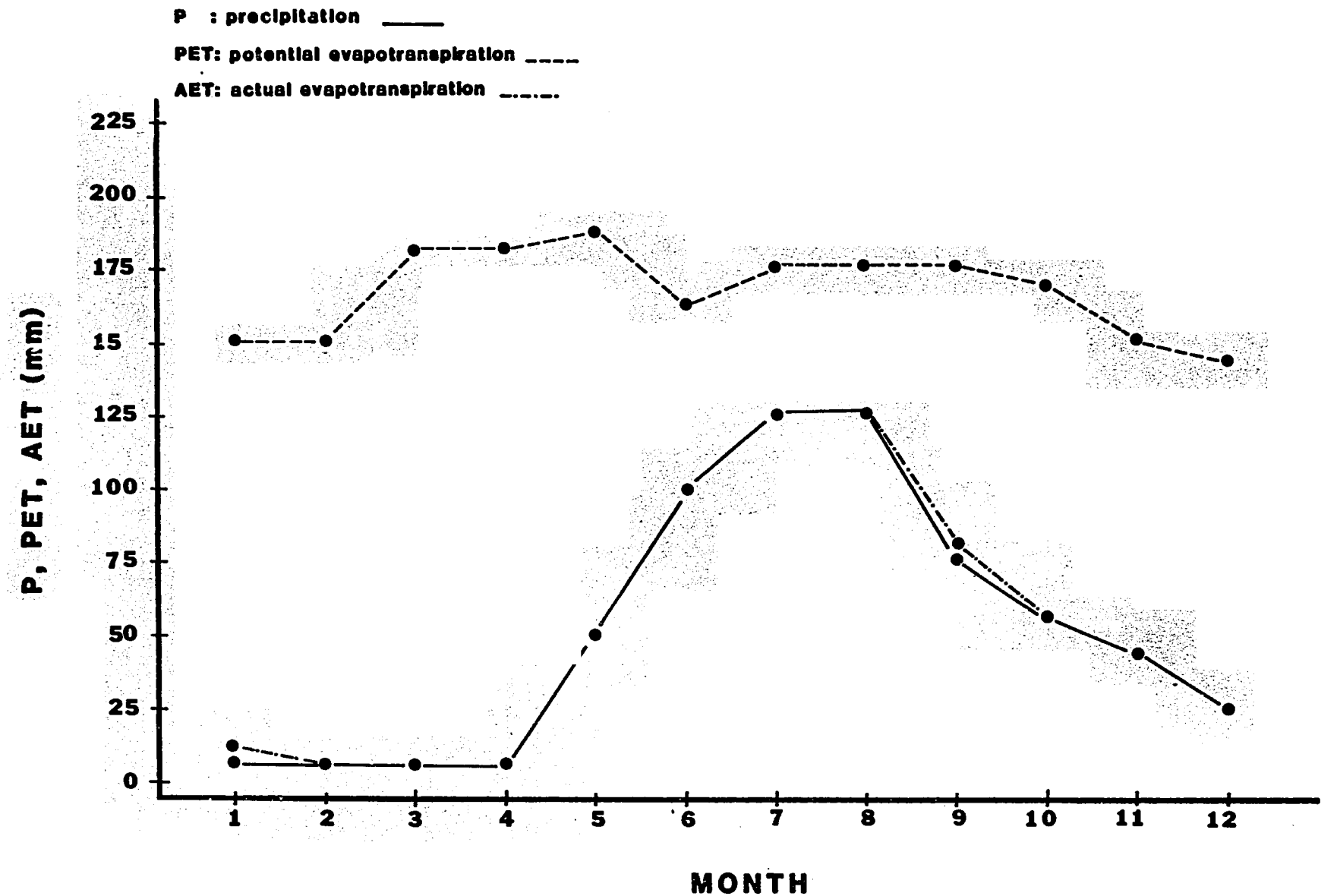
CLIMATIC DIAGRAM

PARAMARIBO, SURINAME



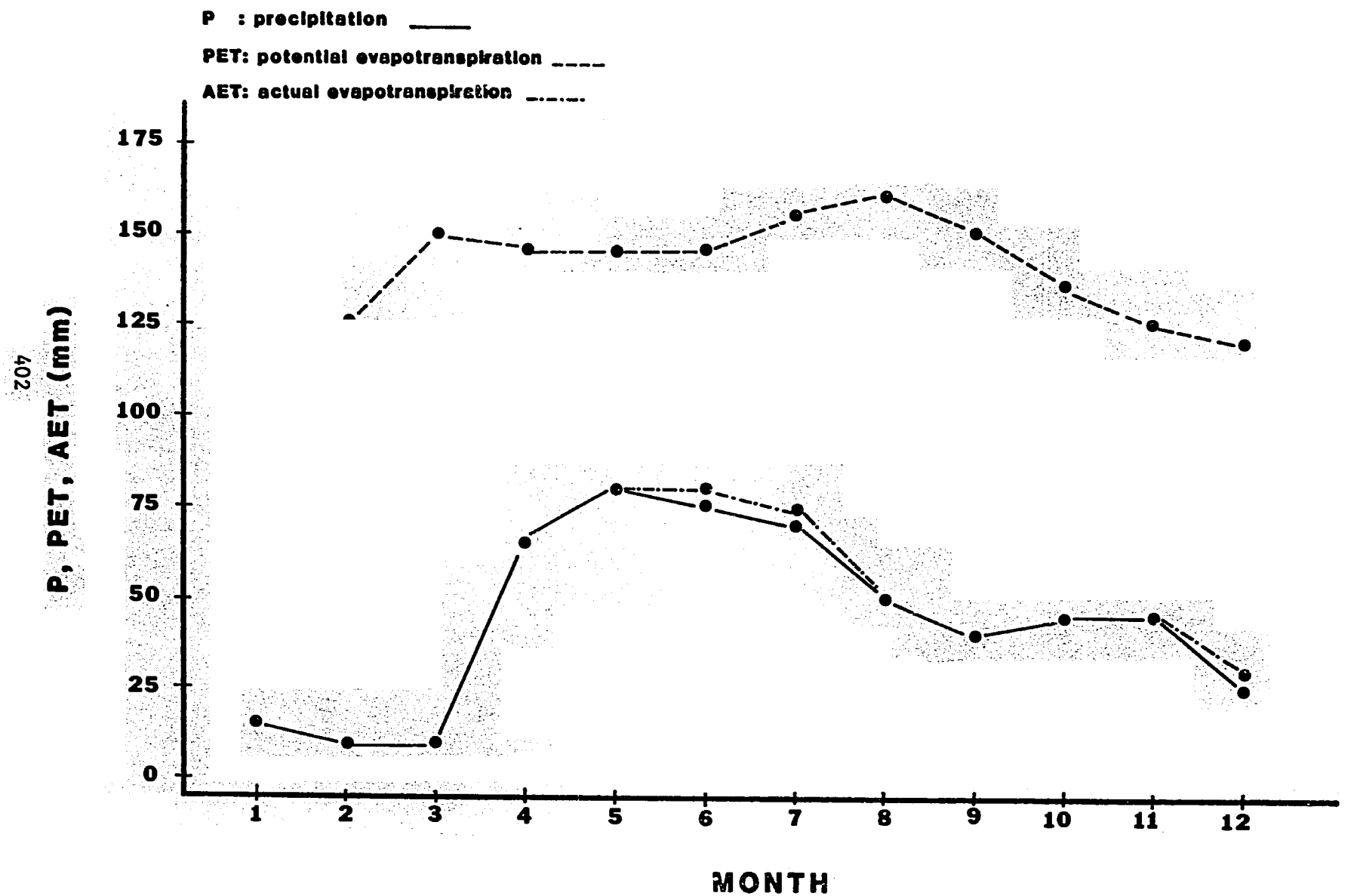
CLIMATIC DIAGRAM

BARCELONA, VENEZUELA



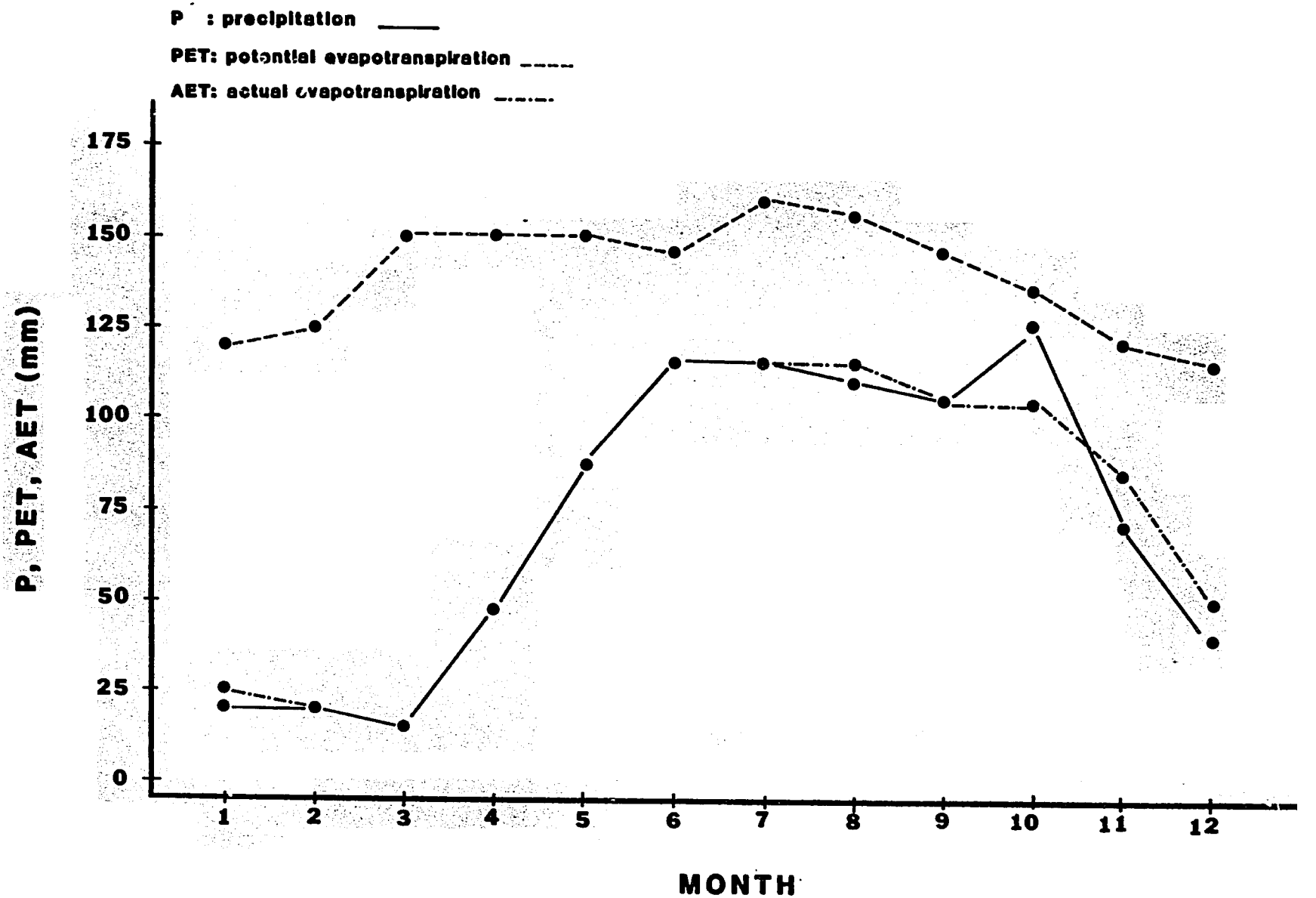
CLIMATIC DIAGRAM

BARQUISIMETO, VENEZUELA



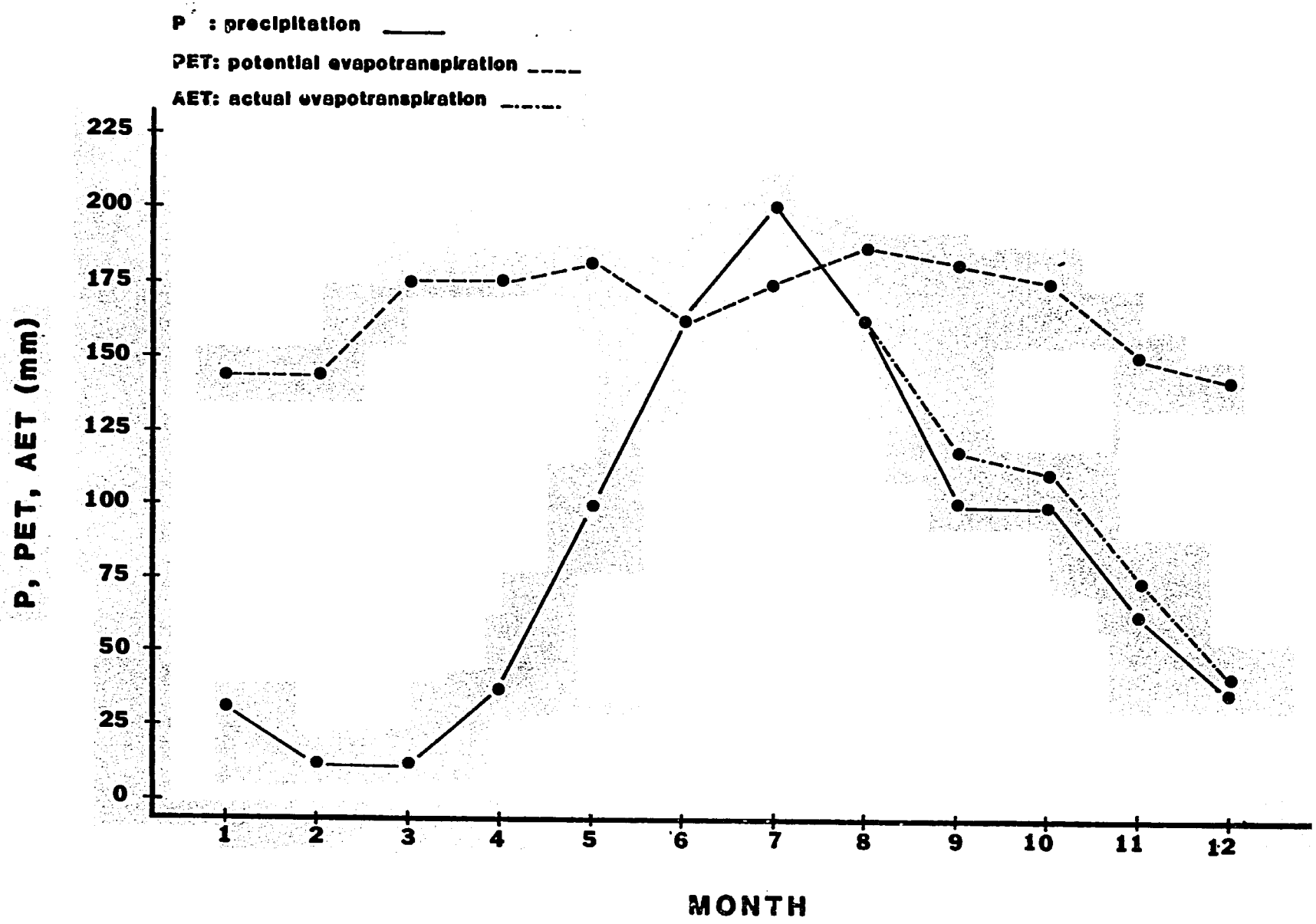
CLIMATIC DIAGRAM

CARACAS/CARLOTA, VENEZUELA



CLIMATIC DIAGRAM

CIUDAD BOLIVAR, VENEZUELA



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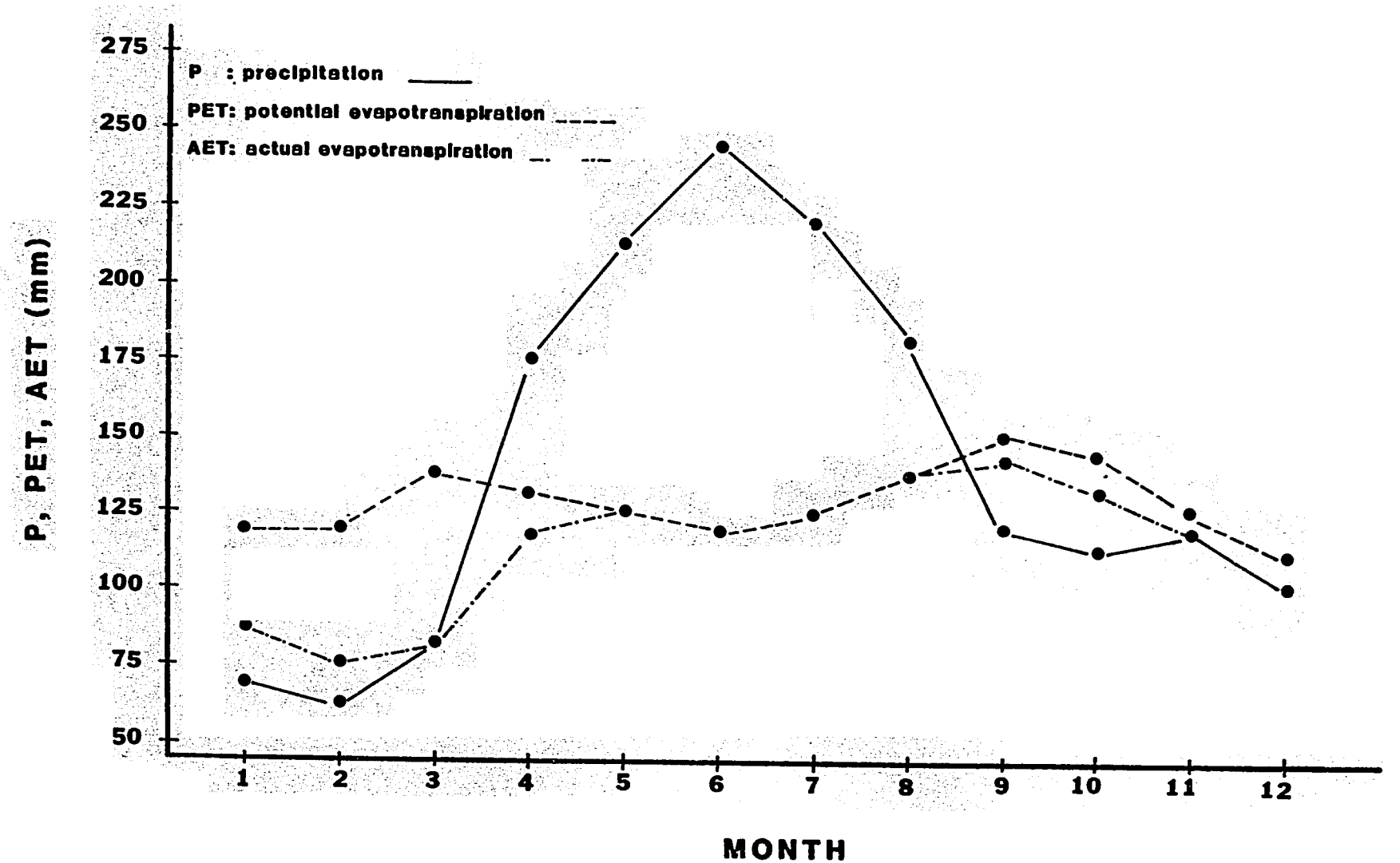
SANTA ELENA, VENEZUELA